Koolyanobbing Iron Ore Project

MS1054 ANNUAL COMPLIANCE ASSESSMENT REPORT 2019

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Revision History

Revision Number	Issue Date	Prepared By	Reviewed By	Distribution
0	30/04/2020	A Vague	R Kerrison	DWER

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1. INTRODUCTION

1.1 Project Overview

Mining has occurred at Koolyanobbing since the 1960's. Formally known as Portman Iron Ore, Cliffs Asia Pacific Iron Ore Pty Ltd (Cliffs) recommissioned the operations following closure by BHP Pty Ltd in the early 1980's and operated the mine from 1994 until 2018.

Cliffs ceased mining operations at Koolyanobbing in mid-2018 and entered into an Asset Sale Agreement with Mineral Resources Limited (MRL) on 12 June 2018. The transaction was completed in August 2018 and included the transfer of legal title in Cliffs mining tenements to MRL and ownership of all remaining iron ore, fixed plant, equipment and non-process infrastructure in the Yilgarn and at the Port of Esperance. All assets were transferred to the wholly owned MRL subsidiary Yilgarn Iron Pty Ltd (YIPL).

YIPL commenced mining at Koolyanobbing in September 2018. Iron ore is mined from a number of open pits, blended, crushed and screened to make products that meet export market specifications. The products are transported by rail from Koolyanobbing to Esperance Port.

Ore from the northern operations of Mt. Jackson, Windarling and Deception (located approximately 70, 100 and 120 km north of Koolyanobbing, respectively) is transported via a private haul road to Koolyanobbing where it is selectively blended with ore from Koolyanobbing, crushed, and screened to meet market specifications.

The location of Mt Jackson, Windarling and Deception mines are shown **Figure 1**.

1.2 The Proponent

Following the Asset Sale Agreement and pursuant to section 38(6) and (7) of the *Environmental Protection Act 1986 (WA) (EP Act)*, YIPL was nominated as the person responsible for the Proposal (Yilgarn Operations, Koolyanobbing Range F Deposit; Assessment No. 2023; Statement No. 1054).

YIPL is a wholly owned subsidiary of MRL and became the beneficial holder of the mining tenements for the Koolyanobbing Iron Ore Project.

1.3 Approvals History

A Proposal was submitted by Cliffs for assessment to the Environmental Protection Authority (EPA) in July 2014 (Cliffs 2014). In September 2014, the EPA (2014) determined the Proposal should be subject to an Environmental Impact Assessment (EIA) at the level of Public Environmental Review (PER).

In October and November 2015, Cliffs' (2015) EIA-PER document was released for public review. The EIA-PER document outlined the location and infrastructure components of the Proposal, assessed the potential for environmental effects, and described Cliffs' proposed management actions to ensure such potential effects are minimised and controlled to an acceptable level.

In September 2016, the EPA (2016) assessment report to the Minister for Environment recommended the Proposal be approved, subject to environmental conditions. In January 2017, the Minister for Environment granted approval of the Proposal through the Statement 1054 approval in accordance with s45(5) of the Environmental Protection Act 1986 (WA).

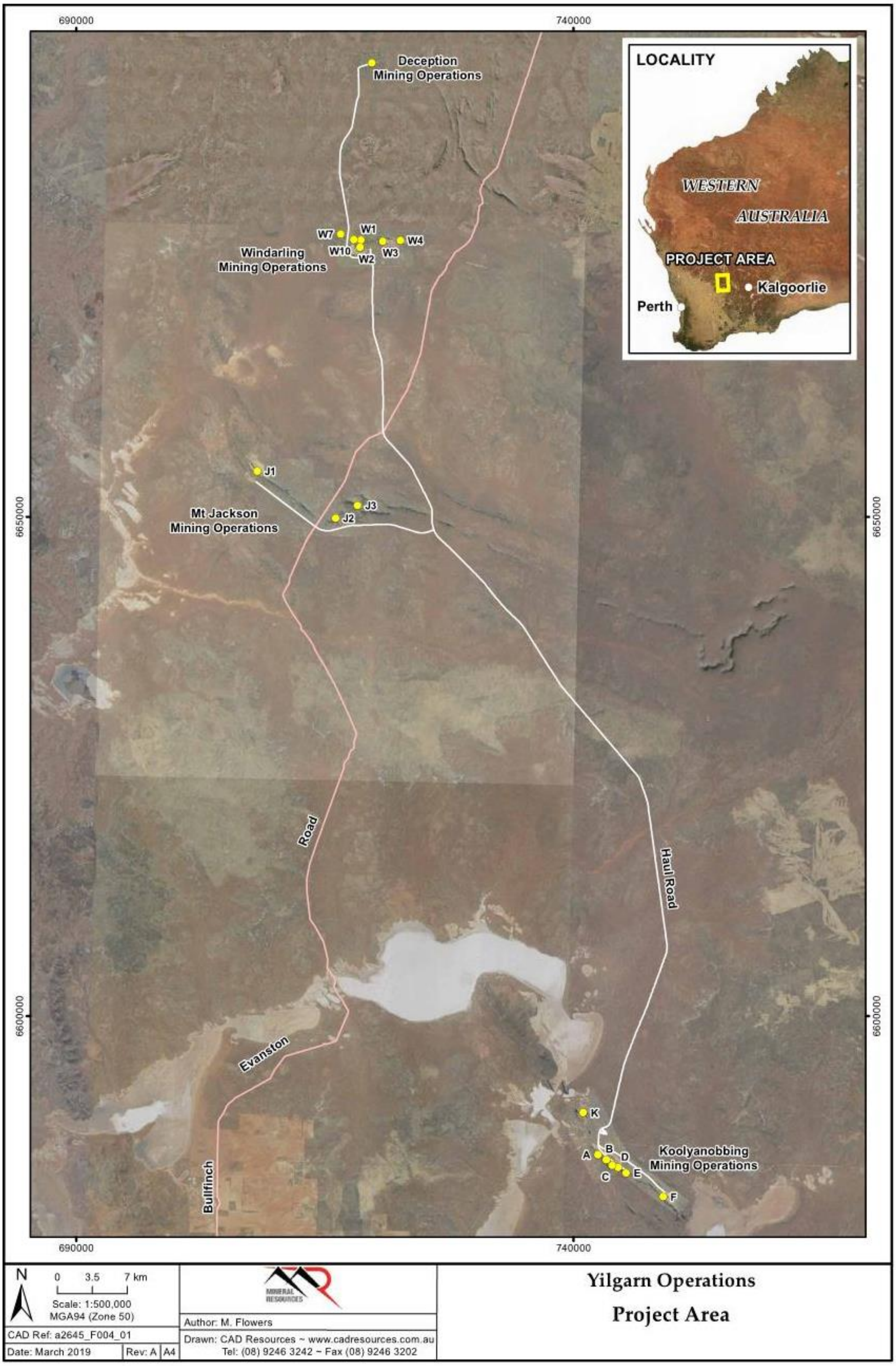

Figure 1: Location of YIPL Yilgarn Operations

1.4 Ministerial Statement MS1054

MS 1054 outlines the conditions regulating the mining of iron ore and construction of mine infrastructure at the F Deposit area, located on the southern Koolyanobbing Range, approximately 50 kilometres north-east of the town of Southern Cross. (See **Figure 1**).

Condition 4.6 of MS 1054 states:

The Proponent shall submit to the CEO a Compliance Assessment report by the 30th of April each year addressing compliance in the previous calendar year, or as agreed in writing by the CEO. The compliance assessment report shall:

1. *Be endorsed by the proponent's CEO or a person delegated to sign on the CEO's behalf;*
2. *Include a statement as to whether the proponent has complied with the conditions;*
3. *Identify all potential non-compliances and describe corrective and preventative actions taken;*
4. *Be made publicly available in accordance with the approved Compliance Assessment Plan; and*
5. *Indicate any proposed changes to the Compliance Assessment Plan required by condition 4-1*

This Annual Compliance Assessment Report was prepared in accordance with Condition 4-6 of MS1054 for the period between 1 January and 31 December 2019.

2. PROJECT STATUS

Operation continued in the F Deposit project area over the reporting period. Active mining at this location is expected to continue for the next 2-5 years.

3. COMPLIANCE

3.1 Non-compliances and Corrective Actions

Two non-compliances were recorded during the 2019 reporting period.

3.1.1 Blast Vibration

During the reporting period MRL identified five blast vibration exceedances. Upon identification, an internal investigation commenced. Contingency actions were developed and implemented to prevent future non-compliance.

Stability conditions of F3 high-wall currently is fundamentally good and absent of signs of development of significant instability.

See Attachment 4 - MS1054 Non- Compliance notification letter and F3 Pit Vibration Investigation (Revision 0). Full details of blasting schedule and vibration monitoring results are included with this CAR as Attachment 10 – 2019 F Deposit F3 Pit Vibration Monitoring Report (Revision 0).

3.1.2 Compliance Reporting

A blast vibration exceedance was not reported within the required 7-day reporting period. Contingency actions, such as the development of a new Blast Vibration Reporting Procedure, were developed and implemented to prevent future non-compliance.

See Attachment 4 – Resolution of Non-Compliance. Full details of blasting schedule and vibration monitoring results are included with this CAR as Attachment 10 – 2019 F Deposit F3 Pit Vibration Monitoring Report (Revision 0).

3.2 Statement of Compliance

YIPL has not complied with all conditions listed in Ministerial Statement 1054 for the 2019 reporting period. Refer to Attachment 1: 2019 Statement of Compliance MS1054.

4. DETAILS OF DECLARED COMPLIANCE STATUS

Assessment of Compliance – Ministerial Statement MS1054 Audit Table (**Attachment** 2) provides the compliance status of each implementation condition for the 2018 reporting period.

Attachment 1: 2019 Statement of Compliance MS1054

Statement of Compliance

1. Proposal and Proponent Details

Proposal Title	*Yilgarn Operations, Koolyanobbing Range F Deposit*
Statement Number	*MS1054*
Proponent Name	*Yilgarn Iron Pty Ltd. (nominated as person responsible under S38(6) and 38(7) of the EP Act)*
Proponent's Australian Company Number *(where relevant)*	ACN: 626 035 078

2. Statement of Compliance Details

Reporting Period	*1/01/19* to *31/12/19*

Implementation phase(s) during reporting period (please tick ✓ relevant phase(s))							
Pre-construction		Construction		Operation	✓	Decommissioning	

Audit Table for Statement addressed in this Statement of Compliance is provided at Attachment:	1
An audit table for the Statement addressed in this Statement of Compliance must be provided as Attachment 2 to this Statement of Compliance. The audit table must be prepared and maintained in accordance with the Department of Water and Environmental Regulation (DWER) *Post Assessment Guideline for Preparing an Audit Table*, as amended from time to time. The 'Status Column' of the audit table must accurately describe the compliance status of each implementation condition and/or procedure for the reporting period of this Statement of Compliance. The terms that may be used by the proponent in the 'Status Column' of the audit table are limited to the Compliance Status Terms listed and defined in Table 1 of Attachment 1.	

Were all implementation conditions and/or procedures of the Statement complied with within the reporting period? (please tick ✓ the appropriate box)			
No (please proceed to Section 3)	✓	Yes (please proceed to Section 4)	

Each page (including Attachment 2) must be initialed by the person who signs Section 4 of this Statement of Compliance.

INITIALS: _ R.K _____

3. Details of Non-compliance(s) and/or Potential Non-compliance(s)

The information required Section 3 must be provided for each non-compliance or potential non-compliance identified during the reporting period covered by this Statement of Compliance.

Non-compliance/potential non-compliance 3-1

Which implementation condition or procedure was non-compliant or potentially non-compliant?
7.7: Ground vibrations along the southern edge of the F3 pit adjacent to the development envelope are not to exceed the following specifications in Table 1 and be included in the Stability Monitoring Program required by condition 7-6.
Was the implementation condition or procedure non-compliant or potentially non-compliant?
Non-Compliant
On what date(s) did the non-compliance or potential non-compliance occur (if applicable)?
22/02/2019 08/03/2019 10/03/2019 08/05/2019 20/08/2019

Was this non-compliance or potential non-compliance reported to the Chief Executive Officer, DWER?	
☑ Yes ☐ Reported to DWER verbally Date __________ ✓ Reported to DWER in writing Date: Various dates	☐ No

What are the details of the non-compliance or potential non-compliance and where relevant, the extent of and impacts associated with the non-compliance or potential non-compliance?

- 22/02/2019: evidence indicated that single hole firing had not been attained. The investigation noted that for larger shots, single hole firing was difficult to achieve with the Nonel system and spread of timing within the initation system. Whilst the shot was free faced, there were a large number of holes (677) in the shot.
- 08/03/2019 & 10/03/2019: In response to the shot 302 exceedance, shot 301 was halved in size forming shot 302a and 302b. This strategy aimed to reduce the number of holes to be fired for each shot by half and reduce the amount of multiple hole firings. The shots (302a and 302b) were free faced but due to its position, 60 to 100 m closer to the monitoring point and confined on three sides, the movement of the blast into the final wall/corner of the shot still resulted in blast exceedance.

  Additionally, for Shot 301a, the investigation found that even by decreasing the amount of holes, the vibration level was unable to be significantly reduced due to the limited distance to the vibration monitor.
- 20/08/2019: Following previous exceedances, a series of corrective actions implemented had resulted in a drop in vibration. The exceedance in shot 460-310 cannot be fully explained and was in excess of the calculated value for the shot.

Each page (including Attachment 2) must be initialed by the person who signs Section 4 of this Statement of Compliance.

INITIALS: _ R.K _____

Firing against the shot had an overall positive influence on blast vibration. This reverse firing creates a buffer of broken material between the high wall and the blast front. However, it is postulated that although the wave dies away quickly, the initiation point still creates a large instantaneous vibration (as it is confined).

Upon receiving the results, as nothing untoward had been reported during or after firing, an investigation commenced. An inspection of the area around the blast, the adjacent walls of the F3 pit and the undisturbed scarp face was completed with no areas of instability or rock displacement identified.

What is the precise location where the non-compliance or potential non-compliance occurred (if applicable)? (please provide this information as a map or GIS co-ordinates)

Koolyabobbing F-Deposit:

GDA 2020 MGA Zone 50: 749737.25E 6581194.92N

What was the cause(s) of the non-compliance or potential non-compliance?

See above section "What are the details of the non-compliance or potential non-compliance and where relevant, the extent of and impacts associated with the non-compliance or potential non-compliance?"

What remedial and/or corrective action(s), if any, were taken or are proposed to be taken in response to the non-compliance or potential non-compliance?

The following actions have been implemented at the Koolyanobbing Project to address the issue of vibration exceedances:

1. YIPL has engaged a drill and blast specialist to provide a detailed and comprehensive vibration analysis using multiple vibration monitoring stations in and around the F3 pit. The objective of this analysis is to determine if there is any directionality or magnification to the vibration waves from local conditions.
2. Deck loading has been initiated in F3 pit, which reduces the level of instantaneous charge by 50%. Initial results (February 2019 to present) indicate a substantial drop in monitored vibration levels. This will be re assessed as the pit develops vertically.
3. Periodic testing of vibration monitors has been implemented to ensure that they are calibrated (to specifications) and properly fixed to competent material.
4. Implementation of discontinuity mapping to provide further understanding of transmission paths for vibrations.
5. Changes in mining methodology implemented, where subject to block model and drilling results, a larger buffer between the pit and the undisturbed/natural ground will be maintained.
6. Introduction of pre-split drilling and single hole split where assessed as needed for the purpose of creating a barrier of broken material to prevent vibration and gas travelling back into the rear wall of the F3 pit.
7. Implementation of a shield shot (a combination of a pre-split, and trim shot surrounding the main production shot)
8. Continuation of the reverse firing method to produce broken buffers to prevent shock wave attenuation.

What measures, if any, were in place to prevent the non-compliance or potential non-compliance before it occurred? What, if any, amendments have been made to those measures to prevent re-occurrence?

See above section “What remedial and/or corrective action(s), if any, were taken or are proposed to be taken in response to the non-compliance or potential non-compliance?”
Please provide information/documentation collected and recorded in relation to this implementation condition or procedure: • in the reporting period addressed in this Statement of Compliance; and • as outlined in the approved Compliance Assessment Plan for the Statement addressed in this Statement of Compliance. (the above information may be provided as an attachment to this Statement of Compliance)

Non-compliance/potential non-compliance 3-2

Which implementation condition or procedure was non-compliant or potentially non-compliant?
4-5 The proponent shall advise the SEO of any non-compliance withing seven (7) days of that non-compliance being known.
Was the implementation condition or procedure non-compliant or potentially non-compliant?
Non-Compliant
On what date(s) did the non-compliance or potential non-compliance occur (if applicable)?
20/08/2019

Was this non-compliance or potential non-compliance reported to the Chief Executive Officer, DWER?		
☑ Yes	☐ Reported to DWER verbally Date ___________ ✓ Reported to DWER in writing Date: 01/11/2019	☐ No

What are the details of the non-compliance or potential non-compliance and where relevant, the extent of and impacts associated with the non-compliance or potential non-compliance?
A blast vibration exceedance was not reported within the required 7-day reporting period.
What is the precise location where the non-compliance or potential non-compliance occurred (if applicable)? (please provide this information as a map or GIS co-ordinates)
Koolyabobbing F-Deposit: GDA 2020 MGA Zone 50: 749737.25E 6581194.92N
What was the cause(s) of the non-compliance or potential non-compliance?
On 20 August 2019, the 460-310 shot in F3 pit was fired and the vibration monitor recorded a Peak Particle Velocity of 12.31 mm/s (Incident). The stability monitoring conducted by Mineral Resources Limited (MRL) as required by condition 7-7 of Ministerial Statement 1054 (and condition 7-8 and/or the report required by condition 7-9 of Ministerial Statement 1054) (Monitoring) did not indicate instability of the pit wall. YILP believed that the requirement to advise the CEO under condition 7-10 is only triggered when the Monitoring indicates instability of the pit wall. As the Monitoring at the time of the Incident did not indicate any instability of the pit wall, the requirement to report to the CEO under condition 7-10 of Ministerial Statement 1054 was not triggered.

What remedial and/or corrective action(s), if any, were taken or are proposed to be taken in response to the non-compliance or potential non-compliance?
Contingency actions, such as the development of a new Blast Vibration Reporting Procedure, were developed and implemented to prevent future non-compliance. See Attachment 4 – Resolution of Non-Compliance. Full details of blasting schedule and vibration monitoring results are included with this CAR as Attachment 10 – 2019 F Deposit F3 Pit Vibration Monitoring Report (Revision 0).
What measures, if any, were in place to prevent the non-compliance or potential non-compliance before it occurred? What, if any, amendments have been made to those measures to prevent re-occurrence?
See above section "What remedial and/or corrective action(s), if any, were taken or are proposed to be taken in response to the non-compliance or potential non-compliance?"
Please provide information/documentation collected and recorded in relation to this implementation condition or procedure: • in the reporting period addressed in this Statement of Compliance; and • as outlined in the approved Compliance Assessment Plan for the Statement addressed in this Statement of Compliance. (the above information may be provided as an attachment to this Statement of Compliance)

For additional non-compliance or potential non-compliance, please duplicate this page as required.

4. Proponent Declaration

I, Richard Kerrison, General Manager, Yilgarn Operations declare that I am authorised on behalf of Yilgarn Iron Pty Ltd. *(being the person responsible for the proposal)* to submit this form and that the information contained in this form is true and not misleading.

Signature: Date: 30/04/2020

Please note that:

- it is an offence under section 112 of the *Environmental Protection Act 1986* for a person to give or cause to be given information that to his knowledge is false or misleading in a material particular; and
- the Chief Executive Officer of the DWER has powers under section 47(2) of the *Environmental Protection Act 1986* to require reports and information about implementation of the proposal to which the statement relates and compliance with the implementation conditions.

5. Submission of Statement of Compliance

One hard copy and one electronic copy (preferably PDF on CD or thumb drive) of the Statement of Compliance are required to be submitted to the Chief Executive Officer, DWER, marked to the attention of Manager, Compliance (Ministerial Statements).

Please note, the DWER has adopted a procedure of providing written acknowledgment of receipt of all Statements of Compliance submitted by the proponent, however, the DWER does not approve Statements of Compliance.

6. Contact Information

Queries regarding Statements of Compliance, or other issues of compliance relevant to a Statement may be directed to Compliance (Ministerial Statements), DWER:

Manager, Compliance (Ministerial Statements)

Department of Water and Environmental Regulation

Postal Address:	Locked Bag 33 Cloisters Square PERTH WA 6850
Phone:	(08) 6364 7000
Email:	compliance@dwer.wa.gov.au

7. Post Assessment Guidelines and Forms

Post assessment documents can be found at www.epa.wa.gov.au

ATTACHMENT 1

Table 1 Compliance Status Terms

Compliance Status Terms	**Abbrev**	**Definition**	**Notes**
Compliant	C	Implementation of the proposal has been carried out in accordance with the requirements of the audit element.	This term applies to audit elements with: • ongoing requirements that have been met during the reporting period; and • requirements with a finite period of application that have been met during the reporting period, but whose status has not yet been classified as 'completed'.
Completed	CLD	A requirement with a finite period of application has been satisfactorily completed.	This term may only be used where: • audit elements have a finite period of application (e.g. construction activities, development of a document); • the action has been satisfactorily completed; and • the DWER has provided written acceptance of 'completed' status for the audit element.
Not required at this stage	NR	The requirements of the audit element were not triggered during the reporting period.	This should be consistent with the 'Phase' column of the audit table.
Potentially Non-compliant	PNC	Possible or likely failure to meet the requirements of the audit element.	This term may apply where during the reporting period the proponent has identified a potential non-compliance and has not yet finalized its investigations to determine whether non-compliance has occurred.
Non-compliant	NC	Implementation of the proposal has not been carried out in accordance with the requirements of the audit element.	This term applies where the requirements of the audit element are not "complete" have not been met during the reporting period.
In Process	IP	Where an audit element requires a management or monitoring plan be submitted to the DWER or another government agency for approval, that submission has been made and no further information or changes have been requested by the DWER or the other government agency and assessment by the DWER or other government agency for approval is still pending.	**The term 'In Process' may not be used for any purpose other than that stated in the Definition Column.** The term 'In Process' may not be used to describe the compliance status of an implementation condition and/or procedure that requires implementation throughout the life of the project (e.g. implementation of a management plan).

Attachment 2: Assessment of Compliance MS1054 Audit Table

Yilgarn Operations – Koolyanobbing Range F Deposit (Statement 1054)

- Phases that apply in this table = Pre-Construction, Construction, Operation, Decommissioning, Overall (several phases).
- The Audit Table provides a summary interpretation of the condition requirements applying to the Proposal under the *Environmental Protection Act 1986* (WA). Please refer to the Statement approval issued for the Proposal for the agreed condition wording and abbreviations.
- Status: C = Compliant; CLD = Completed; NC = Non – compliant; NR = Not Required at this stage; NA = Not Audited; VR = Verification Required; IP = In Process.

Audit Code	Subject	Requirement	How	Evidence	Phase	Timeframe	Status	Further Information
1054:M1-1	**Proposal Implementation**	When implementing the proposal, the proponent shall not exceed the authorised extent of the proposal as defined in Tables 2 and 3 in Schedule 1, unless amendments to the proposal and the authorised extent of the proposal have been approved under the EP Act.	Proposal implementation to be within authorised extent described in defined in Tables 2 and 3 in Schedule 1	Spatial mapping identifying the extent of the Proposal approved and extent of the Proposal as implemented	Overall	Ongoing	C	The proposal has been implemented to requirements described in Table 2 and Table 3 as described in MS 1054:1-1.
		Key Characteristic	**Description**					
	Proposal Implementation – Table 2 – Stage 1	Mine Pits (F2 and F3)	Clearing of no more than 24 hectares in the 203 hectares development envelope				C	To date, 21.87 hectares of land has been progressively cleared for mine pits (F2 and F3). See Attachment **3** Yilgarn Operations Koolyanobbing Range Mine operations 2019 Clearing.
	Proposal Implementation– Table 2- Stage 1	Waste Rock Dump	Clearing of no more than 73 hectares in the 203 hectares development envelope				C	To date, 41.13 hectares has been progressively cleared for the creation of a Waste Rock Landform. See Attachment **3** Yilgarn Operations Koolyanobbing Range Mine operations 2019 Clearing.
	Proposal Implementation– Table 2- Stage 1	Supporting Mine Infrastructure	Clearing of no more than 96 hectares in the 203 hectares development envelope				C	To date, 70.05 hectares of land has been progressively cleared for Supporting Mine Infrastructure. See Attachment **3** Yilgarn Operations Koolyanobbing Range Mine operations 2019 Clearing.
	Proposal Implementation - Table 3- Stage 2	Mine Pit (F1)	Clearing of no more than 9 hectares in the 203 hectares development envelope				NR	There has been no clearing for Stage 2 Mine pit (F1).
	Proposal Implementation – Table 3- Stage 2	Supporting Mine Infrastructure	Clearing of no more than 1 hectares in the 203 hectares development envelope				NR	There has been no clearing for Stage 2 Supporting mine infrastructure.
1054:M2-1	**Contact Details**	The proponent shall notify the CEO of any change of its name, physical address or postal address for the serving of notices or other correspondence within twenty-eight (28) days of such change. Where the proponent is a corporation or an association of persons, whether incorporated or not, the postal address is that of the principal place of business or of the principal office in the State.	Written notification to CEO of change	Written notification to CEO of change	Overall	Within 28 days of change	C	Cliffs entered into an asset sale agreement with Mineral Resources Limited Pty Ltd (MRL) in June 2018, which included the sale of all remaining iron ore at Yilgarn operations, fixed plant, equipment and non-process infrastructure. The asset sale transaction was completed in August 2018, with all assets transferred to the wholly owned MRL subsidiary Yilgarn Iron Pty Ltd (YIPL). Mining recommenced in September 2018. Pursuant to section 38(6) and (7) of the *Environmental Protection Act 1986*, Yilgarn Iron Pty Ltd was nominated as the person responsible for the Proposal on October 19th 2018, and contact details were updated accordingly.
1054:M3-1	**Time Limit for Proposal Implementation**	The proponent shall not commence implementation of the proposal after five (5) years from the date on this Statement, and any commencement, prior to this date, must be substantial.	Proposal implementation to commence within 5 years of the date of	Written notification to CEO of substantial commencement in	Construction, Operation	5 years from the date of this Statement	C	Implementation of the proposal commenced 22 February 2017 with initiation of clearing work. Confirmation that the proposal has been substantially commenced is evidenced by the content of and

Audit Code	Subject	Requirement	How	Evidence	Phase	Timeframe	Status	Further Information
			this Statement, or to not commence after 5 years of the date of this Statement	accordance with Condition 3-2				submission of Annual Compliance Assessment Reports (ACAR) to the DWER.
1054:M3-2	**Time Limit for Proposal Implementation**	Any commencement of implementation of the proposal, on or before five (5) years from the date of this Statement, must be demonstrated as substantial by providing the CEO with written evidence, on or before the expiration of five (5) years from the date of this Statement.	Written notification to CEO of substantial commencement	Written notification to CEO of substantial commencement	Construction, Operation	5 years of the date of this Statement	C	The content and submission of the ACAR to the CEO provides evidence that the proposal had substantially commenced within 5 years of the date of the Statement.
1054:M4-1	**Compliance Reporting**	The proponent shall prepare, submit and maintain a Compliance Assessment Plan to the CEO at least three (3) months prior to the first Compliance Assessment Report required by condition 4-6, or prior to implementation, whichever is sooner.	Preparation and submission of Compliance Assessment Plan (CAP) to CEO	Preparation and submission of CAP to CEO	Pre-construction	Prior to implementation of Proposal	C	OEPA approved the CAP 21 February 2017 and determined that the CAP met the requirements of Conditions 4-1 and 4-2 of Statement 1054 (OEPA Ref: AC05-2017-007). YIPL updated the CAP to reflect changes to the proponent for MS1054 and the location of the publicly available reports in accordance with condition 4-6(4) of MS 1054 The update does not impact on any actions or requirements of the CAP that was approved by OEPA in 2017.
1054:M4-2	**Compliance Reporting**	The Compliance Assessment Plan shall indicate: (1) the frequency of compliance reporting; (2) the approach and timing of compliance assessments; (3) the retention of compliance assessments; (4) the method of reporting of potential non-compliances and corrective actions taken; (5) the table of contents of Compliance Assessment Reports; and (6) public availability of Compliance Assessment Reports.	Preparation and submission of CAP to CEO	Preparation and submission of CAP to CEO	Pre-construction	Prior to implementation of Proposal	C	OEPA approved the CAP 21 February 2017 and determined that the CAP met the requirements of Conditions 4-1 and 4-2 of Statement 1054 (OEPA Ref: AC05-2017-007). All YIPL's CARs are made available to the public through publication on MRL's website at http://www.mineralresources.com.au
1054:M4-3	**Compliance Reporting**	After receiving notice in writing from the CEO that the Compliance Assessment Plan satisfies the requirements of condition 4-2 the proponent shall assess compliance with conditions in accordance with the Compliance Assessment Plan required by condition 4-1.	Assess compliance in accordance with the CAP	CAR Reports prepared in accordance with the CAP	Overall	Ongoing	C	This 2019 annual Compliance Assessment Report (CAR) fulfils the requirement to assess compliance with the conditions of Statement 1054 for the period 1 January 2019 to 31 December 2019.
1054:M4-4	**Compliance Reporting**	The proponent shall retain reports of all compliance assessments described in the Compliance Assessment Plan required by condition 4-1 and shall make those reports available when requested by the CEO.	Retention of CAR as described in the CAP	Retention of CAR as described in the CAP	Overall	Ongoing	C	Annual CARs are retained within and made available on MRL's electronic network and have been submitted to the CEO/Director General – Department of Water and Environmental Regulation (DWER) in accordance with the Compliance Assessment Plan.
1054M:4-5	**Compliance Reporting**	The proponent shall advise the CEO of any potential non-compliance within seven (7) days of that non-compliance being known.	Written notification to CEO of any potential non-compliance	Written notification to CEO of any potential non-compliance	Overall	Ongoing	NC	A blast vibration exceedance was not reported within the required 7 day reporting period. See Attachment 4

Audit Code	Subject	Requirement	How	Evidence	Phase	Timeframe	Status	Further Information
1054:M4-6	**Compliance Reporting**	The proponent shall submit to the CEO a Compliance Assessment Report by 30 April each year addressing compliance in the previous calendar year, or as agreed in writing by the CEO. The first Compliance Assessment Report shall be submitted by 30 April 2017 addressing the compliance for the period from the date of issue of this Statement, notwithstanding that the first reporting period may be less than 12 months. The Compliance Assessment Report shall: (1) be endorsed by the proponent's CEO or a person delegated to sign on the CEO's behalf; (2) include a statement as to whether the proponent has complied with the conditions; (3) identify all potential non-compliances and describe corrective and preventative actions taken; (4) be made publicly available in accordance with the approved Compliance Assessment Plan; and (5) indicate any proposed changes to the Compliance Assessment Plan required by condition 4-1.	CAR submission to CEO	CAR submission to CEO	Overall	30th April, annually	C	The 2016 CAR was submitted in April 2017 in compliance with this condition. This 2019 CAR is the fourth to be submitted as required and covers the period 1 January 2019 to 31 December 2019. This CAR is endorsed by MRL's General Manager of Technical Services, Mr Tim Berryman.
1054:M5-1	**Public Availability of Data**	Subject to condition 5-2, within a reasonable time period approved by the CEO of the issue of this Statement and for the remainder of the life of the proposal the proponent shall make publicly available, in a manner approved by the CEO, all validated environmental data (including sampling design, sampling methodologies, empirical data and derived information products (e.g. maps, survey results, reports)) relevant to the assessment of this proposal and implementation of this Statement.	Public availability of Compliance Assessment Reports in as outlined within the Compliance Assessment Plan approved by the CEO		Overall	Ongoing	C	All YIPL's CAR's and supportive information required under this statement are made available to the public through prompt publication on the MRL website at http://www.mineralresources.com.au
1054:M5-2	**Public Availability of Data**	If any data referred to in condition 5-1 contains particulars of: (1) a secret formula or process; or (2) confidential commercially sensitive information; the proponent may submit a request for approval from the CEO to not make these data publicly available. In making such a request the proponent shall provide the CEO with an explanation and reasons why the data should not be made publicly available.	Written request to CEO		Overall	Ongoing	NR	YIPL does not request that any plans or reports or any sections of plans or reports not to be made publically available during the reporting period.
1054:M6-1	**Flora and Vegetation Management**	Prior to the commencement of any ground disturbing activities, or as otherwise agreed in writing by the CEO, the proponent shall prepare and submit a Condition Environmental Management Plan to the satisfaction of the CEO, on advice of the Department of Parks and Wildlife, to demonstrate that the following environmental outcomes will be met: (1) No adverse effects on native flora and vegetation outside the Stage 1 and 2 development envelopes as shown in Figure 2 in Schedule 1 and delineated by coordinates in Schedule 2 or within the Stage 2 development envelope until the requirements of condition 9 have been met; (2) No adverse effects on greater than 313 *Tetratheca erubescens* plants within the Stage 1 development envelope as shown in Figure 3 in Schedule 1 and delineated by coordinates in Schedule 2; and (3) No adverse effects on greater than 652 *Tetratheca erubescens* plants within the Stage 2 development envelope as shown in Figure 3 in Schedule 1 and delineated by coordinates in Schedule 2 once the requirements of condition 9 have been met.	Preparation and submission of a Condition Environmental Management Plan (Flora and Vegetation Management Plan) to the satisfaction of the CEO	Preparation and submission of a Condition Environmental Management Plan (Flora and Vegetation Management Plan) to the satisfaction of the CEO	Pre-construction	Prior to implementation of Proposal	C	OEPA provided approval (OEPA Ref: 17-012450) on 20 February 2017 for Cliffs to undertake early ground disturbing activities within the proposal area prior to the approval of the Flora and Vegetation Management Plan. The *Yilgarn Operations - Koolyanobbing Range F Deposit – Flora and Vegetation Management Plan* (Revision 0) was submitted to OEPA in November 2019. The Plan was approved by OEPA on 04 February 2020 (OEPA Ref: DWERA-000999).

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1054:M6-2	**Flora and Vegetation Management**	The plan required by condition 6-1 shall include provisions required by condition 6-3 to address indirect impacts on native flora and vegetation (including *Tetratheca erubescens* and Priority flora species) and vegetation health and condition including from, but not limited to dust, weeds and fire as a result of implementation of the proposal. The plan shall be developed in consultation with an independent expert in the assessment and management of dust impacts on plants, to be endorsed in writing by the CEO.	Preparation and submission of a Condition Environmental Management Plan (Flora and Vegetation Management Plan) to the satisfaction of the CEO	Preparation and submission of a Condition Environmental Management Plan (Flora and Vegetation Management Plan) to the satisfaction of the CEO	Pre-construction	Prior to implementation of Proposal	C	The *Yilgarn Operations - Koolyanobbing Range F Deposit – Flora and Vegetation Management Plan* (Revision 0) was submitted to OEPA in November 2019. The Plan was approved by OEPA on 04 February 2020 (OEPA Ref: DWERA-000999).
1054:M6-3	**Flora and Vegetation Management**	The Condition Environmental Management Plan shall: (1) include the results of a suitable, contemporary baseline flora and vegetation survey to determine flora and vegetation health and condition pre-ground disturbance; (2) specify trigger criteria that will trigger the implementation of trigger level actions if exceeded; (3) specify threshold criteria that: (a) provides a limit, which the proponent must not exceed, beyond which the environmental outcome identified in condition 6-1 is not achieved; and (b) will trigger the implementation of threshold contingency actions if exceeded. (4) specify monitoring and analysis to determine if trigger criteria and threshold criteria are exceeded; (5) specify trigger level actions to be implemented in the event that trigger criteria have been exceeded; (6) specify threshold contingency actions to be implemented in the event that threshold criteria are exceeded; (7) provide the format and timing for the reporting of monitoring results and analysis against threshold criteria to demonstrate that condition 6-1 has been met over the reporting period in the Compliance Assessment Report required by condition 4; and (8) provide for reporting of exceedances of the threshold criteria.	Preparation and submission of a Condition Environmental Management Plan (Flora and Vegetation Management Plan) to the satisfaction of the CEO	Preparation and submission of a Condition Environmental Management Plan (Flora and Vegetation Management Plan) to the satisfaction of the CEO	Pre-construction	Prior to implementation of Proposal	C	The *Yilgarn Operations - Koolyanobbing Range F Deposit – Flora and Vegetation Management Plan* (Revision 0) was submitted to OEPA in November 2019. The Plan was approved by OEPA on 04 February 2020 (OEPA Ref: DWERA-000999).
1054:M6-4	**Flora and Vegetation Management**	After receiving notice in writing from the CEO that the Condition Environmental Management Plan satisfies the requirements of condition 6-3 for condition 6-1, prior to the commencement of ground disturbing activities, unless otherwise agreed by the CEO, the proponent shall: (1) commence implementation of the provisions of the Condition Environmental Management Plan; (2) monitor the health and condition of the remaining *Tetratheca erubescens* plants at the Koolyanobbing Range. Parameters to be monitored include, but are not limited to, mortality, recruitment, vegetation health and reproductive health; (3) monitor the health and condition of Priority 1 flora species and native vegetation adjacent to the Development Envelope for Stages 1 and 2; and (4) continue to implement the Condition Environmental Management Plan until the CEO has confirmed by notice in writing that the proponent has demonstrated the outcome specified in condition 6-1 has been met.	Implementation of a Condition Environmental Management Plan (Flora and Vegetation Management Plan) to the satisfaction of the CEO	Yilgarn Iron Ore Project *Tetratheca erubescens* Two Monthly Monitoring Summary Report 2018 (Revision 0) (See Attachment 6) Koolyanobbing F Deposit 2018 Annual Priority Flora and Vegetation Monitoring November 2018 Report (Revision 0) (See attachment 7) Annual *Tetratheca erubescens* Monitoring November 2018 (Revision 0) (See Attachment 8)	Construction, Operation	Ongoing	C	Following OEPA approval of the *Yilgarn Operations - Koolyanobbing Range F Deposit – Flora and Vegetation Management Plan* Revision 0 formal implementation of the Plan commenced. Monitoring was undertaken at the frequency identified within the Plan following commencement of mining in May 2017. The results of this monitoring were compiled into two individual reports. These reports, being the *Koolyanobbing Range Priority Flora and Vegetation Monitoring Report*, November 2017 and the *Koolyanobbing Range* *Two monthly Tetratheca erubescens Monitoring Report*, November 2017 were submitted to OEPA and the Department of Parks and Wildlife (DPaW) on 14 November 2017. Subsequent to these submissions, statistical analysis of the monitoring data was completed in early 2018 & 2019 and the reports updated. Completion and submission of flora and vegetation monitoring reports as attachments to this CAR demonstrates implementation of the Flora and

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								Vegetation Management Plan required by conditions 6-2 and 6-3. Monitoring results indicate that no adverse effects to conservation significant flora and vegetation as a result of proposed actions.
1054:M6-5	**Flora and Vegetation Management**	In the event that monitoring indicates exceedance of threshold criteria specified in the Condition Environmental Management Plan, the proponent shall: (1) report the exceedance in writing within seven (7) days of the exceedance being identified; (2) immediately implement the threshold contingency actions specified in the Condition Environmental Management Plan and continue implementation of those actions until the trigger criteria are being met, or until the CEO has confirmed by notice in writing that it has been demonstrated that the environmental outcome in condition 6-1 is being met and implementation of the trigger level actions and/or threshold contingency actions are no longer required; (3) investigate to determine the cause of the threshold criteria being exceeded; (4) identify additional measures required to prevent the threshold criteria being exceeded in the future; (5) investigate to determine potential environmental harm or alteration of the environment that occurred due to threshold criteria being exceeded; and (6) provide a report to the CEO within ninety (90) days of the exceedance being reported. The report shall include: (a) details of threshold contingency actions implemented; (b) the effectiveness of the threshold contingency actions implemented, monitored and measured against trigger criteria and threshold criteria; (c) the findings of the investigations required by condition 6-5(3) and 6-5(5); (d) additional measures to prevent the threshold criteria being exceeded in the future; and (e) measures to control or abate and mitigate the significant adverse environmental impacts which may have occurred.	Written notification and report to CEO, and implementation of actions and measures and investigations, if required	Written notification and report to CEO, and implementation of actions and measures and investigations, if required	Construction, Operation	Following identification of monitoring indicating an exceedance, if required	NR	No exceedances of threshold criteria were recorded during the 2019 monitoring and reporting period, as outlined in the monitoring reports (See Attachments 5,6and 7).
1054:M6-6	**Flora and Vegetation Management**	The proponent: (1) may review and revise the Condition Environmental Management Plan, or (2) shall immediately review and revise the Condition Environmental Management Plan if the environmental outcomes in condition 6-1 are not being met or as and when directed by the CEO.	Review and revision of the Condition Environmental Management Plan, if required	Review and revision of the Condition Environmental Management Plan, if required	Construction, Operation	Ongoing, if required	C	The *Yilgarn Operations - Koolyanobbing Range F Deposit – Flora and Vegetation Management Plan* (Revision 0) was submitted to OEPA in November 2019. The Plan was approved by OEPA on 04 February 2020 (OEPA Ref: DWERA-000999).
1054:M6-7	**Flora and Vegetation Management**	The proponent shall implement the latest revision of the Condition Environmental Management Plan, which the CEO has confirmed by notice in writing, satisfies the requirements of condition 6-3.	Implementation of the Condition Environmental Management Plan	Ongoing monitoring has been conducted since acquiring of the Koolyanobbing operations. Monitoring reports as per condition 6-2 are attached. Yilgarn Iron Ore Project *Tetratheca erubescens* Two	Construction, Operation	Ongoing	C	The *Yilgarn Operations - Koolyanobbing Range F Deposit – Flora and Vegetation Management Plan* (Revision 0) was submitted to OEPA in November 2019. The Plan was approved by OEPA on 04 February 2020 (OEPA Ref: DWERA-000999). The Plan has continued to be formally implemented since the all remaining iron ore at the Yilgarn operations, fixed plant, equipment and non-process

Audit Code	Subject	Requirement	How	Evidence	Phase	Timeframe	Status	Further Information
				Monthly Monitoring Summary Report 2018 (Revision 0) (See Attachment 5) Koolyanobbing F Deposit 2019 Annual Priority Flora and Vegetation Monitoring November 2018 Report (Revision 0) (See attachment 6) Annual *Tetratheca erubescens* Monitoring November 2019 (Revision 0) (See Attachment 7)				infrastructure assets were transferred to the wholly owned MRL subsidiary Yilgarn Iron Pty Ltd (YIPL) in August 2018.
1054:M7-1	**F3 Pit Wall Stability and Abandonment Bunding**	The proponent shall design and operate the F3 pit, as shown in Figure 3 in Schedule 1, to ensure stability of the southern pit wall during mining and post closure so that the *Tetratheca erubescens* plants adjacent to the southern pit wall, as shown in Figure 3 in Schedule 1, are not adversely impacted.	Design and operation of the F3 Pit southern wall to ensure stability	Southern pit wall is stable during mining and post closure with adjacent *Tetratheca erubescens* not adversely impacted	Construction, Operation, Decommissioning	Ongoing during mining and post mine closure of the F3 Pit	C	The approved *Geotechnical Management Plan: F Pit Development* directs the design, operation and monitoring of F3 pit during mining and for post closure long term stability. In summary, investigations and assessment prior to and during mining have confirmed originally interpreted rock mass conditions including structural conditions (defect distributions), rock type, rock strength and hydrogeological conditions. YIPL continues to operate the F3 pit according to the design identified in Figure 3 in Schedule 1 in order to ensure the stability of the southern pit wall and adjacent *Tetratheca erubescens* not adversely impacted. See Attachment 8: Technical Memorandum, Mineral Resources, Iron Resources, Geotechnical Review Koolyanobbing, Windarling, Deception, Mt Jackson, November 2019. Peter O'Brian and Associates
1054:M7-2	**F3 Pit Wall Stability and Abandonment Bunding**	The Factor of Safety for the final southern wall of the F3 pit, as shown in Figure 3 in Schedule 1, to be no less than 2.	Design of the F3 Pit southern wall to have Factor of Safety of 2	Design of the F3 Pit southern wall to have Factor of Safety of 2	Pre-construction, Construction, Operation	Ongoing during mining of the F3 Pit	C	In 2019, Peter O'Bryan & Associates were commissioned to undertake geotechnical re-assessment of the Yilgarn Operations. Assessment of the F3 pit wall identified that stability conditions are generally good and meet the requirements of condition 7-2. Refer to section 1.4 Technical Memorandum Iron Resources Koolyanobbing Geotechnical Review, Peter O'Bryan and Associates, January 2019 submitted with this CAR. See Attachment 8: Technical Memorandum, Mineral Resources, Iron Resources, Geotechnical Review Koolyanobbing, Windarling, Deception, Mt Jackson, November 2019. Peter O'Brian and Associates
1054:M7-3	**F3 Pit Wall Stability and Abandonment Bunding**	The final separation distance between the edge of the southern wall of the F3 pit and the adjacent development envelope as shown in Figure 3 in Schedule 1, is to be a minimum of 20 metres.	Design of the F3 Pit southern wall to have a 20m separation distance	Design of the F3 Pit southern wall to have a 20m separation distance	Pre-construction, Construction, Operation	Ongoing during mining of the F3 Pit	C	The final separation distance between the southern wall edge of the F3 pit and the adjacent development envelope is greater than 20 metres along its length. See Attachment 9: Final separation distance F3.

Audit Code	Subject	Requirement	How	Evidence	Phase	Timeframe	Status	Further Information
1054:M7-4	**F3 Pit Wall Stability and Abandonment Bunding**	The final pit wall along the southern side of the F3 pit is to be established by means of a cut-back operation of a full 18 metre height batter along 150 metres of strike.	Development of the F3 Pit final southern wall by a cut-back of 18 metre height batter along 150 metres of strike	Development of the F3 Pit final southern wall by a cut-back of 18 metre height batter along 150 metres of strike	Construction, Operation	Ongoing during mining of the F3 Pit	C	The approved *Geotechnical Management Plan: F Pit Development* directs the design, operation and monitoring of F3 pit during mining and for post closure long term stability. See Attachment 8: Technical Memorandum, Mineral Resources, Iron Resources, Geotechnical Review Koolyanobbing, Windarling, Deception, Mt Jackson, November 2019. Peter O'Brian and Associates
1054:M7-5	**F3 Pit Wall Stability and Abandonment Bunding**	During operations rock strength parameters and geotechnical data to be obtained from a deep hole drilled in close proximity to the F3 pit wall. This data to be used to verify assumptions made relating to rock strength parameters, geotechnical data and early analysis, structural data and early analysis and results from the initial rock tests conducted.	Rock strength parameters and geotechnical data obtained from a deep hole drilled in close proximity to the F3 pit wall, geotechnical data and early analysis, structural data and early analysis and results from the initial rock tests conducted	Analysis of rock strength parameters and geotechnical data to verify assumptions made relating to rock strength parameters, geotechnical data and early analysis, structural data and early analysis and results from the initial rock tests conducted	Construction, Operation	Ongoing during mining of the F3 Pit	C	Borehole P17GT001 was drilled in close proximity to the F3 pit wall. Data obtained from Borehole P17GT001 was interpreted and presented by Peter O'Bryan & Associates in *Technical Memorandum - F Deposit Pit 3 Additional Geotechnical Investigation Borehole P17GT001*. The information obtained from Borehole P17GT001 endorses interpretations and inferences made with respect to rock strength, rock mass strength and structural geological conditions derived from initial investigations.
1054:M7-6	**F3 Pit Wall Stability and Abandonment Bunding**	Prior to ground disturbing activities, prepare and submit a Stability Monitoring Program to the satisfaction of the DMP, and submit to the CEO. The Program shall include: (1) routine geotechnical and geological mapping and data interpretation for each established batter along the southern F3 pit wall and continuous slope stability monitoring of the southern F3 pit wall; and (2) vibration monitoring and measurements for each pit firing.	Prepare and submit a Stability Monitoring Program to the satisfaction of the DMP, and submit to the CEO	Stability Monitoring Program prepared and submitted to the satisfaction of the DMP, and submit to the CEO	Pre-construction	Prior to ground disturbing activities	C	The *Geotechnical Management Plan: F Pit Development* (which includes the detail of the F3 pit wall Stability Monitoring Program) was submitted to and approved by the then Department of Mines and Petroleum (DMP) 17 February 2017. The Plan was subsequently submitted to OEPA 17 February 2017. OEPA confirmed that they were satisfied that the Plan met the requirements of Condition 7-6 including the blast vibration limits. The Plan has continued to be implemented since commencement of F Deposit mining activity. Ongoing collection of geotechnical and mapping data has been confirmed by the independent re-assessment undertaken by Peter O'Bryan & Associates See Attachment 8: Technical Memorandum, Mineral Resources, Iron Resources, Geotechnical Review Koolyanobbing, Windarling, Deception, Mt Jackson, November 2019. Peter O'Brian and Associates

Audit Code	Subject	Requirement	How	Evidence	Phase	Timeframe	Status	Further Information
1054:M7-7	**F3 Pit Wall Stability and Abandonment Bunding**	Ground vibrations along the southern edge of the F3 pit adjacent to the development envelope are not to exceed the following specifications in Table 1 and be included in the Stability Monitoring Program required by condition 7-6. Table 1. Blast Vibration Limits Blast Frequency — Vibration PPV Limit No blast greater than — No blast greater than 10 mm/sec 90% of the blasts per year — 5 mm/sec 9 out of 10 consecutive blasts less than — 5 mm/sec	Management of blasting during mining operations to ensure blast vibration limits identified by Table 1 are achieved	Vibration monitoring results	Construction, Operation	Ongoing during mining of the F3 Pit	NC	During the reporting period MRL identified five non-compliances with the condition 7-7. Upon identification, an internal investigation commenced. Contingency actions have been developed and implemented to prevent future non-compliance. Stability conditions of F3 highwall currently is fundamentally good and absent of signs of development of significant instability. See Attachment 4 - MS1054 Non- Compliance notification letter and F3 Pit Vibration Investigation (Revision 0) Full details of blasting schedule and vibration monitoring results are included with this CAR as Attachment 10 – 2019 F Deposit F3 Pit Vibration Monitoring Report (Revision 0)
1054:M7-8	**F3 Pit Wall Stability and Abandonment Bunding**	Implement the Stability Monitoring Program required by condition 7-6.	Implement the Stability Monitoring Program	Geotechnical and geological mapping and data interpretation, slope stability monitoring results, vibration monitoring results	Construction, Operation	Ongoing during mining of the F3 Pit	C	The Plan has continued to be implemented since commencement of F Deposit mining activity. Ongoing collection of geotechnical and mapping data has been confirmed by the independent re-assessment undertaken by Peter O'Bryan & Associates See Attachment 8 - Technical Memorandum, Mineral Resources, Iron Resources, Geotechnical Review Koolyanobbing, Windarling, Deception, Mt Jackson, November 2019. Peter O'Brian and Associates
1054:M7-9	**F3 Pit Wall Stability and Abandonment Bunding**	Prepare and submit a Stability Monitoring Report in consultation with the DMP, and submit to the CEO with the Compliance Assessment Report required by condition 4-6.	Prepare and submit a Stability Monitoring Report in consultation with the DMP, and submit to the CEO	Stability Monitoring Report prepared in consultation with the DMP, and submitted to the CEO	Construction, Operation	30th April (annually) during mining of the F3 Pit	C	Refer to section 2.1 Technical Memorandum, Mineral Resources, Iron Resources, Geotechnical Review Koolyanobbing, Windarling, Deception, Mt Jackson, November 2019. Peter O'Brian and Associates See Attachment 8 - Technical Memorandum, Mineral Resources, Iron Resources, Geotechnical Review Koolyanobbing, Windarling, Deception, Mt Jackson, November 2019. Peter O'Brian and Associates
1054:M7-10	**F3 Pit Wall Stability and Abandonment Bunding**	In the event that stability monitoring required by condition 7-7 and 7-8 and/or the report required by condition 7-9 indicates instability of the pit wall, the proponent shall immediately: (1) investigate to determine the reason(s) for such findings; (2) implement contingency management actions and changes to proposal activities, on advice of the DMP; and (3) advise the CEO within seven (7) days.	Investigate pit wall instability findings, implement contingency actions and report to CEO, if required	Investigate pit wall instability findings, implement contingency actions and report to CEO, if required	Construction, Operation	Ongoing during mining of the F3 Pit, if required, with reporting to the CEO within 7 days of instability being identified	C	In 2019, Peter O'Bryan & Associates were commissioned to undertake geotechnical re-assessment of the Yilgarn Operations. Assessment of the F3 pit wall identified that stability conditions are generally good and meet the requirements of condition 7-8. Refer to section 2.1.1 Technical Memorandum Iron Resources Koolyanobbing Geotechnical Review, Peter O'Bryan and Associates, November 2019 submitted with this CAR. See Attachment 8 - Technical Memorandum, Mineral Resources, Iron Resources, Geotechnical Review Koolyanobbing, Windarling, Deception, Mt Jackson, November 2019. Peter O'Brian and Associates
1054:M7-11	**F3 Pit Wall Stability and Abandonment Bunding**	Post mining safety abandonment bunding and windrows to be installed at locations which ensure that the outcomes in condition 6-1 are met.	Design of abandonment bunding and/or windrows at each Mine Pit to not impact flora and vegetation beyond Proposal area	Design of abandonment bunding and windrows to not impact flora and vegetation beyond Proposal area	Operation, Decommissioning	During mining and post-mining of each Mine Pit.	NR	Abandonment bunding requirements and provisions are being progressively incorporated through mine closure planning and developed plans.

Audit Code	Subject	Requirement	How	Evidence	Phase	Timeframe	Status	Further Information
1054:M7-12	**F3 Pit Wall Stability and Abandonment Bunding**	Six (6) months prior to closure, the proponent shall prepare and submit an independent peer reviewed Close Out Report to the satisfaction of the CEO, on advice of the DMP, to demonstrate that condition 7-1 can be met. The Close Out Report is to be based on the analysis of Stability Monitoring Reports required by condition 7-9 and implementation of any contingency management actions and changes to proposal activities required by condition 7-10. In the event that the analysis indicates that condition 7-1 may not be met, identify additional contingency management actions and changes to proposal activities within the Close Out Report.	Prepare and submit an independent peer reviewed Close Out Report to the satisfaction of the CEO, on advice of the DMP	Close Out Report prepared and submitted to the satisfaction of the CEO, on advice of the DMP	Operation	6 months prior to mine closure	NR	
1054:M7-13	**F3 Pit Wall Stability and Abandonment Bunding**	The proponent shall implement any additional contingency management actions and changes to proposal activities identified in the Close Out Report required in condition 7-12, until the CEO has confirmed by notice in writing, satisfies the requirements of condition 7-1.	Implement actions or changes identified in the Close Out Report, if required	Actions or changes identified in the Close Out Report, if required, are implemented to the satisfaction of the CEO	Operation, Decommissioning	During mining and post-mining of the F3 Pit	NR	
1054:M8-1	**Stage 1 Offsets**	The proponent shall provide an offset to counterbalance the significant residual impact on *Tetratheca erubescens* as a result of implementation of Stage 1 of the proposal, as defined in Table 2 of Schedule 1 and delineated by coordinates in Schedule 2.	Provide an offset to counterbalance the effect to *Tetratheca erubescens* from Stage 1 mining in accordance with Condition 8-2	Provide an offset as outlined within the Stage 1 *Tetratheca erubescens* Offset Plan	Pre-construction	Prior to ground disturbing activities that impact *Tetratheca erubescens*	C	The *Koolyanobbing Range F Deposit, Stage 1* Tetratheca erubescens Offsets Plan, August 2017, (Revision 0) was approved on 16 August 2017 (Ref: AC05-2017-0006, DWERDA-003235).
1054:M8-2	**Stage 1 Offsets**	Prior to commencement of any ground-disturbing activities that impact *Tetratheca erubescens*, or as unless otherwise agreed by the CEO, the proponent shall prepare and submit a Stage 1 *Tetratheca erubescens* Offset Plan to the satisfaction of the CEO on advice of Parks and Wildlife, as described in conditions 8-3 to the CEO. The objectives of the Stage 1 *Tetratheca erubescens* Offset Plan are to: (1) determine the methods to support translocation of *Tetratheca erubescens*; and (2) establish a new self-sustaining population of at least 313 mature individuals of *Tetratheca erubescens* on suitable landform that is suitable for the species.	Prepare and submit a Stage 1 *Tetratheca erubescens* Offset Plan to the satisfaction of the CEO	Stage 1 *Tetratheca erubescens* Offset Plan prepared and submitted to the satisfaction of the CEO	Pre-construction	Prior to ground disturbing activities that impact *Tetratheca erubescens*	C	The *Koolyanobbing Range F Deposit, Stage 1* Tetratheca erubescens Offsets Plan, August 2017, (Revision 0) was approved on 16 August 2017 (Ref: AC05-2017-0006, DWERDA-003235).
1054:M8-3	**Stage 1 Offsets**	The Stage 1 *Tetratheca erubescens* Offset Plan shall include, but not be limited to, the following: (1) develop a research program to identify methods to translocate and establish *Tetratheca erubescens* in the field. The outcomes of the research program are to be provided to the CEO and Parks and Wildlife; (2) detail the plant material to be used for translocation, to promote the viability of the species, on advice of Parks and Wildlife; (3) identify and map suitable translocation sites agreed to by Parks and Wildlife, and provide a scientifically robust analysis of the habitat requirements of the species; (4) identify the number of mature plants that each translocation site could support; (5) identify the area of translocation sites within which new plants will be established, in relation to the area of occupancy for the species impacted by implementation of the proposal; (6) describe the ongoing protection measures afforded to the translocated plants from threats including, but not limited	Prepare and submit a Stage 1 *Tetratheca erubescens* Offset Plan to the satisfaction of the CEO	Stage 1 *Tetratheca erubescens* Offset Plan prepared and submitted to the satisfaction of the CEO	Pre-construction	Prior to ground disturbing activities	C	The *Koolyanobbing Range F Deposit, Stage 1* Tetratheca erubescens Offsets Plan, August 2017, (Revision 0) was approved on 16 August 2017 (Ref: AC05-2017-0006, DWERDA-003235).

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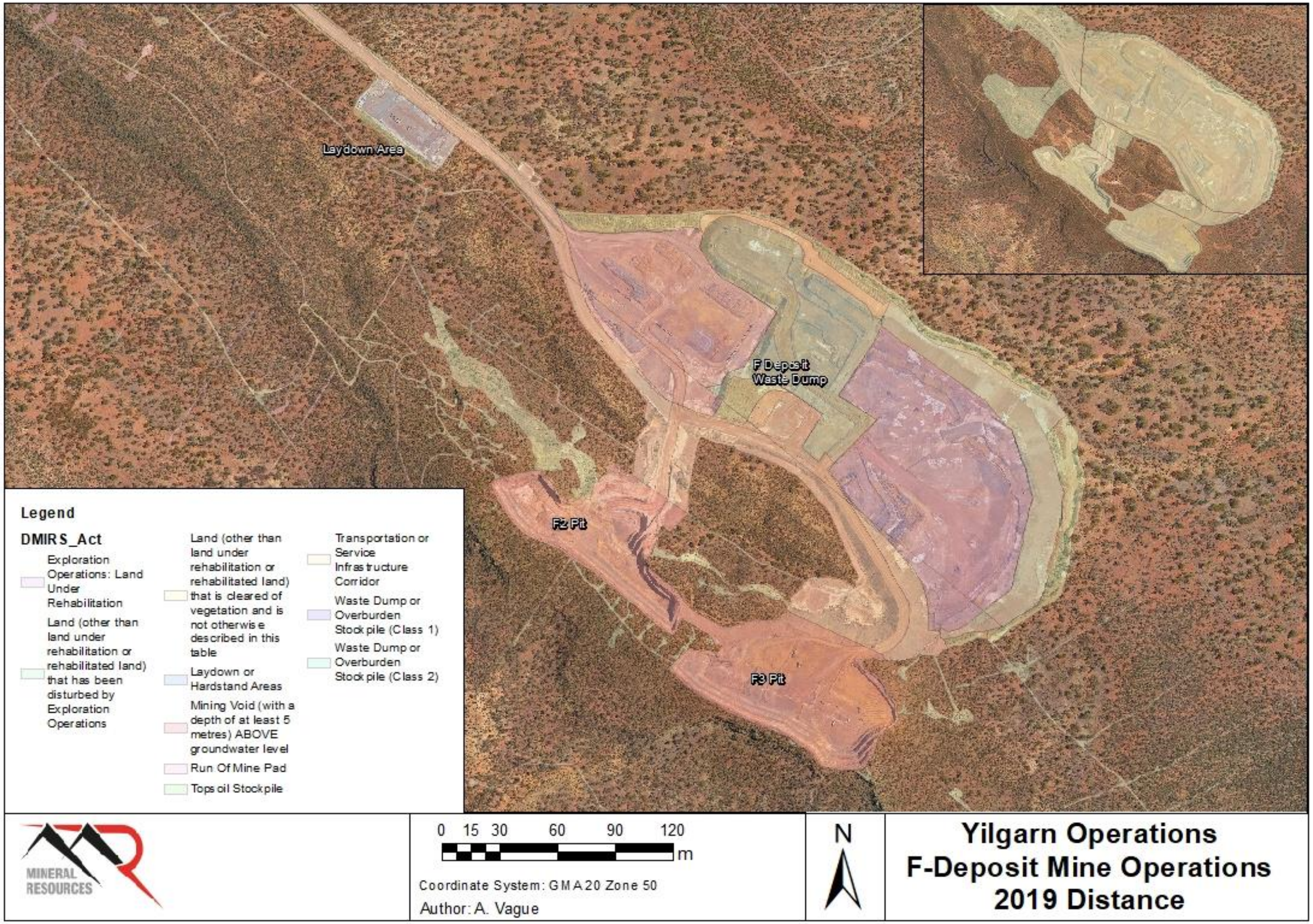
		to, fire, grazing and the proponent's future exploration and mining; (7) identify success criteria to demonstrate that the translocated plants have established, are in good health and reproducing, in consultation with Parks and Wildlife; (8) identify timeframes and responsibilities for implementation; (9) identify reporting procedures, including the content, format, timing and frequency for the reporting of monitoring data against the success criteria, in accordance with condition 8-3; (10) identify management and contingency measures should success criteria not be met, on advice of Parks and Wildlife; and (11) identify any ongoing management requirements for the translocation sites post completion of the plan.						
1054:M8-4	**Stage 1 Offsets**	After receiving notice in writing from the CEO that the Stage 1 *Tetratheca erubescens* Offset Plan satisfies the requirements of condition 8-3, prior to the commencement of ground disturbing activities that impact *Tetratheca erubescens*, unless otherwise agreed by the CEO, the proponent shall: (1) implement the Stage 1 *Tetratheca erubescens* Offset Plan; and (2) continue to implement the Stage 1 *Tetratheca erubescens* Offset Plan until the CEO, on advice of Parks and Wildlife, has confirmed by notice in writing that it has been demonstrated that the outcome in condition 8-1 has been met.	Implement the Stage 1 *Tetratheca erubescens* Offset Plan	Implement the Stage 1 *Tetratheca erubescens* Offset Plan	Construction, Operation, Decommissioning	Ongoing	C	The *Koolyanobbing Range F Deposit, Stage 1* Tetratheca erubescens *Offsets Plan,* August 2017, (Revision 0) was approved on 16 August 2017 (Ref: AC05-2017-0006, DWERDA-003235). YIPL will continue to implement this plan until it has met outcomes set out in condition 8.1
1054:M8-5	**Stage 1 Offsets**	The proponent shall monitor the success of implementation of the Stage 1 *Tetratheca erubescens* Offset Plan required by condition 8-2 and provide a written report, including monitoring data, to the CEO and Parks and Wildlife every twelve (12) months on the progress of this implementation of the Stage 1 *Tetratheca erubescens* Offset Plan until success criteria have been met. The first report must be submitted within fifteen (15) months of receiving the notice under condition 8-4.	Monitor the outcomes of the Stage 1 *Tetratheca erubescens* Offset Plan and provide a written report to the CEO and Parks and Wildlife	Written report to the CEO and Parks and Wildlife	Construction, Operation, Decommissioning	Submit written report within 15 months of approval of the Stage 1 *Tetratheca erubescens* Offset Plan, then each 12 months after	C	Cliffs and Botanic Gardens and Parks Authority have implemented the research and translocation trials as outlined in the Plan. YIPL has continued to implement this plan through its continued collaboration with Botanic Gardens and Parks Authority. The Tetratheca erubescens Translocation Annual Research Report 2 is submitted as evidence of implementation of this Plan and is in line with compliance reporting requirements. See Attachment 11 - Botanic Gardens and Parks Authority *Tetratheca erubescens Translocation Annual Research Report 2* (2020) (Revision O)
1054:M8-6	**Stage 1 Offsets**	Should the outcome of the Stage 1 *Tetratheca erubescens* Offset Plan required by condition 8-2 not be achieved within ten (10) years from the approval of the Stage 1 *Tetratheca erubescens* Offset Plan, the proponent shall submit a revised Stage 1 *Tetratheca erubescens* Offset Plan to the satisfaction of the CEO on advice of Parks and Wildlife, outlining management strategies to achieve the outcome specified in condition 8-2. The revised plan must be submitted within three months of the ten (10) year period lapsing.	Submit a revised Stage 1 *Tetratheca erubescens* Offset Plan to the satisfaction of the CEO, if required	Stage 1 *Tetratheca erubescens* Offset Plan submitted to the satisfaction of the CEO, if required	Construction, Operation, Decommissioning	Within 10 years after approval of the Stage 1 *Tetratheca erubescens* Offset Plan, if required	NR	
1054:M8-7	**Stage 1 Offsets**	The proponent: (1) may review and revise the Stage 1 *Tetratheca erubescens* Offset Plan, or (2) shall review and revise the Stage 1 *Tetratheca erubescens* Offset Plan as and when directed by the CEO.	Review and revise the Stage 1 *Tetratheca erubescens* Offset Plan, if required	Reviewed/revised Stage 1 *Tetratheca erubescens* Offset Plan submitted to the satisfaction of the CEO, if required	Construction, Operation, Decommissioning	Ongoing, as may be required	NR	No revisions to the Plan were made during the reporting period.

Audit Code	Subject	Requirement	How	Evidence	Phase	Timeframe	Status	Further Information
1054:M8-8	**Stage 1 Offsets**	The proponent shall implement the latest revision of the Stage 1 *Tetratheca erubescens* Offset Plan, which the CEO, on advice of Parks and Wildlife, has confirmed by notice in writing, satisfies the requirements of condition 8-2.	Implement the Stage 1 *Tetratheca erubescens* Offset Plan to the satisfaction of the CEO	Stage 1 *Tetratheca erubescens* Offset Plan implemented to the satisfaction of the CEO	Construction, Operation, Decommissioning	Ongoing	C	The *Koolyanobbing Range F Deposit, Stage 1* Tetratheca erubescens Offsets Plan, August 2017, (Revision 0) was approved on 16 August 2017 (Ref: AC05-2017-0006, DWERDA-003235). YIPL has continued to implement the Plan. No revisions to the Plan were made during the reporting period.
1054:M9-1	**Access to Stage 2 Mining Area**	No ground disturbance may occur within the Stage 2 mining area as shown in Figure 3 in Schedule 1 and delineated by coordinates in Schedule 2 until: (1) the CEO on advice of Parks and Wildlife has confirmed by notice in writing that the proponent has demonstrated that the objectives in condition 8-2 have been met; and (2) the proponent has received notice in writing from the CEO that ground disturbance may occur within the Stage 2 mining area as shown in Figure 3 in Schedule 1 and delineated by coordinates in Schedule 2.	No ground disturbing activity within the Stage 2 mining area until Condition 8-2 has been met and the CEO has provided written notice that ground disturbance may occur	No ground disturbing activity within the Stage 2 mining area until Condition 8-2 has been met and the CEO has provided written notice that ground disturbance may occur	Construction, Operation	Ongoing	C	No ground disturbing activity has occurred within the Stage 2 mining area. YIPL approvals team are currently seeking to access the Stage 2 mining area during this CAR reporting period. YIPL is developing a Stage 2 Offsets plan in conjunction with Strategen.
1054:M10-1	**Stage 2 Offsets**	The proponent shall provide an offset to counterbalance the significant residual impact on *Tetratheca erubescens* as a result of implementation of Stage 2 of the proposal, as defined by Table 3 in Schedule 1 and delineated by coordinates in Schedule 2.	Provide an offset to counterbalance the effect to *Tetratheca erubescens* from Stage 2 mining in accordance with Condition 10-2	Provide an offset as outlined within the Stage 2 *Tetratheca erubescens* Offset Plan	Pre-construction (of Stage 2 mining area)	Prior to ground disturbing activities that impact *Tetratheca erubescens* within the Stage 2 mining area	NR	YIPL approvals team are currently seeking to access the Stage 2 mining area during this CAR reporting period. YIPL is developing a Stage 2 Offsets plan in conjunction with Strategen.
1054:M10-2	**Stage 2 Offsets**	Prior to commencement of any ground-disturbing activities within the Stage 2 mining area as shown in Figure 3 in Schedule 1, the proponent shall prepare and submit a Stage 2 *Tetratheca erubescens* Offset Plan, using the research and findings from the Stage 1 *Tetratheca erubescens* Offset Plan required under condition 8-2, to the satisfaction of the CEO on advice of Parks and Wildlife, as described in condition 10-3 to the CEO. The objective of the Stage 2 *Tetratheca erubescens* Offset Plan as defined in Table 3 in Schedule 2 is to: (1) establish a new self-sustaining population of at least 652 mature individuals of *Tetratheca erubescens* on landform that is suitable for the species.	Prepare and submit a Stage 2 *Tetratheca erubescens* Offset Plan to the satisfaction of the CEO	Stage 2 *Tetratheca erubescens* Offset Plan prepared and submitted to the satisfaction of the CEO	Pre-construction (of Stage 2 mining area)	Prior to ground disturbing activities that impact *Tetratheca erubescens* within the Stage 2 mining area	NR	YIPL approvals team are currently seeking to access the Stage 2 mining area during this CAR reporting period. YIPL is developing a Stage 2 Offsets plan in conjunction with Strategen.
1054:M10-3	**Stage 2 Offsets**	The Stage 2 *Tetratheca erubescens* Offset Plan shall specify the research and management actions to be undertaken to ensure the outcomes specified in condition 10-2 are met. The Stage 2 *Tetratheca erubescens* Offset Plan Shall include, but not be limited to, the following: (1) build on the research and findings from the Stage 1 *Tetratheca erubescens* Offset Plan; (2) detail the plant material to be used for translocation, to promote the viability of the species, on advice of Parks and Wildlife; (3) identify suitable translocation sites approved by the CEO on advice of Parks and Wildlife, and provide a scientifically robust analysis of the habitat requirements of the species; (4) identify the number of mature plants that each translocation site could support; (5) identify the area of translocation sites within which new plants will be established, in relation to the area of occupancy for the species impacted by implementation of the proposal;	Prepare and submit a Stage 2 *Tetratheca erubescens* Offset Plan to the satisfaction of the CEO	Stage 2 *Tetratheca erubescens* Offset Plan prepared and submitted to the satisfaction of the CEO	Pre-construction (of Stage 2 mining area)	Prior to ground disturbing activities that impact *Tetratheca erubescens* within the Stage 2 mining area	NR	YIPL approvals team are currently seeking to access the Stage 2 mining area during this CAR reporting period. YIPL is developing a Stage 2 Offsets plan in conjunction with Strategen.

Audit Code	Subject	Requirement	How	Evidence	Phase	Timeframe	Status	Further Information
		(6) describe the ongoing protection measures afforded to the translocated plants from threats including, but not limited to, fire, grazing and the proponent's future exploration and mining; (7) identify success criteria to demonstrate that the translocated plants have established, are in good health and reproducing, in consultation with Parks and Wildlife; (8) identify timeframes and responsibilities for implementation; (9) identify reporting procedures, including the content, format, timing and frequency for the reporting of monitoring data against the success criteria, in accordance with condition 10-3; (10) identify management and contingency measures should success criteria not be met, on advice of Parks and Wildlife; and (11) identify arrangements for the translocation sites post completion of the plan.						
1054:M10-4	**Stage 2 Offsets**	After receiving notice in writing from the CEO that the Stage 2 *Tetratheca erubescens* Offset Plan satisfies the requirements of condition 10-3, the proponent shall: (1) implement the research and management actions in accordance with the requirements of the Stage 2 *Tetratheca erubescens* Offset Plan; and (2) continue to implement the research and management actions in accordance with the requirements of the Stage 2 *Tetratheca erubescens* Offset Plan until the CEO on advice of Parks and Wildlife has confirmed by notice in writing that it has been demonstrated that the objective in condition 10-2 has been met.	Implement the Stage 2 *Tetratheca erubescens* Offset Plan	Implement the Stage 2 *Tetratheca erubescens* Offset Plan	Construction, Operation, Decommissioning	Ongoing	NR	Notice in writing from the CEO that the Stage 2 Tetratheca erubescens Offset Plan satisfies the requirements of condition 10-3, has not been granted.
1054:M10-5	**Stage 2 Offsets**	The proponent shall monitor the success of implementation of the Stage 2 *Tetratheca erubescens* Offset Plan required by condition 10-2 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 success criteria have been met. The first report must be submitted within fifteen (15) months of receiving the notice under condition 10-4.	Monitor the outcomes of the Stage 2 *Tetratheca erubescens* Offset Plan and provide a written report to the CEO and Parks and Wildlife	Written report to the CEO and Parks and Wildlife	Construction, Operation, Decommissioning	Submit written report within 15 months of approval of the Stage 2 *Tetratheca erubescens* Offset Plan, then each 12 months after	NR	Notice in writing from the CEO that the Stage 2 Tetratheca erubescens Offset Plan satisfies the requirements of condition 10-3, has not been granted
1054:M10-6	**Stage 2 Offsets**	Should the outcome of the Stage 2 *Tetratheca erubescens* Offset Plan required by condition 10-2 not be achieved within ten (10) years from implementation of the Plan, the proponent shall submit a revised Stage 2 *Tetratheca erubescens* Offset Plan to the satisfaction of the CEO on advice of Parks and Wildlife, outlining management strategies to achieve the outcome specified in condition 10-2. The revised plan must be submitted within three months of the ten (10) year period lapsing.	Submit a revised Stage 2 *Tetratheca erubescens* Offset Plan to the satisfaction of the CEO, if required	Stage 2 *Tetratheca erubescens* Offset Plan submitted to the satisfaction of the CEO, if required	Construction, Operation, Decommissioning	Within 10 years after approval of the Stage 2 *Tetratheca erubescens* Offset Plan, if required	NR	Notice in writing from the CEO that the Stage 2 Tetratheca erubescens Offset Plan satisfies the requirements of condition 10-3, has not been granted
1054:M10-7	**Stage 2 Offsets**	The proponent: (1) may review and revise the Stage 2 *Tetratheca erubescens* Offset Plan, or (2) shall review and revise the Stage 2 *Tetratheca erubescens* Offset Plan as and when directed by the CEO.	Review and revise the Stage 2 *Tetratheca erubescens* Offset Plan, if required	Reviewed/revised Stage 2 *Tetratheca erubescens* Offset Plan submitted to the satisfaction of the CEO, if required	Construction, Operation, Decommissioning	Ongoing, as may be required	NR	Notice in writing from the CEO that the Stage 2 Tetratheca erubescens Offset Plan satisfies the requirements of condition 10-3, has not been granted
1054:M10-8	**Stage 2 Offsets**	The proponent shall implement the latest revision of the Stage 2 *Tetratheca erubescens* Offset Plan, which the CEO, on advice of	Implement the Stage 2 *Tetratheca erubescens*	Stage 2 *Tetratheca erubescens* Offset Plan	Construction, Operation, Decommissioning	Ongoing	NR	Notice in writing from the CEO that the Stage 2 Tetratheca erubescens Offset Plan satisfies the requirements of condition 10-3, has not been granted

Audit Code	Subject	Requirement	How	Evidence	Phase	Timeframe	Status	Further Information
		Parks and Wildlife, has confirmed by notice in writing, satisfies the requirements of condition 10-3.	Offset Plan to the satisfaction of the CEO	implemented to the satisfaction of the CEO				
1054:M11-1	**Staging of Plans**	Where a plan, program, report, survey, strategy or other document is required by these conditions to be prepared, submitted or endorsed by the CEO, prior to commencement of an activity, the plan, program, report, survey, strategy or other document may be prepared, submitted and endorsed by the CEO as per the relevant condition requirements, for a component of, or stage of the proposal or activity, provided the implementation of that component or stage of the proposal does not make the condition obsolete insofar as it applies to the remaining components or stages of the proposal or activity.	Prepare and submit documentation in a component/staged approach as may be required	Prepare and submit documentation in a component/staged approach as may be required	Pre-construction, Construction, Operation, Decommissioning	Ongoing, as may be required	C	Relevant plans and documentation have been prepared and submitted for approval in a component/ staged approach as outlined below. The *Geotechnical Management Plan: F Pit Development* was submitted to OEPA February 2017. The *Koolyanobbing Range F Deposit, Stage 1* Tetratheca erubescens Offsets Plan, August 2017, (Revision 0) was approved on 16 August 2017 (Ref: AC05-2017-0006, DWERDA-003235). The *Koolyanobbing Range F Deposit, Stage 1* Tetratheca erubescens *Offsets Plan,* August 2017 (Revision 0) was submitted to DWER August 2017. The development, submission and implementation of these plans prior to commencement of any proposal component as required by the conditions of MS 1054, has not rendered any existing conditions obsolete insofar as they apply to the remaining components or stages of the proposal.
1054:M11-2	**Staging of Plans**	Condition 11-1 does not apply to conditions relating to the submission of environmental baseline surveys or environmental baseline reports.	Prepare and submit documentation in a component/staged approach, as may be required	Prepare and submit documentation in a component/staged approach, as may be required	Pre-construction, Construction, Operation, Decommissioning	Ongoing, as may be required	C	Relevant plans and documentation have been prepared and submitted for approval in a component/ staged approach. The *Geotechnical Management Plan: F Pit Development* approved by the then Department of Mines and Petroleum (DMP) and OEPA in February 2017. The *Koolyanobbing Range F Deposit, Stage 1* Tetratheca erubescens Offsets Plan, August 2017, (Revision 0) was approved on 16 August 2017 (Ref: AC05-2017-0006, DWERDA-003235). The *Koolyanobbing Range F Deposit, Stage 1* Tetratheca erubescens *Offsets Plan,* August 2017, (Revision 0) was approved on 16 August 2017 (Ref: AC05-2017-0006, DWERDA-003235).

Attachment 3: Yilgarn Operations Koolyanobbing Range Mine Operations 2019 Clearing



Attachment 4: DWER Resolution of Non-Compliance Letter

Government of **Western Australia**
Department of **Water and Environmental Regulation**

Your ref: Ministerial Statement 1054
Our ref: DWERA-000306
Enquiries: Jaala Ayliffe, Ph 6364 6743

Mr Tim Berryman
General Manager - Technical Services
Yilgarn Iron Pty Ltd
1 Sleat Road
APPLECROSS WA 6153

Dear Mr Berryman

STATEMENT 1054 – YILGARN OPERATIONS, KOOLYANOBBING RANGE F DEPOSIT – RESOLUTION OF NON-COMPLIANCE

Thank you for your response dated 17 January 2020 and 21 February 2020 to the Notice of Non-Compliance (NoNC) issued by the Department of Water and Environmental Regulation (the department) on 18 December 2019.

Resolution of non-compliance:
Following the department's site visit conducted on 29 January 2020, it has been determined that YIPL has satisfactorily completed the actions required to address the identified non-compliance, as detailed below:

Item (1) – On 17 January 2020, YIPL provided documentation regarding revised blast vibration mitigation measures being implemented by YIPL in the F3 Pit. The department has found these mitigation measures to be satisfactory and YIPL has demonstrated compliance can be achieved under Condition 7-7.

However, the department requests that YIPL provide blast vibration results, as measured under Condition 7-7, on a fortnightly basis to compliance@dwer.wa.gov.au, allowing the department timely oversight of the blast vibration results. Results are to be provided for the F3 Pit until blasting operations cease.

Item (2) – On 21 February 2020, YIPL submitted the "MRL (2020) Koolyanobbing F Deposit *Tetratheca erubescens* Monitoring Plot 11 Assessment" which provided a summary of historical monitoring results of the *Tetratheca erubescens* population at Plot 11 where the rockfall occurred.

The department has reviewed the report and has found it to be satisfactory in meeting the requirements of Item 2 of the NoNC.

YIPL is required to continue its monitoring in accordance with Condition 6 of the Statement and the approved Condition Environmental Management Plan.

Item (3) – On 21 February 2020, YIPL submitted the "Peter O'Bryan & Associates (2020) F Deposit Natural Scarp Stability Technical Memorandum" which assessed the stability of the F3 Pit southern scarp.

The department has reviewed the report and has found it to be satisfactory in meeting the requirements of Item 3 of the NoNC.

The department notes that blasting within the F3 pit is due to be completed in May 2020.

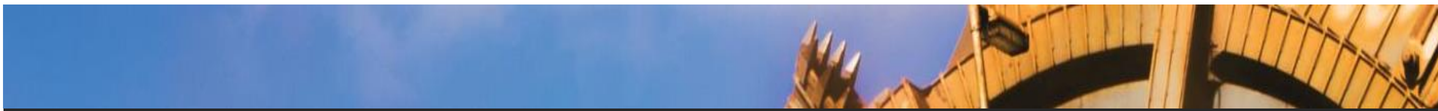
The department considers the non-compliance to be resolved. Thank you for your cooperation in achieving this resolution in a timely fashion.

Yours sincerely

Stuart Cowie
Executive Director
Compliance and Enforcement
for the Chief Executive Officer
under Notice of Delegation date 3 July 2017

27 / 02 / 2020

Attachment 5: MRL (2019) Yilgarn Iron Ore Project *Tetratheca erubescens* Two Monthly Monitoring Summary Report 2019 (Revision 0)



Yilgarn Iron Ore Project

Tetratheca erubescens TWO MONTHLY MONITORING SUMMARY REPORT 2019

Proponent:	Yilgarn Iron Pty Ltd
Address:	1 Sleat Road, Applecross, WA 6153
Postal Address:	Locked Bag 3, Canning Bridge LPO, Applecross, WA 6153
Corporate contact:	Tim Berryman
Phone:	+61 8 9329 3713
	timothy.berryman@mrl.com.au

Report Reference: ENV-TS-RP-0219

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1 Introduction

In 2018 Mineral Resources Limited (MRL) acquired Cliffs Asia Pacific Iron Ore Pty Ltd.'s (Cliffs) Yilgarn Operations. This includes the mining of iron ore from open cut mines at the Koolyanobbing Range, Mt Jackson Range, Windarling Range and Deception, ore processing at Koolyanobbing, road and rail transport between these operations and the Port of Esperance where the processed ore is exported to international customers.

Tetratheca erubescens is a small shrub declared as threatened under the *Wildlife Conservation Act 1950* (WA) and only recorded at the southern Koolyanobbing Range. A census in 2013 estimated the population of *T. erubescens* within the Koolyanobbing Range at approximately 6,333 (6,202 live) individuals (Maia 2013). The current recorded distribution of *T. erubescens* is identified in **Figure 2.1**.

In January 2017, Cliffs received approval under the *Environmental Protection Act 1986* to implement the F deposit mine proposal (Minister for the Environment and Heritage 2017). Under this approval, Cliffs were required to develop and implement a Condition Environmental Management Plan to the satisfaction of the CEO. This document was approved by the CEO in June 2017 (Cliffs 2017).

MRL continues to the implement the approved F Deposit Flora and Vegetation Management Plan (FVMP) which includes a monitoring programme developed to assess the stability and condition of the *Tetratheca erubescens* population at defined monitoring plots along the southern Koolyanobbing Range.

The F Deposit Flora and Vegetation Management Plan outlines provisions to address indirect impacts on native flora and vegetation (including *Tetratheca erubescens*) including, but not limited to, dust, weeds and fire. The plan identifies trigger and threshold criteria that when exceeded will initiate the implementation of management actions to address any potential impacts on the population.

The FVMP states that for *Tetratheca erubescens*, the trigger criterion will be met when "Monitoring indicates a statistically significant relationship between condition (Index of Chlorophyll Fluorescence (ICF) and/or % live material) and dust deposition, distance from the proposal boundary or mine-related factor."

The threshold criteria for *Tetratheca erubescens* include:

- Monitoring of *Tetratheca erubescens* indicates a statistically significant relationship between mortality and dust deposition, distance from the proposal boundary or mine-related causal factor.
- Monitoring of *Tetratheca erubescens* indicates a statistically significant relationship between condition (ICF and/or % live material) and dust deposition, distance from the proposal boundary or mine-related causal factor for two consecutive two-monthly monitoring dates in year 1 or two consecutive quarterly monitoring dates in year 2.
- For dust deposition, the trigger criterion is "Dust deposition at any (non-reference) dust monitoring site exceeds 80g/m2/month (Sa) during the first 12 months from commencement of mining; 40g/m2/month (Sa) after 12 months from commencement of mining." There is no threshold criterion for dust deposition.

This report documents and discusses the results of monitoring from January to November 2019 and against data from monitoring that was conducted prior to ground disturbing activities in the F-Deposit area. The statistical tool is then used to compare these results against the trigger and threshold criteria.

2 Methodology

2.1 Monitoring Design

Cliffs, in consultation with the then Department of Parks and Wildlife (DPaW), Office of the Environmental Protection Authority (OEPA) and Data Analysis Australia (DAA), designed a monitoring program to identify any adverse effects to the *Tetratheca erubescens* population as a result of mining activities (including dust deposition).

2.2 Initial Monitoring

In October 2016, 15 *Tetratheca erubescens* individuals were randomly selected for monitoring in each of the 11 monitoring plots. Each plant was tagged with a unique identification number. The identification number was glued onto the rock surface as close as possible to the *T. erubescens* individual. The following information was recorded for each individual:

- Plot number
- Unique plant identification number
- Presence of flowers/fruits/buds
- Presence of soft tips (indicating new growth)
- Plant Status (Reproductive, Vegetative, Juvenile (1-3years old) or Seedling (<1-year-old)
- Condition Assessment (percentage of plant alive)
- Percentage of plant with dust (grouped into categories as shown in Table 2.1

Table 2.1: Dust categories and their description

Dust Category	Description
0	No visible dust
1	1-25% of plant covered with dust
2	25-50% of plant covered with dust
3	51-75% of plant covered with dust
4	76-100% of plant covered with dust

In November 2016, an additional plot (plot 26) including 15 *Tetratheca erubescens* individuals was added to the monitoring program. During the November 2016 monitoring, chlorophyll fluorescence (Fv/Fm) was also added as a monitoring parameter. Each individual had an index of chlorophyll fluorescence measurement taken using a plant efficiency analyser (pocket PEA) unit. Using information gained from fluorescence measurements, samples may be screened effectively for particular types of stress factors which limit the photosynthetic performance of the sample (Hansatech 2006). A clip was attached to a live stem of each *Tetratheca erubescens* individual, with the stem subsequently dark adapted. An index of chlorophyll fluorescence was then measured with the PEA unit and recorded on the data sheet.

A further plot (plot 13) including 15 *Tetratheca erubescens* individuals was included in the monitoring program from December 2016. Monitoring was conducted monthly from December 2016 to March 2017. Additional *Tetratheca erubescens* individuals were included in monitoring plots 7, 9, 11, 13 and 14 during May 2017.

2.3 Current Monitoring

Since May 2017, a total of 251 individuals have been monitored on a two-monthly basis using the following parameters:

- Presence of flowers/fruits/buds
- Presence of soft tips (indicating new growth)
- Plant Status (Reproductive, Vegetative, Juvenile (1-3years old) or Seedling (<1-year-old)
- Condition Assessment (percentage of plant alive)
- Chlorophyll Fluorescence value (Fv/Fm)
- Percentage of plant with dust (grouped into categories as shown in Table 2.1)

Table 2.2 shows the number of individuals monitored per plot and their distance from the mine pit boundary, whilst the location of each monitoring plot in relation to F pit is shown in Figure 2.1.

The results from May 2017, therefore represent the first complete monitoring dataset and can be assumed to be natural results (as mining was commencing at the same time and indirect effects would not yet have occurred).

Table 2.2: Number of individuals monitored per plot and their distance from mine boundary

Distance from boundary	Plot Number													Total
	3	5	7	9	10	11	13	14	16	18	21	25	26	
<20m			19	13		14	21	15						82
20-50m			6	12		13	6	12						49
>50m	15	15			15				15	15	15	15	15	120
Plot totals	**15**	**15**	**25**	**25**	**15**	**27**	**27**	**27**	**15**	**15**	**15**	**15**	**15**	**251**

2.3.1 Dust Deposition Gauge Monitoring

Dust deposition gauges have been established at each monitoring plot and two control locations at F Deposit, as shown in Figure 2.2

2.3.2 Statistical Analysis

Data Analysis Australia (DAA) was engaged to design data analysis tools to test for significant changes in chlorophyll fluorescence, condition assessment and mortality for *Tetratheca erubescens.* The tool was finalised in January 2018 in accordance with the parameters outlined in the F Deposit Flora and Vegetation Management Plan (MRL 2019) to enable routine analysis of the monitoring data after each monitoring event.

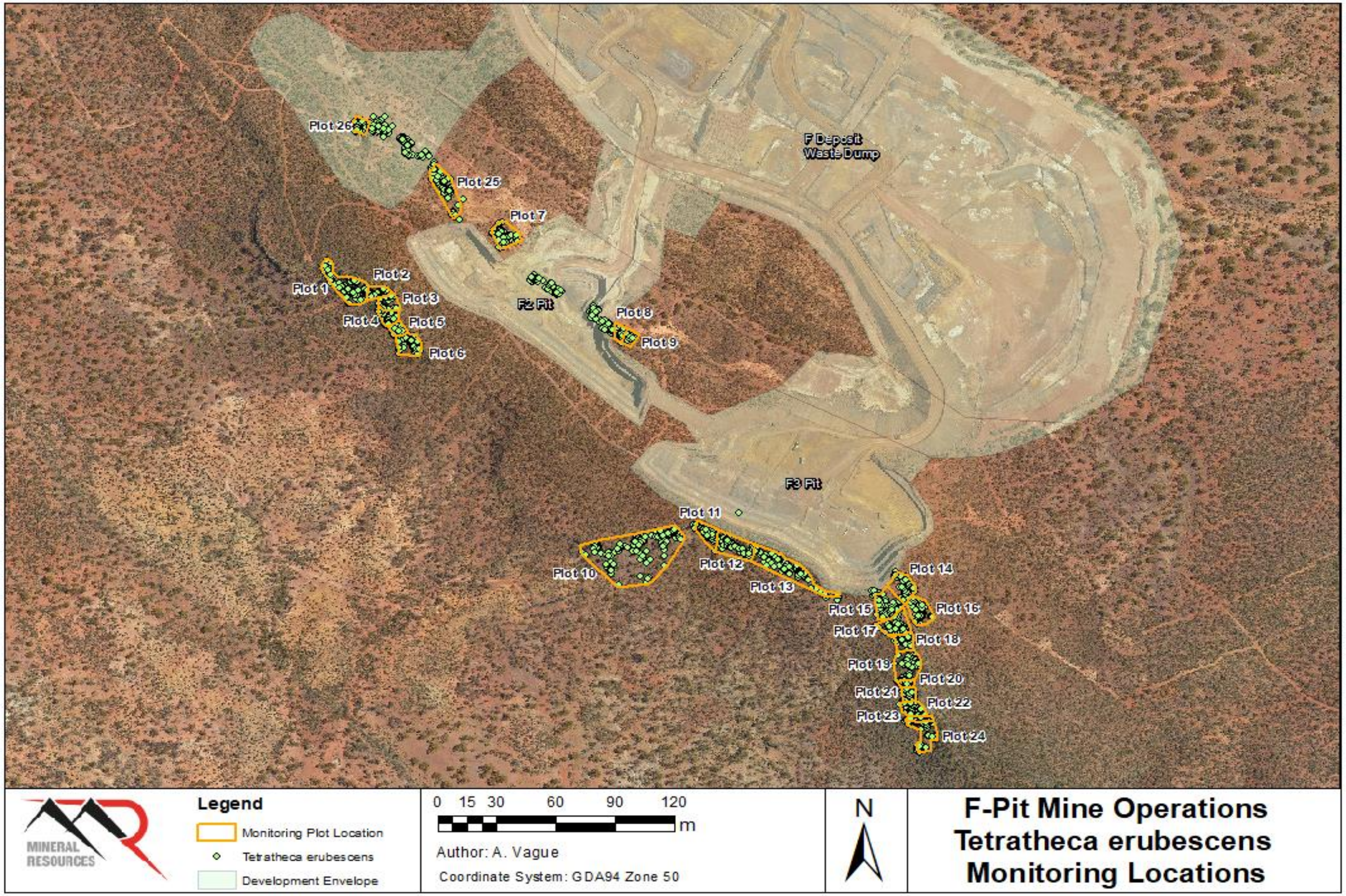

Figure 2.1: Location of Tetratheca erubescens and monitoring plots at Koolyanobbing. (The monitored plots are highlighted in orange.)

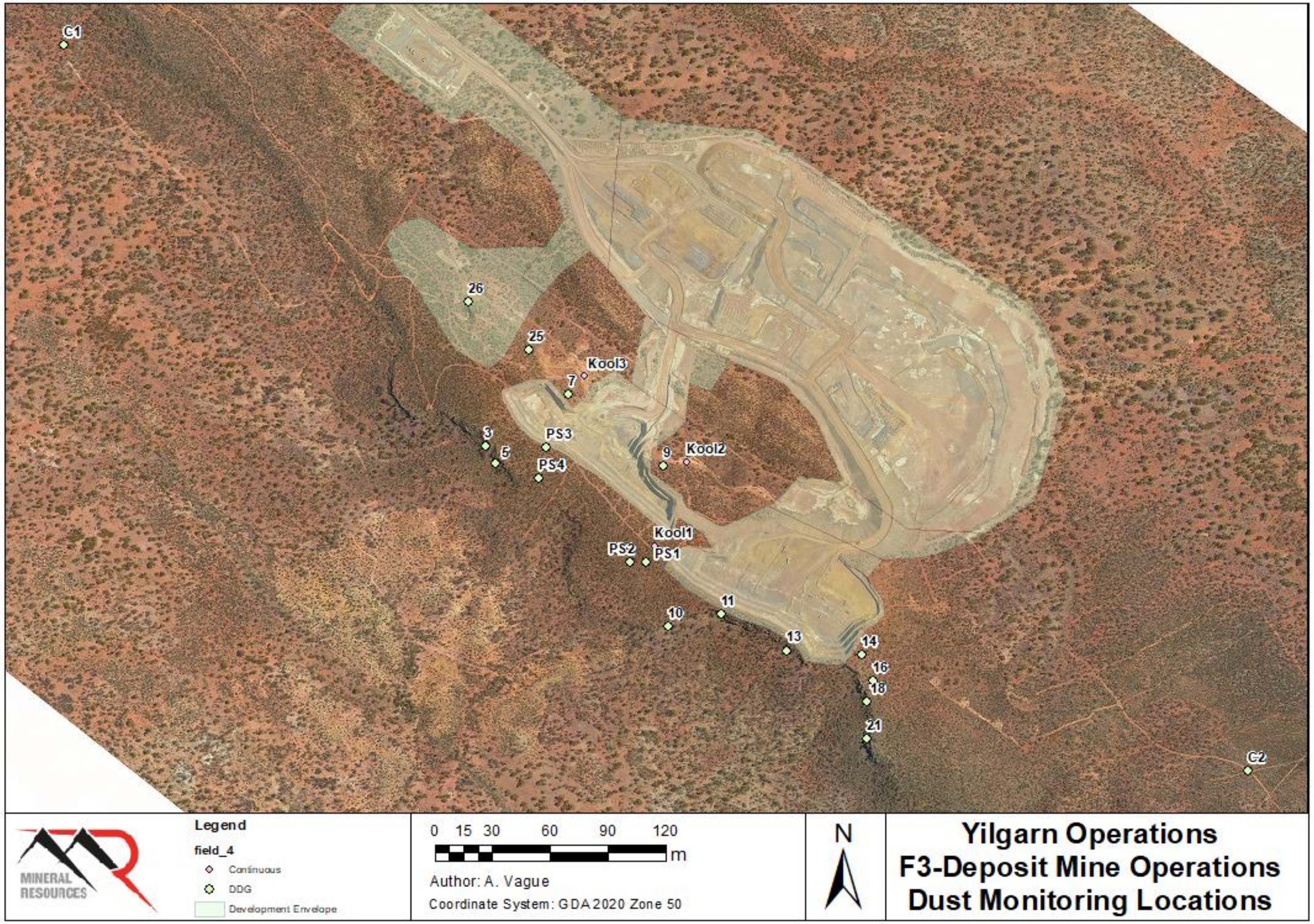

Figure 2.2 : Location of Dust Deposition Gauges

3 Results

January 2017 data has been used as a baseline as it would likely represent the lowest health/most stressed data available prior to commencement of mining (and therefore natural results).

3.1 Rainfall

The total monthly rainfall recorded at Koolyanobbing during 2017, 2018 and 2019 is shown in **Figure 3.1**, along with the long term average monthly rainfall (BoM 2019). A total of 351.8mm of rain fell in 2018 with a majority of this recorded during the summer months (147.5mm in January and February). In comparison the 2019 reporting period recorded 212.5mm with a considerable reduction in summer rain with January and February receiving 4.4mm and 26.6mm respectively (BoM 2019). Below average rainfall was also recorded for the months of January, February, March, April, May, July, August, September, October and November.

In contrast, only 60% of the 2018 annual rainfall was recorded during 2019 (212.5mm). This 2019 total was also only 81% of the long term annual average rainfall (261.7mm). The months of June and December had the only above average monthly rainfalls (for the monitoring period) with 32% for June and 9% for December of the annual total. All other months had below average rainfall (**Figure 3.1**).

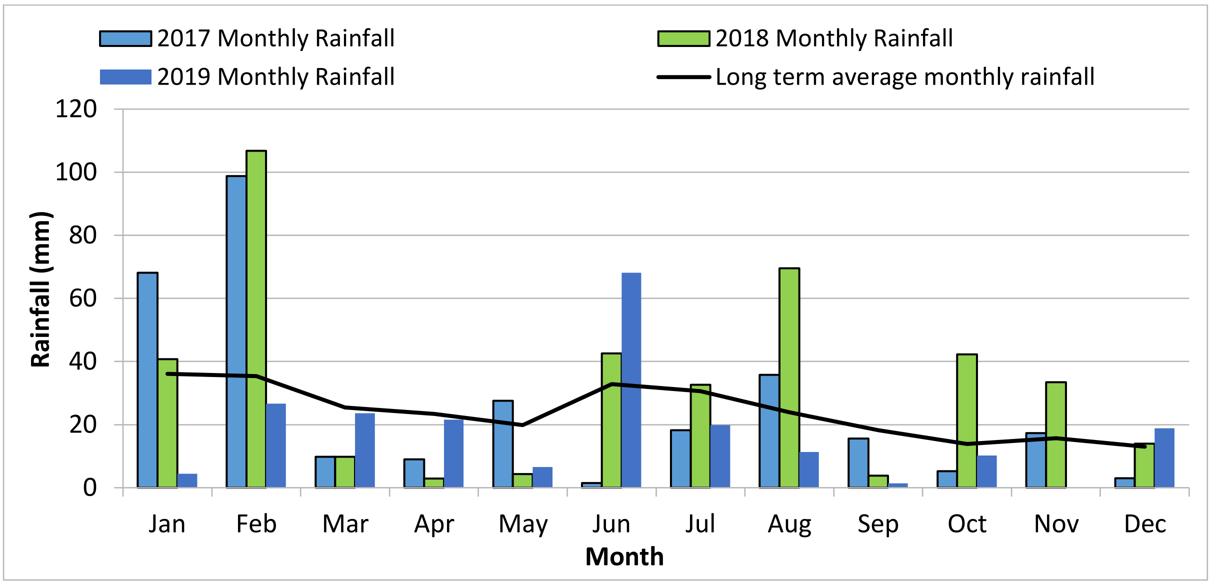

Figure 3.1: Monthly rainfall recorded at Koolyanobbing during 2017, 2018 and 2019, as well as the long term monthly average rainfall.

The total rainfall recorded in the two months prior to each monitoring event is shown in

Table 3.1, along with the average maximum temperature during monitoring.

Table 3.1: Rainfall and average maximum temperatures recorded in the two months prior to each monitoring event during the 2019 monitoring.

Monitoring Dates	Rainfall recorded prior to monitoring (mm)	Average maximum temperature on monitoring dates (°C)
12-14 January 2018	47.4	39.5
10-11 March 2019	31	36.8
16-18 May 2019	45.2	16.6
12-13 July 2019	74.7	16.8
14-15 September 2019	31.2	29.9
8-10 November 2019	11.6	35.1

3.2 Tetratheca erubescens

3.2.1 Reproductive Status

Figure 3.2 presents the percentage of plants that were reproductive per plot and distance from mining operations for each monitoring period. The September monitoring recorded the highest percentage of individuals reproductive, with a range between 66.7% (Plot 7, 20-50m from mining) and 100% (multiple plots), whilst in January the lowest percentage was scored, with a range between 0% (multiple plots) and 66.7% (Plot 10 >50m) reproductive.

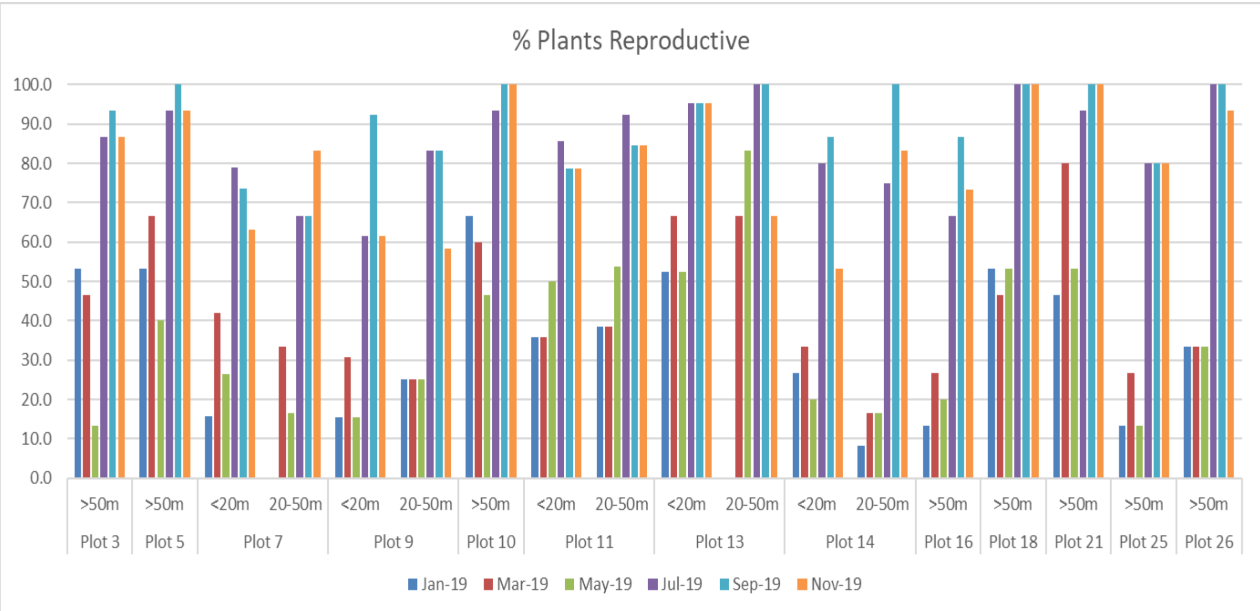

Figure 3.2: Percentage of plants reproductive per plot and monitoring event.

3.2.2 Condition Assessment

Figure 3.3 presents the average condition assessment (percentage of plant alive) per plot and distance from mining operations for each monitoring period. Average condition assessment varied between plots and between monitoring periods. The January 2019 monitoring found average condition ranged between 44.2% (Plot 13, 20-50m) and 65.7% (Plot 11, <20m), whilst the November monitoring identified a range of 35.8% (Plot 7, 20-50m) to 54.3% (Plot 25, >50). For the entire monitored population, average condition assessment was lowest during September (25.8%) and highest during May (66.5%). Condition Assessment results (± standard deviation) are also shown in table form in

Appendix 1 Tabular results of chlorophyll fluorescence and average condition assessment ± standard deviation.

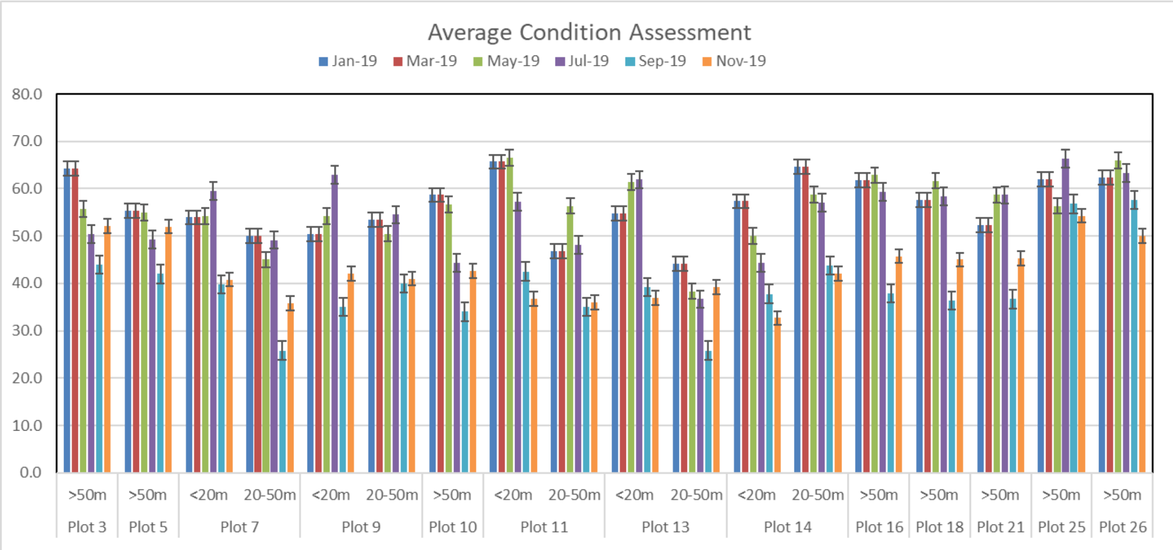

Figure 3.3: Average condition assessment (and standard deviation) per plot and monitoring event.

3.2.3 Chlorophyll Fluorescence (CF)

Figure 3.4 presents the Fv/Fm (index of chlorophyll fluorescence) monitoring results per plot and distance from mining for the monitoring period. The January 2019 monitoring recorded average chlorophyll fluorescence readings between 0.50 (Plot 7, 20-50m) and 0.74 (Plot 9, 20-50m), whilst the November monitoring recorded levels between 0.55 (Plot 14 20-50m) and 0.79 (two plots). For the entire monitored population, average chlorophyll fluorescence was lowest during March (0.48) and highest in September (0.81).

Chlorophyll Fluorescence results (± standard deviation) are also shown in table form in

Appendix 1 Tabular results of chlorophyll fluorescence and average condition assessment ± standard deviation.

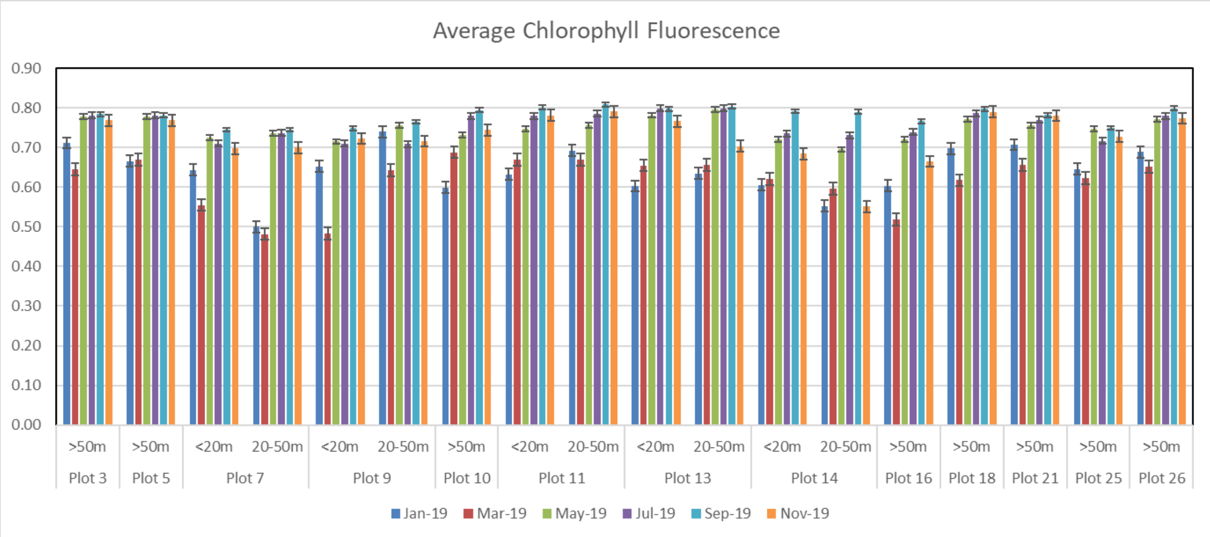

Figure 3.4: Average chlorophyll fluorescence (and standard deviation) per plot and monitoring event.

3.2.4 Soft Tips (new growth)

Figure 3.5 presents the percentage of plants with soft tips signifying new growth, per plot and distance from mining for each monitoring event. The January 2019 monitoring recorded between 0% (two plots) and 66.7% (Plot 10, >50m) of plants per plot with soft tips, whilst the November monitoring recorded between 25.0% (Plot 14, 20-50m) and 100% (two plots).

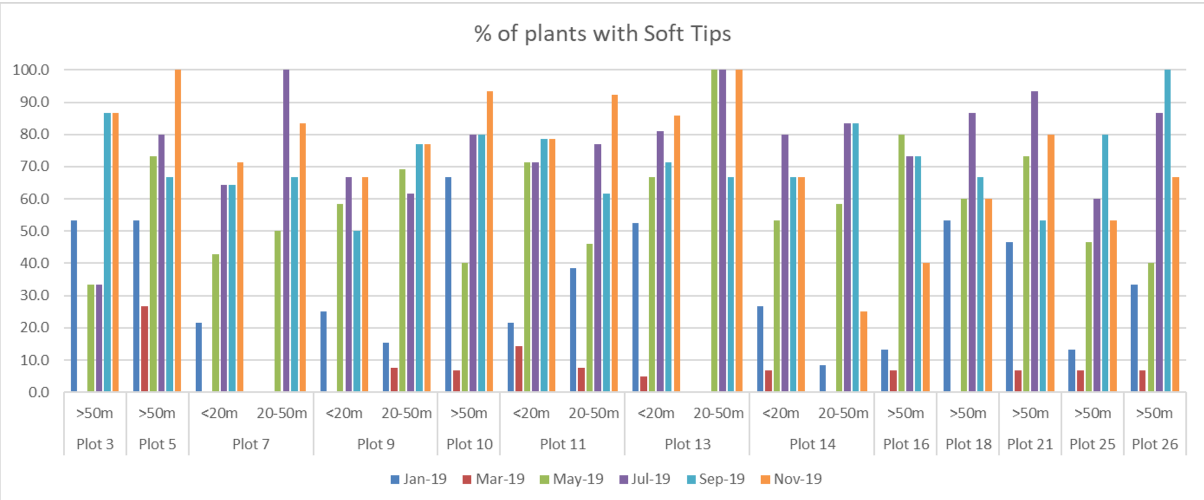

Figure 3.5 : Percentage of Plants with Soft Tips (New Growth)

3.2.5 Mortality

Four individuals were identified as having no live tissue (NLT) from the January monitoring period onwards. One of these however was due to a fallen tree. There were five individuals then showing signs of NLT from May onwards and one was uprooted during a rock fall incident. The results of the statistical analysis for the November 2019 monitoring event are presented in Figure 3.6. The results confirm that the mortality does not appear to be attributable to any mine related factor.

Model Anova Results	Df	Sum Sq	Mean Sq	F value	p-value
BeforeOrAfterMining	1	0	0	0	0.997
Location	2	0.943	0.471	0.471	0.624
ash_transformed	1	2.574	2.574	2.574	0.109
BeforeOrAfterMining:Location	2	0	0	0	1

Mean (95% Confidence Interval)	<20m	20-50m	>50m
Before	0 (0,1)	0 (0,1)	0 (0,1)
After	0.01 (0,0.03)	0 (0,0.03)	0 (0,0.01)

No statistically significant association was found between mining activity and Mortality for Tetrathcea erubescens after allowing for Ash, p-value >= 0.1

Figure 3.6: Model ANOVA results for mining activity and mortality after allowing for Ash.

3.2.6 Leaf surface dust

Figure 3.7 illustrates the percentage of plants identified in each dust category vs. distribution per plot and distance from mining, for each monitoring event. Plot 7 (<50m from approval boundary) recorded the highest percentage of individuals within the 1-25% dust cover category, with 56% in March and 42% in September. Leaf surface dust at other sites were minimal.

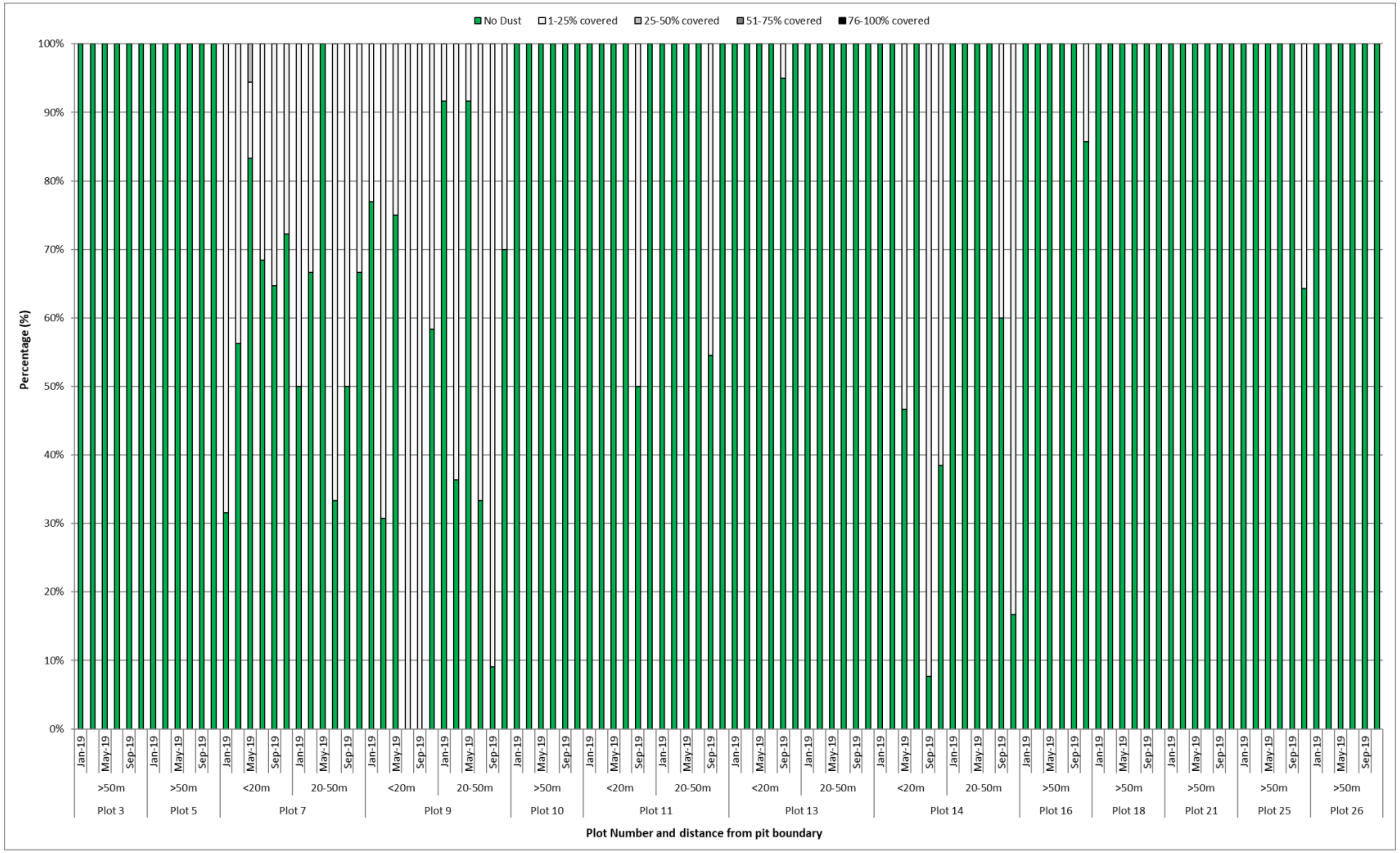

Figure 3.7 Percentage of monitored plants in each dust category per monitoring event. (Plots not shown are recorded as dust free in all monitoring events)

3.2.7 Dust Deposition

Figure 3.8 presents the results of the dust deposition gauge (DDG) monitoring at each plot for each monitoring event. The trigger criteria level of 40g/m²/month is also identified. Dust levels were low at most plots for all monitoring events, except plot 14 during the September and November monitoring periods. DDG at PS1 recorded elevated dust levels at the start of the year but has since settled and a similar observation was seen at PS2 and PS3. Dust at all other locations and monitoring events was low, with 92% of all monitoring events across all locations at less than 20g/m²/month. There were two recorded dust deposition levels above the trigger criteria level of 40g/m²/month at Plot 14 (45g and 96g/m2/month during September and November) and an investigation was initiated for this exceedance.

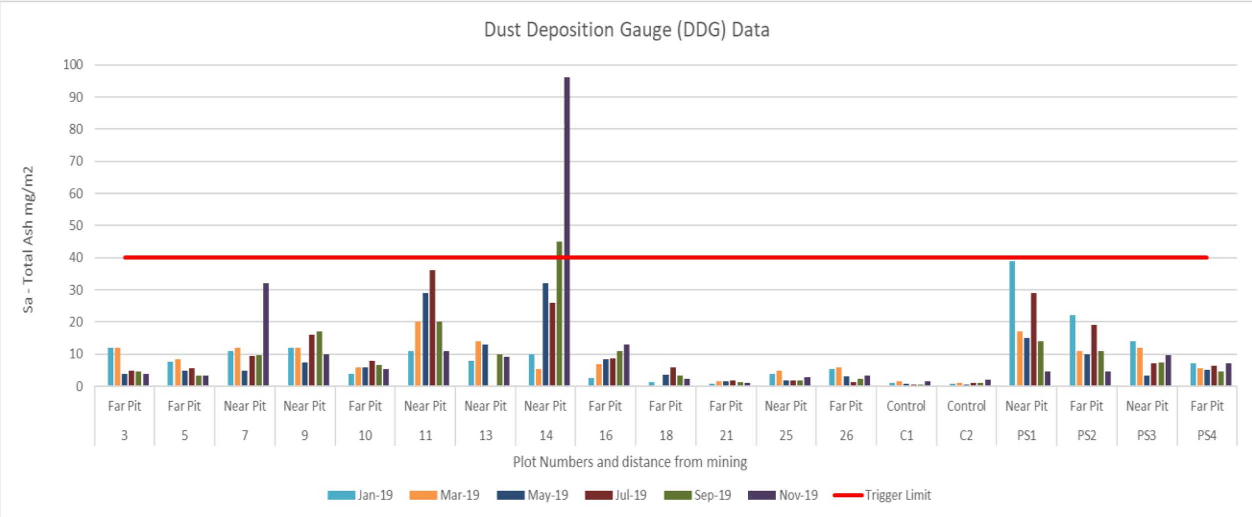

Figure 3.8: Mine related dust recorded in each plot during DDG monitoring

3.3 Statistical Analysis

No statistically significant negative relationship was found between mining activity and condition assessment, chlorophyll fluorescence or mortality of *Tetratheca erubescens* at a widely accepted 84% confidence interval (Figure 3.9). Appendix 2 Results of the statistical analysis, January - November 2019 presents the results of the statistical analysis from January to November 2019.

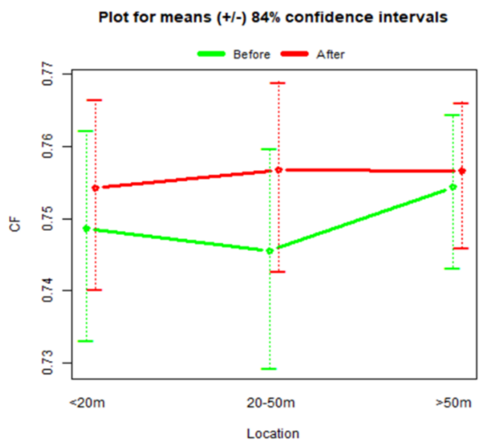

Figure 3.9: Chlorophyll Fluorescence readings on monitored plants before and after the commencement of mining.

4 Discussion and Conclusion

The monitoring suggests the *Tetratheca erubescens* plants are displaying a slight decrease in condition, with the greatest period for condition decline occurring during autumn (May monitoring) as opposed to summer (September monitoring). As expected, most plants (over 90%) were reproductive during the spring monitoring compared with 30% during the January monitoring. The majority of individuals (over 76%) recorded soft tips (new growth) in winter, compared with 5% in autumn. Results are attributable to unfavourable weather conditions (lower than average rainfall for 5 months of the year) resulting in individuals being more stressed and exhibiting reduced growth.

Average chlorophyll fluorescence measurement is a more reliable indicator of plant health than condition assessment. The method directly measures physiological function and thus offers significant advantages over the more traditional measures of vegetation condition that use indirect indicators such as dead/live leaf material or leaf colour. Fv/Fm (index of chlorophyll fluorescence) has a normal range of 0.7 to 0.8 across a broad range of different vascular plant taxa. The ratio declines when plants experience stress. Various literatures (Ritchie 2006; Percival 2005) suggest values below 0.6 indicate plant stress. The March monitoring recorded low chlorophyll fluorescence values (average of 0.62), with individual plants recording values as low as 0.48. It is possible the low March values were influenced by the observed lower than average rainfall (up to 31.7mm below the monthly average for January) experienced over the monitoring periods compared to subsequent monitoring events recording higher chlorophyll fluorescence values. The July and September monitoring recorded similar values (averages of 0.76 and 0.78 respectively), while in November (when plants are experiencing moisture and thermal stress) the average CF value recorded for all individuals was 0.73. These results suggest the monitored *Tetratheca erubescens* individuals are in a healthy condition.

The first mortality of the monitored individuals was recorded in July 2018, with 4 individuals recorded as no live tissue (NLT). 2019 recorded the same four individuals but also an additional 5 but the end of the year which included one individual being dislodged by a rock fall event. The remaining individuals are most likely due to the potential of tissue damage when conducting the CF monitoring, especially on small individuals.

The stems of the *Tetratheca erubescens* are quite brittle and the use of a clip in order to take a CF reading every two months often results in irreversible damage to the stem. Where individuals only have a few stems, the same stems are likely to be sampled repeatedly, resulting in potential damage to the individual and/or reducing its chance of survival. Due to this current monitoring practices avoid collecting CF measurements from those individuals with reduced number of live stems or those that are showing signs of stress due to physical disturbance from monitoring. CF measurement will recommence once the individuals have sufficiently recovered. Visual observations such as condition and dust assessments, reproductive status will still be collected until such a time that the individuals can withstand CF monitoring.

Dust deposition levels were relatively low at most plots for each monitoring event, however was recorded at levels requiring investigation at Plot 14. The high dust deposition value recorded at plot 14 during the November 2019 monitoring was due to low rainfall and above average temperatures. Dust deposition levels were observed to correlate with leaf surface dust as observed in Plot 14 (highest DDG reading) which recorded the highest number of individuals with leaf surface dust (60%).

4.1 Comparisons against trigger and threshold criteria

The F Deposit Flora and Vegetation Management Plan (MRL 2019) outlines trigger and threshold criteria that require further reporting and contingency actions. The following section compares the results of the monitoring against the relevant criterion.

4.1.1 Trigger criteria

1. Monitoring of *Tetratheca erubescens* indicates a statistically significant relationship between condition (Index of Chlorophyll Fluorescence (ICF) and/or %live material) and dust deposition, distance from proposal boundary or mine related factor.

   No statistically significant negative relationship was found between mining activity and condition assessment, chlorophyll fluorescence or mortality of *Tetratheca erubescens* as outlined in Section 3.4. Therefore, this trigger criterion has not been met.

2. Dust deposition at any (non-reference) dust monitoring site exceeds 80g/m2/month (S_a) during the first 12 months from commencement of mining; 40g/m2/month (S_a) after 12 months from commencement of mining.

   Elevated dust deposition levels (limit of 40g/m^2/month (S_a)) were observed at Plot 14 for the September and November monitoring events, as outlined in Section 3.2.7 and in Figure 3.8. Therefore, this trigger criterion has been met. As a result and following internal reporting processes an incident was raised and an investigation carried out recommending remedial actions to reduce fugitive dust emissions.

4.1.2 Threshold criteria

1. Monitoring of *Tetratheca erubescens* indicates a statistically significant relationship between mortality and dust deposition, distance from the proposal boundary or mine-related causal factor.

   The mortality of monitored *Tetratheca erubescens* individuals, recorded no statistically significant relationship with any mine-related causal factor, as outlined in Section 3.2.5. Therefore, this threshold criterion has not been met.

2. Monitoring of *Tetratheca erubescens* indicates a statistically significant relationship between condition (Index of Chlorophyll Fluorescence (ICF) and/or % live material) and dust deposition, distance from the proposal boundary or mine-related factor.

   No statistically significant negative relationship was found between mining activity and condition assessment, chlorophyll fluorescence or mortality of *Tetratheca erubescens*. As outlined in Section 3.4. Therefore, this threshold criterion has not been met.

4.2 Review of monitoring data, methods and trigger levels

It is proposed to amend the trigger and threshold criteria to identify statistically significant *negative* relationships (i.e. high levels of dust coinciding with lower condition assessment or chlorophyll fluorescence), as opposed to also identifying and reporting on positive relationships such as those recorded during the 2018 monitoring (where dust was positively associated with condition assessment). A further review of the monitoring methods, data collected and appropriateness of trigger and threshold levels is proposed.

5 References

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Hansatech (2006) *Handy PEA, Pocket PEA & PEA Plus Software.* Hansatech Instruments Ltd. Version 1.0, December 2006.

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Minister for the Environment and Heritage (2017). *Statement 1054. Yilgarn Operations – Koolyanobbing Range F Deposit.* Statement that a proposal may be implemented (*Environmental Protection Act 1986*). January 2017, Perth Western Australia.

Percival (2005) *The use of Chlorophyll Fluorescence to Identify Chemical and Environmental Stress in Leaf Tissue of Three Oak (QUERCUS) Species.* Journal of Arboriculture 31 (5): September 2005. p215.

Ritchie (2006) *Chlorophyll Fluorescence: What is it and What do the Numbers Mean?* National Proceedings Forest and Conservation Nursery Associations – 2005. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 160p.

6 Appendix 1 Tabular results of chlorophyll fluorescence and average condition assessment ± standard deviation

A1 1: Average Chlorophyll Fluorescence per plot (± standard deviation)

Plot Number	Distance from pit	Jan-19		Mar-19		May-19		Jul-19		Sep-19		Nov-19	
		CF	SD	CF	SD	CF	SD	CF	SD	CF	SD	CF	SD
Plot 3	>50m	0.711429	0.06062	0.644286	0.123893	0.778571	0.028516	0.780714	0.032455	0.784286	0.024718	0.768571	0.038201
Plot 5	>50m	0.666	0.090932	0.669333	0.11973	0.777333	0.036541	0.780667	0.019074	0.781333	0.026957	0.768667	0.02615
Plot 7	<20m	0.643158	0.101929	0.555	0.114134	0.725	0.083402	0.709444	0.058256	0.744444	0.040761	0.697778	0.034904
	20-50m	0.5	0.147784	0.481667	0.085186	0.736667	0.033267	0.736667	0.02582	0.745	0.042308	0.7	0.0502
Plot 9	<20m	0.652308	0.118894	0.483077	0.133065	0.715	0.076456	0.71	0.04899	0.74875	0.027313	0.7225	0.05119
	20-50m	0.74	0.051854	0.642	0.065794	0.756	0.035653	0.709	0.056065	0.765	0.021213	0.716	0.044522
Plot 10	>50m	0.599333	0.130081	0.688	0.126446	0.732	0.077201	0.779333	0.020166	0.794667	0.016417	0.744	0.066526
Plot 11	<20m	0.632143	0.105625	0.669231	0.130605	0.746154	0.073319	0.78	0.030277	0.800769	0.011875	0.781429	0.025975
	20-50m	0.692308	0.11663	0.67	0.203511	0.756667	0.056461	0.785385	0.017614	0.808182	0.01328	0.790909	0.01446
Plot 13	<20m	0.602857	0.125982	0.654762	0.130062	0.781429	0.026132	0.799	0.019167	0.7975	0.014824	0.76619	0.057834
	20-50m	0.635	0.034496	0.656667	0.089368	0.796667	0.008165	0.798333	0.016021	0.803333	0.012111	0.703333	0.118265
Plot 14	<20m	0.605333	0.122116	0.62	0.116289	0.720769	0.057946	0.735385	0.056364	0.791154	0.017578	0.683846	0.181316
	20-50m	0.5525	0.048077	0.595833	0.10518	0.695	0.085227	0.730833	0.051603	0.79	0.020449	0.550833	0.18875
Plot 16	>50m	0.603846	0.117441	0.518462	0.143982	0.720769	0.053613	0.738462	0.060669	0.766154	0.02256	0.664615	0.164601
Plot 18	>50m	0.697333	0.107602	0.617333	0.120917	0.772	0.025411	0.786	0.025298	0.797333	0.017099	0.79	0.026186
Plot 21	>50m	0.707333	0.066705	0.656667	0.125452	0.756	0.03247	0.77	0.027255	0.782	0.024842	0.78	0.026726
Plot 25	>50m	0.646	0.124946	0.623571	0.088978	0.747857	0.051168	0.716429	0.04684	0.749286	0.039509	0.727857	0.045095
Plot 26	>50m	0.688667	0.110316	0.652	0.124108	0.770667	0.059096	0.779333	0.029391	0.798667	0.030206	0.773333	0.029196

A1 2: Average Condition Assessment per plot (± standard deviation)

Plot Number	Distance from pit	Jan-19		Mar-19		May-19		Jul-19		Sep-19		Nov-19	
		CA	SD	CA	SD	CA	SD	CA	SD	CA	SD	CA	SD
Plot 3	>50m	64.29	15.17	55.71	19.00	50.36	19.26	43.93	13.33	46.79	10.85	52.14	14.64
Plot 5	>50m	55.33	23.34	55.00	16.48	49.33	21.29	42.00	17.91	49.00	12.42	52.00	14.74
Plot 7	<20m	53.95	16.96	54.21	15.30	59.47	22.10	39.74	23.89	46.39	16.07	40.79	21.81
	20-50m	50.00	10.95	45.00	18.71	49.17	15.94	25.83	13.57	35.83	12.01	35.83	19.08
Plot 9	<20m	50.38	14.50	54.23	21.10	62.92	14.22	35.00	14.46	46.67	18.50	42.08	15.59
	20-50m	53.50	18.42	50.50	21.66	54.50	24.43	40.00	15.63	37.00	13.58	41.00	19.55
Plot 10	>50m	58.67	17.67	56.67	19.88	44.33	22.35	34.00	22.93	44.00	18.24	42.67	14.86
Plot 11	<20m	65.71	15.67	66.54	18.97	57.31	18.78	42.50	25.17	51.07	22.72	36.79	19.38
	20-50m	46.82	19.27	56.36	19.51	48.18	18.48	35.00	17.75	47.50	15.68	36.00	11.74
Plot 13	<20m	54.76	23.05	61.43	20.87	61.90	19.07	39.25	21.42	52.25	21.91	36.90	17.64
	20-50m	44.17	18.55	38.33	25.82	36.67	23.17	25.83	17.44	39.17	13.20	31.67	18.35
Plot 14	<20m	57.33	17.41	50.00	24.18	44.31	24.07	37.77	21.90	50.38	23.32	32.69	19.00
	20-50m	64.58	19.71	58.75	24.97	57.08	28.80	43.75	29.24	55.00	25.94	42.08	25.36
Plot 16	>50m	61.79	13.24	62.86	17.51	59.29	15.79	37.86	15.78	51.54	16.25	45.71	12.84
Plot 18	>50m	57.67	16.24	61.67	17.80	58.33	15.77	36.33	17.57	45.33	19.22	45.00	12.96
Plot 21	>50m	52.33	18.31	58.67	20.13	58.67	18.27	36.67	15.43	49.00	16.92	45.33	16.31
Plot 25	>50m	62.00	12.36	56.33	16.74	66.33	20.04	56.79	18.97	53.57	16.57	54.29	18.80
Plot 26	>50m	62.33	17.41	66.00	20.63	63.33	25.47	57.67	23.59	50.33	15.64	50.00	22.99

7 Appendix 2 Results of the statistical analysis, January - November 2019

A2 1: Statistical analysis of Chlorophyll Fluorescence (excluding Ash)

Model for CF - excluding effect of Ash

Primary analysis (omitting outlier(s))

transformed CF ~ BeforeOrAfterMining*Location + Plot(Random) + Tag_num(Random)

Model Results	Value	Std.Error	DF	t-value	p-value
(Intercept)	2.272	0.063	3464	35.889	0
BeforeOrAfterMining_After	-0.114	0.025	3464	-4.596	0
Location 20-50m	-0.096	0.106	236	-0.912	0.363
Location <20m	-0.108	0.104	236	-1.039	0.3
BeforeOrAfterMining_After:Location 20-50m	0.072	0.05	3464	1.46	0.144
BeforeOrAfterMining_After:Location <20m	0.068	0.044	3464	1.523	0.128

Model Anova Results	numDF	denDF	F-value	p-value
(Intercept)	1	3464	2058.596	0
BeforeOrAfterMining	1	3464	20.457	0
Location	2	236	0.242	0.786
BeforeOrAfterMining:Location	2	3464	1.743	**0.175**

No statistically significant association was found between mining activity and Chlorophyll Fluorescence for Tetrathcea erubescens, p-value >= 0.1

Mean (95% Confidence Interval)	<20m	20-50m	>50m
Before	0.75 (0.73,0.77)	0.75 (0.73,0.77)	0.76 (0.75,0.77)
After	0.74 (0.72,0.76)	0.75 (0.73,0.76)	0.75 (0.73,0.76)

January 2019

Model for CF - excluding effect of Ash

Primary analysis (omitting outlier(s))

transformed CF ~ BeforeOrAfterMining*Location + Plot(Random) + Tag_num(Random)

Model Results	Value	Std.Error	DF	t-value	p-value
(Intercept)	2.272	0.064	3706	35.473	0
BeforeOrAfterMining_After	-0.162	0.025	3706	-6.431	0
Location 20-50m	-0.097	0.107	236	-0.907	0.365
Location <20m	-0.108	0.105	236	-1.023	0.307
BeforeOrAfterMining_After:Location 20-50m	0.069	0.05	3706	1.361	0.174
BeforeOrAfterMining_After:Location <20m	0.059	0.045	3706	1.298	0.194

Model Anova Results	numDF	denDF	F-value	p-value
(Intercept)	1	3706	1954.541	0
BeforeOrAfterMining	1	3706	51.224	0
Location	2	236	0.296	0.744
BeforeOrAfterMining:Location	2	3706	1.387	**0.25**

No statistically significant association was found between mining activity and Chlorophyll Fluorescence for Tetrathcea erubescens, p-value >= 0.1

Mean (95% Confidence Interval)	<20m	20-50m	>50m
Before	0.75 (0.73,0.77)	0.75 (0.73,0.77)	0.76 (0.75,0.77)
After	0.74 (0.72,0.76)	0.74 (0.72,0.76)	0.74 (0.73,0.76)

March 2019

Model for CF - excluding effect of Ash *Primary analysis (omitting outlier(s))*

transformed CF ~ BeforeOrAfterMining*Location + Plot(Random) + Tag_num(Random)

Model Results	Value	Std.Error	DF	t-value	p-value
(Intercept)	2.272	0.063	3945	36.267	0
BeforeOrAfterMining_After	-0.146	0.025	3945	-5.919	0
Location 20-50m	-0.092	0.105	236	-0.88	0.38
Location <20m	-0.109	0.103	236	-1.059	0.291
BeforeOrAfterMining_After:Location 20-50m	0.059	0.049	3945	1.199	0.23
BeforeOrAfterMining_After:Location <20m	0.053	0.044	3945	1.204	0.229

Model Anova Results	numDF	denDF	F-value	p-value
(Intercept)	1	3945	2065.811	0
BeforeOrAfterMining	1	3945	43.598	0
Location	2	236	0.388	0.679
BeforeOrAfterMining:Location	2	3945	1.134	**0.322**

No statistically significant association was found between mining activity and Chlorophyll Fluorescence for Tetrathcea erubescens, p-value >= 0.1

Mean (95% Confidence Interval)	<20m	20-50m	>50m
Before	0.75 (0.73,0.77)	0.75 (0.73,0.77)	0.76 (0.75,0.77)
After	0.74 (0.72,0.76)	0.74 (0.72,0.76)	0.75 (0.73,0.76)

May 2019

Model for CF - excluding effect of Ash *Primary analysis (omitting outlier(s))*

transformed CF ~ BeforeOrAfterMining*Location + Plot(Random) + Tag_num(Random)

Model Results	Value	Std.Error	DF	t-value	p-value
(Intercept)	2.272	0.064	4183	35.472	0
BeforeOrAfterMining_After	-0.127	0.024	4183	-5.279	0
Location 20-50m	-0.088	0.107	236	-0.82	0.413
Location <20m	-0.11	0.105	236	-1.049	0.295
BeforeOrAfterMining_After:Location 20-50m	0.049	0.048	4183	1.02	0.308
BeforeOrAfterMining_After:Location <20m	0.049	0.043	4183	1.122	0.262

Model Anova Results	numDF	denDF	F-value	p-value
(Intercept)	1	4183	1987.338	0
BeforeOrAfterMining	1	4183	34.578	0
Location	2	236	0.445	0.641
BeforeOrAfterMining:Location	2	4183	0.905	**0.405**

No statistically significant association was found between mining activity and Chlorophyll Fluorescence for Tetrathcea erubescens, p-value >= 0.1

Mean (95% Confidence Interval)	<20m	20-50m	>50m
Before	0.75 (0.73,0.77)	0.75 (0.73,0.77)	0.76 (0.75,0.77)
After	0.74 (0.72,0.76)	0.74 (0.72,0.76)	0.75 (0.73,0.76)

July 2019

Model for CF - excluding effect of Ash

Primary analysis (omitting outlier(s))

transformed CF ~ BeforeOrAfterMining*Location + Plot(Random) + Tag_num(Random)

Model Results	Value	Std.Error	DF	t-value	p-value
(Intercept)	2.272	0.064	4420	35.273	0
BeforeOrAfterMining_After	-0.099	0.024	4420	-4.177	0
Location 20-50m	-0.089	0.108	236	-0.825	0.41
Location <20m	-0.109	0.106	236	-1.032	0.303
BeforeOrAfterMining_After:Location 20-50m	0.053	0.047	4420	1.12	0.263
BeforeOrAfterMining_After:Location <20m	0.047	0.043	4420	1.086	0.278

Model Anova Results	numDF	denDF	F-value	p-value
(Intercept)	1	4420	2000.082	0
BeforeOrAfterMining	1	4420	19.188	0
Location	2	236	0.503	0.605
BeforeOrAfterMining:Location	2	4420	0.956	**0.384**

No statistically significant association was found between mining activity and Chlorophyll Fluorescence for Tetrathcea erubescens, p-value >= 0.1

Mean (95% Confidence Interval)	<20m	20-50m	>50m
Before	0.75 (0.73,0.77)	0.75 (0.73,0.77)	0.76 (0.75,0.77)
After	0.74 (0.72,0.76)	0.75 (0.73,0.76)	0.75 (0.74,0.76)

September 2019

Model for CF - excluding effect of Ash

Primary analysis (omitting outlier(s))

transformed CF ~ BeforeOrAfterMining*Location + Plot(Random) + Tag_num(Random)

Model Results	Value	Std.Error	DF	t-value	p-value
(Intercept)	2.272	0.066	4659	34.597	0
BeforeOrAfterMining_After	-0.09	0.023	4659	-3.86	0
Location 20-50m	-0.089	0.11	236	-0.817	0.415
Location <20m	-0.11	0.108	236	-1.024	0.307
BeforeOrAfterMining_After:Location 20-50m	0.032	0.047	4659	0.677	0.498
BeforeOrAfterMining_After:Location <20m	0.041	0.042	4659	0.972	0.331

Model Anova Results	numDF	denDF	F-value	p-value
(Intercept)	1	4659	1922.093	0
BeforeOrAfterMining	1	4659	17.908	0
Location	2	236	0.34	0.712
BeforeOrAfterMining:Location	2	4659	0.565	**0.568**

No statistically significant association was found between mining activity and Chlorophyll Fluorescence for Tetrathcea erubescens, p-value >= 0.1

Mean (95% Confidence Interval)	<20m	20-50m	>50m
Before	0.75 (0.73,0.77)	0.75 (0.73,0.77)	0.76 (0.75,0.77)
After	0.74 (0.72,0.76)	0.74 (0.72,0.76)	0.75 (0.74,0.77)

November 2019

A2 2: Statistical analysis of Condition Assessment (including Ash)

Model for CA - including effect of Ash ***Extended analysis***

CA ~ BeforeOrAfterMining*Location + log(Ash) + Plot(Random) + Tag_num(Random)

Model Results	Value	Std.Error	DF	t-value	p-value
(Intercept)	48.179	1.788	2081	26.942	0
BeforeOrAfterMining_After	2.491	0.915	2081	2.722	0.007
Location 20-50m	-5.097	3.128	236	-1.63	0.105
Location <20m	3.282	2.854	236	1.15	0.251
ash_transformed	-1.566	0.321	2081	-4.882	0
BeforeOrAfterMining_After:Location 20-50r	1.188	1.482	2081	0.801	0.423
BeforeOrAfterMining_After:Location <20m	1.789	1.335	2081	1.34	0.18

Model Anova Results	numDF	denDF	F-value	p-value
(Intercept)	1	2081	1515.171	0
BeforeOrAfterMining	1	2081	0.166	0.684
Location	2	236	5.301	0.006
ash_transformed	1	2081	22.236	0
BeforeOrAfterMining:Location	2	2081	0.978	0.376

No statistically significant association was found between mining activity and Condition Assessment for Tetrathcea erubescens after allowing for Ash, p-value >= 0.1

Ash was statistically significant associated with Condition Assessment for Tetrathcea erubescens, p-value < 0.05

Mean (95% Confidence Interval)	<20m	20-50m	>50m
Before	51.46 (47,55.92)	43.08 (37.94,48.2	48.18 (44.67,51.68)
After	55.74 (51.29,60.1	46.76 (41.55,51.97	50.67 (47.16,54.18)

January 2019

Model for CF - including effect of Ash ***Secondary extended analysis***

transformed CF ~ BeforeOrAfterMining*Location + log(Ash) + Plot(Random) + Tag_num(Random)

Model Results	Value	Std.Error	DF	t-value	p-value
(Intercept)	2.188	0.066	3364	33.389	0
BeforeOrAfterMining_After	-0.014	0.027	3364	-0.503	0.615
Location 20-50m	-0.076	0.108	236	-0.705	0.482
Location <20m	-0.05	0.107	236	-0.467	0.641
ash_transformed	-0.062	0.007	3364	-8.486	0
BeforeOrAfterMining_After:Location 20-50m	0.134	0.051	3364	2.638	0.008
BeforeOrAfterMining_After:Location <20m	0.078	0.046	3364	1.686	0.092

Model Anova Results	numDF	denDF	F-value	p-value
(Intercept)	1	3364	1953.681	0
BeforeOrAfterMining	1	3364	23.151	0
Location	2	236	0.191	0.827
ash_transformed	1	3364	66.059	0
BeforeOrAfterMining:Location	2	3364	3.961	0.019

There is a statistically significant association between mining activity and Chlorophyll Fluorescence for Tetrathcea erubescens after allowing for Ash, p-value < 0.05

Ash was statistically significant associated with Chlorophyll Fluorescence for Tetrathcea erubescens, p-value < 0.05

Mean (95% Confidence Interval)	<20m	20-50m	>50m
Before	0.75 (0.73,0.77)	0.74 (0.72,0.76)	0.75 (0.74,0.77)
After	0.75 (0.73,0.77)	0.76 (0.74,0.77)	0.75 (0.74,0.76)

March 2019

Model for CF - including effect of Ash ***Secondary extended analysis***

transformed CF ~ BeforeOrAfterMining*Location + log(Ash) + Plot(Random) + Tag_num(Random)

Model Results	Value	Std.Error	DF	t-value	p-value
(Intercept)	2.17	0.067	3830	32.335	0
BeforeOrAfterMining_After	0	0.027	3830	-0.013	0.99
Location 20-50m	-0.073	0.111	236	-0.654	0.514
Location <20m	-0.045	0.11	236	-0.411	0.682
ash_transformed	-0.077	0.007	3830	-10.986	0
BeforeOrAfterMining_After:Location 20-50m	0.127	0.05	3830	2.536	0.011
BeforeOrAfterMining_After:Location <20m	0.064	0.046	3830	1.397	0.162

Model Anova Results	numDF	denDF	F-value	p-value
(Intercept)	1	3830	1817.429	0
BeforeOrAfterMining	1	3830	44.696	0
Location	2	236	0.363	0.696
ash_transformed	1	3830	114.636	0
BeforeOrAfterMining:Location	2	3830	3.474	0.031

There is a statistically significant association between mining activity and Chlorophyll Fluorescence for Tetrathcea erubescens after allowing for Ash, p-value < 0.05

Ash was statistically significant associated with Chlorophyll Fluorescence for Tetrathcea erubescens, p-value < 0.05

Mean (95% Confidence Interval)	<20m	20-50m	>50m
Before	0.75 (0.72,0.76)	0.74 (0.72,0.76)	0.75 (0.73,0.76)
After	0.75 (0.73,0.77)	0.76 (0.74,0.77)	0.75 (0.73,0.76)

May-2019

Model for CF - including effect of Ash ***Secondary extended analysis***

transformed CF ~ BeforeOrAfterMining*Location + log(Ash) + Plot(Random) + Tag_num(Random)

Model Results	Value	Std.Error	DF	t-value	p-value
(Intercept)	2.182	0.067	4042	32.38	0
BeforeOrAfterMining_After	0.006	0.027	4042	0.241	0.81
Location 20-50m	-0.075	0.112	236	-0.671	0.503
Location <20m	-0.047	0.11	236	-0.428	0.669
ash_transformed	-0.067	0.007	4042	-10.023	0
BeforeOrAfterMining_After:Location 20-50m	0.108	0.049	4042	2.201	0.028
BeforeOrAfterMining_After:Location <20m	0.044	0.045	4042	0.972	0.331

Model Anova Results	numDF	denDF	F-value	p-value
(Intercept)	1	4042	1812.926	0
BeforeOrAfterMining	1	4042	37.263	0
Location	2	236	0.456	0.635
ash_transformed	1	4042	96.133	0
BeforeOrAfterMining:Location	2	4042	2.494	0.083

While not statistically significant at the usually accepted 5% level, the result is suggestive of an association between mining activity and Chlorophyll Fluorescence for Tetrathcea erubescens after allowing for Ash, 0.05 <= p-value <0.1

Ash was statistically significant associated with Chlorophyll Fluorescence for Tetrathcea erubescens, p-value < 0.05

Mean (95% Confidence Interval)	<20m	20-50m	>50m
Before	0.75 (0.72,0.77)	0.74 (0.72,0.76)	0.75 (0.74,0.77)
After	0.75 (0.73,0.77)	0.76 (0.74,0.77)	0.75 (0.74,0.77)

July 2019

Model for CF - including effect of Ash ***Secondary extended analysis***

transformed CF ~ BeforeOrAfterMining*Location + log(Ash) + Plot(Random) + Tag_num(Random)

Model Results	Value	Std.Error	DF	t-value	p-value
(Intercept)	2.204	0.067	4279	32.751	0
BeforeOrAfterMining_After	0.006	0.027	4279	0.219	0.827
Location 20-50m	-0.077	0.112	236	-0.69	0.491
Location <20m	-0.051	0.11	236	-0.464	0.643
ash_transformed	-0.05	0.007	4279	-7.658	0
BeforeOrAfterMining_After:Location 20-50m	0.096	0.049	4279	1.974	0.048
BeforeOrAfterMining_After:Location <20m	0.031	0.045	4279	0.698	0.485

Model Anova Results	numDF	denDF	F-value	p-value
(Intercept)	1	4279	1853.93	0
BeforeOrAfterMining	1	4279	21.062	0
Location	2	236	0.52	0.595
ash_transformed	1	4279	55.56	0
BeforeOrAfterMining:Location	2	4279	1.962	0.141

No statistically significant association was found between mining activity and Chlorophyll Fluorescence for Tetrathcea erubescens after allowing for Ash, p-value >= 0.1

Ash was statistically significant associated with Chlorophyll Fluorescence for Tetrathcea erubescens, p-value < 0.05

Mean (95% Confidence Interval)	<20m	20-50m	>50m
Before	0.75 (0.73,0.77)	0.75 (0.72,0.76)	0.75 (0.74,0.77)
After	0.75 (0.73,0.77)	0.76 (0.74,0.77)	0.76 (0.74,0.77)

September 2019

Model for CF - including effect of Ash ***Secondary extended analysis***

transformed CF ~ BeforeOrAfterMining*Location + log(Ash) + Plot(Random) + Tag_num(Random)

Model Results	Value	Std.Error	DF	t-value	p-value
(Intercept)	2.201	0.068	4518	32.251	0
BeforeOrAfterMining_After	0.02	0.026	4518	0.765	0.445
Location 20-50m	-0.077	0.113	236	-0.68	0.497
Location <20m	-0.051	0.112	236	-0.457	0.648
ash_transformed	-0.052	0.006	4518	-8.264	0
BeforeOrAfterMining_After:Location 20-50m	0.078	0.048	4518	1.636	0.102
BeforeOrAfterMining_After:Location <20m	0.03	0.044	4518	0.673	0.501

Model Anova Results	numDF	denDF	F-value	p-value
(Intercept)	1	4518	1797.994	0
BeforeOrAfterMining	1	4518	20.071	0
Location	2	236	0.337	0.714
ash_transformed	1	4518	65.883	0
BeforeOrAfterMining:Location	2	4518	1.365	0.256

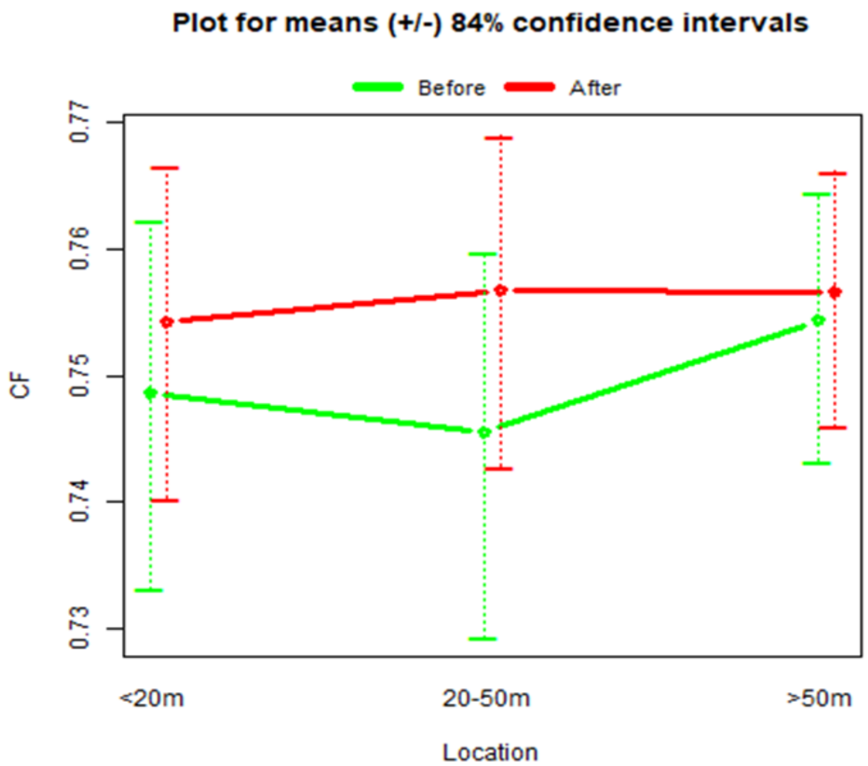
No statistically significant association was found between mining activity and Chlorophyll Fluorescence for Tetrathcea erubescens after allowing for Ash, p-value >= 0.1

Ash was statistically significant associated with Chlorophyll Fluorescence for Tetrathcea erubescens, p-value < 0.05

Mean (95% Confidence Interval)	<20m	20-50m	>50m
Before	0.75 (0.73,0.77)	0.74 (0.72,0.76)	0.75 (0.74,0.77)
After	0.75 (0.73,0.77)	0.76 (0.74,0.77)	0.76 (0.74,0.77)

November 2019

Note; Ash was positively associated with Chlorophyll Fluorescence, as the figure below demonstrates (Mean CF Levels were higher after mining than before)



A2 3: Comparison of condition assessment results before and after mining (including effect of Ash)

Attachment 6: Ecotec (WA) Pty Ltd (2019) Koolyanobbing F Deposit 2018 Annual Priority Flora and Vegetation Monitoring November 2019 (Revision 0)

Koolyanobbing F Deposit 2019 Annual Priority Flora and Vegetation Monitoring Report

November 2019

Prepared by
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Mineral Resources Ltd
1 Sleat Rd, Applecross, WA 6153
Koolyanobbing Operations

CONTENTS

FIGURES

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1.0 INTRODUCTION

Mineral Resources Limited (MRL) operations include iron ore mines at the Koolyanobbing Range, Mt Jackson Range and the Windarling Range in the Yilgarn; ore processing at Koolyanobbing, and road and rail transport between these operations and the Port of Esperance where the processed ore is exported to international customers. These operations were acquired by MRL from Cliffs Asia Pacific Iron Ore Pty Ltd (Cliffs) in 2018.

The F Deposit mining proposal was approved in January 2017 under the Environmental Protection Act 1986 (Minister for the Environment and Heritage 2017). Under this approval, Cliffs developed and implemented a Condition Environmental Management Plan which outlines provisions to address indirect impacts on native flora and vegetation including, but not limited to dust, weeds and fire (Cliffs 2017). The plan identifies trigger criteria that will initiate the implementation of actions if exceeded, and specifies threshold criteria that must not be exceeded. MRL have subsequently acquired the requirements of this management plan, which remains unchanged.

For priority flora, the trigger criterion is “Monitoring of priority species indicates a statistically significant relationship between condition (chlorophyll fluorescence and/or % live material) and dust deposition, distance from the proposal boundary or mine-related causal factor.”

For priority flora and native vegetation, the threshold criterion is “Monitoring of priority species and/or native vegetation indicates a statistically significant relationship between mortality, dust deposition, distance from the proposal boundary or mine-related causal factor.”

Cliffs commenced mining at the southern Koolyanobbing Range (F Pit) during May 2017 and continued until April 2018. MRL recommenced mining at F Pit in January 2019 and continue to mine up to the present time.

As outlined in the Management Plan, a monitoring program was implemented that covers defined monitoring plots along the Koolyanobbing Range in order to assess the condition of the native vegetation and Priority Flora populations. This program of monitoring commenced in 2017 and continued in 2018 and 2019. This report outlines and discusses the results of the 2019 annual monitoring, conducted by Ecotec in September 2019, and compares them against the trigger and threshold criteria.

2.0 METHODOLOGY

2.1 Monitoring Design

The monitoring program design was developed by Cliffs in consultation the then Department of Parks and Wildlife (DPaW), Office of the Environmental Protection Authority (OEPA) and Data Analysis Australia (DAA) in order to identify any adverse effects to the native vegetation and Priority flora species adjacent to F Deposit mine pits as a result of mining activities.

2.2 Plot Establishment and Initial Monitoring

In 2017, twelve 20m x 20m monitoring plots were established around the F Deposit mine pits. Each plot was marked with a metal fence dropper at each corner and a plot identification number was attached to the fence dropper in the north-west corner. At each plot the following information was recorded:

- Plot Number
- Monitoring Date
- GPS location (GDA94) taken from NW corner of plot
- Photographic record taken from NW corner of plot

Plot locations are identified in Figure 2.1.

The first monitoring event was conducted in September 2017 when each plot was visited and data recorded on the Priority flora and native vegetation, as outlined in the following sections.

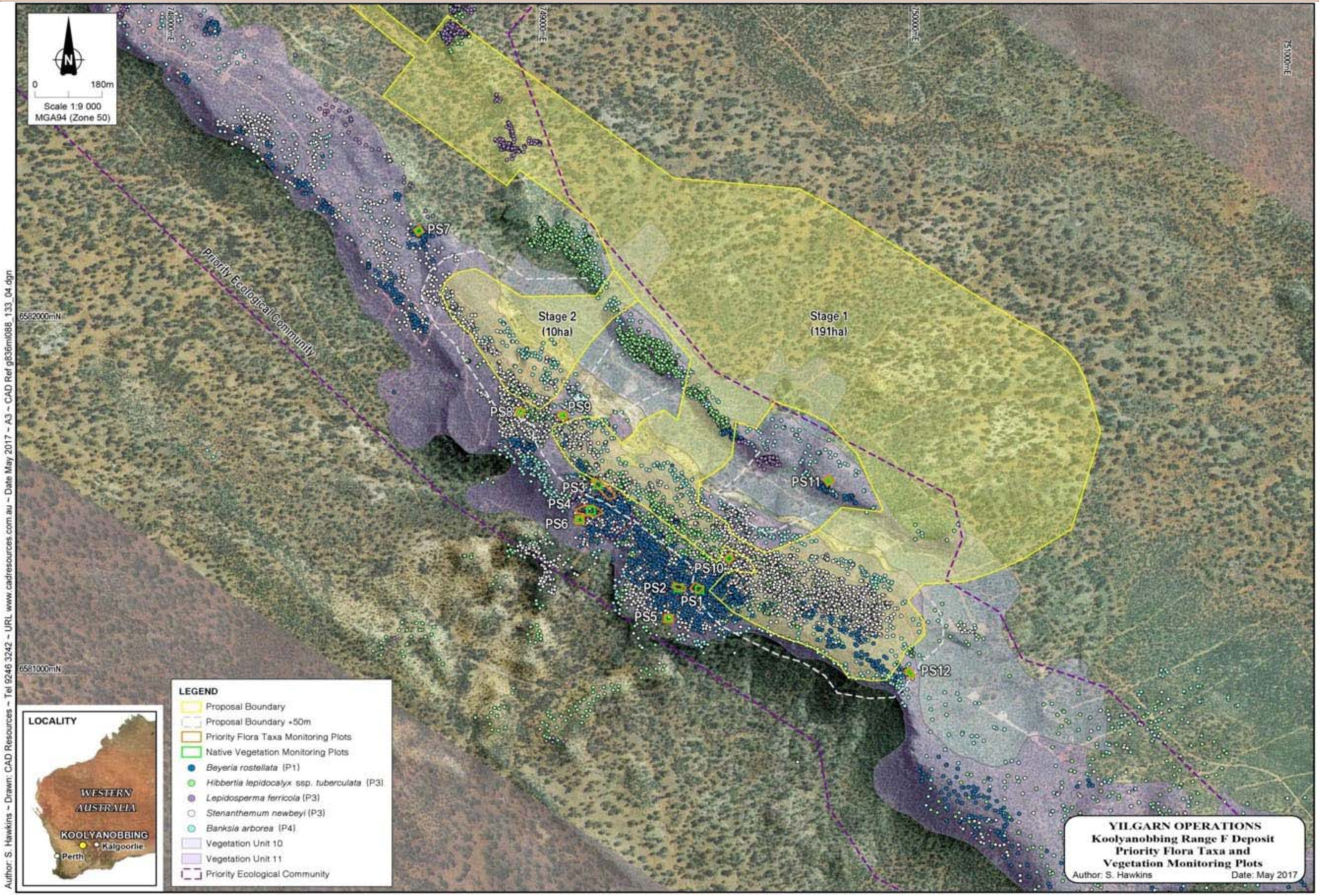

Figure 2.1: **Location of Priority flora and vegetation monitoring plots.**

2.3 Priority Flora Monitoring

To provide sufficient statistical power to detect changes in the health of Priority flora, a sample size of 15 individuals per species per plot is required. Within 10 of the 12 plots, there are 15 individuals of the Priority flora species *Beyeria rostellata* (P1), *Stenanthemum newbeyi* (P3), *Lepidosperma ferricola* (P3) and/or *Hibbertia lepidocalyx* subsp. *tuberculata* (P3). Table 2.1 outlines the Priority Flora species with sufficient (15 or more) numbers to be monitored within each of the 12 plots. The plots less than 50m from the pit are considered to be "near pit" and those plots greater than 50m from the pit are considered "far pit".

During each annual monitoring event, the following data is recorded for each individual:

- Reproductive status – vegetative, presence of buds, flowers and/or fruit
- Condition assessment - percentage of live material
- Leaf surface dust - visual estimate as outlined in Table 2.2
- Chlorophyll Fluorescence (Fv/Fm).

The two plots that don't contain the 15 individuals required for statistical analysis are also visited and data collected from Priority species to provide additional information. These plots also contain *Banksia arborea* (P4) individuals which are monitored for reproductive status, condition assessment and a photographic record taken of each individual.

Table 2.1: Priority flora species monitoring in each plot.

Plot Number	Distance from Pit	*Beyeria rostellata*	*Stenanthemum newbeyi*	*Lepidosperma ferricola*	*Hibbertia lepidocalyx* subsp. *tuberculata*
PS1	<50m	✓	✓	✓	
PS2	>50m	✓	✓	✓	✓
PS3	<50m	✓	✓	✓	
PS4	>50m	✓	✓	✓	✓
PS5	>50m				
PS6	>50m			✓	
PS7	>50m	✓		✓	
PS8	>50m		✓		
PS9	<50m		✓		
PS10	<50m		✓		
PS11	>50m	✓			
PS12	<50m				

Table 2.2: Description of dust categories.

Dust Category	Description
0	No visible dust
1	1-25% of plant covered with dust
2	25-50% of plant covered with dust
3	51-75% of plant covered with dust
4	76-100% of plant covered with dust

The index of chlorophyll fluorescence (Variable fluorescence (Fv)/Maximum fluorescence (Fm)) reading is taken using a 'Pocket PEA' portable chlorophyll fluorimeter. Chlorophyll fluorescence measurements provide an indication of photosynthetic performance thus enabling identification of plant stress (Hansatech 2006). A special leaf clip is attached to a live leaf of each monitored individual and the sample allowed to become dark adapted. The chlorophyll fluorescence is then measured by the PEA unit and recorded.

2.4 Native Vegetation Monitoring

Since 2017, annual monitoring of the native vegetation is also conducted. In 2019, following location of the plot, the boundary was demarcated with measuring tape and the plot further divided into 4-5 manageable sections with measuring tape or flagging tape. Two to three personnel then monitored a section each.

Within each plot the following information is recorded:

- Number of native species
- Number of individuals of each native species
- Number of weed species
- Number of individuals of each weed species
- Vegetation condition ranking using the Keighery (1994) scale (Table 2.3).

Table 2.3: The Keighery vegetation condition scale.

Condition Ranking	Description
Pristine	Pristine or nearly so, no obvious signs of disturbance.
Excellent	Vegetation structure intact, disturbance affecting individual species and weeds are non-aggressive species.
Very Good	Vegetation structure altered; obvious signs of disturbance. For example, disturbance to vegetation structure caused by repeated fires, the presence of some more aggressive weeds, dieback, logging and grazing.
Good	Vegetation structure significantly altered by very obvious signs of multiple disturbances. Retains basic vegetation structure or ability to regenerate it. For example, disturbance to vegetation structure caused by very frequent fires, the presence of some very aggressive weeds at high density, partial clearing, dieback and grazing.
Degraded	Basic vegetation structure severely impacted by disturbance. Scope for regeneration but not to a state approaching good condition without intensive management. For example, disturbance to vegetation structure caused by frequent fires, the presence of very aggressive weeds, partial clearing, dieback and grazing.
Completely Degraded	The structure of the vegetation is no longer intact and the area is completely or almost completely without native species. These areas are often described as "parkland cleared' with the flora comprising weed or crop species with isolated native trees or shrubs.

2.5 Statistical Analysis

Data Analysis Australia (DAA) were engaged to design data analysis tools to test for significant changes in chlorophyll fluorescence, condition assessment and mortality for Priority flora, and changes in number of species and number of individuals for native vegetation monitoring. The 2019 annual monitoring data was incorporated into the post-mining data set and the data analysis tools utilised to assess post-mining data (September / October 2017 - 2019) against pre-mining data (November / December 2016 and May 2017), in accordance with parameters outlined in the F Deposit Flora and Vegetation Management Plan (Cliffs 2017).

3.0 RESULTS

3.1 Priority Flora

Photographic records, taken from the north west corner of each monitoring plot, are shown in Appendix 1.

Photographic records of the *Banksia arborea* (Ba) monitoring are shown in Appendix 2.

3.1.1 Reproductive Status

The percentage of *Beyeria rostellata* plants reproductive in 2019 ranged from 93% to 100%, as shown in Figure 3.1. One individual each in Plots PS2 and PS11 was recorded as dead. The percentage reproductive ranged from 87% - 100% in 2018 and 86% - 100% in 2017. Plot PS7 has recorded 100% of plants reproductive in all three years of monitoring.

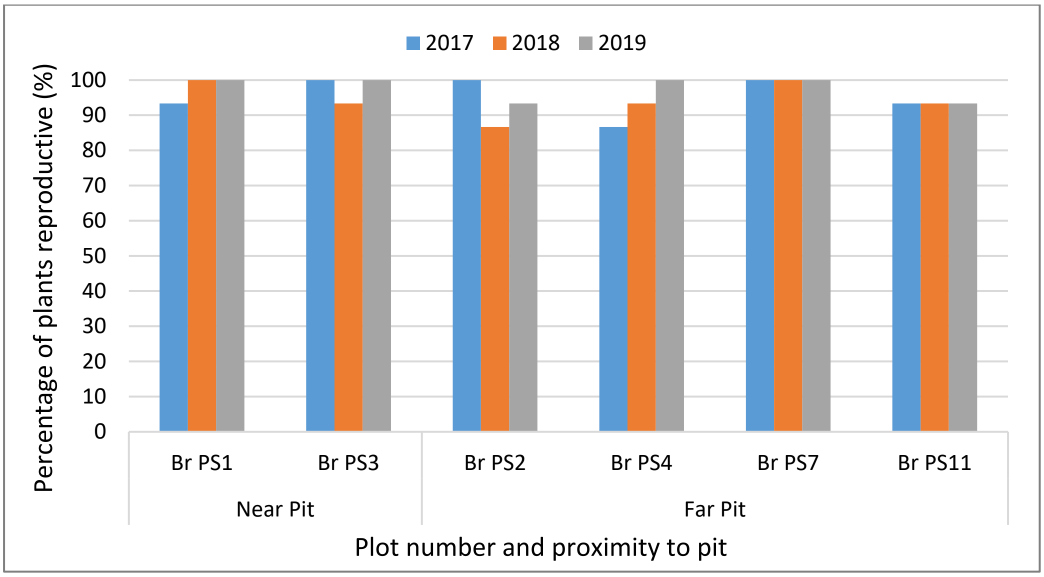

Figure 3.1: Percentage of *Beyeria rostellata* individuals recorded as reproductive 2017 – 2019.

The percentage of *Stenanthemum newbeyi* individuals recorded as reproductive in 2019 ranged from 80% to 100%. Reproductive individuals in Plot PS10 (Near pit) have decreased from 100% in 2017 and 93% in 2018 to 80% in 2019. This is due to the death of a total of three individuals; 1 in 2018 and an additional 2 in 2019. The largest increase in reproductive individuals is in Plot PS3 (Near pit) which recorded 64% reproductive in 2018 and 93% in 2019.

The percentage of reproductive *Stenanthemum newbeyi* individuals recorded each year in each plot is shown in Figure 3.2.

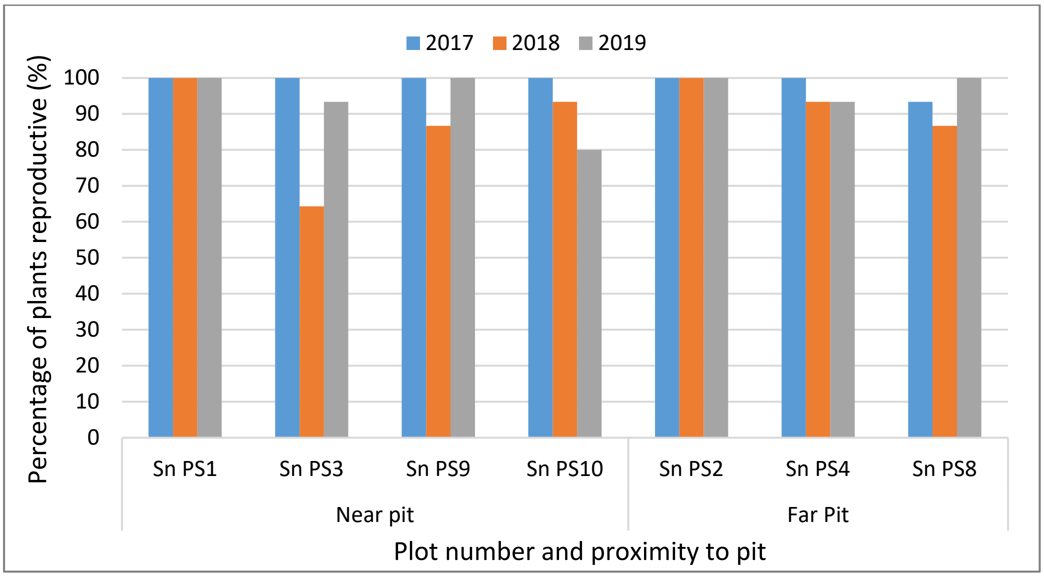

Figure 3.2: Percentage of *Stenanthemum newbeyi* individuals recorded as reproductive 2017 – 2019.

Figure 3.3 shows the percentage of monitored *Lepidosperma ferricola* individuals recorded as reproductive in each plot. All plots were recorded as 100% reproductive apart from Plot PS3 (60%) and Plot PS6 (87%). Plot PS3 (Near pit) has recorded the lowest proportion of reproductive individuals in all monitoring years.

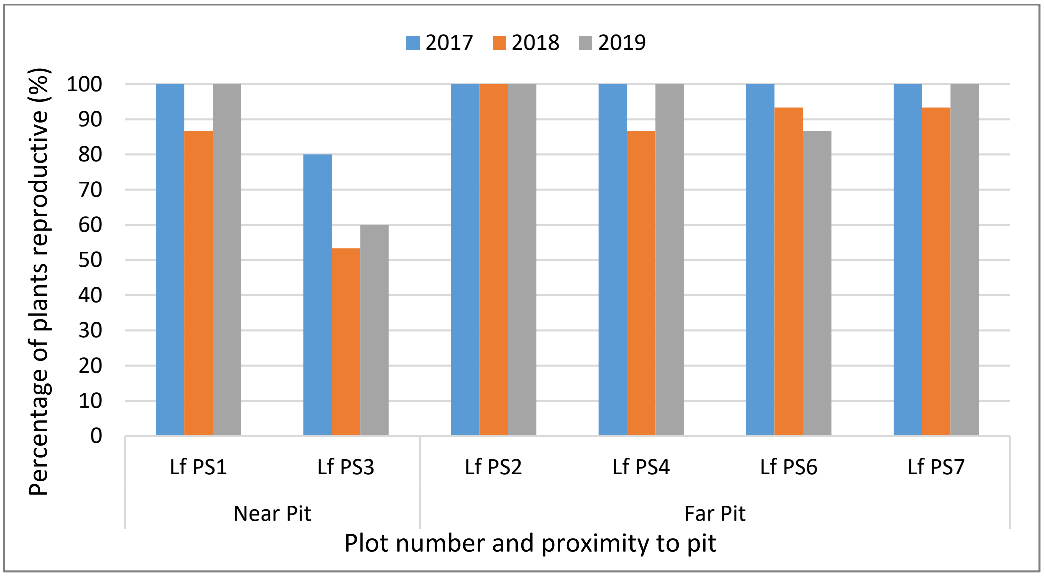

Figure 3.3: Percentage of *Lepidosperma ferricola* individuals recorded as reproductive 2017 – 2019.

The percentage of *Hibbertia lepidocalyx* subsp. *tuberculata* individuals recorded as reproductive in 2019 ranged from 93% - 100%. In 2018 only Plot PS2 recorded any reproductive individuals (40% reproductive). All plots had 100% of plants reproductive during the 2017 monitoring, as shown in Figure 3.4. It was noted during monitoring that at least one individual identified as *Hibbertia lepidocalyx* subsp. *tuberculata* was actually a similar species *Hibbertia exasperata.*

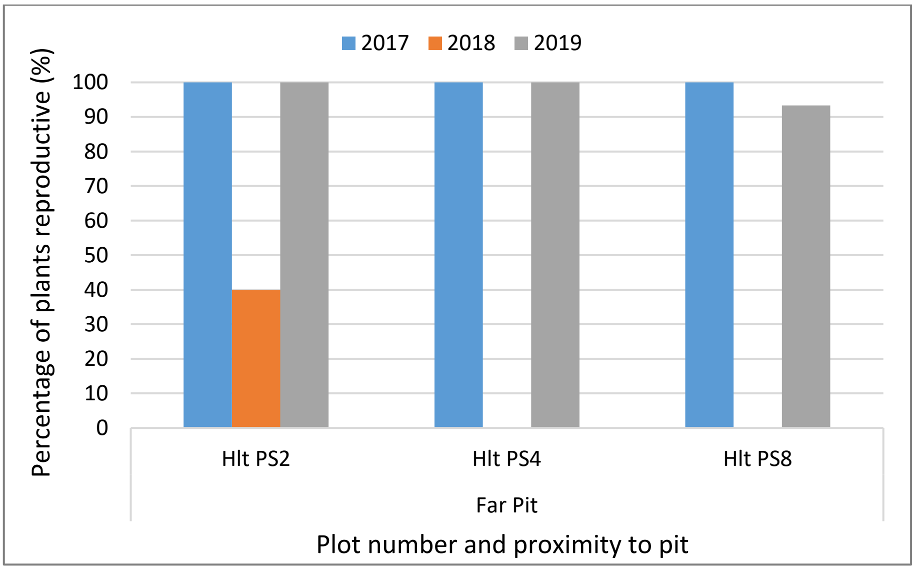

Figure 3.4: Percentage of *Hibbertia lepidocalyx* subsp. *tuberculata* individuals recorded as reproductive 2017 – 2019.

3.1.2 Condition Assessment

The average condition assessment (percentage of live growth) of *Beyeria rostellata* individuals ranged from 84% to 91% in 2019. Condition ranged from 81% to 92% in 2018, compared to 71% and 92% in 2017, as shown in Figure 3.5. Plot PS3 (Near pit) has recorded the lowest average condition score across all years.

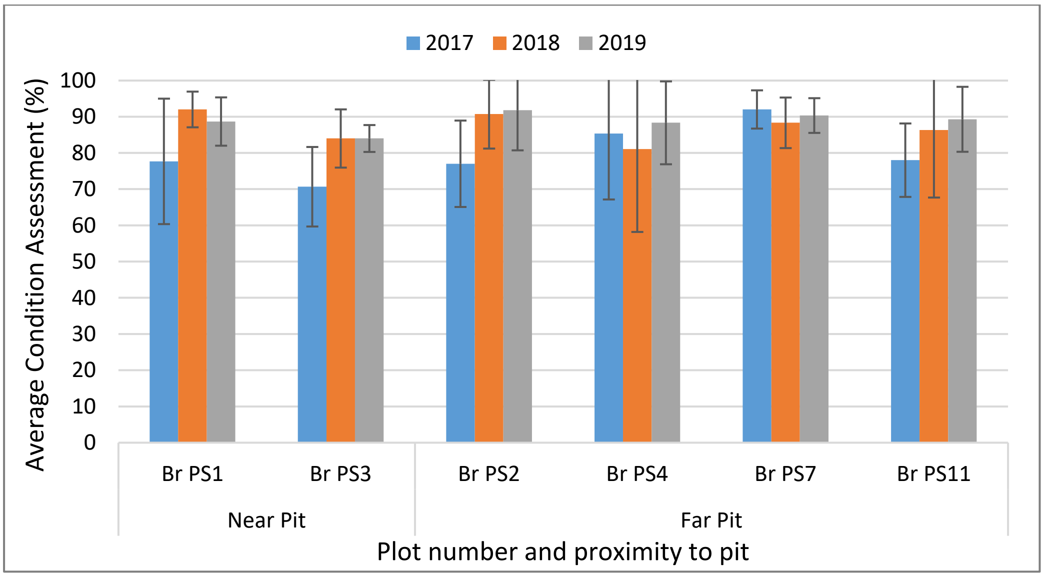

Figure 3.5: Average condition assessment with standard deviation of *Beyeria rostellata* in all plots 2017 - 2019.

Figure 3.6 presents the average condition assessment per plot for *Stenanthemum newbeyi*. Average condition ranged from 64% in Plot PS1 to 81% in Plot PS8. Two plots located less than 50m from the pit, Plots PS3 and PS9, and two plots located further than 50m from the pit, Plots PS4 and PS8, recorded increased condition compared to 2018.

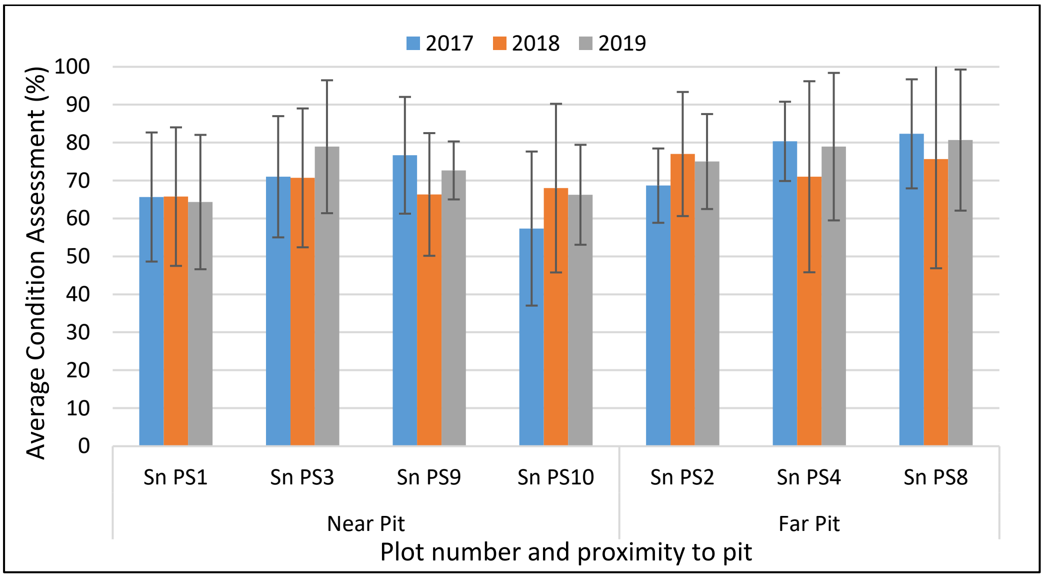

Figure 3.6: Average condition assessment with standard deviation of *Stenanthemum newbeyi* in all plots 2017 - 2019.

Figure 3.7 presents the average condition assessment per plot for *Lepidosperma ferricola* individuals. Average condition was higher in all plots compared with 2018. Average condition assessment scores ranged from 50% in Plot PS4 (Far pit) to 78% in Plot PS6 (Far pit) in 2019. Scores ranged from 43% to 72% in 2018, and 53% to 69% in 2017. Plot PS4 has recorded the lowest average condition of *Lepidosperma ferricola* in all monitoring years.

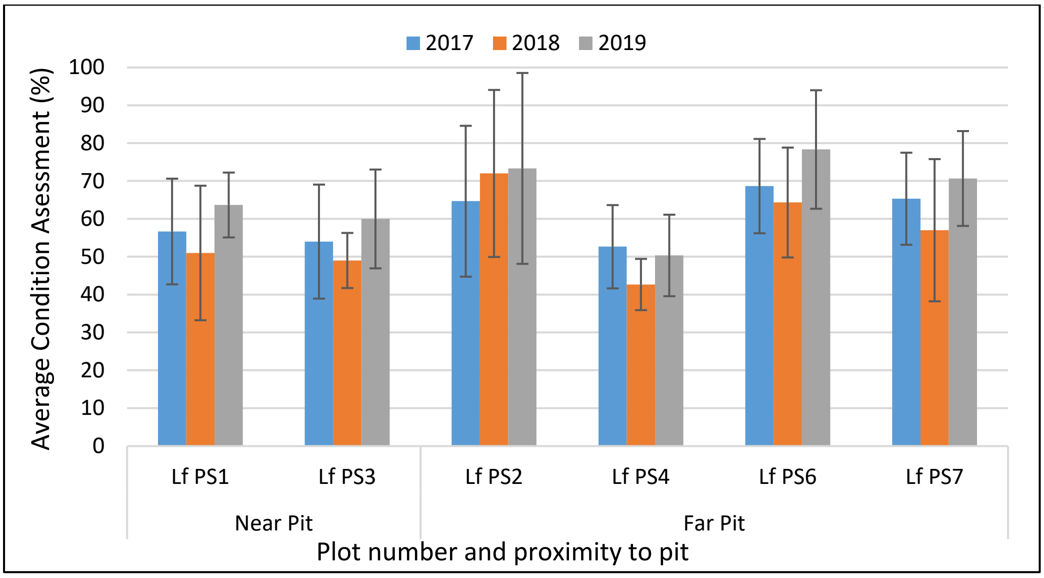

Figure 3.7: Average condition assessment with standard deviation of *Lepidosperma ferricola* in all plots 2017 - 2019.

The average condition of *Hibbertia lepidocalyx* subsp. *tuberculata* ranged from 83% to 92% as shown in Figure 3.8.

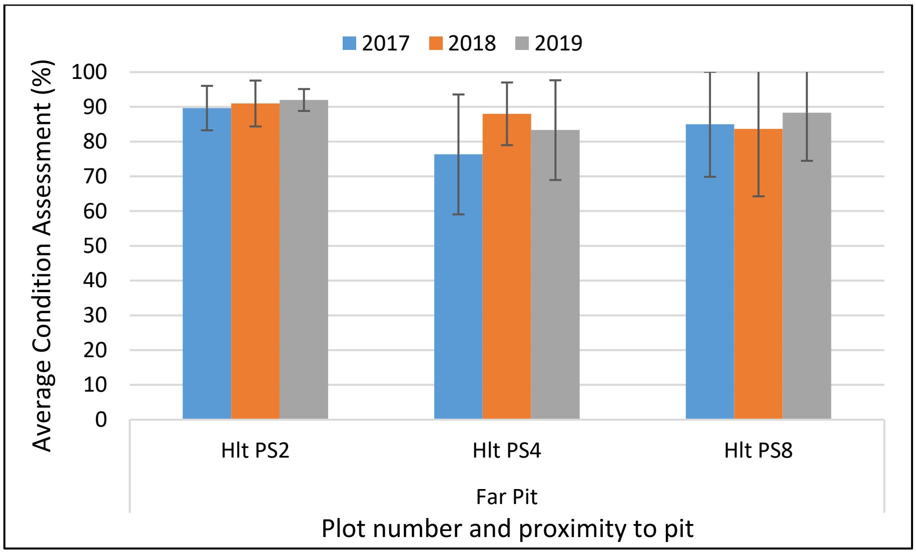

Figure 3.8: Average condition assessment with standard deviation of *Hibbertia lepidocalyx* subsp. *tuberculata* in all plots 2017 - 2019.

The average condition of the Priority species in "Near pit" plots and "Far pit" plots is displayed in Figure 3.9. *Hibbertia lepidocalyx* subsp. *tuberculata* are not included as all monitored individuals are located in plots that are further than 50m from the pit (Far pit). *Banksia arborea* (Ba) individuals have been included although there are insufficient individuals in each plot for statistical analysis.

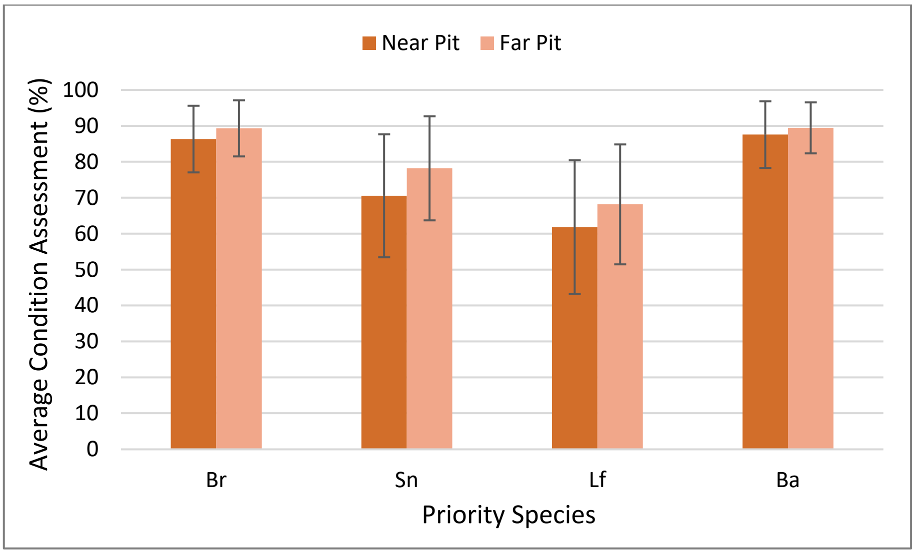

Figure 3.9: Average condition assessment with standard deviation of four Priority species in near pit and far pit plots in 2019.

3.1.3 Chlorophyll Fluorescence

Average chlorophyll fluorescence and standard deviation of *Beyeria rostellata* individuals in each plot for 2017 to 2019 is displayed in Figure 3.10. There was little variation in average chlorophyll fluorescence in 2019, ranging from 0.72 in Plot PS4 to 0.75 in Plots PS1 and PS2. Two plots, Plot PS3 (Near pit) and PS11 (Far pit), recorded lower chlorophyll fluorescence compared to the previous year and all plots were lower than recorded in 2017.

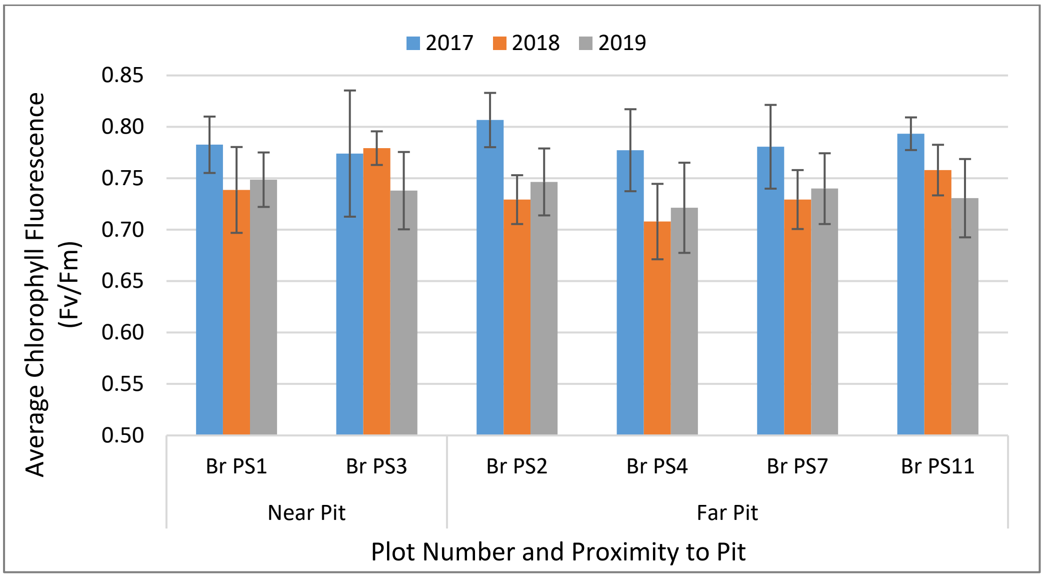

Figure 3.10: Average chlorophyll fluorescence with standard deviation of *Beyeria rostellata* in each plot 2017 – 2019.

Average chlorophyll fluorescence of *Stenanthemum newbeyi* individuals ranged from 0.68 to 0.74. Three "near pit" plots (Plots PS3, PS9 and PS10) recorded the lowest average chlorophyll fluorescence of all the plots. Average chlorophyll fluorescence in Plots PS1 and PS3 was lower than in 2018 and all plots recorded lower average chlorophyll fluorescence in 2019 than 2017. Figure 3.11 shows the average chlorophyll fluorescence and standard deviation per plot for *Stenanthemum newbeyi* individuals for all monitoring years.

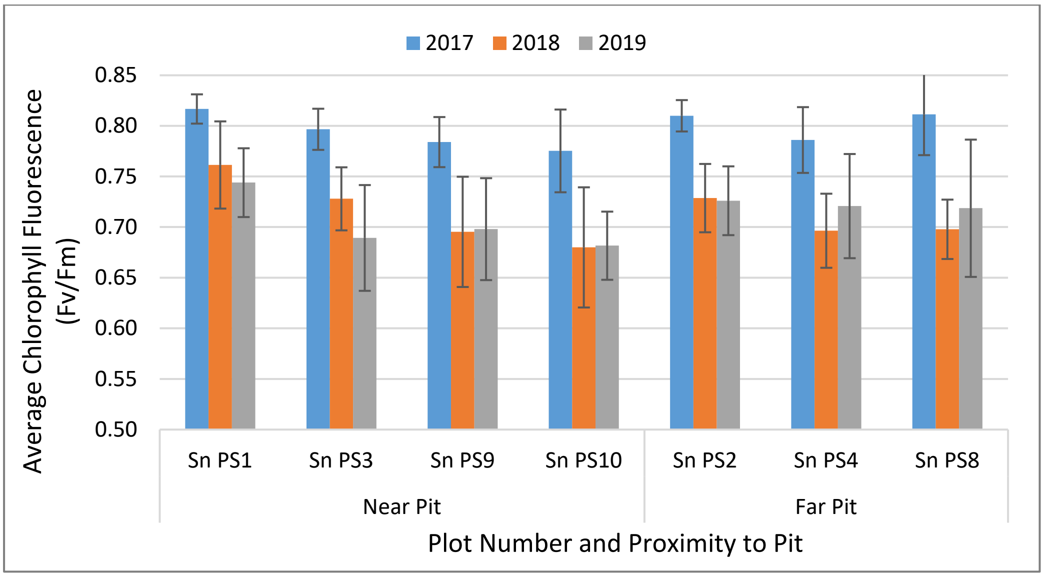

Figure 3.11: Average chlorophyll fluorescence with standard deviation of *Stenanthemum newbeyi* in each plot 2017 – 2019.

Figure 3.12 shows the average chlorophyll fluorescence for *Lepidosperma ferricola* individuals in all plots from 2017 to 2019. Average chlorophyll fluorescence across the plots showed little variation in 2019, ranging from 0.71 to 0.73. All plots recorded higher average chlorophyll fluorescence than in 2018, conversely, the average in all plots was lower than in 2017.

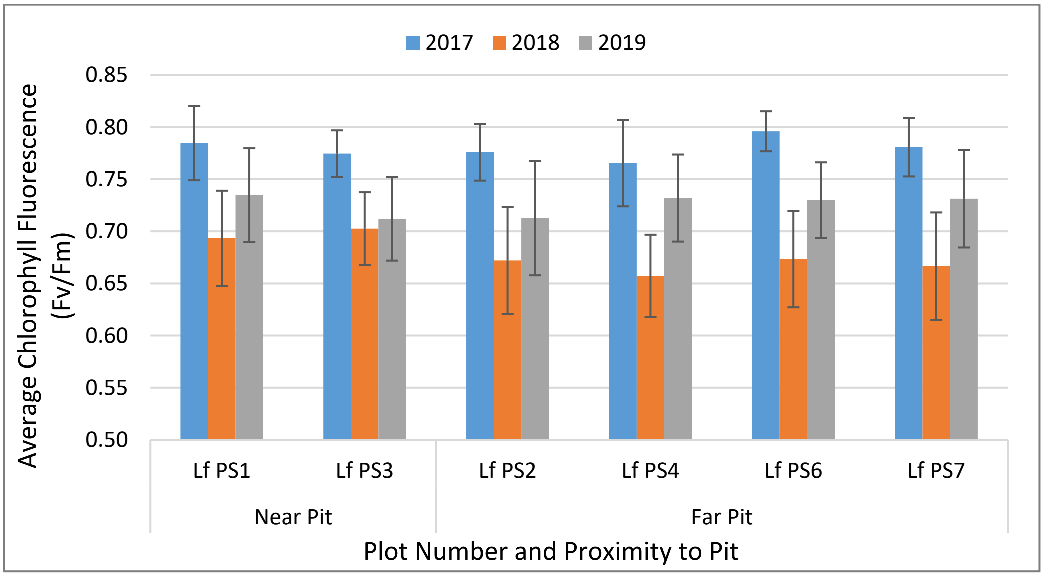

Figure 3.12: Average chlorophyll fluorescence with standard deviation of *Lepidosperma ferricola* in each plot 2017 – 2019.

Figure 3.13 shows the average chlorophyll fluorescence per plot for *Hibbertia lepidocalyx* subsp. *tuberculata* individuals. Average chlorophyll fluorescence values in 2019 ranged from 0.68 to 0.72. Plot PS2 recorded higher average chlorophyll fluorescence than in 2018. All plots had higher readings in 2017 than both 2018 and 2019.

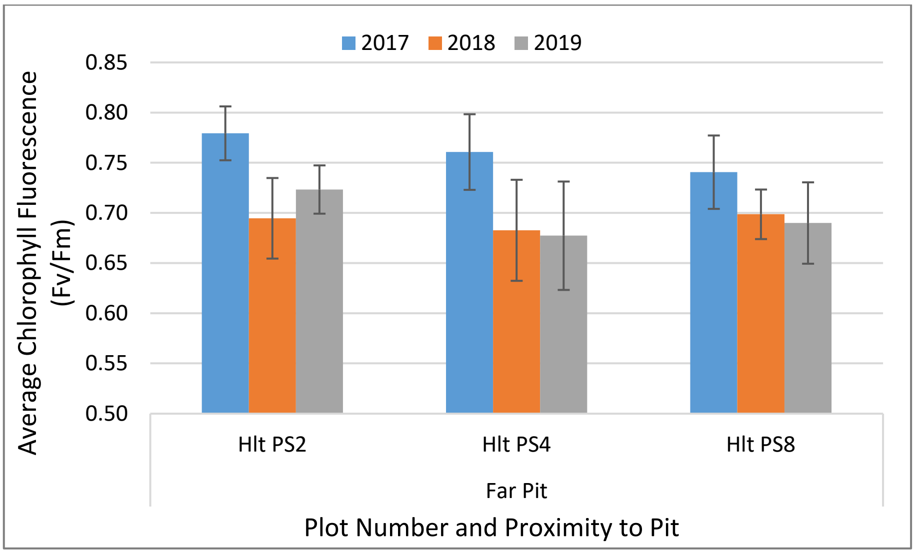

Figure 3.13: Average chlorophyll fluorescence with standard deviation of *Hibbertia lepidocalyx* subsp. *tuberculata* in each plot 2017 – 2019.

The average chlorophyll fluorescence of the Priority species in "Near pit" plots and "Far pit" plots is displayed in Figure 3.14.

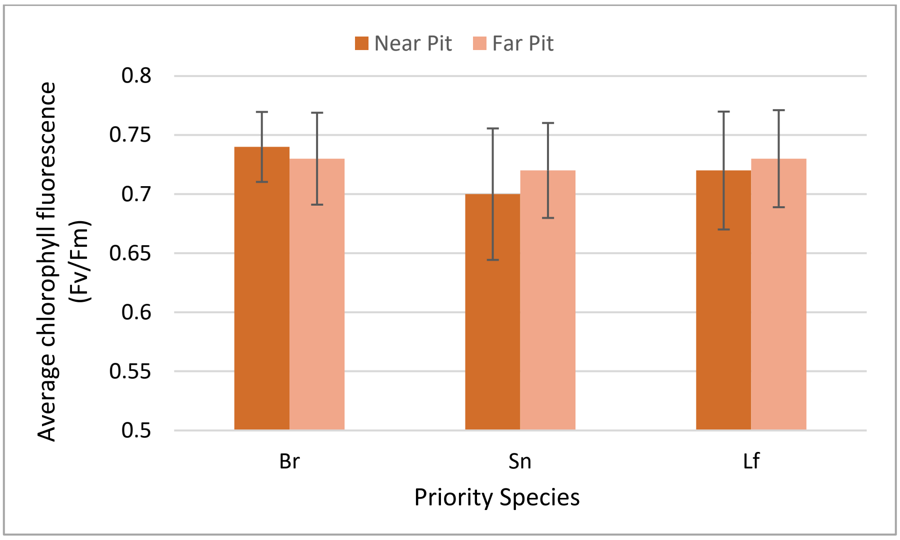

Figure 3.14: Average chlorophyll fluorescence with standard deviation of Priority species in near pit and far pit plots in 2019.

3.1.4 Leaf Surface Dust

No visible leaf surface dust was recorded on any of the *Lepidosperma ferricola* or *Hibbertia lepidocalyx* subsp. *tuberculata* individuals in any plot monitored in 2019. In 2018 no visible leaf surface dust was recorded on any individuals in any plot.

In 2019, leaf surface dust was recorded in all *Stenanthemum newbeyi* plots with the exception of Plot PS4 in which no leaf surface dust was recorded. In all plots, with the exception of Plot PS4 and PS8, 100% of individuals recorded some leaf dust. Plot PS1 recorded 87% of individuals with Dust Category 2 (26 – 50% covered) and 13% with Dust Category 3 (51 – 75% covered). In Plots PS10 and PS2, 50% or more individuals recorded leaf surface Dust Category 2. Figure 3.15 displays the proportion of individuals with leaf surface dust recorded in each plot and the dust category as defined in Table 2.2.

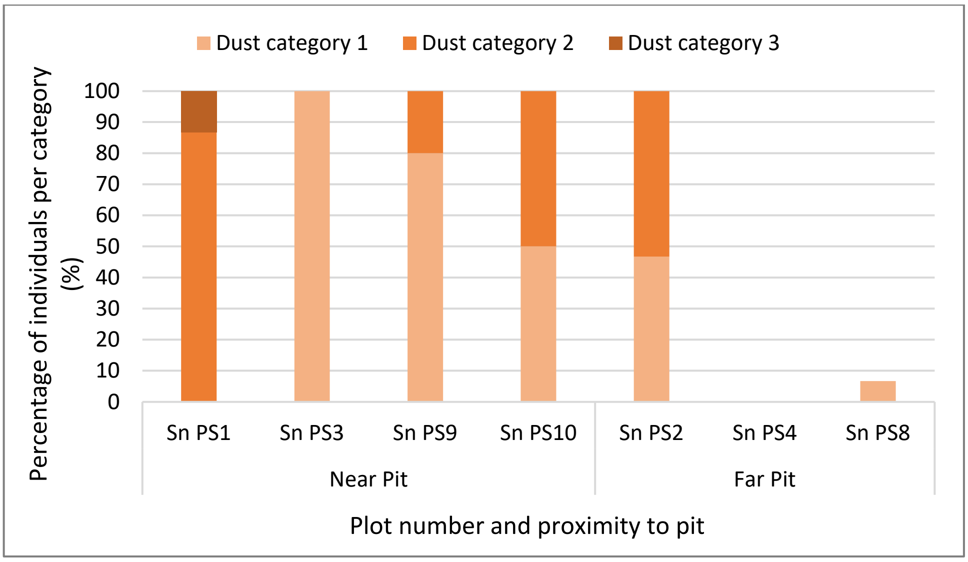

Figure 3.15: Leaf surface dust on *Stenanthemum newbeyi* in each plot in 2019.

Leaf surface dust was recorded on individuals in half the *Beyeria rostellata* monitoring plots in 2019. Plot PS1 recorded 100% of individuals with leaf surface Dust Category 1 (1 – 25% covered). Three of the four plots located further from the pit recorded no visible leaf surface dust, as displayed in Figure 3.16.

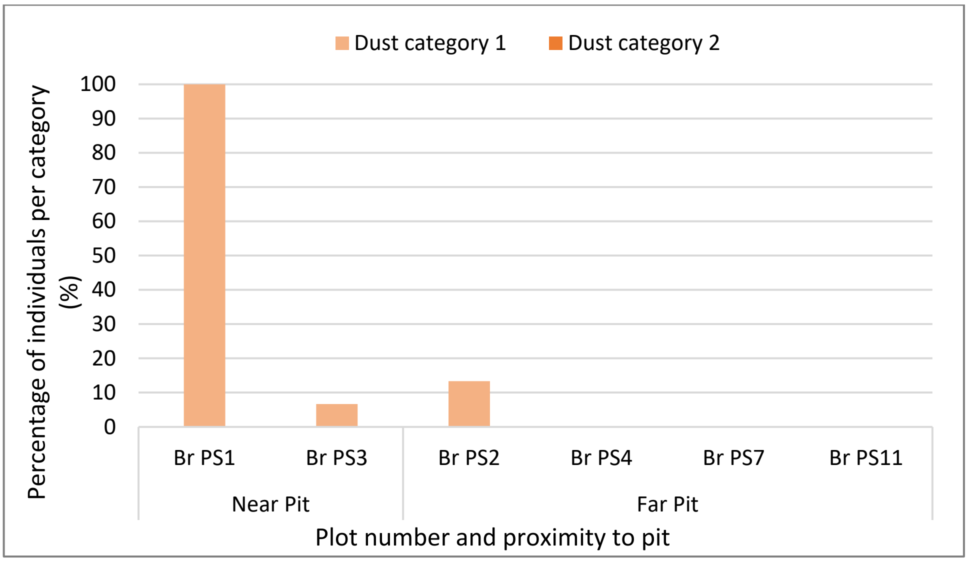

Figure 3.16: Leaf surface dust on *Beyeria rostellata* in each plot in 2019.

3.1.5 Mortality

There were 13 dead individuals recorded in 8 plots in 2019. Dead *Stenanthemum newbeyi* (Sn), *Beyeria rostellata* (Br) and *Banksia arborea* (Ba) individuals were recorded, as shown in Figure 3.17. Of these dead individuals, two *Stenanthemum newbeyi*, one *Beyeria rostellata* and one *Banksia arborea* were recorded as dead in 2018. Note that Plots PS5 and PS12 are not included in the statistical analysis data but contain *Banksia* individuals. Plots PS10 and PS12 recorded the highest number of dead individuals (3 dead).

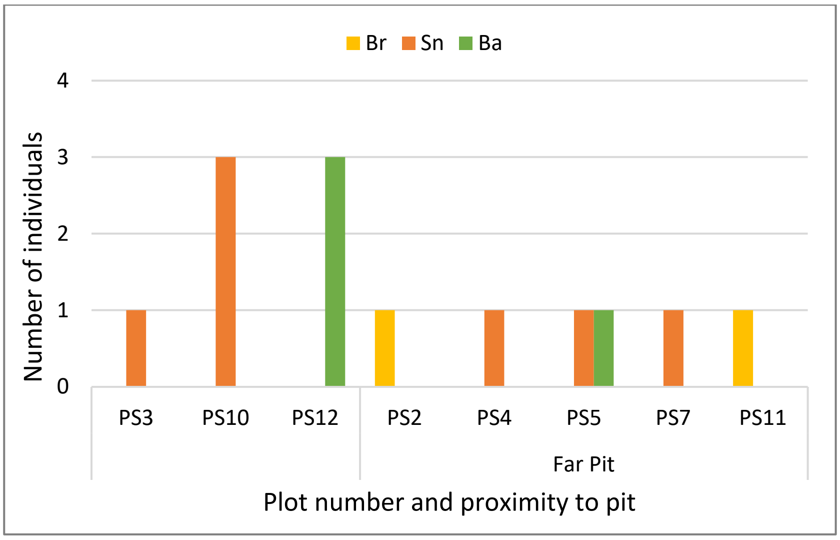

Figure 3.17: Number of dead individuals recorded in monitoring plots in 2019.

3.1.6 Statistical Analysis

The 2019 Priority flora monitoring data was included in the post-mining data set and analysed by the statistical analysis tool in November 2019.

No statistically significant association was found between mining activity and condition assessment or chlorophyll fluorescence for *Lepidosperma ferricola*. Analysis was not conducted on the association between mining activity and mortality for *Lepidosperma ferricola* due to insufficient data.

No statistically significant association was found between mining activity and condition assessment or chlorophyll fluorescence for *Stenanthemum newbeyi*. No statistically significant association was found between mining activity and mortality for *Stenanthemum newbeyi* or *Beyeria rostellata.*

No statistically significant association was found between mining activity and condition assessment for *Beyeria rostellata* following primary analysis, however, following extended analysis including the effect of dust, there was a statistically significant association found between mining activity and condition assessment for *Beyeria rostellata*. An increase in the condition of the species occurred between pre- and post- mining periods. The data used in the statistical analysis (mean condition assessment at 95% confidence interval) is displayed in Figure 3.18.

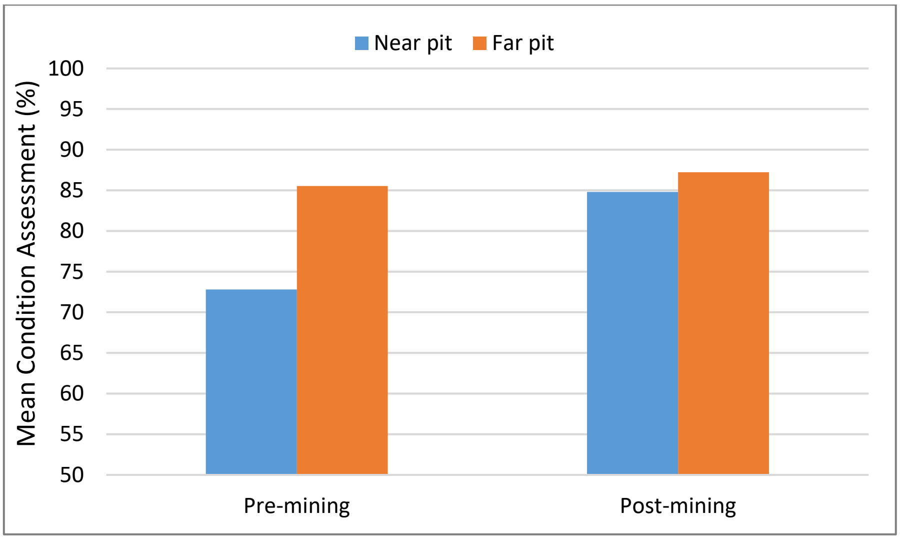

Figure 3.18: Mean (95% confidence interval) condition assessment of *Beyeria rostellata* used in extended statistical analysis.

Following primary analysis and excluding the effect of dust, a statistically significant association was found between mining activity and chlorophyll fluorescence for *Beyeria rostellata.* As was the case for condition assessment results, this is a positive association as there was an increase in chlorophyll fluorescence between the pre- and post - mining period. Further statistical analyses, and including the effect of dust, found no statistically significant association between mining activity and chlorophyll fluorescence for *Beyeria rostellata.*

Appendix 3 presents the results of the statistical tool analysis for Priority Flora.

3.2 Native Vegetation

3.2.1 Vegetation Condition

Table 3.1: Vegetation condition in each plot.Table 3.1 presents the results of the vegetation condition monitoring for all years of monitoring. In 2019 all monitoring plots were ranked from ‘Good’ to ‘Excellent’, as defined by Keighery (1994).

Table 3.1: Vegetation condition in each plot.

Plot Number	Proximity to Pit	2017 Condition	2018 Condition	2019 Condition
PS1	Near pit	Excellent	Excellent	Excellent
PS2	Far pit	Excellent	Excellent	Excellent
PS3	Near pit	Excellent	Good	Good
PS4	Far pit	Excellent	Excellent	Excellent
PS5	Far pit	Excellent	Very good	Excellent
PS6	Far pit	Excellent	Excellent	Excellent
PS7	Far pit	Excellent	Very good	Excellent
PS8	Far pit	Very good	Very good	Very good
PS9	Near pit	Excellent	Very good	Very good
PS10	Near pit	Very good	Very good	Very good
PS11	Far pit	Excellent	Very good	Excellent
PS12	Near pit	Excellent	Very good	Good

3.2.2 Species Diversity and Richness

Total species richness in each plot (number of species per plot) from 2017 to 2019 is shown in Figure 3.19. Species richness in 2019 ranged from 24 species in Plot PS9 (Near pit) to 44 species in Plot PS12 (Near pit). Plot PS9 had the lowest species richness in all years, recording 16 species in 2017 and 2018, while Plot PS12 recorded the highest species richness in all years, with 31 species in 2017 and 26 species recorded in 2018. Species richness in all plots was higher in 2019 compared to the two previous years. In 2019 a total of 15 annual species were recorded.

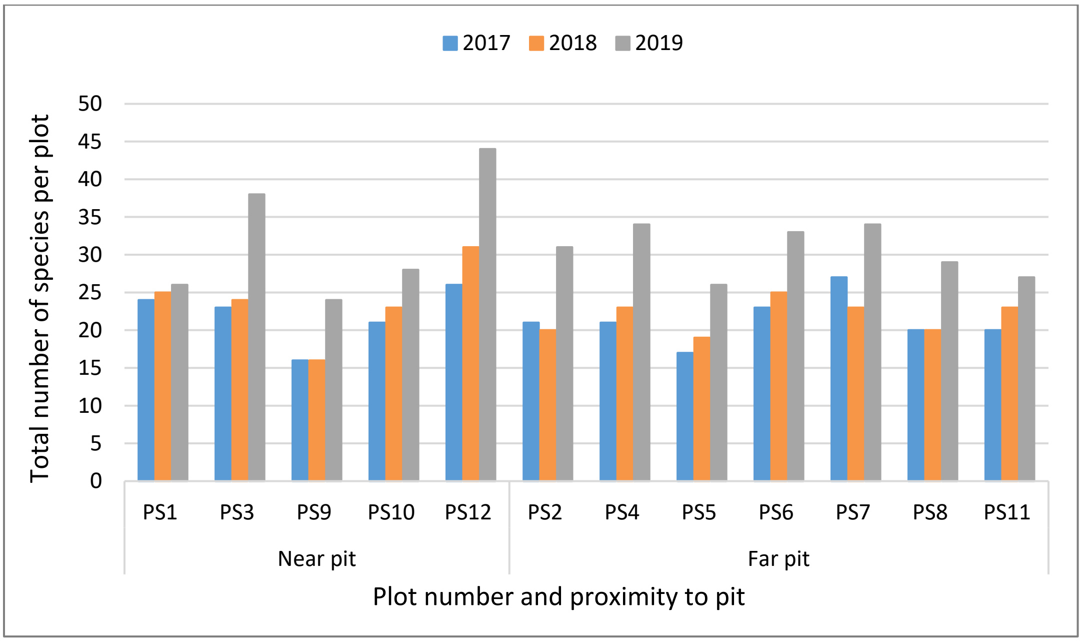

Figure 3.19: Total species richness per plot 2017 - 2019.

The average number of live adult individuals in 2019 ranged from 9.9 in Plot PS5 (Far pit) to 35.7 in Plot PS7 (Far pit), as shown in Figure 3.20. In 2019 an increase in average number of individuals was recorded in nine of the plots when compared to 2018 and 2017 results. Plot PS5 has recorded the lowest number of individuals in all years of monitoring.

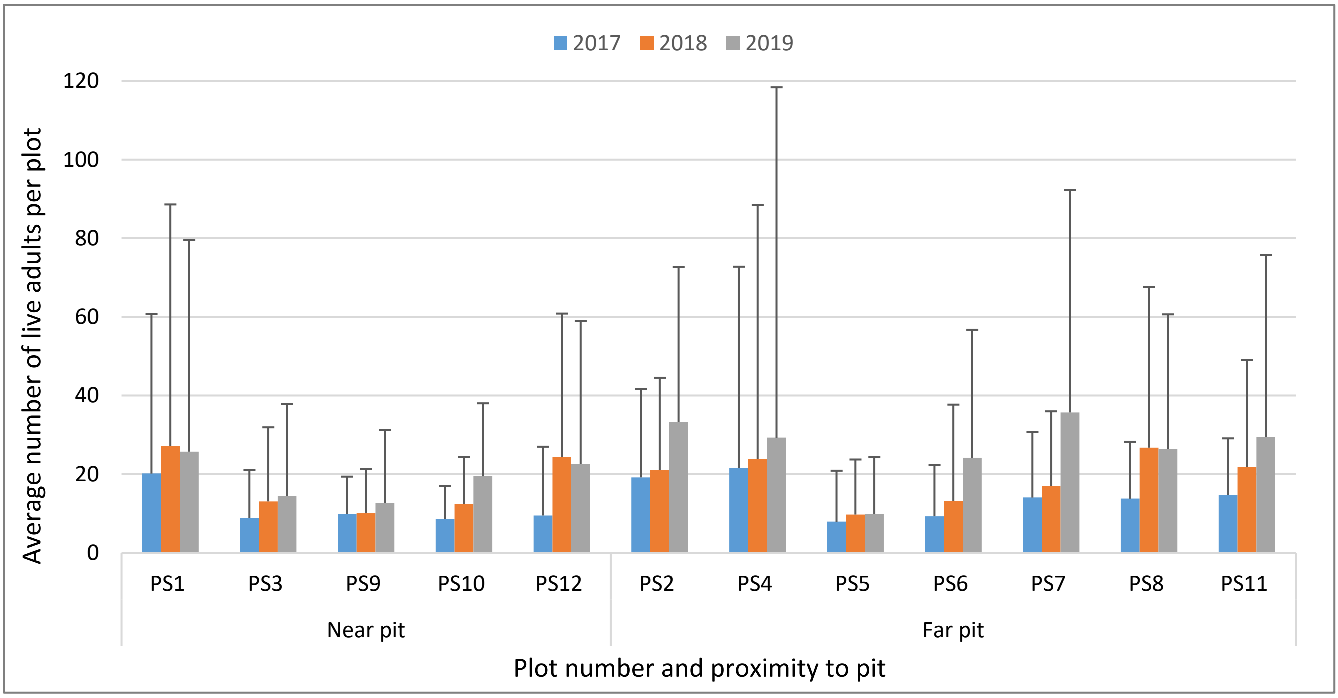

Figure 3.20: Average number of live adult plants per plot, with standard deviation, 2017 – 2019.

3.2.3 Recruitment and Mortality

The number of seedlings recorded in 2019 ranged from three seedlings in Plot PS9 (Near pit) to 71 seedlings in Plot PS11 (Far pit). Of the 71 seedlings in Plot PS11 there were 13 each of *Alyxia buxifolia* and *Dianella revoluta* var. *divaricata* and 17 *Eremophila clarkei*. Plot PS9 recorded two and three seedlings in 2017 and 2018. The number of seedlings recorded in each plot in 2017 to 2019 is displayed in Figure 3.21.

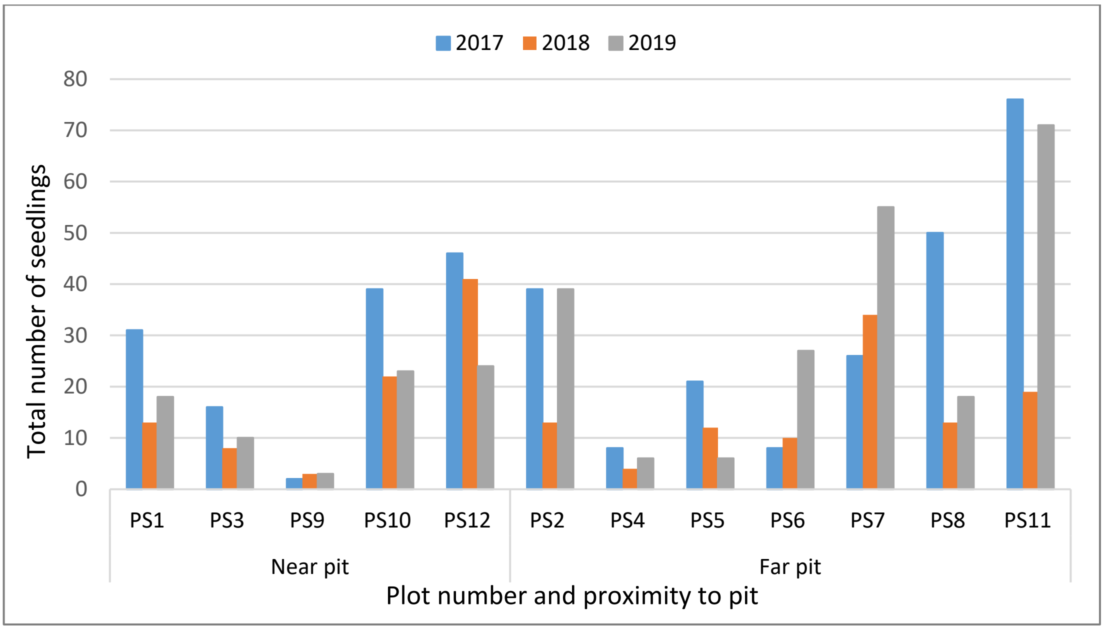

Figure 3.21: Total number of seedlings in each plot 2017 – 2019.

In 2019 the plots which recorded the highest number of dead individuals were plot PS12 (Near pit) with 162 dead individuals and Plot PS7 (Far pit) which recorded 209 dead individuals. In the previous year the largest number of dead individuals was three individuals recorded in plot in Plot PS10. In 2017, 13 dead individuals were recorded in Plot PS7.

Figure 3.22 displays the numbers of dead individuals recorded in each plot in 2017 to 2019.

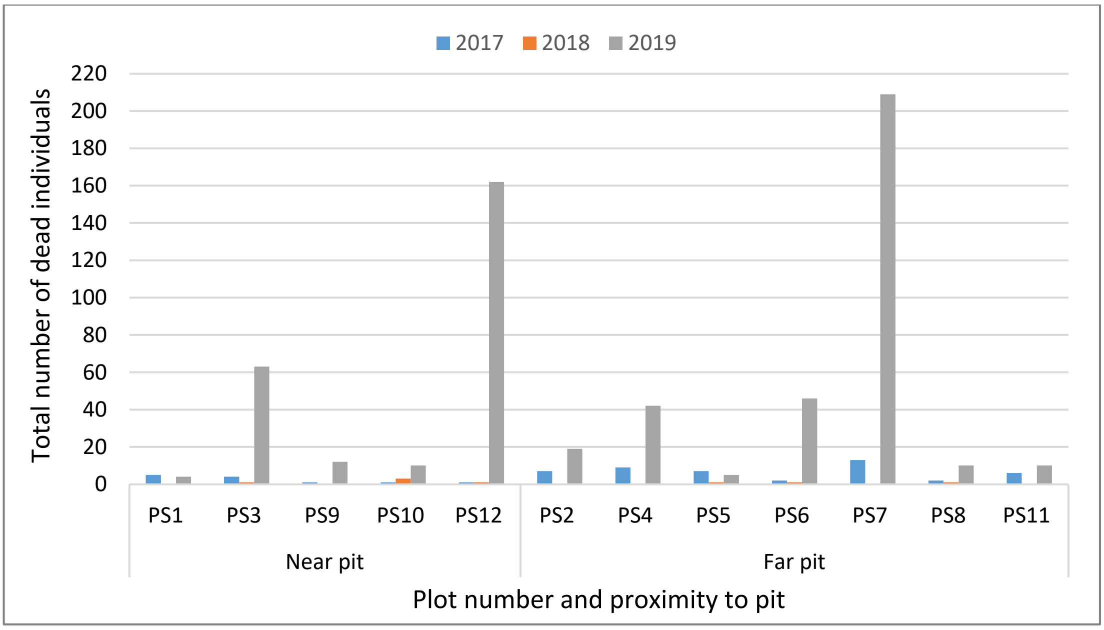

Figure 3.22: Total number of dead individuals in each plot 2017 – 2019.

A large portion of the dead individuals recorded in 2019 are the species, *Cheilanthes sieberi* subsp. *sieberi* (54 dead individuals in Plot PS3 and 100+ dead individuals in Plot PS7), *Drosera macrantha* (100+ dead individuals in Plot PS7) and *Rhodanthe battii* (131 dead individuals in Plot PS12). To provide a relative comparison on previous years, Figure 3.23 displays the numbers of dead individuals recorded in each plot in 2017 to 2019 excluding these three species.

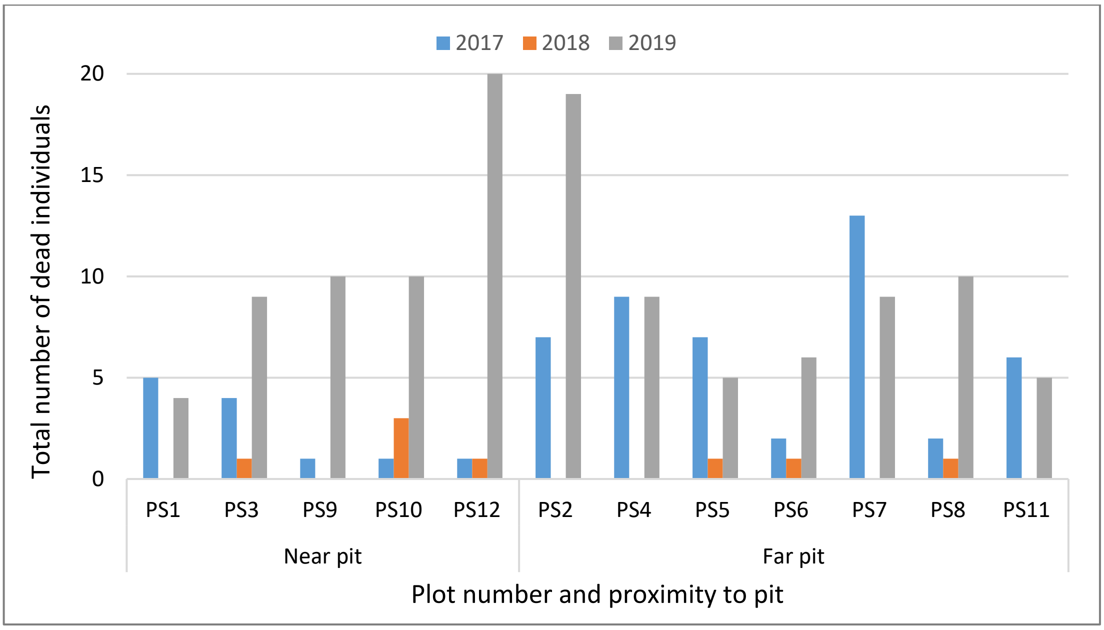

Figure 3.23: Total number of dead individuals in each plot 2017 – 2019 excluding *Cheilanthes sieberi* subsp. *sieberi, Drosera macrantha* and *Rhodanthe battii.*

3.2.4 Weeds

Three weed species, *Carrichtera annua* (Wards weed), *Monoculus monstrosus* (Stinking Roger) and *Sonchus oleraceus* (Common sowthistle) were recorded in 2019. Four sowthistle were recorded in Plot PS3 and 30 Wards weeds*,* 22 Stinking Roger and 20 sowthistle were recorded in Plot PS12.

3.2.5 Statistical Analysis

Statistical analysis was conducted on the 2019 native vegetation data in November 2019. No statistically significant association was found between mining activity and live plant abundance or mortality.

3.3 Rainfall

In the 12 months prior to the 2019 monitoring (October 2018 – September 2019), Koolyanobbing recorded 276.8 mm of rain. The 2001-2019 average rainfall for Koolyanobbing is 286.7 mm (BoM 2019).

Figure 3.24 shows the total monthly rainfall received at Koolyanobbing prior to the current and previous monitoring events, as well as the 2001-2019 monthly average. Below average rainfall was received at Koolyanobbing in the months prior to the monitoring event. Above average rainfall was received (almost three times the monthly average) in the month of June.

In 2018 Koolyanobbing received 344.5mm rainfall, approximately 58mm above average. Approximately 34% of the total annual rainfall fell in February 2018 with over double the average rainfall occurring in August and October 2018. A similar trend occurred in 2017, with high rainfall in January and February and above average in August.

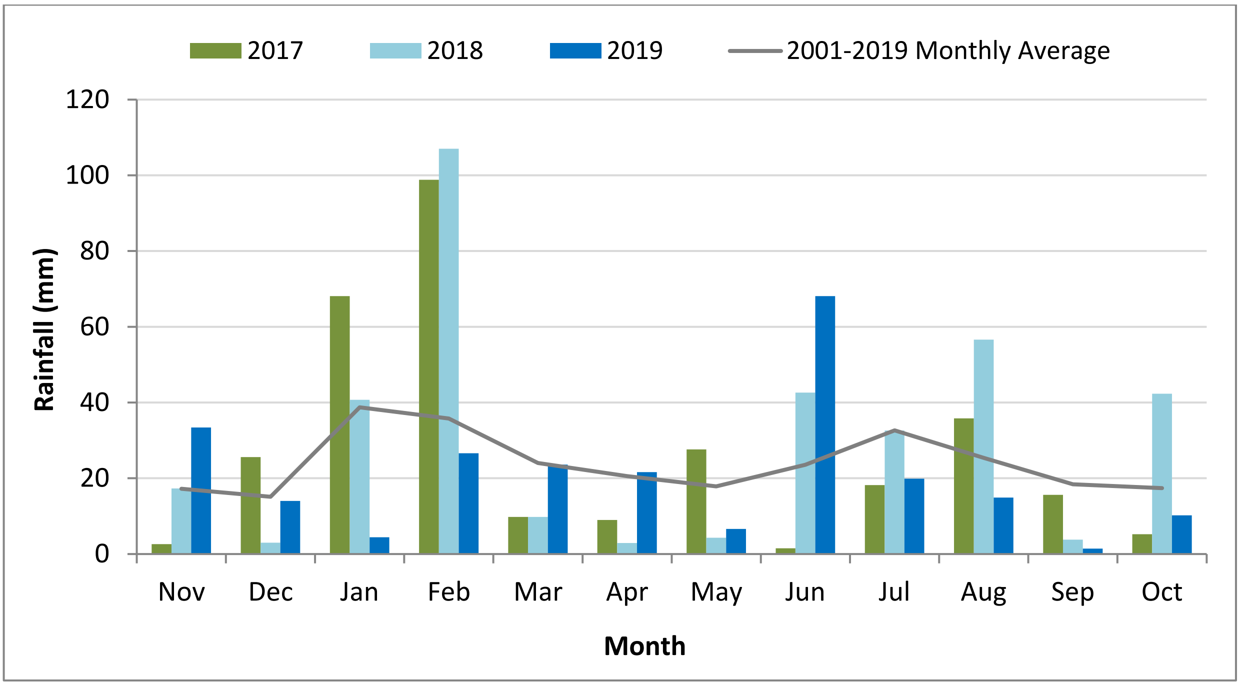

Figure 3.24: Monthly rainfall 2017 – 2019 and 2001 – 2019 monthly average rainfall at Koolyanobbing.

4.0 DISCUSSION AND CONCLUSION

The 2019 monitoring is the third year of monitoring the Priority flora and vegetation at F pit, as the 2017 monitoring results are considered baseline. Mining activities commenced at F pit in May 2017 and ceased in April 2018. MRL recommenced mining in early December 2018. Overall, the results of the 2019 monitoring indicate that the Priority flora and native vegetation populations in the F pit area are in a maintaining their condition. However, some patterns may be emerging that indicate potential impacts to flora and vegetation in some plots.

The majority of monitored Priority flora were found to be reproductive during the 2019 monitoring. With the exception of two plots, over 90% of individuals were recorded as reproductive. One *Stenanthemum newbeyi* plot, Plot PS10, located less than 50m from the pit (Near pit), was 80% reproductive. This is due to three individuals being recorded as dead. Plot PS3, also located "Near pit", recorded 60% of *Lepidosperma ferricola* individuals as reproductive in 2019, 53% in 2018 and 80% in 2017. This is the poorest performing plot of all years in terms of reproduction.

The *Hibbertia lepidocalyx* subsp. *tuberculata* plots also displayed good reproductive results, with 93% – 100% of individuals fruiting. This is in contrast to the results last year in which only one plot recorded reproductive individuals. The lack of reproductive *Hibbertia* individuals observed in 2018 was most likely due to variability in timing of reproduction associated with monthly rainfall or different timing of annual monitoring events. There was no indication that the *Hibbertia* population was unhealthy or stressed as condition assessment and chlorophyll fluorescence readings were good in 2018 and were comparable to the previous year.

Although the number of individuals recorded as reproductive is good overall, the plots which contain lower number of reproductive individuals are those that are located less than 50m from the pit.

It was observed during monitoring that at least one *Hibbertia lepidocalyx* subsp. *tuberculata* individual is actually another very similar species, *Hibbertia exasperata* (Hlt 31 in Plot PS4). Identification of the two species is difficult when not flowering therefore there may be other individuals that have been incorrectly identified. To ensure the Priority species is being monitored, it is suggested that all tagged *Hibbertia* individuals be checked for correct identification.

Overall the average condition assessment for Priority flora species in 2019 was comparative to last year with some slight variability above or below last year's condition scores. Several plots recorded higher condition compared to 2017. No obvious annual trends are apparent as this is only the third year of monitoring and since condition assessment is a subjective indicator some variation year to year is to be expected.

The condition assessment results of *Beyeria rostellata* individuals were good, with average scores over 84% alive material. Plot PS3, located near the pit, has recorded the lowest condition for all monitoring years. All plots in "Far pit" locations recorded increased condition compared to 2018. The average condition of *Stenanthemum newbeyi* varied from 64.3% to 80.7%. Four of the *Stenanthemum newbeyi* plots had increased condition compared to 2018. The average condition of *Lepidosperma ferricola* ranged from 50% to 78% in 2019. Average condition of *Lepidosperma ferricola* individuals in all plots was higher than in 2018 and only one plot recorded lower condition compared to 2017. *Hibbertia lepidocalyx* subsp. *tuberculata* individuals recorded good average condition in all plots, ranging from 83% – 92%.

The 2019 average condition assessment in all plots located less than 50m from the pit show consistent lower condition compared to the plots further than 50m from the pit for *Beyeria rostellata, Stenanthemum newbeyi* and *Hibbertia lepidocalyx* subsp. *tuberculata* as well as *Banksia arborea* (Figure 3.9).

Across all Priority flora plots there was little change in average chlorophyll fluorescence readings recorded this year, compared to last year. The average readings for all Priority individuals was 0.72 in 2019 and 0.71 in 2018, both being lower than the average of 0.78 recorded in 2017. Average chlorophyll fluorescence results for all species in all plots were lower in 2019 than in 2017. Various literature indicates that optimal chlorophyll fluorescence (Fv/Fm) readings, associated with healthy non-stressed plants, can range from around 0.75 to 0.84, and values around 0.6 are indicative of severe plant stress (Maxwell and Johnson 2000; Percival 2005; Ritchie 2006). These values can vary across different species, and although no statistically significant associations have been found between pre- and post- mining periods, the 2017 results, with average chlorophyll fluorescence ranging from 0.74 – 0.82, reflect the potential if not optimal results for these species. Lower results from the last two years compared to 2017 may be an indicator of reduced vitality of the Priority populations.

Beyeria rostellata showed little variation in chlorophyll fluorescence readings across the plots. Two plots recorded lower chlorophyll fluorescence than in 2018, Plot PS3 (Near pit) and Plot PS11 (Far pit). The *Hibbertia lepidocalyx* subsp. *tuberculata* plots are all located further than 50m from the pit and no major change was recorded in 2019 compared to 2018. Average chlorophyll fluorescence in all *Lepidosperma ferricola* plots increased in 2019 compared to 2018. There was no apparent trend in chlorophyll fluorescence and the proximity to the pit for these three Priority species.

The chlorophyll fluorescence results for *Stenanthemum newbeyi* showed slight variation on 2018 results. Three "Near pit" plots (Plots PS3, PS9 and PS10) recorded the lowest chlorophyll fluorescence reading of all the *Stenanthemum newbeyi* plots.

No dust was observed on any *Lepidosperma ferricola* or *Hibbertia lepidocalyx* subsp. *tuberculata* individuals during monitoring in 2019. Dust was observed on all *Stenanthemum newbeyi* in all plots with the exception of two "Far pit" plots. Of the *Beyeria rostellata* plots, one "Near pit" plot, PS1, recorded 100% of individuals with Category 1 dust level (1-25% covered) with two other plots recording some dust (<14% with Dust Category 1). Observations of dust levels in the field indicate that Plots PS3, PS9, PS10 and PS12 were recorded as being visibly dusty. It was also observed was that dust tends not to collect as readily on the leaves of the *Lepidosperma* or *Hibbertia,* as supported by the results.

Statistical analyses of the Priority flora data found that there was an association found between mining activity and condition assessment for *Beyeria rostellata*, this was following extended analysis including the effect of dust. As was the case in 2018, assessment of the *Beyeria rostellata* data confirms that the association is a positive one, with an increase in the condition of the species occurring between the pre- and post-mining periods (Figure 3.18). No other statistically significant associations were found between mining activity and Priority flora at F pit.

The 2019 native vegetation monitoring found the vegetation around F pit to be in a generally healthy condition, with all but two plots ranked as 'Excellent' or 'Very Good' as defined by Keighery (1994). Species richness is higher and there were many more annual species than in previous years. A greater number of live adults than 2017 and 2018 were recorded in every plot except for Plot PS1 and PS12 which had lower number of live adults than in 2018.

Plots PS3 and PS12 were ranked 'Good' in 2019, a lower condition than the other plots. Plot PS12 was ranked 'Very Good' in 2018 and 'Excellent' in 2017. These two plots are less than 50m from the pit and amongst the closest plots to the mining activity. Observations recorded during the monitoring event indicate the presence of damaged vegetation including fallen shrubs, broken branches and dusty conditions in these plots. Some of the damage may be from severe storms in 2017, however there were some obvious signs of vegetation damage, presumably from blasting activities, as was the case last year. Continued regular monitoring will determine whether this is a continuing trend.

The large size of the vegetation monitoring plots and the requirement to count all individuals in the plot contains inherent errors. It is likely to be difficult to maintain consistency year on year due to different personnel conducting the monitoring and potentially different methodology used when conducting counts. A more effective monitoring design would be to divide the plot into more manageable transects or subplots.

A large portion of the dead individuals recorded in 2019 are the species, *Cheilanthes sieberi* subsp. *sieberi* (54 dead in Plot PS3; 100+ dead recorded in Plot PS7), *Drosera macrantha* (100+ dead recorded in Plot PS7) and *Rhodanthe battii* (131 dead recorded in Plot PS12). *Cheilanthes sieberi* subsp. *sieberi* is a rhizomatous herb or fern and *Drosera macrantha* is a tuberous perennial herb or climber, both species are known to die off in dry conditions. *Rhodanthe battii* is an annual paper daisy. Given the dry conditions in the month preceding the monitoring event, the high mortality of these species is not unexpected. To provide a more reasonable comparison on previous years, when these three species with most dead individuals are removed from the data, Plot PS12 had the highest number of dead individuals (20 dead individuals) and Plot PS2, which is further than 50m from the pit, recorded the second highest at 19 dead individuals.

Statistical analysis conducted on the native vegetation data found no statistically significant associations between mining activity and live plant abundance or mortality.

Most of the data suggests that the Priority and vegetation populations in the F pit area are relatively healthy. Considering the below average rainfall in the months prior to the monitoring event these results are positive. With 2019 being only the third year of annual monitoring, identification of long-term trends is not possible. However, there is some indication that the plots located closer to the pit are performing poorer than those further from the pit. This is the case for reproductive performance and condition assessment for all species and for chlorophyll fluorescence for *Stenanthemum newbeyi and Lepidosperma ferricola*. Although minor differences in some cases, these results may be an early indicator of decreasing health or population stress of flora and vegetation closer to the mining activity. Observations in some plots, such as Plot PS3 and PS12 support these results, for example, dusty conditions, damaged vegetation, reduced vegetation condition score, the presence of weeds and dead mature *Banksia* individuals. Continued monitoring and adherence to disciplined mining practices, including ensuring strict blasting practices, will minimise any potential impact of mining activities on Priority flora and native vegetation in close proximity to the pits.

4.1 Comparisons against trigger and threshold criteria

The F Deposit Flora and Vegetation Management Plan (Cliffs 2017) outlines trigger and threshold criteria that require further reporting and contingency actions. The following section compares the results of the monitoring against the relevant criterion.

4.1.1 Trigger Criteria

Monitoring of Priority species indicates a statistically significant relationship between condition (chlorophyll fluorescence and/or % live material) and dust deposition, distance from the proposal boundary or mine related causal factor.

No statistically significant association was found between mining activity and condition assessment or chlorophyll fluorescence for *Lepidosperma ferricola* or *Stenanthemum newbeyi*.

A statistically significant (positive) association was found between mining activity and condition assessment (% live material) for *Beyeria rostellata*, following extended analysis and including dust results.

Therefore, the trigger has not been met.

4.1.2 Threshold Criteria

Monitoring of Priority species and/or native vegetation indicates a statistically significant relationship between mortality, dust deposition, distance from the proposal boundary or mine related causal factor.

No statistically significant association was found between mining activity and mortality of *Stenanthemum newbeyi* and *Beyeria rostellata*. Analysis was not conducted on the association between mining activity and mortality for *Lepidosperma ferricola* due to insufficient data.

No statistically significant association was found between mining activity and mortality of native vegetation.

Therefore, the threshold criteria have not been met.

5.0 REFERENCES

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Attachment 7: Ecotec (WA) Pty Ltd (2018) Annual *Tetratheca erubescens* Monitoring November 2019 (Revision 0)

2019 Annual *Tetratheca erubescens* Monitoring Report

November 2019

Revision 1 11-2-2020

Prepared by
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CONTENTS

FIGURES

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APPENDICES

1.0 INTRODUCTION

Mineral Resources Ltd (MRL) operations include iron ore mines at the Koolyanobbing Range, Mt Jackson Range and Windarling Range in the Yilgarn region, ore processing at Koolyanobbing, and road and rail transport between these operations and the Port of Esperance where the processed ore is exported to international customers. These operations were acquired by MRL from Cliffs Asia Pacific Iron Ore Pty Ltd (Cliffs) in 2018.

Tetratheca erubescens is a small shrub growing to approximately 0.5m tall that grows on banded ironstone ridges and cliffs on the southern Koolyanobbing range. The only recorded population of the species occurs at the Koolyanobbing Range. *T. erubescens* is declared as Threatened Flora under the Western Australian Biodiversity Conservation Act 2016. The population of *T. erubescens* at the Koolyanobbing Range prior to mining was approximately 6,321 individuals (Maia 2013) and was estimated at approximately 6,222 after commencement of mining.

The F Deposit mining operation was approved in January 2017 under the Environmental Protection Act 1986 (Minister for the Environment and Heritage 2017). Under this approval, Cliffs developed and implemented a Condition Environmental Management Plan which outlines provisions to address indirect impacts of factors including, but not limited to, dust, weeds and fire on native flora and vegetation (including *Tetratheca erubescens*)(Cliffs 2017). Cliffs commenced mining at the southern Koolyanobbing Range (F Pit) during May 2017 and continued until April 2018. MRL recommenced mining at F Pit in January 2019 and continue to mine up to the present time.

A monitoring program was implemented by Cliffs in 2017 to evaluate defined monitoring plots along the Koolyanobbing Range, in order to assess the stability and condition of the *Tetratheca erubescens* population. MRL continued with this program in 2018 and 2019, with annual monitoring conducted by Ecotec (WA) Pty Ltd (Ecotec). This report documents and discusses the results of the 2019 monitoring, the third annual monitoring event since mining commenced.

2.0 METHODOLOGY

2.1 Monitoring Design

The monitoring design utilised by MRL has been adopted from that previously developed by Cliffs in consultation with Data Analysis Australia (DAA), with the aim of capturing changes in population dynamics (DAA 2015).

2.2 Initial Monitoring

Following the recommended design outlined by DAA, 10 plots (3, 5, 7, 9, 10, 11, 14, 16, 18 and 21) were monitored along the Koolyanobbing Range in 2015. These plots were randomly selected following the process outlined by DAA (2015). Figure 2.1 displays the plot locations and the recorded distribution of *T. erubescens* along the Koolyanobbing Ridge.

At each plot, all accessible *T. erubescens* occurring within the area were tagged with a unique identification number. The identification number was glued onto the rock surface as close as possible to the *T. erubescens* individual. The following information was recorded for each individual:

- Plot number
- Unique plant identification number
- Presence of flowers/fruits/buds
- Plant Status - Reproductive, Vegetative, Juvenile (1-3 years old) or Seedling (<1 year old).

Additionally, a number of individuals were randomly selected for a condition assessment (percentage of total plant alive). The random selection of individuals was chosen based on a method developed by DAA (DAA 2015).

Monitoring in 2016 followed the same methodology as used in the 2015 monitoring. All *T. erubescens* individuals recorded during the 2015 monitoring were revisited and re-assessed. Any new seedlings encountered were also tagged and assessed using the same methodology. During November and December 2016, three additional monitoring plots (13, 25 and 26) were established. The establishment of these additional plots followed the same methodology used in the previous monitoring, including the selection of additional individuals for condition assessment monitoring. The location of these additional monitoring plots is shown in Figure 2.1.

In 2016, individuals monitored for condition assessment also had an index of chlorophyll fluorescence reading taken using a pocket PEA unit. Chlorophyll fluorescence measurements provide an indication of photosynthetic performance thus enabling identification of plant stress (Hansatech 2006). Measurements are taken by attaching a clip to a live stem of the *T. erubescens* individual, with the stem subsequently dark adapted. An index of chlorophyll fluorescence (Fv/Fm) is then measured with the PEA unit and recorded. As this monitoring involves physical access to the plants (to attach clips) as opposed to visually estimating the condition, some of the plants selected for condition monitoring in 2015 were replaced with the nearest accessible plant.

2.3 2019 Monitoring

The 2019 monitoring was conducted from 17-23 September by Ecotec. The 2019 monitoring followed the same methodology as used in previous years. All *T. erubescens* individuals recorded during the 2018 monitoring were revisited and re-assessed for status and presence of flowers, fruits and/or buds. Any new individuals encountered within the plots were tagged and assessed using the same method described in Section 2.2. A total of 249 individuals were monitored for condition in 2019. Chlorophyll fluorescence measurements were carried out on 237 individuals by the MRL Environmental Advisor at a separate monitoring event from 14 – 15 September.

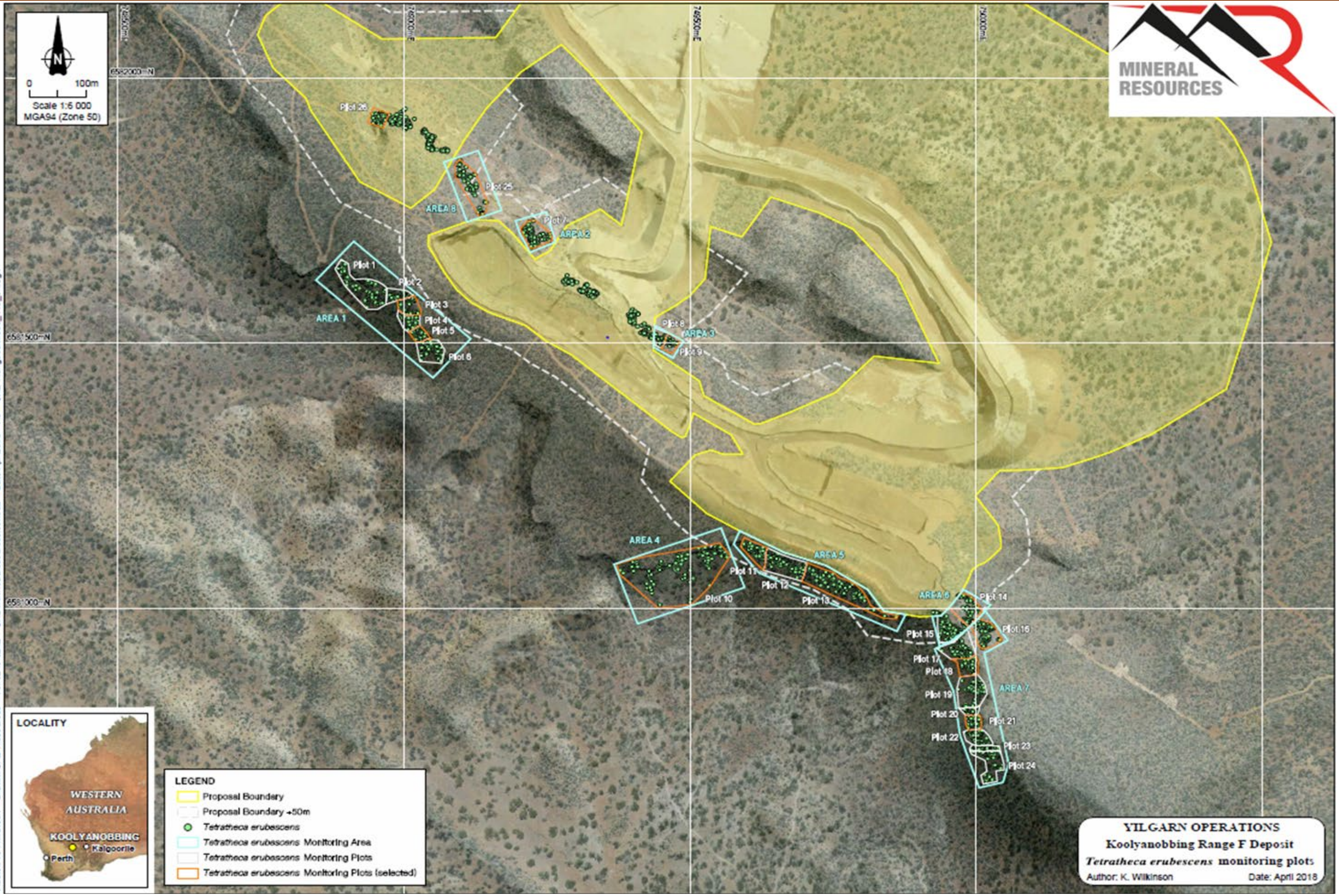

Figure 2.1: Distribution of *Tetratheca erubescens* and location of annual monitoring plots

3.0 RESULTS

Table 3.1 presents a summary of results from all monitoring years since 2016. The 2016 monitoring is considered baseline (initial) data as it includes all 13 plots monitored prior to the commencement of mining.

In 2019, 1679 *T. erubescens* individuals were recorded, of which 19 were seedlings (1% of population), 16 were juveniles (1% of population), 191 were dead (11% of population), 1,309 were reproductive (78% of population) and 136 were vegetative (8% of population). Eight individuals were not monitored as they could not be located or were inaccessible.

Four individuals recorded as dead during 2018 had re-sprouted and were alive in 2019.

Seedlings recorded in 2018 were considered juveniles in 2019, unless found to be reproductive (therefore considered adults).

Table 3.1: Summary of results from 2016 - 2019 annual monitoring

Plant Status / Category	2016	2017	2018	2019
Dead	135	142	156	191
Seedling	3	19	25	19
Juvenile	2	3	11	16
Vegetative	180	119	90	136
Reproductive	1276	1352	1363	1309
Not located	1	0	16	8
Total Alive	**1461**	**1493**	**1489**	**1480**
Total Population	**1597**	**1635**	**1661**	**1679**

Figure 3.1 presents a summary of the results from 2016 - 2019, showing the proportion of the population in each category.

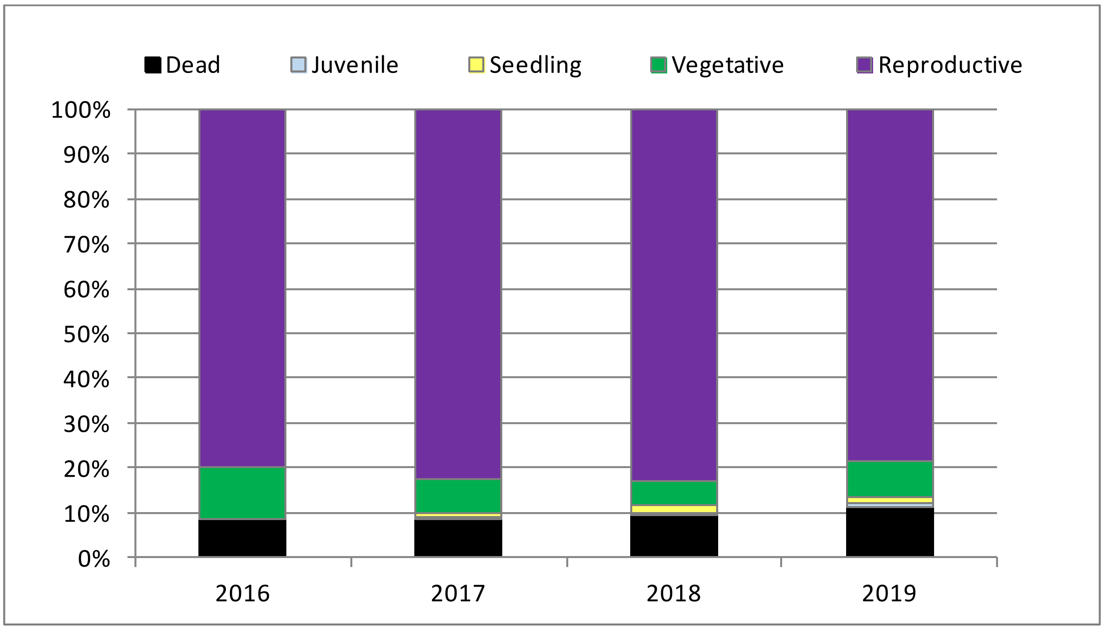

Figure 3.1: Percentage of *Tetratheca erubescens* population in each life stage, 2016 -2019

3.1 Health Assessment

3.1.1 Condition Assessment

During the 2019 monitoring, 243 individuals were assessed for condition. The percentage of foliage alive ranged from 10 – 95%. Four of the condition assessment individuals were newly dead (0% alive) and one plant was not found in 2019. Figure 3.2 displays the condition assessment for individuals ranked in each category for 2016 to 2019.

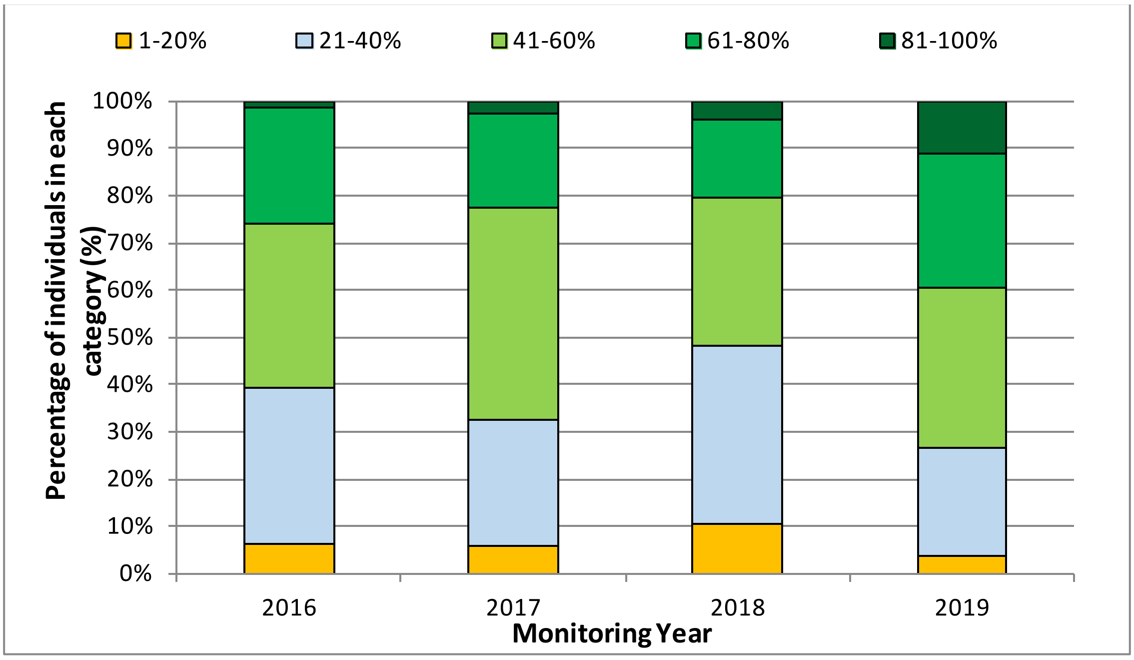

Figure 3.2: Condition assessment rankings for 2016 - 2019.

The average overall condition was higher in 2019 compared to results from all previous years. In 2019 average condition was 57%, compared to 52% in both 2016 and 2017 and 46% in 2018. In 2019 all plots recorded an increase in average condition compared to 2018 except Plot 5 and Plot 14 which recorded a decrease in condition of 0.7% and 1.1% respectively.

Error! Not a valid bookmark self-reference. lists the average condition assessment results and standard deviation for each plot in relation to distance from the pit.

Table 3.2: Average condition assessment and standard deviation for each plot in 2019.

Distance from pit	Plot number	Average condition assessment (%)	Standard Deviation
>50m from pit boundary	**3**	52.5	11.9
	5	46.7	15.4
	10	68.2	20.8
	16	61.4	21.4
	18	64.0	11.7
	21	55.7	21.7
	26	63.3	21.9
<50m from pit boundary	**7**	57.4	19.9
	9	57.8	23.1
	11	58.1	19.3
	13	51.7	18.8
	14	49.8	29.1
	25	61.7	22.9

Figure 3.3 compares the average condition assessment (including standard deviation) for *T. erubescens* plants in each monitoring plot and in relation to proximity to the pit boundary, for the current year (2019) and three previous years (2016 - 2018). In 2019 average condition varied from 47% in Plot 5 to 68% in Plot 10. In 2018 the average condition ranged from 37% in Plot 3 to 56% in Plot 25.

Appendix 2 displays the average condition assessment for each plot in relation to the pit location.

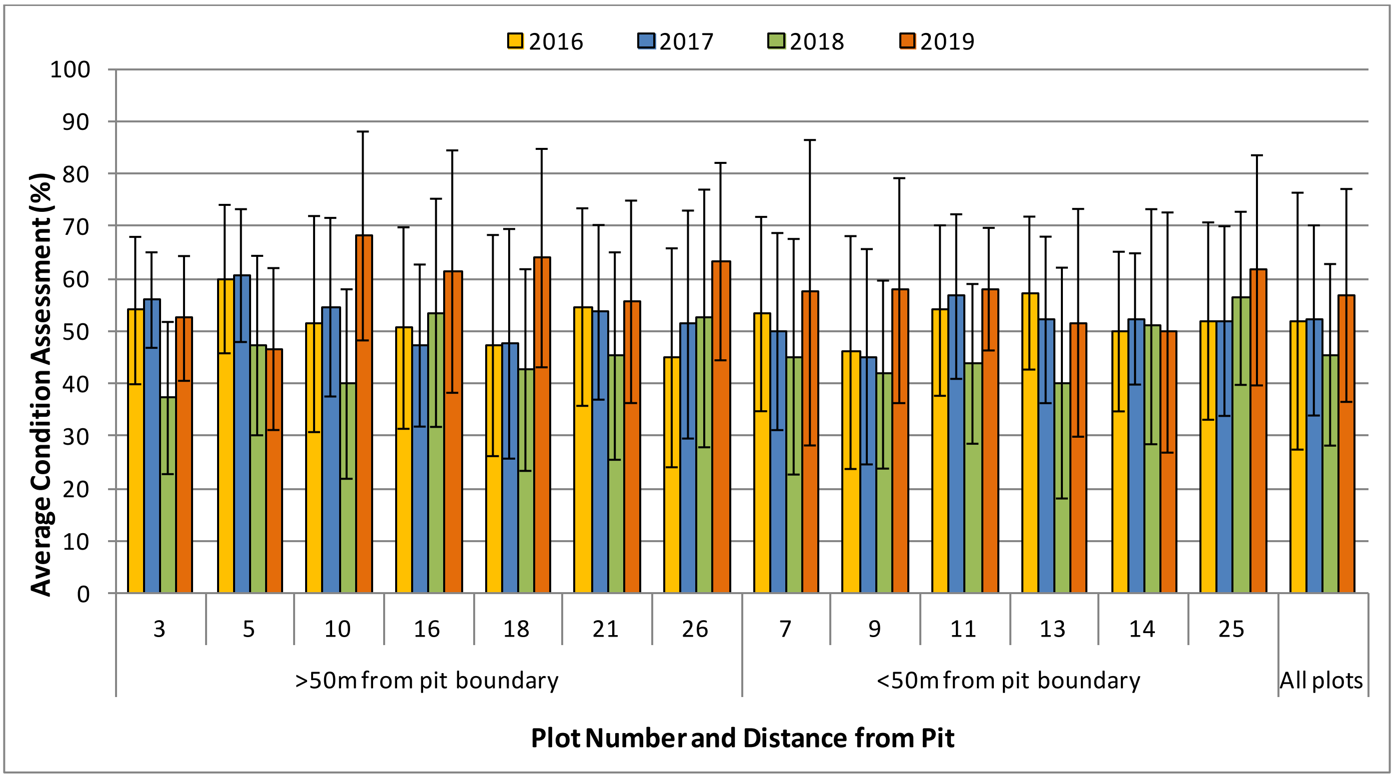

Figure 3.3: Average condition assessment with standard deviation for each plot 2016 - 2019.

3.1.2 Chlorophyll Fluorescence Assessment

The individuals assessed for condition also had chlorophyll fluorescence measurements taken. Chlorophyll fluorescence readings were conducted from 14 -15 September 2019, separately to the annual status and condition assessment monitoring.

In 2019, the overall average chlorophyll fluorescence reading of 0.78 was higher than in all previous years, and all plots recorded higher chlorophyll fluorescence readings compared to the previous year. The average chlorophyll fluorescence ranged from 0.74 in Plot 7 (less than 50m from pit boundary) to 0.80 in Plots 18 and 26 (greater than 50m from pit boundary) and Plots 11 and 13 (less than 50m from pit boundary).

The average chlorophyll fluorescence measurements ranged from 0.73 (Plot 9) to 0.81 (Plot 18) in 2016, 0.64 (Plot 10) to 0.78 (Plot 21) in 2017 and 0.52 (Plot 5) to 0.75 (Plots 11 and 14) in 2018.

Plot 5 (over 50m from pit boundary) recorded the greatest change of all plots in 2019. The average chlorophyll fluorescence in Plot 5 increased from 0.52 in 2018 to 0.78 in 2019. This plot recorded the largest decrease in condition in the 2018 monitoring from 0.77 (2017) to 0.52 (2018).

The average chlorophyll fluorescence readings with standard deviation are listed in Table 3.3 and presented in Figure 3.4.

Table 3.3: Average chlorophyll fluorescence and standard deviation for all monitoring plots in 2019.

Distance from pit	Plot number	Average chlorophyll fluorescence (Fv/Fm)	Standard Deviation
>50m from pit boundary	**3**	0.78	0.02
	5	0.78	0.03
	10	0.79	0.02
	16	0.77	0.02
	18	0.80	0.02
	21	0.78	0.02
	26	0.80	0.03
<50m from pit boundary	**7**	0.74	0.04
	9	0.76	0.03
	11	0.80	0.01
	13	0.80	0.01
	14	0.79	0.02
	25	0.75	0.04

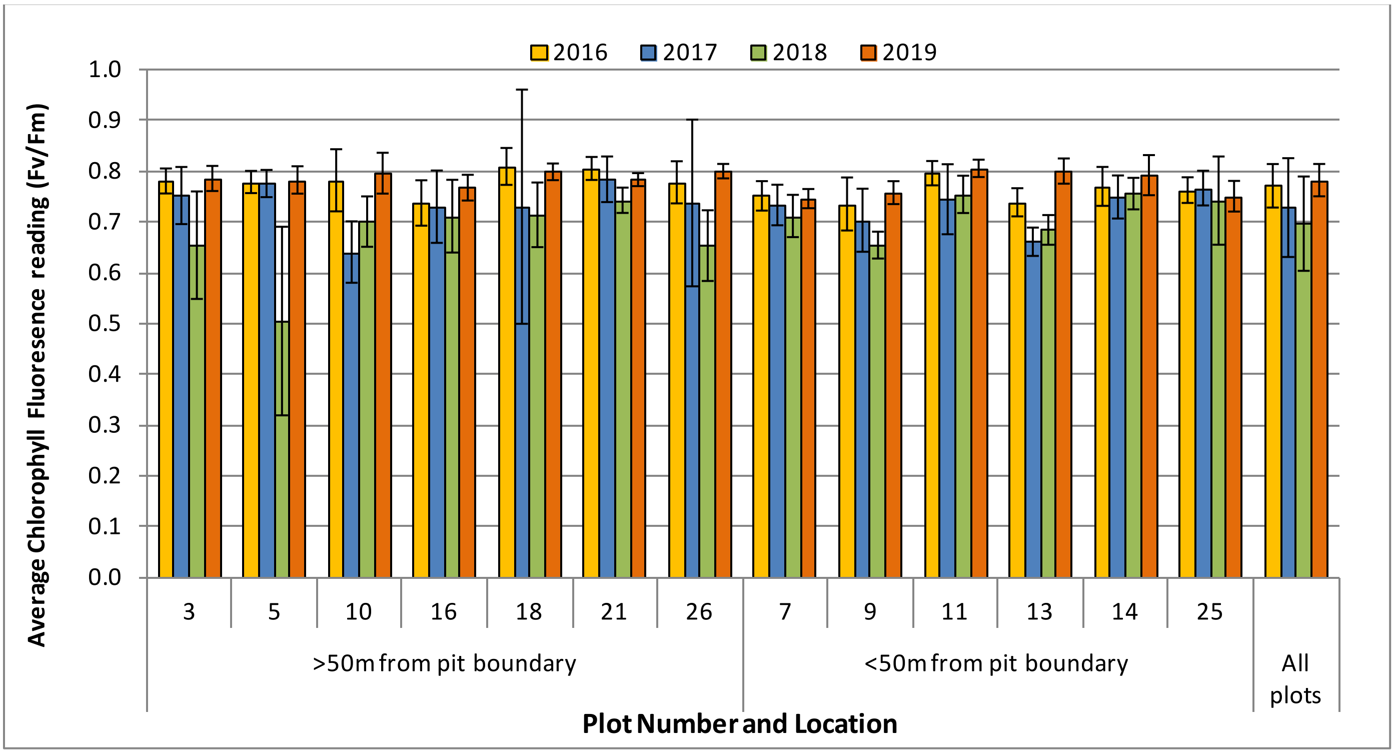

Figure 3.4: Average chlorophyll fluorescence with standard deviation for all plots 2016 -2019.

3.2 Reproductive Status

The 2019 monitoring recorded over 91% of the live adult *T. erubescens* population as reproductive, compared with approximately 93% in 2018, 92% in 2017 and 85% in 2016.

Figure 3.5 displays the percentage of the reproductive population that displayed buds, fruits and/or flowers during the 2018 and 2019 monitoring. The most notable difference is less reproductive individuals recorded fruit present in 2019 (30%) compared to 2018 (68%).

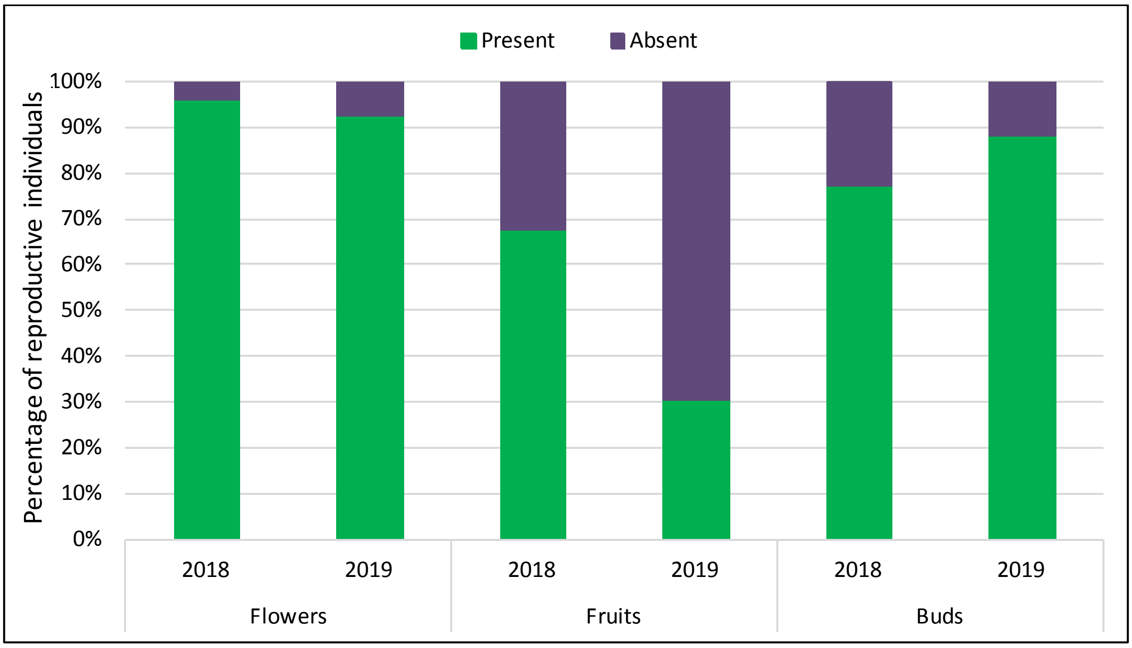

Figure 3.5: Proportion of reproductive individuals displaying flowers, fruits and/or buds in the previous year (2018) and current year (2019).

3.3 Life Stage, Mortality and Seedling Recruitment

Figure 3.6 shows the percentage of the monitored *T. erubescens* population in each life stage (dead, reproductive, vegetative, juvenile or seedling) for the 2018 and 2019 monitoring.

A total of 39 individuals were recorded as new deaths during the 2019 monitoring. All plots recorded at least one death with the exception of Plots 10 and 26 which recorded no deaths. Plot 7 and 14 (less than 50m from pit boundary) each recorded six dead, the highest number of deaths for all plots. Three of these were recorded as almost dead during the 2018 monitoring. All of the plots that are situated less than 50m from the pit boundary recorded more than 4 deaths. These plots recorded a total of 30 dead, 77% of all dead individuals recorded in 2019.

Figure 3.7 provides a comparison of the number of dead individuals recorded in the 2017 – 2019 monitoring events.

Four individuals recorded as dead in 2018 had re-sprouted and were recorded as alive during the 2019 monitoring. A total of 19 new seedlings were recorded during 2019 - three during the annual monitoring and an additional 16 recorded during a separate seedling search conducted by MRL personnel in December, with the information provided to Ecotec for completion of this report. Twenty five seedlings were recorded in 2018. Seedlings were recorded in all plots except Plots 7, 16 and 25 during 2019.

Appendix 1 displays the mortality and recruitment per plot in relation to proximity to mining.

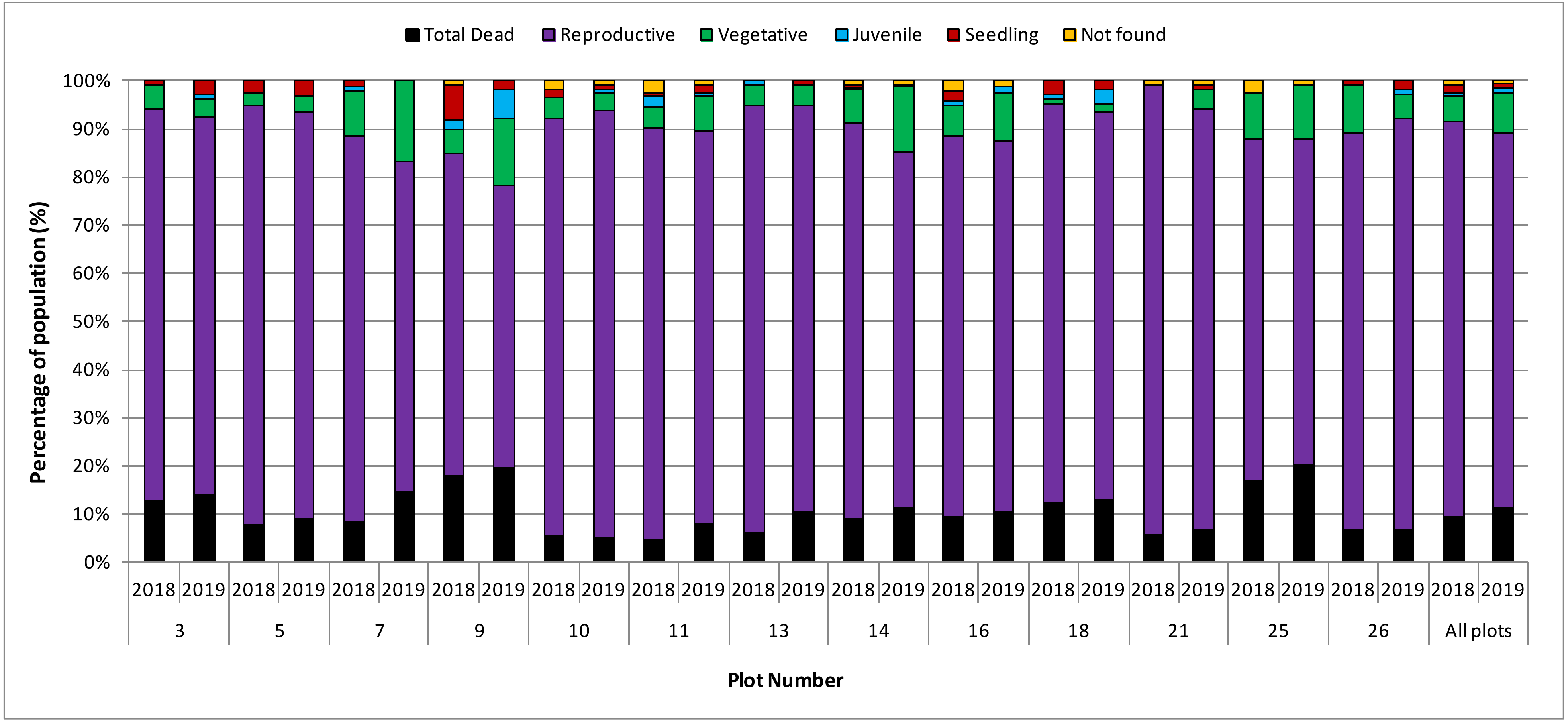

Figure 3.6: Percentage of *T. erubescens* in each life stage during previous year (2018) and current year (2019) monitoring.

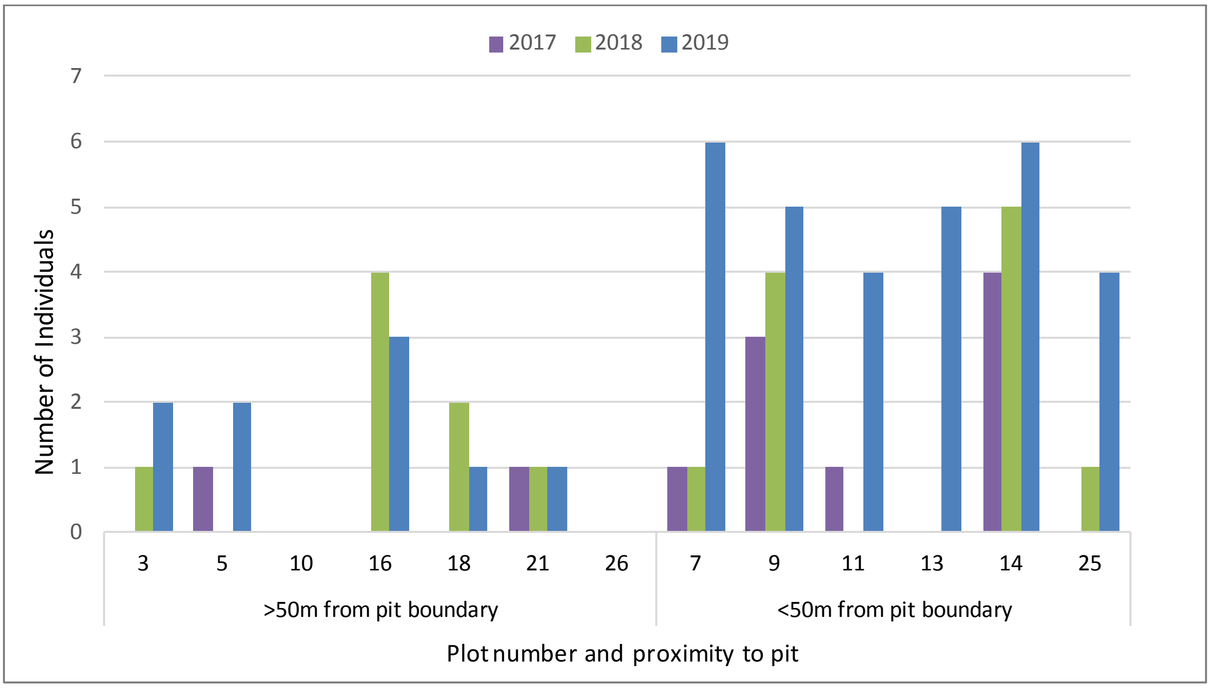

Figure 3.7: Number of dead individuals recorded per plot in relation to proximity to pit, 2017 – 2019.

3.4 Rainfall

In the 12 months prior to the 2019 monitoring (October 2018 – September 2019), Koolyanobbing recorded 276.8 mm of rain. The 2001-2019 average rainfall for Koolyanobbing is 286.7 mm (BoM 2019).

Figure 3.8 shows the total monthly rainfall received at Koolyanobbing prior to the current and previous monitoring events, as well as the 2001-2019 monthly average. Below average rainfall was received at Koolyanobbing in the months prior to the monitoring event. Above average rainfall was received (almost three times the monthly average) in the month of June.

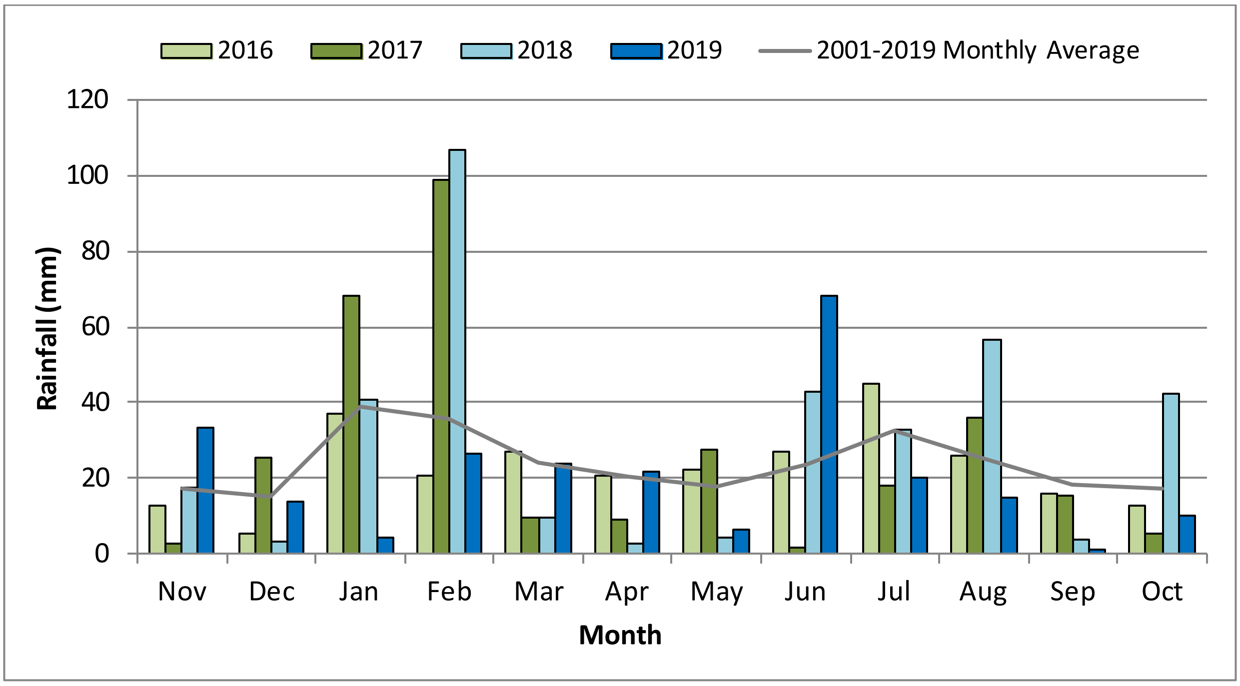

Figure 3.8: Monthly rainfall and average monthly rainfall at Koolyanobbing 2016 -2019

4.0 DISCUSSION AND CONCLUSION

The results from the 2019 annual *T. erubescens* monitoring indicate that 88% of the adult population was alive and nearly 91% of the live population was reproductive at the time of monitoring. The live adult population is approximately 1% - 3% smaller than previous years. The proportion of the population that is reproductive is 1 - 2% less than 2017 and 2018 but 3% more than 2016. Condition assessment and chlorophyll fluorescence results suggest that live monitored individuals were in healthy condition.

In 2019, the overall average chlorophyll fluorescence reading of 0.78 was higher than in all previous years, and all plots recorded higher average chlorophyll fluorescence readings compared to last year. Literature suggests that chlorophyll fluorescence readings below 0.60 are indicative of plant stress (Ritchie 2006; Percival 2005). The lowest individual chlorophyll fluorescence reading recorded in September 2019 was 0.68, indicating that the individuals assessed were not undergoing stress at the time.

The average chlorophyll fluorescence was marginally lower in plots less than 50m from the pit boundary (0.77) than in those further than 50m from the pit boundary (0.79), however the reverse was the case in 2018. In 2018 plots closer to the pit recorded a slightly higher average chlorophyll fluorescence (0.72) than those greater than 50m from the pit boundary (0.67). Plot 5 (>50m from the pit boundary) showed the greatest recovery in terms of chlorophyll fluorescence in 2019, increasing from 0.52 in 2018 to 0.78 in 2019.

The average condition assessment of the entire population was 57% in 2019, an increase from 46% in 2018 and 52% in 2017. Although a subjective indicator, the comparison year on year suggests an overall increase in the health of the monitored individuals. On average, condition assessment in 2019 was higher for those plots located further from the pit (58.8%) than those close to the pit (56.1%). This was also the case in 2017 (53.0% and 51.4%). Conversely, plots further from the pit recorded slightly lower condition in 2018 (46.4% and 45.5%).

Condition assessment can be a deceptive indicator of population health as *T. erubescens* individuals retain much of their dead material for long periods of time, with older plants often seen with large 'skirts' of dead material attached to very healthy and reproducing live material. Therefore, the condition assessment results should be considered in combination with other factors such as reproduction, recruitment and mortality to assess the health of the population.

The health of *T. erubescens* is likely to be related to changes in rainfall patterns. Good rainfall years are expected to result in production of more seedlings and good health of the population overall, while poor rainfall years result in lower recruitment and/or a reduction in overall health. Observations by research scientists at F Deposit in the months prior to the 2019 annual monitoring suggested good germination rates following the above average rainfall in June. These observations are somewhat supported by the total number of seedlings recorded in 2019. During the annual monitoring in September there were only three seedlings recorded, however an additional 16 seedlings were found in December during a separate search by MRL personnel. During the monitoring in September, new germinants may not have been recorded due to being of insufficient size to be positively identified as *T. erubescens*. The relatively high number of seedlings is a positive sign given the below average rainfall received in the months following June.

The number of newly dead individuals recorded in 2019 is 39, the highest since the first monitoring event in 2015 when 102 individuals were recorded as dead. Of those dead in 2019 two were seedlings and three were recorded as almost dead in 2018. There appears to be some correlation between mortality and proximity to the pit boundary. The plots located closer to the pit boundary recorded 30 deaths, 77% of all deaths in 2019.

Observations noted in the field during monitoring provide additional information on the environmental conditions and condition of some of the *T. erubescens* individuals. In Plot 7 observations included some individuals as being dusty, brown and appearing unhealthy. Some plants were recorded as being very dusty, making it difficult to determine alive material from dead material. In Plot 11 observations suggested recent rock fall had occurred, with plants and tags impacted. Specific comments made during monitoring included that a few identification tags were buried by rocks and that the rock on which plants were located had broken away.

Given that the live population is reproductive and that the condition of the population appears good, the factors causing mortality appear to be localised or specific to the near-pit plots, and not attributable to climatic conditions such as rainfall. If climatic conditions were the main causative factor, impacts could be expected across the population.

The 2019 monitoring is the third year of monitoring since commencement of mining activities at F Pit. Approximately 12 months of mining activity occurred from May 2017 – April 2018, then mining temporarily ceased during acquisition of the project by MRL. Mining recommenced in January 2019 and continues to the present time. The slightly lower health results (condition assessment and chlorophyll fluorescence) in the plots closer to the pit compared to the far pit plots may be early indicators of potential impacts from mining activities, although the differences observed are minor. These indicators combined with the higher mortality in plots closer to the pit suggest that the proximity to mining activities is potentially impacting the *T. erubescens* population. Dust from mining activities, isolated rockfall events and disturbance to the rocky substrate on which the *T erubescens* is growing by blast vibration are possible causes of mortality and lower health results. Examination of dust monitoring data, bimonthly monitoring results and investigation of rock fall in plots nearer the mining activity may provide more insight into the cause of mortality in those areas.

5.0 REFERENCES

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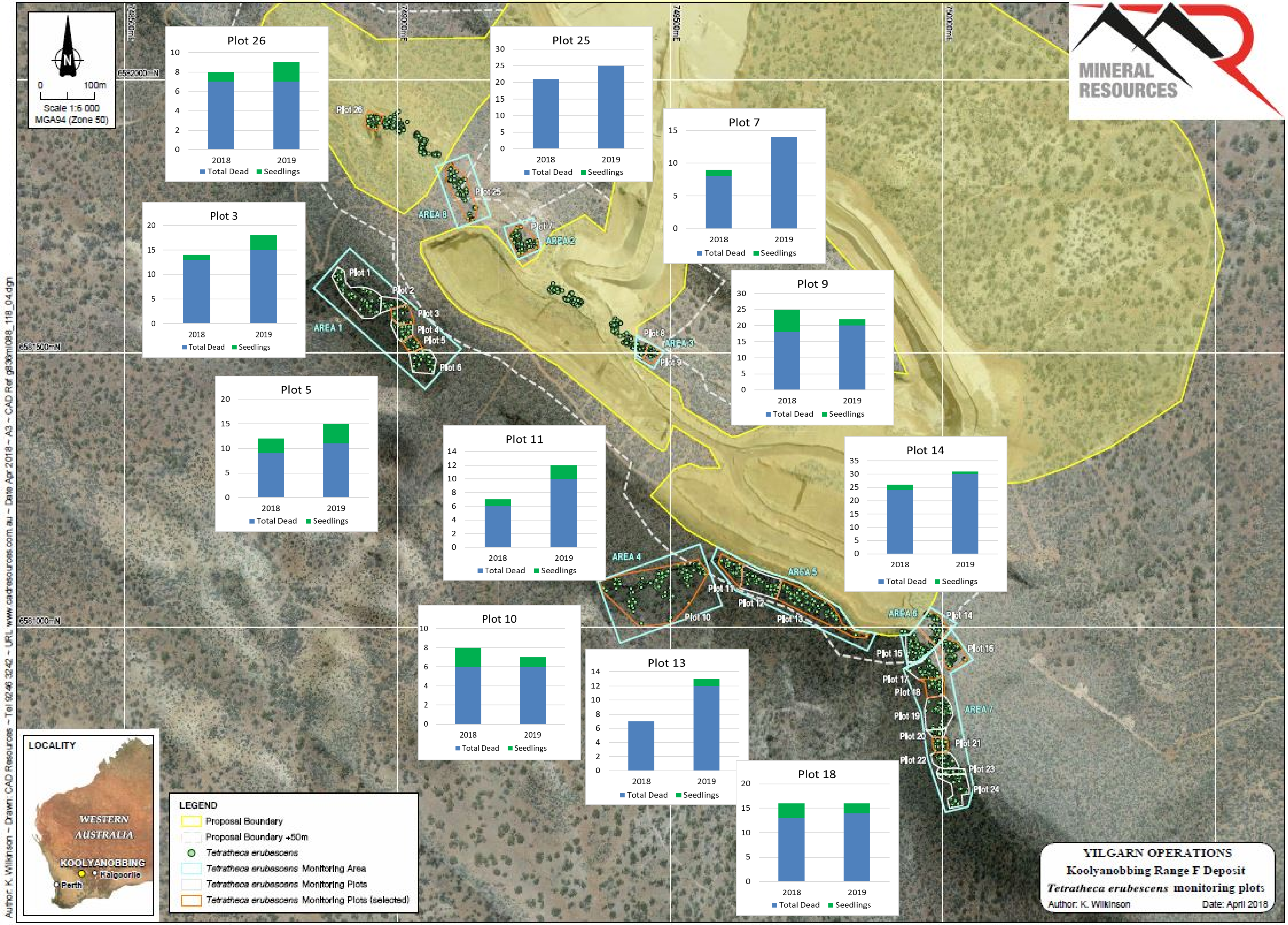
Percival (2005) *The use of Chlorophyll Fluorescence to Identify Chemical and Environmental Stress in Leaf Tissue of Three Oak (QUERCUS) Species*. Journal of Arboriculture 31 (5): September 2005. p215.

Ritchie (2006) *Chlorophyll Fluorescence: What is it and What do the Numbers Mean?* National Proceedings Forest and Conservation Nursery Associations – 2005. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 160p.

Appendix 1

Mortality and recruitment per plot in relation to proximity to mining, 2019



Author: K. Wilkinson - Drawn: CAD Resources - Tel 9246 3242 - URL www.cadresources.com.au - Date Apr 2018 - A3 - CAD Ref g836m088_118_04.dgn
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100m
Scale 1:6 000
MGA94 (Zone 50)
MINERAL RESOURCES
Plot 26
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6
4
2
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2019
Total Dead
Seedlings
Plot 25
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15
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5
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2018
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Total Dead
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15
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2018
2019
Total Dead
Seedlings
Plot 3
20
15
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5
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2019
Total Dead
Seedlings
Plot 9
30
25
20
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2018
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Total Dead
Seedlings
Plot 5
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Plot 11
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8
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2019
Total Dead
Seedlings
Plot 14
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30
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2019
Total Dead
Seedlings
Plot 10
10
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4
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0
2018
2019
Total Dead
Seedlings
Plot 13
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Plot 18
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Total Dead
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AREA 1
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AREA 3
AREA 4
AREA 5
AREA 6
AREA 7
AREA 8
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Plot 2
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Plot 4
Plot 5
Plot 6
Plot 7
Plot 8
Plot 9
Plot 10
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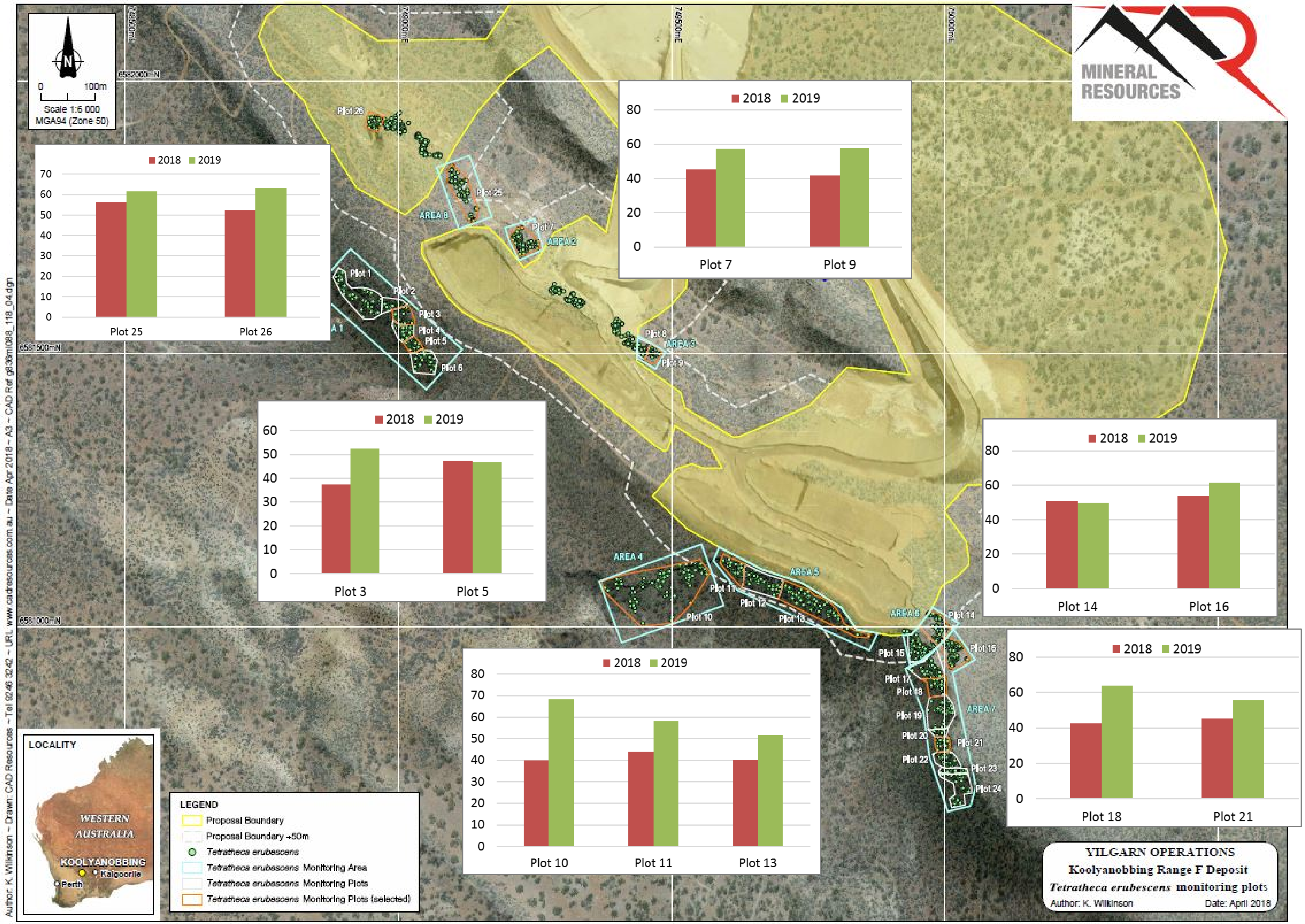
WESTERN AUSTRALIA
KOOLYANOBBING
Kalgoorlie
Perth
LEGEND
Proposal Boundary
Proposal Boundary +50m
Tetratheca erubescens
Tetratheca erubescens Monitoring Area
Tetratheca erubescens Monitoring Plots
Tetratheca erubescens Monitoring Plots (selected)
YILGARN OPERATIONS
Koolyanobbing Range F Deposit
Tetratheca erubescens monitoring plots
Author: K. Wilkinson
Date: April 2018

Appendix 2

Average condition assessment per plot in relation to proximity to mining



MINERAL RESOURCES
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Scale 1:6 000
MGA94 (Zone 50)
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Plot 3
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AREA 4
AREA 5
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AREA 7
AREA 8
Plot 1
Plot 2
Plot 3
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LOCALITY
WESTERN AUSTRALIA
KOOLYANOBBING
Kalgoorlie
Perth
LEGEND
Proposal Boundary
Proposal Boundary +50m
Tetratheca erubescens
Tetratheca erubescens Monitoring Area
Tetratheca erubescens Monitoring Plots
Tetratheca erubescens Monitoring Plots (selected)
YILGARN OPERATIONS
Koolyanobbing Range F Deposit
Tetratheca erubescens monitoring plots
Author: K. Wilkinson
Date: April 2018
Author: K. Wilkinson ~ Drawn: CAD Resources ~ Tel 9246 3242 ~ URL www.cadresources.com.au ~ Date Apr 2018 ~ A3 ~ CAD Ref g836mi098_118_04.dgn

Attachment 8: Peter O'Brian and Associates (2019) Technical Memorandum, Mineral Resources, Iron Resources, Geotechnical Review Koolyanobbing, Windarling, Deception, Mt Jackson, January 2019.

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TECHNICAL MEMORANDUM

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Attention: Paul Smallbone

18 November 2019

KOOLYANOBBING OPERATIONS
GEOTECHNICAL REVIEW
F3 OPEN PIT WALL STABILITY

1. Introduction

This memorandum summarises the findings of a review of as-mined highwall stability conditions within the F3 Pit located at Mineral Resources Limited (MRL) / Iron Resources Pty Ltd's (IRPL) Koolyanobbing Iron Ore Operations, Western Australia.

The as-mined configuration of the pit in mid-October is shown as Figure 1. The minimum floor elevation at that time was 454mRL (a highwall height ~ 52m to 53m). IRPL proposes to mine the F3 Pit to attain a final highwall height of ~ 115m (a minimum floor elevation of 394mRL).

1.1 Scope of Work

Inspect and map the F3 Pit highwall to:

- ⇨ Assess current highwall stability conditions; and
- ⇨ Make judgment on likely future highwall stability conditions, both during and beyond the life of planned mining at F3.

In particular, consider the potential for adverse influence on the stability of the local natural scarp variously located ~ 10m to 20m south of the crest of the highwall. This steep natural slope hosts a population of rare flora, *Tetratheca erubescens*.

1.2 Sources of Data

Assessment of as-mined wall stability conditions within the highwall of the F3 open pit has considered:

- ⇨ Inspection of as-mined conditions in the F3 pit during a site visit to the Koolyanobbing Iron Ore Operations carried out by Peter O'Bryan in September 2019.
- ⇨ Photogrammetric mapping carried out by Grace Connell of Peter O'Bryan & Associates during a site visit in October 2019.
- ⇨ Processing of mapping data using the Datamine program *Sirovision* (Version 6.2.1.1) [1] and Roscience programs *DIPS* (Version 7.0) [2] and *SWEDGE* (Version 6.0) [3].
- ⇨ Findings based on geotechnical data gathered and analyses performed prior to and during earlier open pit mining at F Deposit [4 → 8].
- ⇨ Consideration of experience in the Koolyanobbing area and geotechnical assessment of wall stability of similar scale in similar geological/ geotechnical settings.

1.3 Current Mining Status

As noted, by mid-October 2019 mining in the F3 Pit had advanced to a floor elevation of 454mRL. The configuration of the pit is shown as Figure 1.

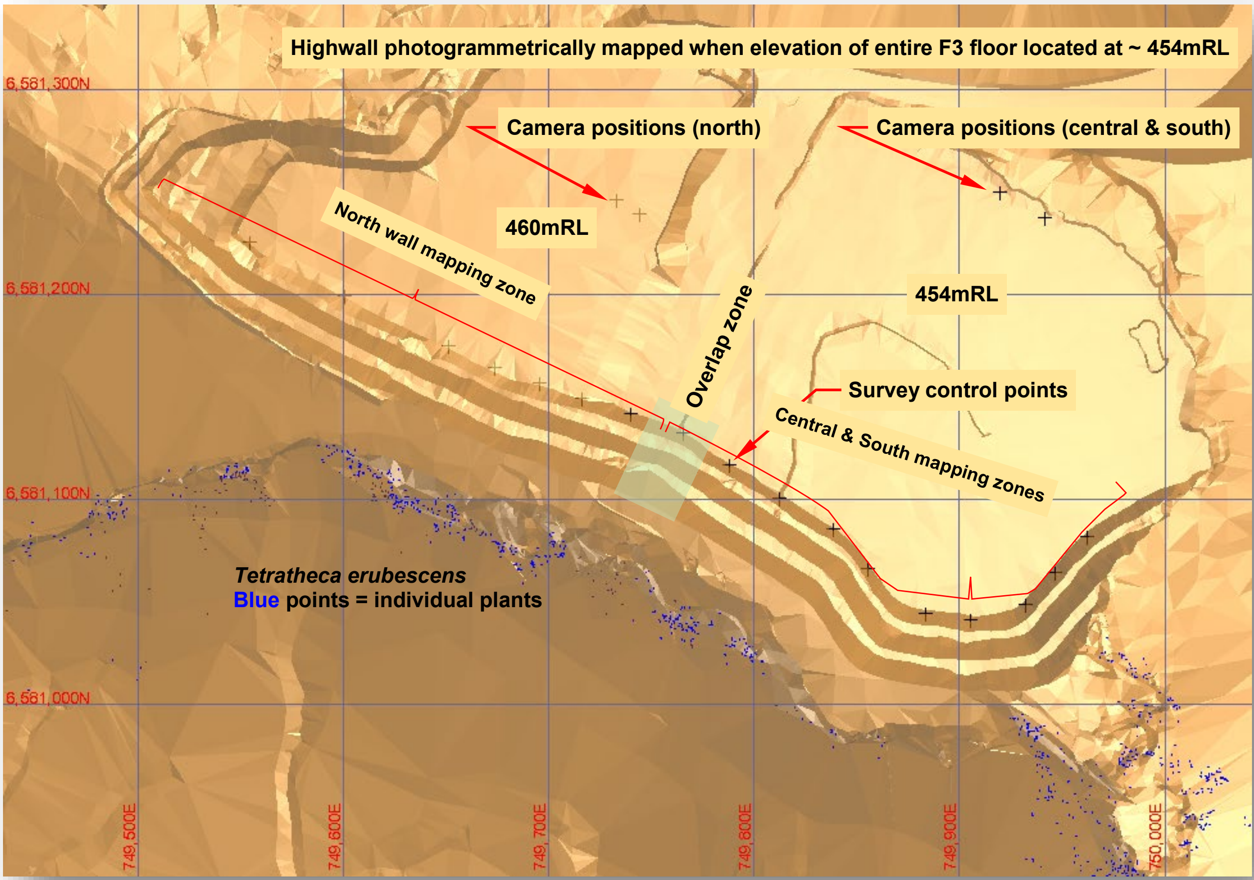


Figure 1 **F3 open pit as-mined to mid-October 2019 showing photogrammetric mapping areas & survey control & camera positions**

1.4 Current Wall Stability Conditions

Current wall stability conditions at F3 are assessed to be *good*# on average. There are no obvious signs of potential for development of significant wall instability.

A few instances of localised sub-batter scale fretting have occurred; however, these do not present potential for extension of adverse influence to batter scale or overall slope stability.

A piecewise overview of the current highwall is presented in Plates 1 through 12. The plates show a sequence of 'south looking' views of the highwall, progressing along the wall from east to west.

Wall Stability Conditions Descriptors

Good: The rock/rock mass is apparently competent (in relation to the height and angle of slope being formed). No failures are evident and there is no real sign of potential for failure.

Fair: Stability and safety (against wall related hazards) are adequate for mining purposes. Minor, localised failures may exist, and there may be potential for (further) such events. There are no obvious signs of impending or possible major wall failure. Local minor design adjustments may be necessary to improve stability conditions.

Poor: Potential for failure is clearly evident, and future failure is expected (if some instability has not already occurred). It is likely that failure will be of large scale and/or that a large proportion of the wall (or sector of wall in question) would be adversely affected by such. Failure(s) may be averted by remedial work and/or significant design adjustments.

Very poor: There is usually already some degree of collapse, with progressive collapse expected, or future failure is highly likely. Failure is not likely to be averted.

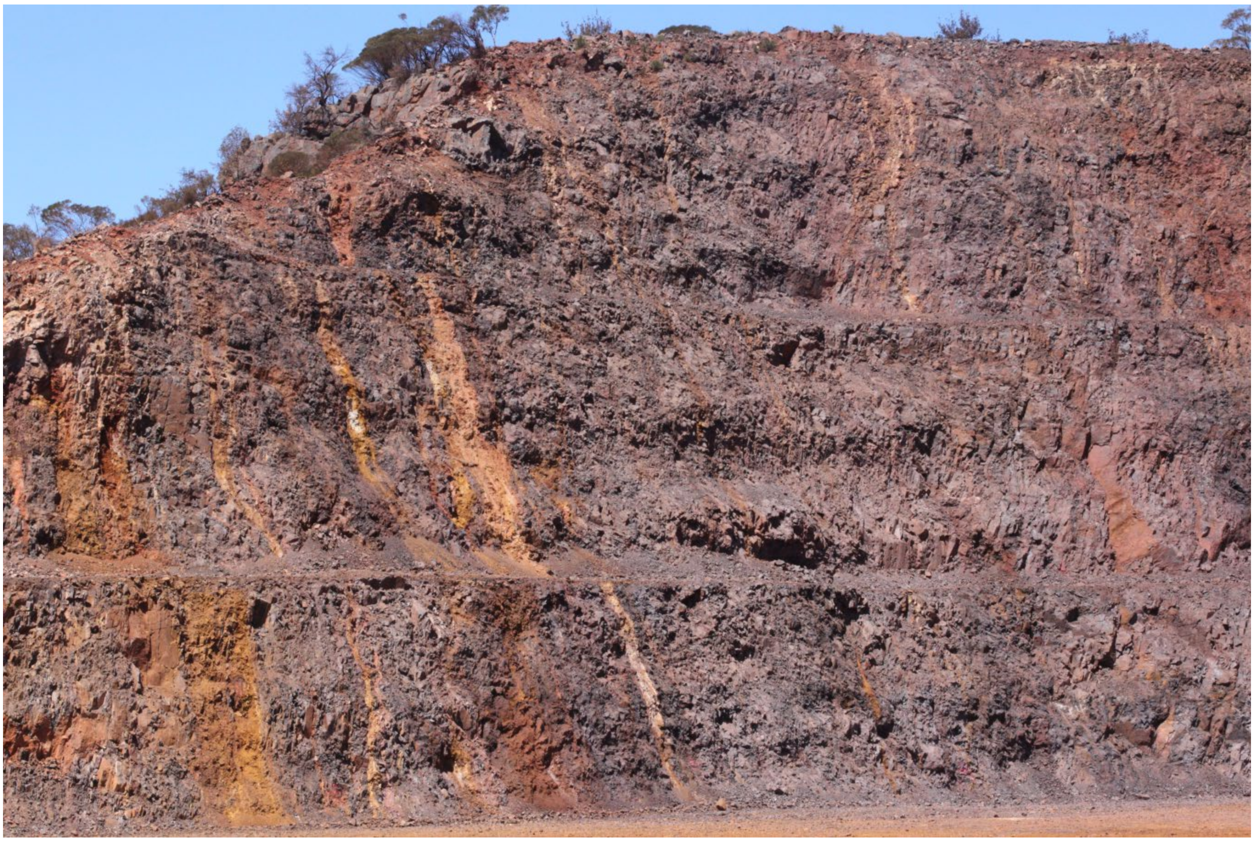


Plate 1 F3 highwall, eastern endwall 1

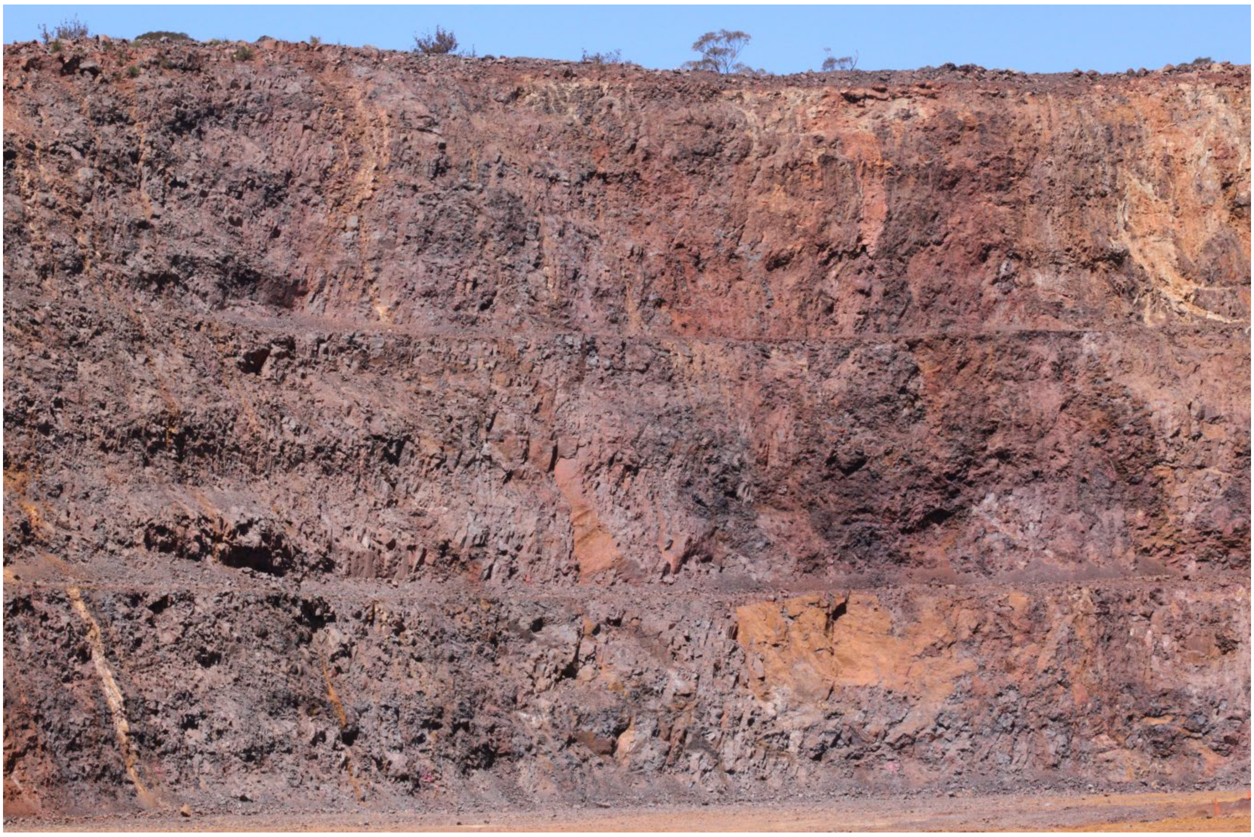


Plate 2 F3 highwall, eastern endwall 2

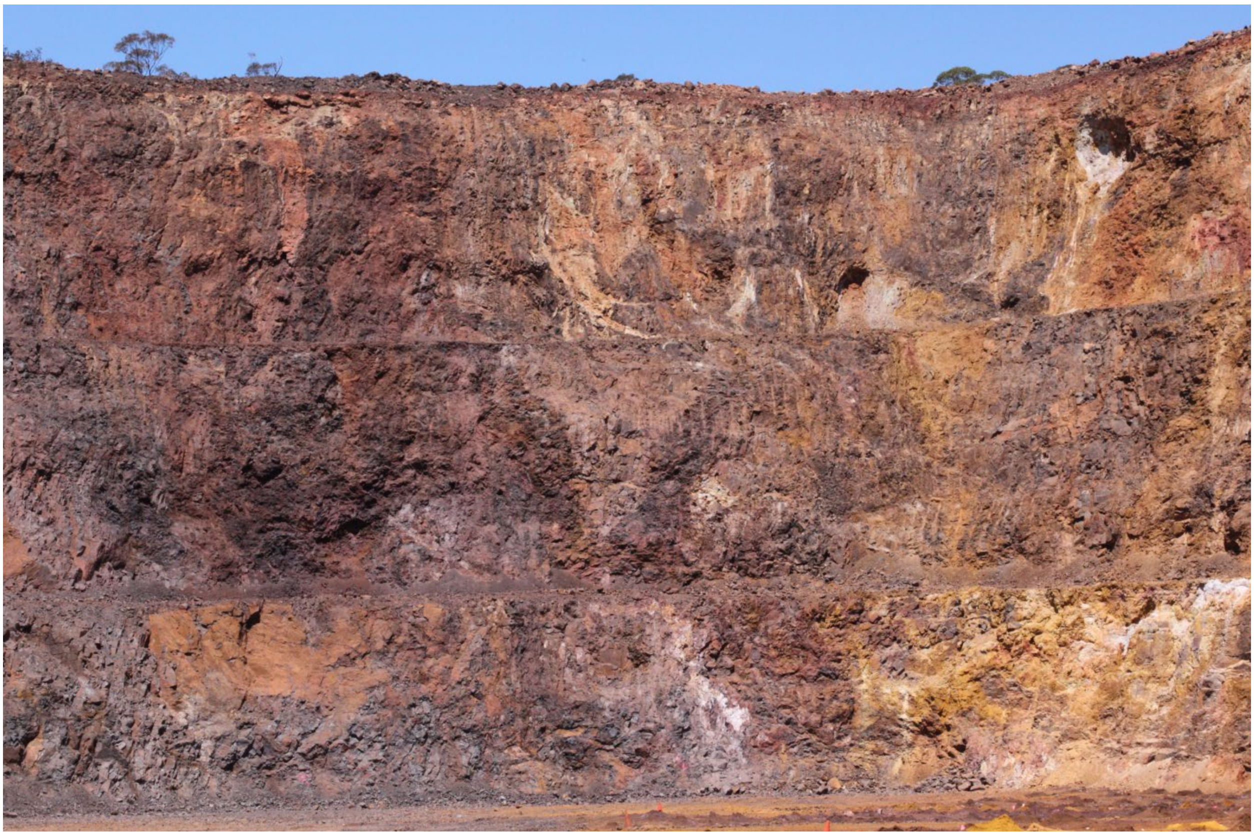


Plate 3 F3 highwall, eastern endwall 3

Plate 4 F3 highwall, eastern highwall 1

Plate 5 F3 highwall, eastern highwall 2

Plate 6 F3 highwall, eastern highwall 3

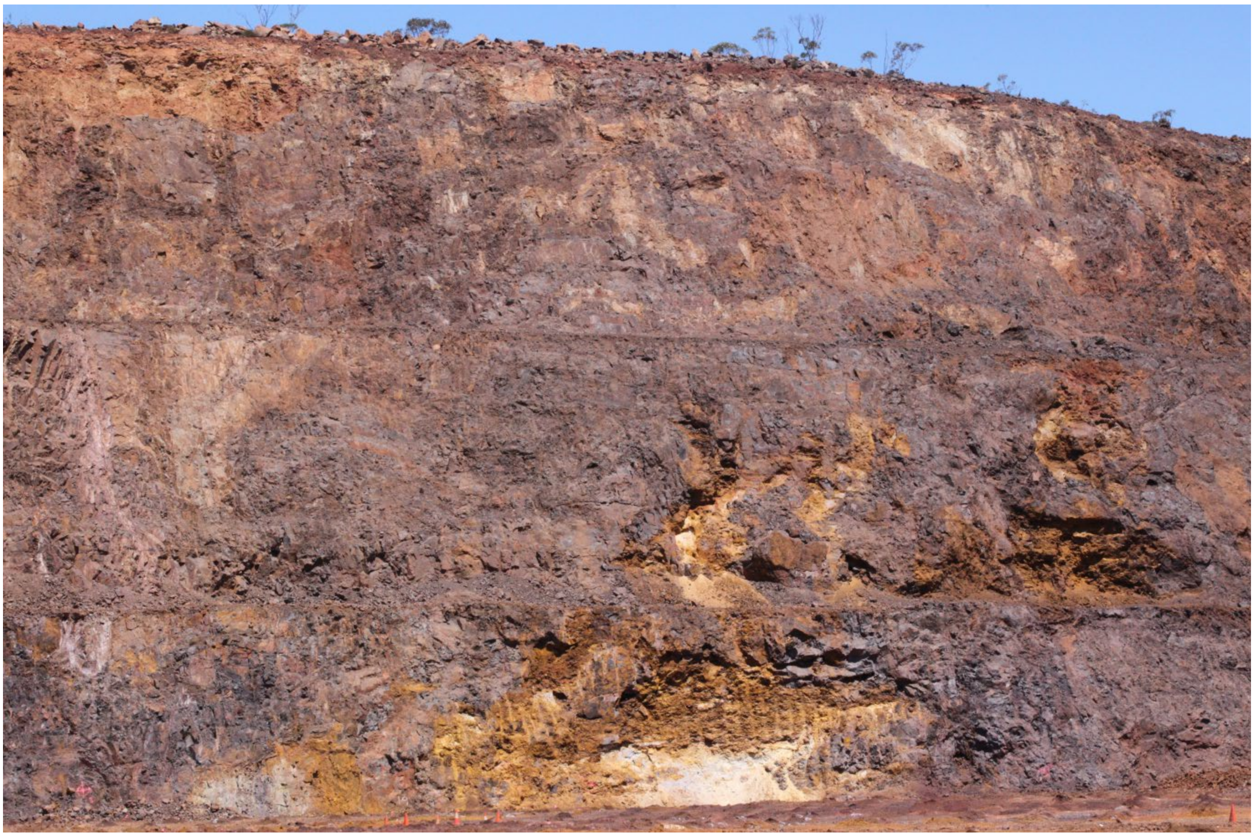


Plate 7 F3 highwall, central highwall 1

Plate 8 F3 highwall, central highwall 2

Plate 9 F3 highwall, central highwall 3

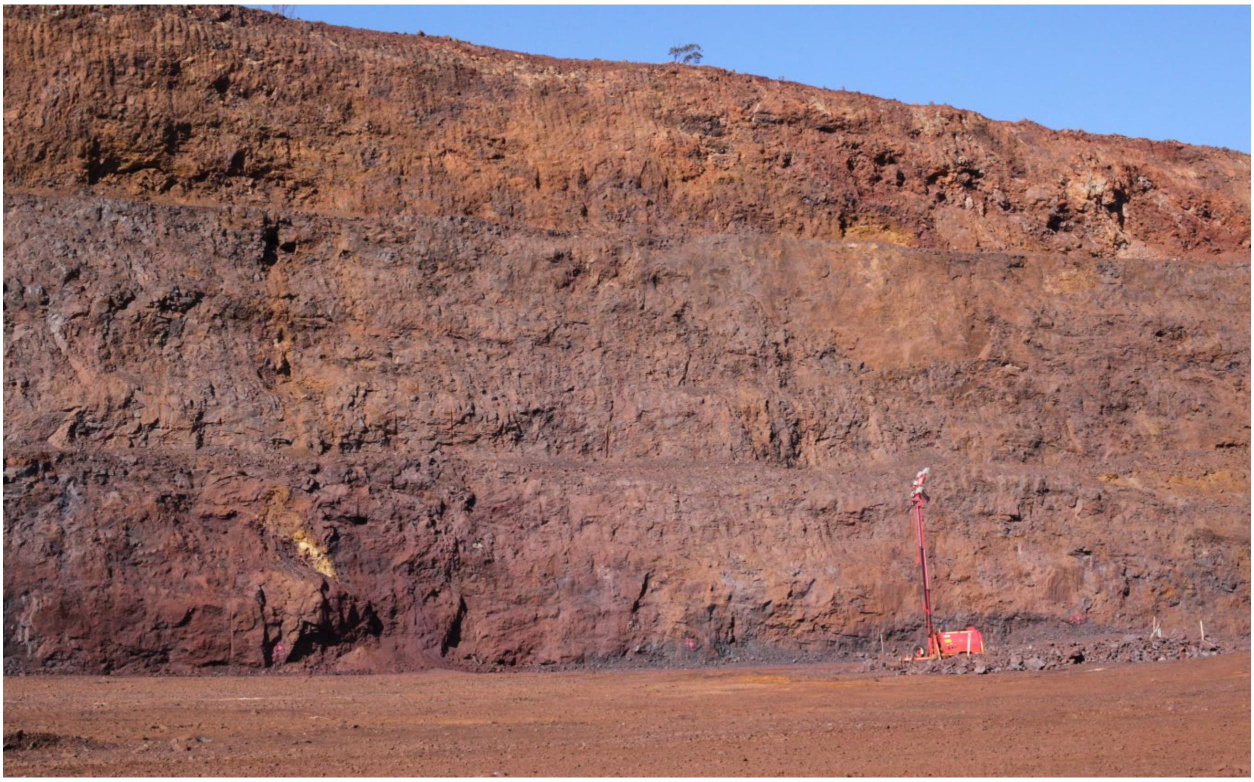


Plate 10 F3 highwall, central highwall 4

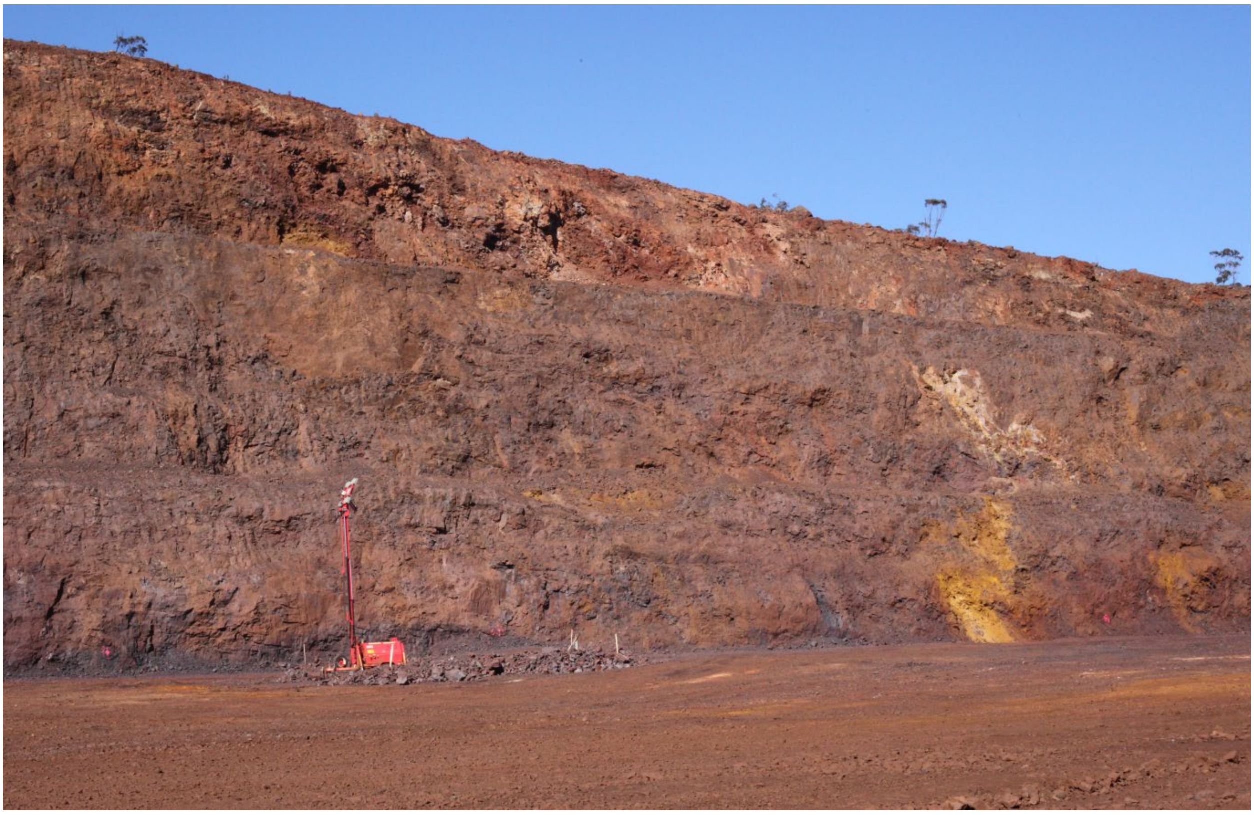


Plate 11 F3 highwall, western highwall 1

Plate 12 F3 highwall, western highwall 2

Summarising conditions evident in Plates 1 to 12 and/ or observed during highwall inspection/ review it is noted that:

Plate 1 The area has generally *good* wall stability, despite localised evidence of 'peel-off' on bedding, which is frequently evident along the wall, without influence on batter or overall slope stability.

Plate 2 Local 'peel-off' on bedding only.

Plate 3 Localised fretting of friable material (weak limonitic zone and/ or denatured BIF material).

Plate 4 The same fretting zones evident in Plate 3 are evident in Plate 4.

Plate 5 Generally *good* wall stability conditions.

Plate 6 Generally *good* wall stability conditions.

Plate 7 Friable material is exposed near the 454mRL toe, and sub-batter scale undercut is evident in the 484-466mRL batter, with some readily excavatable limonitic material exposed locally between 466mRL and the floor at 454mRL. Given that this limonitic material could fret with time, the area must be monitored closely.

However, it is pertinent to note that in this and other similar instances, experience indicates that degradation of such zones is typically surficial only, with portions of the zone deeper into the wall being well-confined and constrained with minimal impact on batter or overall slope stability.

Plate 8 The area noted above (Plate 7) is also shown in Plate 8. Other than that the plate shows only local 'peel-off' to bedding locally defining batter faces.

Plate 9 Generally *good* wall stability conditions, with localised exposure of friable materials.

Plate 10 Generally *good* wall stability conditions, though local undercutting evident in the top batter. This undercutting appears to be related to blasting disturbance and has not developed progressively with time (following initial exposure).

Plate 11 Generally *good* wall stability conditions, with some potentially friable material evident in the lower two batters.

Plate 12 Generally *good* wall stability conditions to the western end of the highwall and into the western endwall.

2. Geotechnical Conditions

2.1 Geological Structure

The F3 Pit highwall will be developed entirely within a sub-vertical to very steeply dipping banded iron formation. Bedding is the dominant structural feature in the highwall, with a number of sub-parallel and sub-orthogonal joint sets also present. Cross-cutting faults are present; however, despite the local presence of poorer quality rock, these features are typically benign to wall stability.

Geological structure data were collected by photogrammetric mapping conducted during a site visit to Koolyanobbing in October 2019. Photogrammetric mapping and processing were performed using the Datamine *Sirovision* program (*Sirovision* Version 6.2.1.1).

These data were subsequently assessed using the Roscience DIPS program [1].

Figures 2 and 3 respectively show lower hemisphere equal angle pole plots of all identified/ mapped defect orientations from the north and central and south walls respectively.

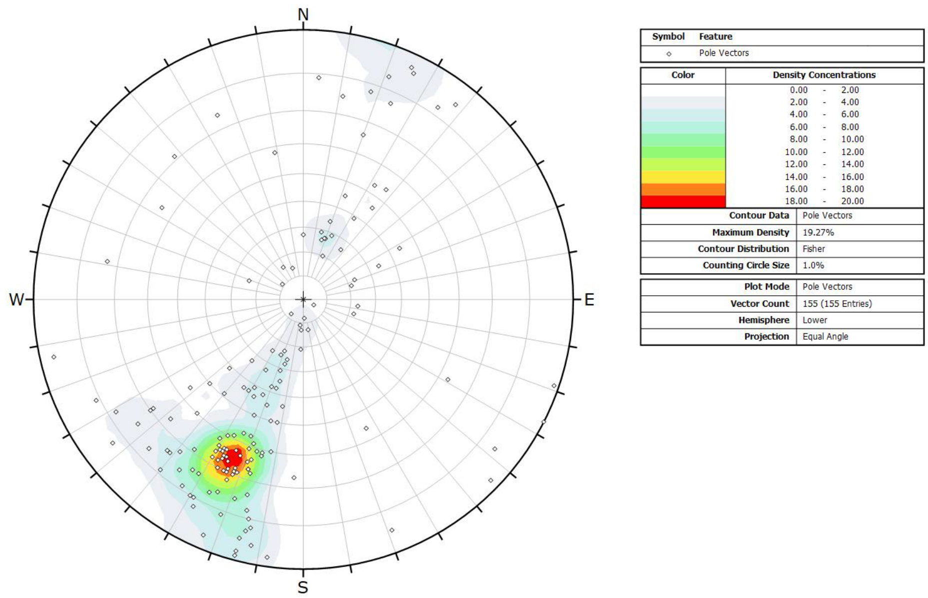


Figure 2 Pole plot of mapped defects, north wall

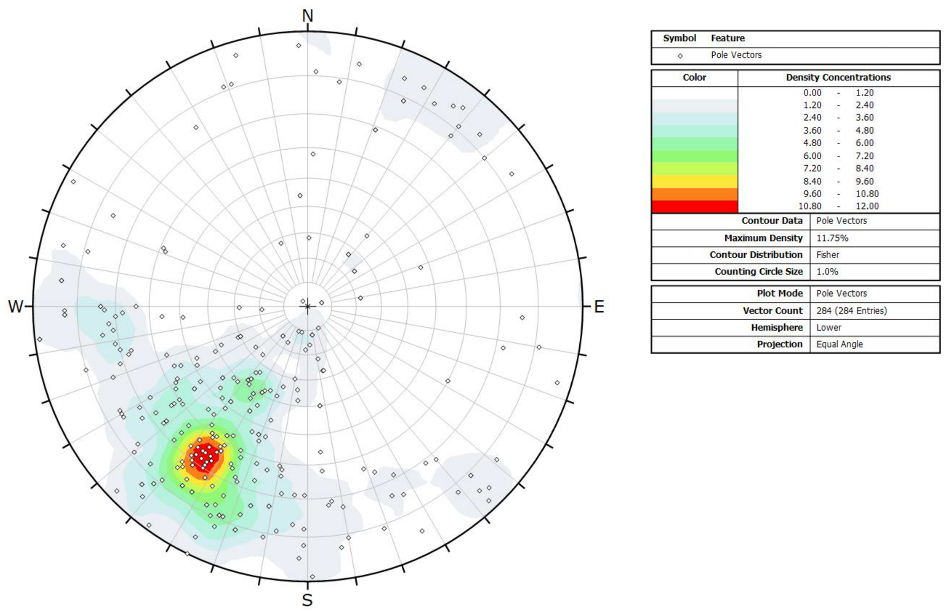


Figure 3 Pole plot of mapped defects, central & south walls

Figures 4 and 5 respectively show the clusters identified from the north wall and central & south wall mapped data as representing major defect sets. The mean orientations of these sets are listed in Tables 1 and 2.

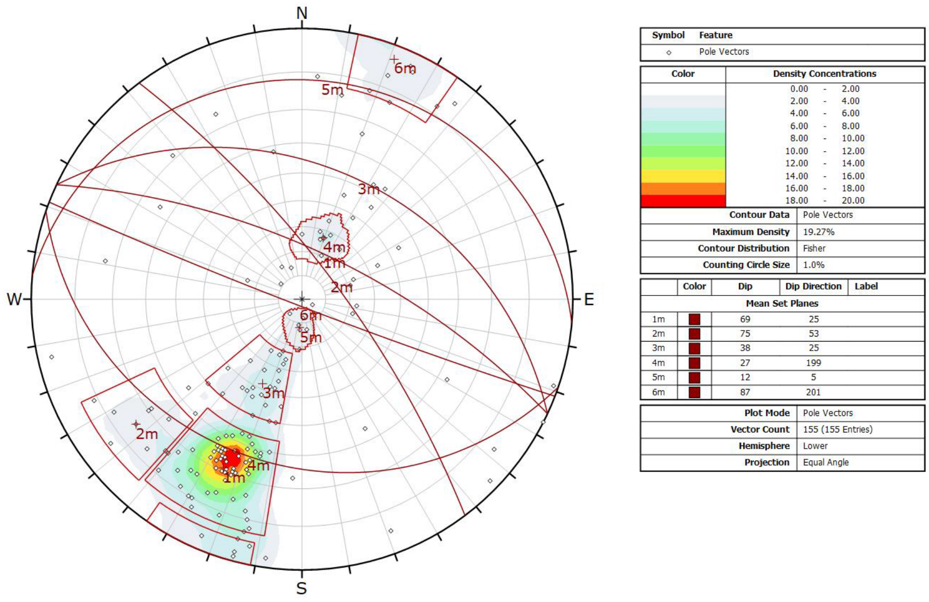


Figure 4 Stereoplot of sets identified during analysis of north wall mapped data

Table 1 Defect sets identified from mapped data obtained from the north wall

Set	Average dip	Average dip direction
1	69°	025°
2	75°	053°
3	38°	025°
4	27°	199°
5	12°	005°
6	87°	201°

Stereoplots from exploration surface mapping, previous conventional geotechnical/ structural core logging, televiewer logging and pit wall mapping are provided for comparison are attached.

Defect orientation data from all sources reveal a basically consistent pattern across the deposit area. Local variations exist, typically reflecting the influence of along strike and/ or down dip undulations in bedding orientation; however, the fundamental structural conditions and associated implications for wall stability are consistent across the deposit.

2.2 Rock Strength

Intact rock strength in the BIF formation range from low (uniaxial compressive strength (UCS) ≤ 5 MPa to exceptionally strong (UCS ≥ 400 MPa).

Lower strengths are associated with narrow, bedding-parallel zones of limonitic/ goethitic materials and cross-cutting faults (intersecting the wall at high angles). As such the influence of weaker zones on wall stability is limited.

2.3 Hydrogeology

All proposed mining at F3 will be above the groundwater table.

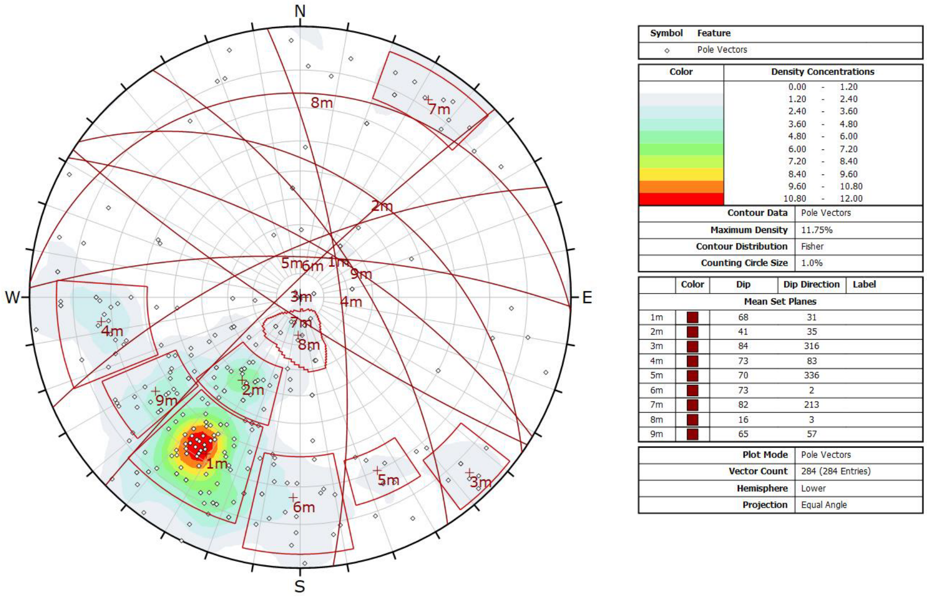


Figure 5 Stereoplot of sets identified during analysis of central & south wall mapped data

Table 2 Defect sets identified from mapped data obtained from the central & south wall

Set	Average dip	Average dip direction
1	68°	031°
2	41°	035°
3	84°	316°
4	73°	083°
5	70°	336°
6	73°	002°
7	82°	213°
8	16°	003°
9	65°	057°

3. Implications for Highwall Stability

Sustained highwall stability at F3 is necessary to protect a population of *tetratheca erubescens* growing within and around a breakaway scarp located ~ 30m behind the pit crest, typically at positions ≥ 15m vertically lower than the crest elevation. The toe of the highwall at 454mRL (in mid-October 2019) was located ~ 70m to 85m horizontally and ~ 15m to 30m vertically below the area inhabited by the plants. Some plants are located ~ 10m behind the crest of the pit south-eastern endwall.

Wall stability both during and after operations at the F3 Pit will be governed dominantly by geological structure, with long term degradation occurring via the interacting processes of relaxation and erosion. The manner/ order in which slope disturbance can occur will be dictated by structure.

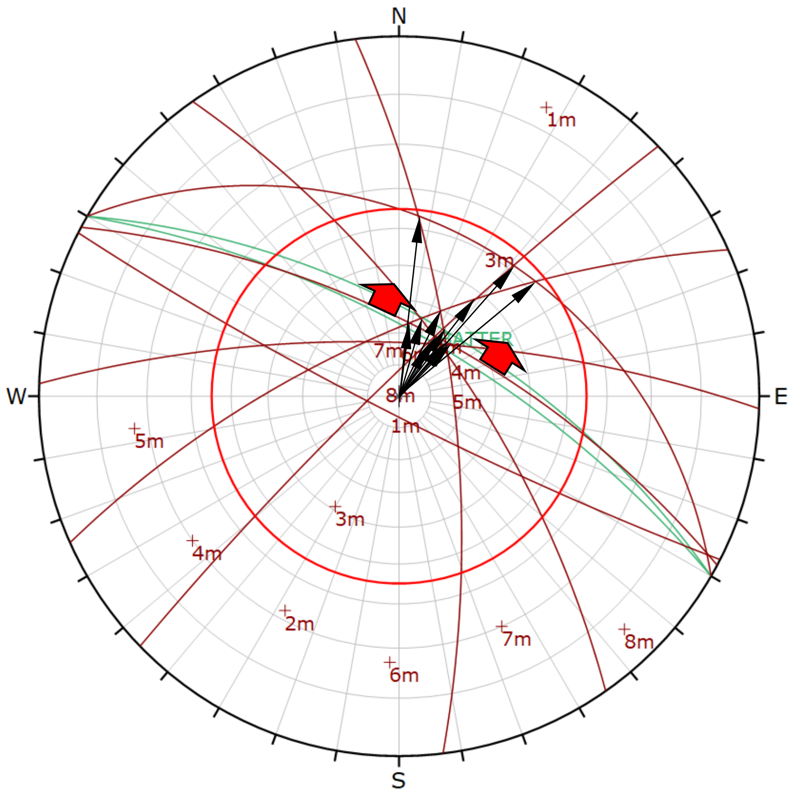
Kinematic stability analyses have been performed using stereographic methods (tetrahedral wedges) and basic mechanics methods (SWEDGE for tetrahedral and pentahedral wedges) for 65°and 70° batters facing 030° (highwall slope facing direction). The analyses assume ubiquitous presence of all defect sets, which is a conservative over-estimation.

The analyses show theoretical potential for several defect combinations to form unstable wedges. However; it is pertinent to note that the combination needs to be viable and the defects need to be located close to an excavated wall position for the interaction to be realised.

Figure 6 succinctly summarises the potential for displacement of tetrahedral wedges from 65°or 70° batters on the highwall. It indicates that most theoretically possible wedges, if exposed, would be slender/ surficial features. Wedge movement at these steeply dipping inclinations would occur on exposure or during excavation, and most would not be discernible as wedge failures. Rather these features would be noted as expected irregularities on the batter face.

Wedges with more moderately and shallowly dipping potential sliding vectors, if exposed in batter faces could slide; however, experience to date shows that such features occur rarely, and at small, (sub-batter) scale, when occurrent (refer Plates 1 through 12).

Figure 6 also clearly shows why bedding partings frequently define highwall batters at F3.



	Color	Dip	Dip Direction	Label
User Planes				
1		65	30	BATTER
2		70	30	
Mean Set Planes				
1m		84	207	
2m		68	28	
3m		39	30	
4m		70	55	
5m		73	83	
6m		73	2	
7m		70	336	
8m		84	316	

Mean orientations of defect sets shown.

Green great circles represent 65° & 70° batter faces

Block arrows (red) indicate potential for planar sliding. In this instance sliding will be dominantly controlled by bedding.

Solid (black) arrows indicate daylighted, possibly unstable, tetrahedral wedges.

Analysis assumes ubiquitous presence of all defect sets, which will not be the case in every (any?) instance.

Other instances of instability could result from the presence of outlier defects.

Figure 6 Kinematic stability analysis for F3 Pit highwall batters (65° & 70°)

The Rocscience program SWEDGE has been used to analyse theoretical potential for wedge/ block sliding from the F3 highwall. Analyses considered potential for tetrahedral and pentahedral wedge sliding via all possible combinations of the mean orientations of defect sets identified by highwall mapping investigations.

The analyses confirm that the majority of theoretically feasible unstable wedges are slender. Figure 7 shows a typical example of a relatively thin pentahedral wedge (a tetrahedral wedge truncated by a third defect). As noted, such wedges are expected to slide on exposure, and will not adversely impact on the stability of adjacent portions of the batter, or on overlying or underlying portions of the slope.

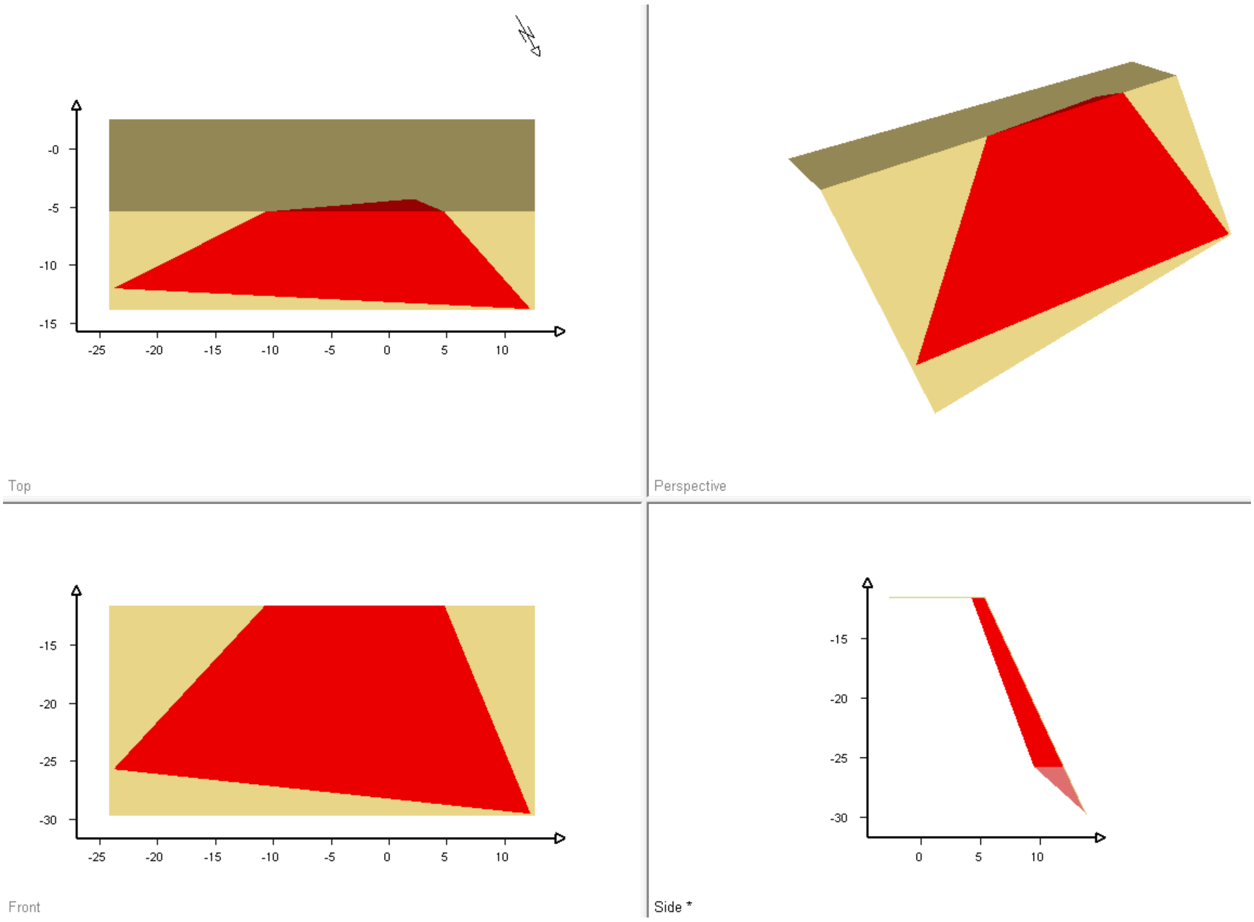


Figure 7 SWEDGE kinematic stability output for pentahedral wedge

Analysis results for wedges/ blocks/ slabs with Factors of Safety ≤ 2 are presented in Tables 3 and 4 for tetrahedral wedges in batters facing 030° (highwall) and Tables 5 and 6 for wedges in batters facing 310° (the south-eastern endwall).

Theoretically unstable wedges in the highwall all have widths (from berm crest to wedge apex) < 1m. Significantly long defect persistences (of ~ 28m) are required for these features to occur at maximum size in 18m high batters.

Larger tetrahedral wedges which could theoretically be daylighted in the highwall face are assessed as stable due to the shear strength adopted for analyses. The Barton-Bandis criterion used is inferred to be realistic, based on observed defect shapes, surface conditions and wall rock strengths.

All south-eastern endwall wedges, as defined by the mean defect orientations, are assessed to be stable.

Table 3 **Facing 030 TETRAHEDRAL WEDGES**

Barton-Bandis shear strength criterion:
JRC = 8
JCS = 30 MPa
Base friction = 30°
Dilation = 3°
Unit weight = 28 kNm^{-3}

Safety Factor	Weight (kN)	Pers J1	Pers J2	Height	Width	Length	Spill	Dip J1	D Dirn J1	Dip J2	D Dirn J2
0.81	1348	28.3	19.4	18.0	0.7	22.2	4.2	68	28	70	55
0.83	915	28.3	19.6	18.0	0.6	20.8	3.6	68	28	70	336
0.85	1476	28.3	19.5	18.0	0.8	22.7	4.4	68	28	73	83
0.86	1268	28.3	19.4	18.0	0.7	20.9	4.2	68	28	84	316
1.01	15	19.3	19.3	18.0	0.2	1.5	0.0	70	55	73	2
1.02	671	19.9	19.9	18.0	1.7	4.8	0.0	70	55	70	336
1.07	58	19.4	19.4	18.0	0.5	2.0	0.0	73	83	73	2
1.11	82	19.4	19.4	18.0	0.6	1.5	0.0	70	55	84	316
1.36	1589	20.7	20.7	18.0	3.6	5.3	0.0	73	83	70	336
1.65	337	19.9	19.9	18.0	2.0	2.0	0.0	73	83	84	316
1.66	1434	28.3	19.6	18.0	0.8	22.9	0.0	68	28	73	2
4.91	2016	22.9	22.9	18.0	7.4	5.4	0.0	70	336	84	316

Table 4 **Facing 310 TETRAHEDRAL WEDGES**

Safety Factor	Weight (kN)	Pers J1	Pers J2	Height	Width	Length	Spill	Dip J1	D Dirn J1	Dip J2	D Dirn J2
1.80	1139	20.7	20.7	18.0	2.7	5.6	0.0	84	207	70	336
2.82	4588	30.3	30.3	18.0	7.0	21.4	0.0	39	30	73	83
4.47	2450	20.6	20.6	14.9	8.0	6.3	0.0	84	207	73	2
7.60	659	11.9	11.9	5.0	8.0	5.9	0.0	39	30	70	55

Table 5 **Facing 030 PENTAHEDRAL WEDGES**
Barton-Bandis shear strength criterion:
JRC = 8
JCS = 30 MPa
Base friction = 30°
Dilation = 3°
Unit weight = 28 kNm^{-3}

Safety Factor	Weight (kN)	Pers J1	Pers J2	Pers BJ	Height	Width	Length	Spill	Dip J1	D Dirn J1	Dip J2	D Dirn J2	Dip BJ	D Dirn BJ
0.81	1347	9.3	19.4	27.8	18.0	0.7	21.9	4.3	84	207	70	55	68	28
0.81	1348	19.4	0.3	28.0	18.0	0.7	21.9	4.3	70	55	73	2	68	28
0.81	1348	19.4	0.3	28.0	18.0	0.7	21.9	4.3	70	55	73	83	68	28
0.81	1348	19.4	0.3	28.0	18.0	0.7	21.9	4.3	70	55	84	316	68	28
0.81	1348	28.3	0.5	19.4	18.0	0.7	22.2	4.2	68	28	70	336	70	55
0.83	913	9.3	19.6	27.8	18.0	0.6	20.4	3.6	84	207	70	336	68	28
0.83	915	0.3	19.6	28.0	18.0	0.6	20.4	3.6	73	2	70	336	68	28
0.83	915	0.3	19.6	28.0	18.0	0.6	20.4	3.6	73	83	70	336	68	28
0.83	915	19.6	0.3	28.0	18.0	0.6	20.4	3.6	70	336	84	316	68	28
0.83	915	0.3	19.6	28.0	18.0	0.6	20.4	3.6	70	55	70	336	68	28
0.83	1429	28.3	13.4	6.0	18.0	0.7	22.7	4.3	68	28	70	55	73	83
0.85	1475	9.3	19.5	27.8	18.0	0.8	22.4	4.4	84	207	73	83	68	28
0.85	1476	28.3	0.5	19.5	18.0	0.8	22.7	4.4	68	28	70	336	73	83
0.85	1476	28.3	0.5	19.5	18.0	0.8	22.7	4.4	68	28	84	316	73	83
0.85	1476	19.5	0.3	28.0	18.0	0.8	22.4	4.4	73	83	73	2	68	28
0.86	1266	9.3	19.4	27.8	18.0	0.7	20.5	4.3	84	207	84	316	68	28
0.86	1268	0.3	19.4	28.0	18.0	0.7	20.5	4.3	73	2	84	316	68	28
0.86	1268	0.3	19.4	28.0	18.0	0.7	20.5	4.3	73	83	84	316	68	28
1.00	598	19.6	6.7	13.0	18.0	1.2	4.7	0.0	70	55	73	2	70	336
1.01	15	19.3	0.5	19.3	18.0	0.2	1.4	0.0	73	2	70	336	70	55
1.01	15	19.3	0.5	19.3	18.0	0.2	1.4	0.0	73	2	84	316	70	55
1.01	15	19.3	0.5	19.3	18.0	0.2	1.5	0.0	70	55	73	83	73	2

Safety Factor	Weight (kN)	Pers J1	Pers J2	Pers BJ	Height	Width	Length	Spill	Dip J1	D Dirn J1	Dip J2	D Dirn J2	Dip BJ	D Dirn BJ
1.01	15	0.7	19.3	19.3	18.0	0.2	1.4	0.0	68	28	73	2	70	55
1.02	671	19.9	0.6	19.9	18.0	1.7	4.7	0.0	70	55	84	316	70	336
1.02	671	19.9	0.5	19.9	18.0	1.7	4.7	0.0	70	55	73	83	70	336
1.02	539	4.7	19.2	18.9	18.0	0.0	4.7	0.0	84	207	70	55	70	336
1.03	46	11.5	19.3	18.8	18.0	0.3	1.9	0.0	70	55	73	2	73	83
1.07	58	19.4	0.5	19.4	18.0	0.5	1.9	0.0	73	2	70	336	73	83
1.07	58	19.4	0.5	19.4	18.0	0.5	1.9	0.0	73	2	84	316	73	83
1.07	58	0.7	19.4	19.4	18.0	0.5	1.9	0.0	68	28	73	2	73	83
1.08	62	19.3	11.7	7.7	18.0	0.4	1.5	0.0	70	55	73	2	84	316
1.11	82	0.5	19.4	19.4	18.0	0.6	1.5	0.0	70	336	84	316	70	55
1.11	82	19.4	0.5	19.4	18.0	0.6	1.5	0.0	70	55	73	83	84	316
1.11	82	0.7	19.4	19.4	18.0	0.6	1.5	0.0	68	28	84	316	70	55
1.21	5558	38.4	19.6	13.3	18.0	1.2	36.0	0.0	68	28	73	83	39	30
1.22	5392	38.3	19.6	13.8	18.0	1.2	36.0	0.0	68	28	70	55	39	30
1.23	884	18.1	20.0	18.8	18.0	1.8	5.3	0.0	70	55	70	336	73	83
1.28	2558	23.3	23.3	2.2	18.0	8.0	5.8	0.0	70	336	84	316	39	30
1.32	1206	19.9	10.2	9.8	18.0	2.0	5.2	0.0	73	83	73	2	70	336
1.34	13902	23.5	23.3	11.1	18.0	8.0	11.8	0.0	73	83	70	336	39	30
1.36	1589	20.7	0.6	20.7	18.0	3.6	5.2	0.0	73	83	84	316	70	336
1.37	1086	6.0	19.3	18.9	18.0	0.1	5.2	0.0	84	207	73	83	70	336
1.39	11594	23.5	23.3	13.3	18.0	8.0	8.3	0.0	73	83	84	316	39	30
1.39	32948	28.0	23.3	19.5	18.0	8.0	23.0	0.0	70	55	70	336	39	30
1.42	30759	28.0	23.3	21.1	18.0	8.0	19.5	0.0	70	55	84	316	39	30
1.42	33692	23.5	27.9	20.5	18.0	8.0	21.7	0.0	73	83	73	2	39	30
1.42	52887	28.0	27.9	31.3	18.0	8.0	32.8	0.0	70	55	73	2	39	30
1.51	5982	40.3	19.6	15.1	18.0	1.3	36.0	0.0	68	28	84	316	39	30
1.51	172	16.5	19.5	18.8	18.0	0.8	2.0	0.0	70	55	84	316	73	83
1.56	167	19.5	16.0	3.5	18.0	0.8	2.0	0.0	73	83	73	2	84	316

Safety Factor	Weight (kN)	Pers J1	Pers J2	Pers BJ	Height	Width	Length	Spill	Dip J1	D Dirn J1	Dip J2	D Dirn J2	Dip BJ	D Dirn BJ
1.65	337	0.5	19.9	19.9	18.0	2.0	2.0	0.0	70	336	84	316	73	83
1.66	1433	9.3	19.6	27.8	18.0	0.8	22.5	0.0	84	207	73	2	68	28
1.73	22138	27.9	23.3	21.7	18.0	8.0	15.7	0.0	73	2	84	316	39	30
1.91	791	36.2	4.3	35.6	18.0	0.0	36.0	0.0	84	207	73	83	39	30
1.91	760	36.2	4.3	35.7	18.0	0.0	36.0	0.0	84	207	70	55	39	30
1.97	5258	40.4	19.7	15.3	18.0	1.2	36.0	0.0	68	28	70	336	39	30
2.21	812	36.1	4.2	36.1	18.0	0.0	36.0	0.0	84	207	84	316	39	30

Table 6 Facing 310 PENTAHEDRAL WEDGES

Safety Factor	Weight (kN)	Pers J1	Pers J2	Pers BJ	Height	Width	Length	Spill	Dip J1	D Dirn J1	Dip J2	D Dirn J2	Dip BJ	D Dirn BJ
1.79	1037	3.7	19.8	19.0	18.0	1.5	4.9	0	73	83	70	336	84	207
1.79	1093	2.8	20.1	19.0	18.0	2.0	5.1	0	70	55	70	336	84	207
1.80	805	19.6	6.9	13.9	18.0	0.4	5.0	0	84	207	84	316	70	336
1.80	1134	2.8	20.5	20.0	18.0	2.6	5.5	0	68	28	70	336	84	207
1.80	1126	2.8	20.3	20.0	18.0	2.3	5.5	0	39	30	70	336	84	207
1.80	1139	0.6	20.7	20.7	18.0	2.7	5.6	0	73	2	70	336	84	207
2.76	3348	25.7	11.8	17.9	18.0	2.5	21.1	0	73	83	70	336	39	30

4. Long Term Highwall Stability

Long term overall stability conditions in the F3 Pit highwall are expected to be *good*. There are no indicators of developing wall instability and no obvious mechanisms which could cause large scale wall instability have been identified.

Localised structurally controlled instability (at sub-batter and possibly batter scale) is theoretically possible; however, wall performance and rock mass conditions observed to date suggest that such events will be of limited scale and occur in isolation such that the potential for progressive degradation of conditions to the point where large scale failure could occur is considered to be very low.

This inference assumes that appropriate methods are continued to be used, and successfully implemented, for final wall and near wall blasting.

The distance between the natural scarp to the south of the highwall crest and production and wall blasting will increase as pit development advances. The potential for disturbance to the scarp and surrounding surface areas from such activity will therefore decrease with time.

Nevertheless, the scarp which hosts the *tetratheca erubescens* is prone to natural wastage, as attested by the evidence of boulder loss prior to commencement of mining, hence it is important to continue control over blasting to aim to avoid premature loss of material from the scarp, even though such losses will inevitably occur with time.

5. Closure

We trust that the information provided meets your immediate requirements. Should there be any need for further explanation, do not hesitate to contact us.

Yours faithfully

PETER O'BRYAN *& Associates*
per:

Peter O'Bryan
BE (Mining) MEngSc MAusIMM (CP)
Principal

Grace Connell
BSc (Civil Engineering & Accounting)
Geotechnical Engineer

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ATTACHMENT

F DEPOSIT GEOTECHNICS

FUNDAMENTAL DATA FROM PRIOR ASSESSMENTS

PETER O'BRYAN *& Associates*

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43 York Street Subiaco WA 6008
PO Box 1157 West Leederville WA 6901

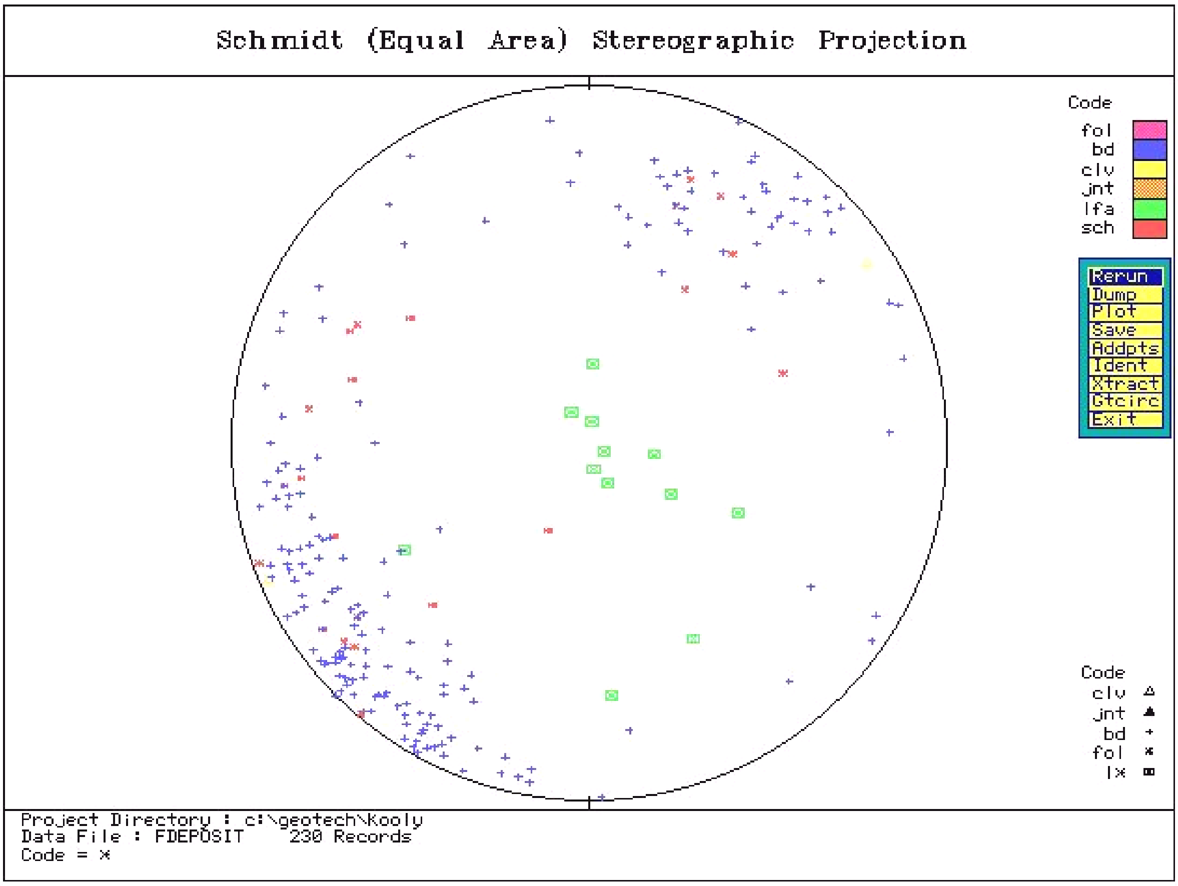


Figure A1 F Deposit surface mapping (after Hoppe, 2002) [2]

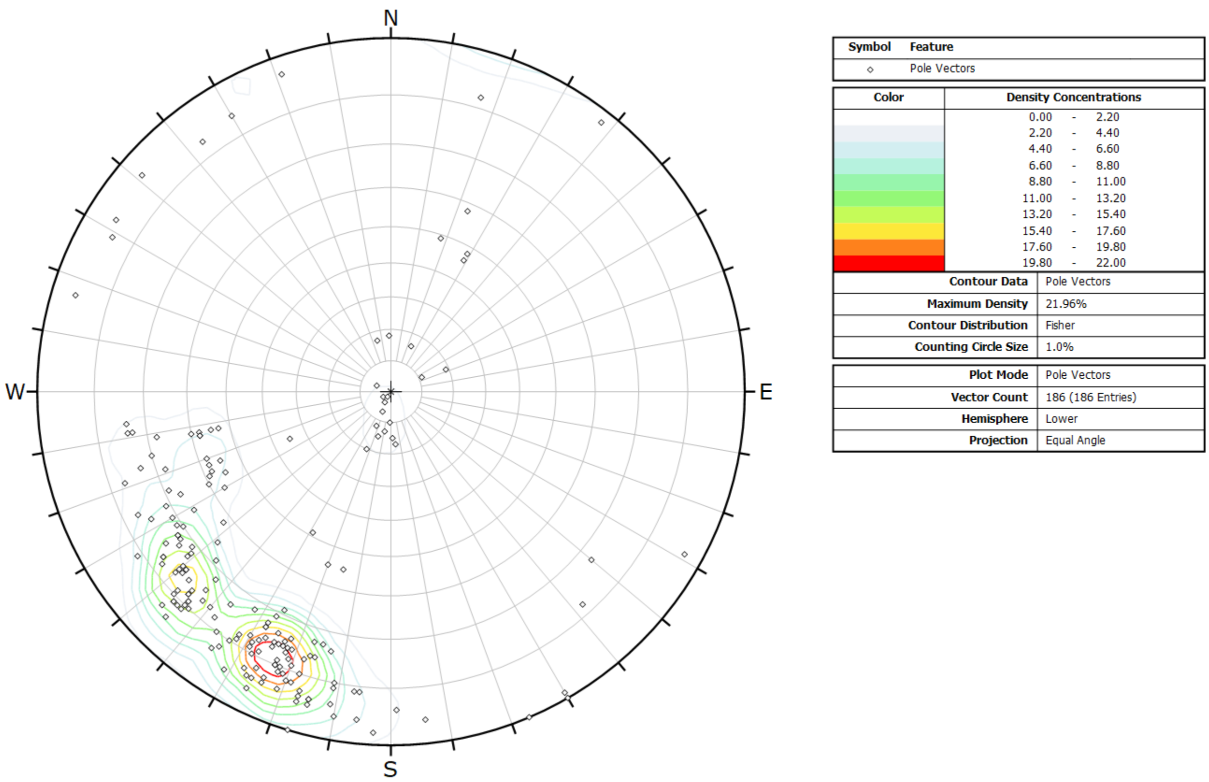


Figure A2 F3 Deposit structural defects (Televiewer logging data) [1]

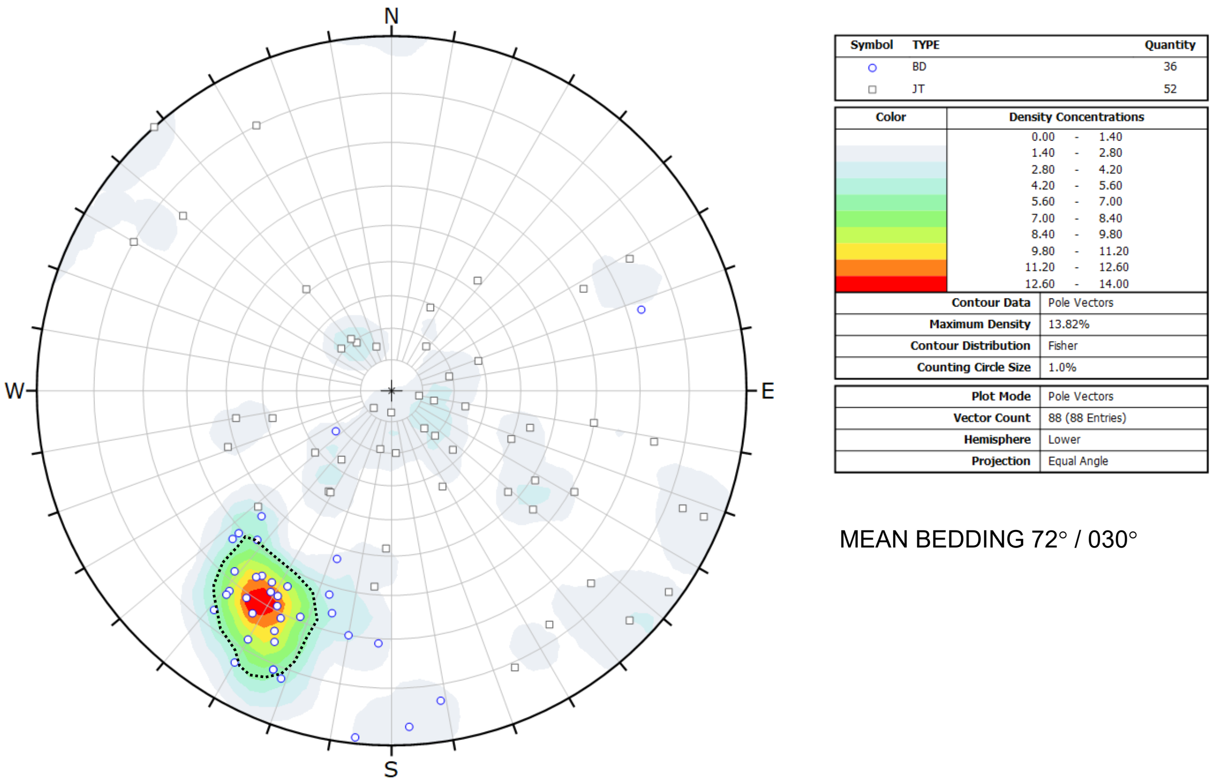


Figure A3 F3 Pit: Borehole P17GT001: all geotechnically logged defect orientation data [3]

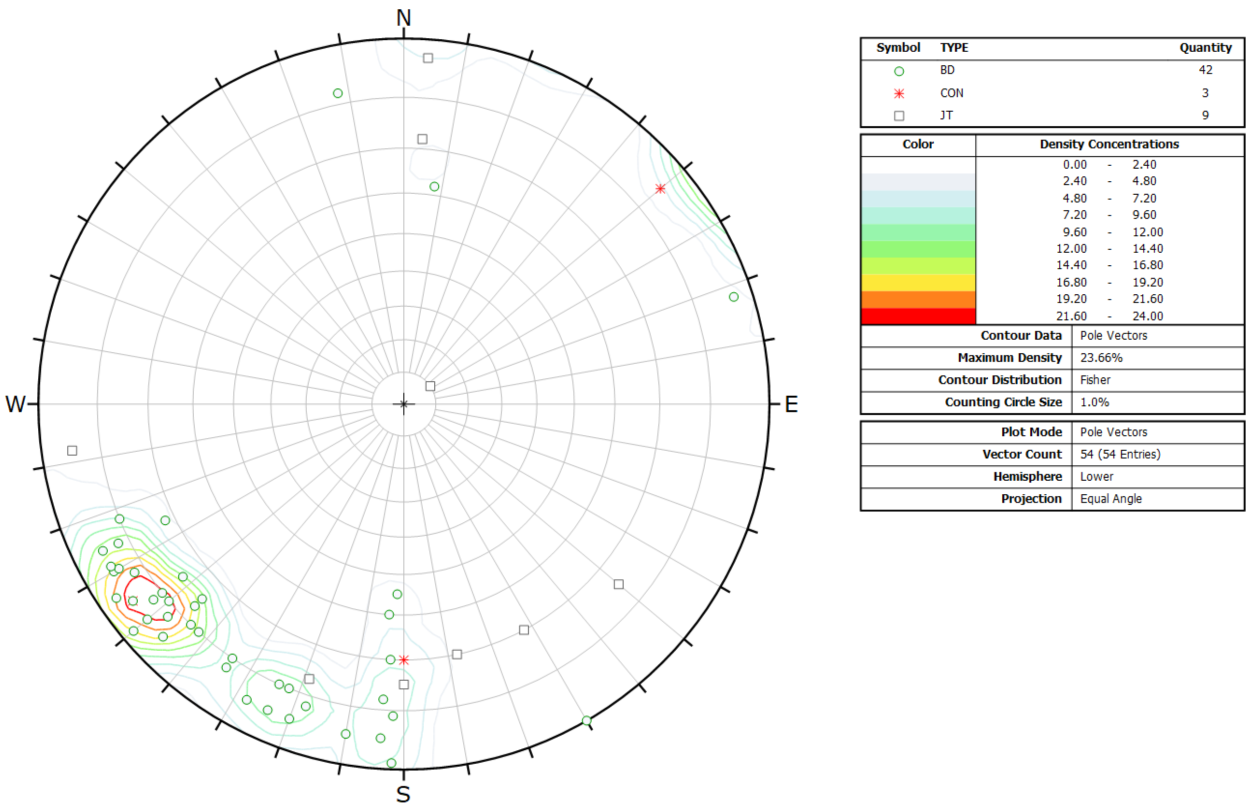


Figure A4 F2 Pit: upper highwall mapping data (after Cleveland Cliffs, 2017) [4]

Table A1 Uniaxial Compressive Strength Test Results F & E Deposits Samples (WASM, 2016) [6]

WASM Sample No.	Client Sample No.	Borehole ID	Depth (m)	Lithology	Diameter (mm)	Length (mm)	Mass (g)	Unit Weight (kN/m^3)	Load (kN)	UCS (MPa)	Failure Feature		
											Mode	Angle (°)	Nature
1	S1	-	Surface	BIF	45.00	112.15	636.40	34.99	652.2	410	A, Bi, Bs	27	Violent
2 #	S2	-	Surface	BIF	44.80	105.07	581.40	34.42	673.4	427	C	-	Violent
3	S3	-	Surface	BIF	44.76	115.87	643.20	34.60	764.1	486	A, C	-	Violent
4 $	N1	-	Surface	BIF	45.22	91.26	506.90	33.92	582.5	363	A, C	-	Violent
5	N2	-	Surface	BIF			Poor core recovery due to open bedding planes						
6	N3	-	Surface	BIF	45.14	113.23	570.00	30.85	304.2	190	A, Bi, Bs	20	Quiet
7	E1	-	Surface	BIF			Poor core recovery due to open bedding planes						
8	E2	-	Surface	BIF	45.20	113.15	580.70	31.37	466.2	291	C	-	Violent
9	E3	-	Surface	BIF	45.23	113.37	647.10	34.84	647.1	403	A, Bi, Bs	18	Quiet
10 #	E4	-	Surface	BIF	45.11	108.75	603.70	34.06	714.5	447	Bi, Bs	17	Violent

Note: 1) Failure Modes: A: Axial splitting
B: Shear (Bi for shear through intact rock and Bs for shear along structure)
C: Multiple cracking
2) The samples were tested using an INSTRON machine.
3) The failure angles were measured between the loading axis and the failure plane.
- Sample length slightly less than prescribed in ISRM standard.
$ - Sample length considerably less than prescribed in ISRM standard.

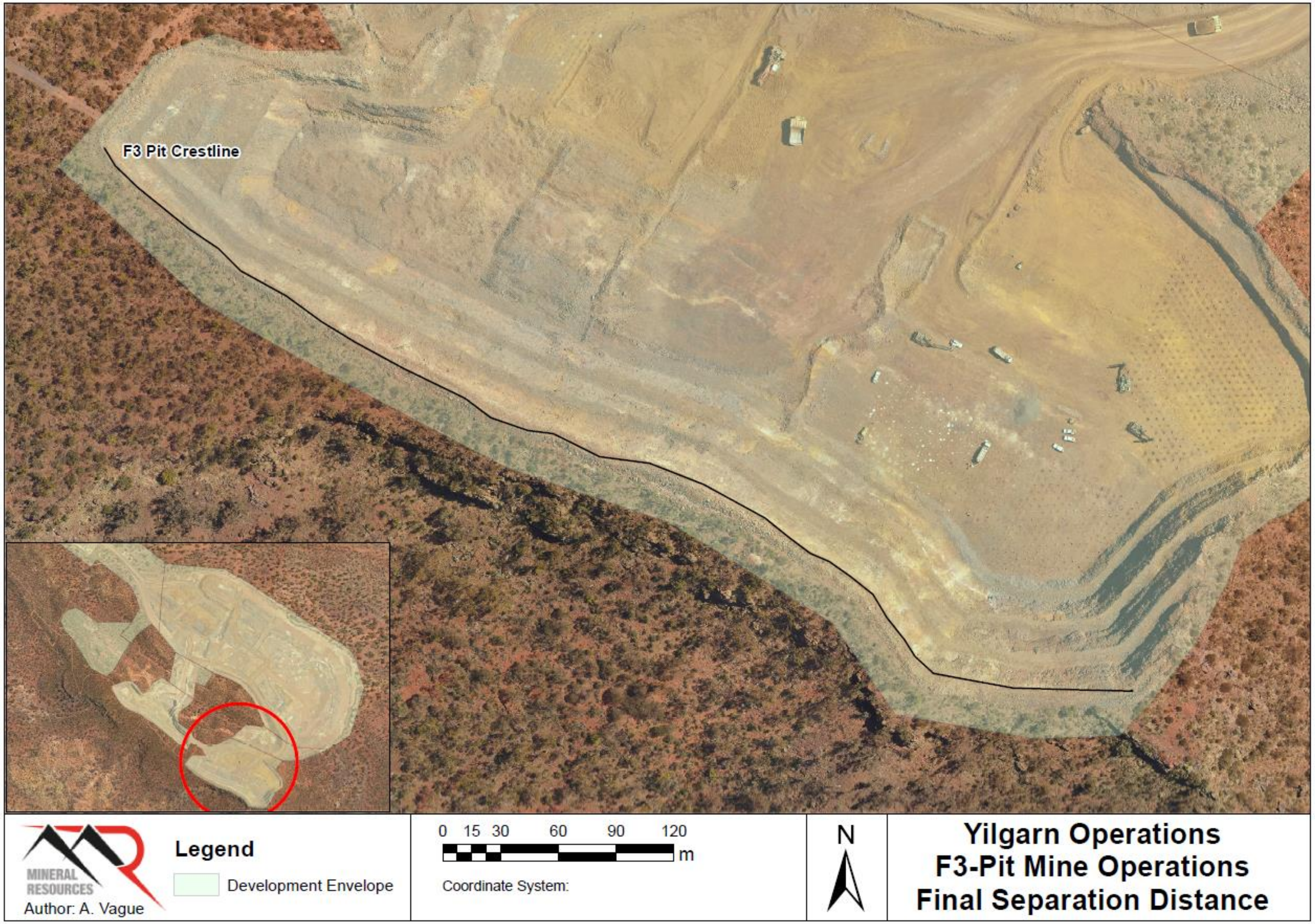
Table A2 Defect Direct Shear Strength Test Results F & E Deposits Samples (WASM, 2016) [6]

WASM Sample No.	Client Sample No.	Client Borehole ID.	Depth (m)	Lithology	Shearing Area (mm^2)	Peak Strength		Residual Strength	
						Cohesion (kPa)	Friction Angle (°)	Cohesion (kPa)	Friction Angle (°)
14	DS F1	DS12011	40.80 ~ 40.80	BIF Bedding	3180	111	37.4	91	37.2
15	DS F2	DS12011	44.40 ~ 44.40	BIF Bedding	3280	64	41.1	64	41.1
16	DS E1	DS12003	75.84 ~ 75.84	BIF Bedding	2310	384	32.8	142	32.4
17	DS E2	DS12003	83.35 ~ 83.35	BIF Bedding	2220	157	38.4	157	38.4
18	FS	In situ	Surface	BIF Bedding	5340	41	42.0	1	39.9
19	FN	In situ	Surface	BIF Bedding	5270	35	34.9	16	33.7

Note: The load and displacements were acquired automatically using software from National Instruments.

F Deposit samples highlighted

Attachment 9: Final Separation Distances F3 Pit



Attachment 10: MRL (2019) Vibration Monitoring Report 2018 (Revision 0)

Koolyanobbing Iron Ore Project

2019 F-DEPOSIT VIBRATION MONITORING REPORT

Proponent:	Yilgarn Iron Pty Ltd
Address:	1 Sleat Road, Applecross, WA 6153
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Email:	les.purves@mrl.com.au

30 April 2020

Report Reference: ENV-TS-RP-0216

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Revision History

Revision Number	Issue Date	Prepared By	Reviewed By	Approved By	Document Purpose
0	30/04/2020	A Vague	D Swain	R Kerrison	MS 1054 Reporting

CONTENTS

TABLES

FIGURES

ATTACHMENTS

1. INTRODUCTION

The Yilgarn Iron Ore Operations (Yilgarn Operations) are located north east of Southern Cross, Western Australia, with these operations comprising of mining operations at the Koolyanobbing Range, Mt Jackson Range and Windarling Range; ore processing at Koolyanobbing prior to railing to the Port of Esperance for export.

In January 2017, Cliffs Asia Pacific Iron Ore Pty Ltd (Cliffs) received approval under the *Environmental Protection Act 1986* to implement the F deposit mining proposal (Minister for the Environment and Heritage 2017). Under Ministerial Statement 1054 (MS 1054), Cliffs were required to develop and implement a Stability Monitoring Program to ensure the stability of the southern pit (F3 Pit) wall during mining and post closure so that the Tetratheca erubescens plants adjacent to the southern pit wall are not adversely impacted. Condition 7-6(2) of MS 1054 required the Stability Monitoring Program to include vibration monitoring and measurements for each firing of the southern F3 pit.

In August 2018, Cliffs completed an asset sale transaction with Mineral resources Limited (MRL), with the new proponent of the Yilgarn Operations being Yilgarn Iron Pty Ltd (YIPL). As the proponent of the Yilgarn Operations, YIPL assumed all responsibilities under MS 1054, including the monitoring and recording of vibration measurements for the Project's F3 pit. Specifically, Condition 7-7 required that ground vibrations along the southern edge of the F3 pit adjacent to the development envelope were not to exceed the specifications in **Table 1** (below).

TABLE 1: BLAST VIBRATION LIMITS

Blast Frequency	Vibration PPV Limit
No blast greater than	10mm/sec
90% of blaster per year	5mm/sec
9 out of 10 consecutive blaster less than	5mm/sec

This Report presents F3 pit blast vibration results for 2019 period: 1 January – 31 December.

2. METHODOLOGY

Vibration monitoring was established at the F Deposit F3 Pit as per the Stability Monitoring Program (Geotechnical Management Plan: F Pit Development, Cliffs 2017), approved by the Department of Mines, Industry, Regulation and Safety (DMIRS)/ Environmental Protection Authority (EPA) under Condition 7-6(2) in February 2017.

To establish site specific empirical relationships for calculation of blast induced vibration parameters including peak particle velocity (PPV) and site and rock properties, a series of five (5) test blasts where carried out within the boundaries of F3 pit shell to develop site laws to ensure compliance with site conditions. These tests were concluded on contour at the top of the ridge of F deposit.

To monitor the ground vibration, two standard tri-axial geophones were installed along the southern ridge of F Deposit, one at F3 and one at F2. The geophones use a suspended mass between two magnets to convert the ground vibrations into voltage deflections. During a seismic activity, this mass moves relative to the magnets thus producing a voltage which can be measured, recorded and analysed at a later stage.

Vibration predictions were made before each blast using the equation: $V=[R/\surd Q]-\beta$

Where:

- V is the peak particle velocity (PPV) in mm/sec.
- R is the distance between the blast and the point of measurement in meters.
- Q is the maximum instantaneous charge in kilograms.
- K & β are constants related to site and rock mass properties.

3. RESULTS

Blasting continued in F3 pit during 2019. **Figure 1** presents the vibration monitoring results from January to December 2019. The raw data is included in **Attachment 1.**

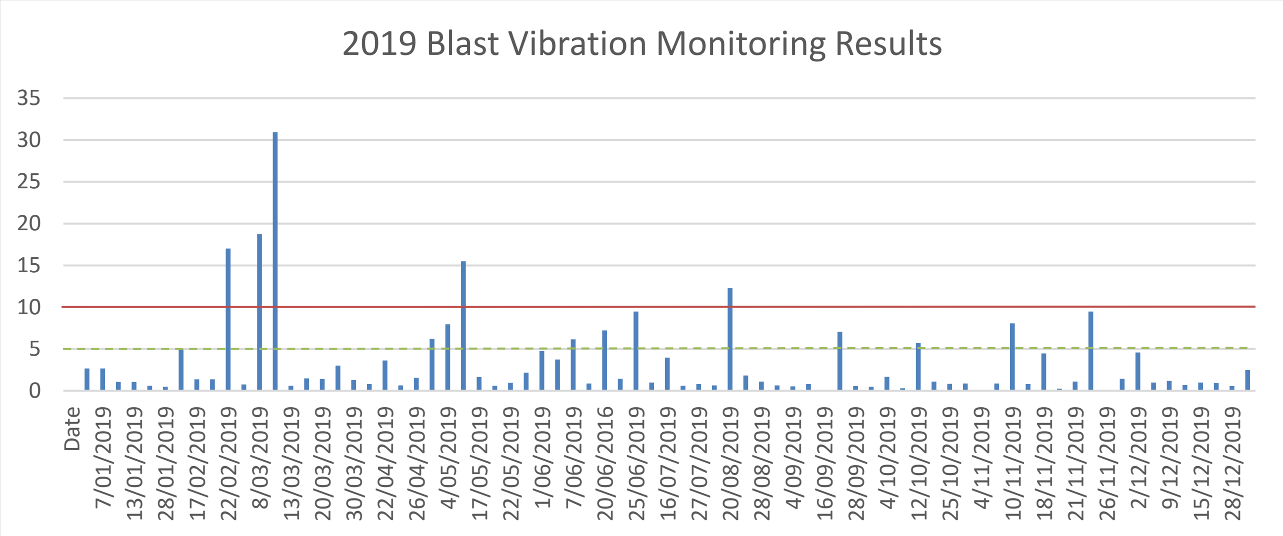

FIGURE 1: BLAST VIBRATION MONITORING RESULTS

A total of 75 blasts were conducted during the 2019 period, with results indicating:

- A total of 7 (seven)blasts registered a recording of between >5.0 - <10mm/sec.
- A total of five (5) blasts exceeded the 10mm/sec PPV limit.
- A total of 63 blasts registered less than 5mm/sec.

Based on the above, a total annual compliance of 84% was recorded for the 2019 reporting period.

3.1. Exceedance Summary

Five (5) blast vibrations exceeding the allowable vibration limits for F3 pit, as specified in Condition 7-7 were recorded (**Table 2**).

TABLE 2: EXCEEDANCE SUMMARY - 2019

Date	Shot	Peak Particle Velocity (mm/s)
22 February 2019	478-302	17.01
8 March 2019	478-301A	18.78
10 March 2019	478-301B	30.93
8 May 2019	472-301	15.49
20 August 2019	460-310	12.31

An investigation was undertaken to determine the potential contributing factors for the above mentioned exceedances. In each event, an inspection of the area around the blast, adjacent walls of the F3 pit and the undisturbed scarp face was completed, with these inspections finding no areas of instability or rock displacement.

As indicated in the Vibration Investigation reports, the following contributing factors were identified for the five (5) exceedances:

- Shot 478-302: evidence indicated that single hole firing was not been attained. The investigation noted that for larger shots, single hole firing was difficult to achieve with the Nonel system and spread of timing within the detonation system. Although the shot was free faced, there were a large number of holes (677) in the shot.
- Shot 478-301 a & b: In response to the shot 302 exceedance, shot 301 was halved in size forming shot 302a and 302b. This strategy aimed to reduce the number of holes to be fired for each shot by half and reduce the amount of multiple hole firings. The shots (302a and 302b) were free faced but due to its position, 60 to 100 m closer to the monitor and confined on three sides, the movement of the blast into the final wall/corner of the shot still resulted in blast exceedance.

  Additionally, for Shot 301a, the investigation found that even by decreasing the amount of holes, the vibration level was unable to be significantly reduced due to the limited distance to the vibration monitor.
- Shot 460-310: Following previous exceedances, the series of corrective actions implemented had resulted in a drop in vibration. The exceedance in shot 460-310 cannot be fully explained and was in excess of the calculated value for the shot.

  Firing against the shot had an overall positive influence on blast vibration. This reverse firing creates a buffer of broken material between the high wall and the blast front. However, it is postulated that although the wave dies away quickly, the initiation point still creates a large instantaneous vibration (as it is confined).Remedial Actions:

The following remedial actions have been implemented at the Koolyanobbing Project to address the issue of vibration exceedances:

1. YIPL has engaged a drill and blast specialist to provide a detailed and comprehensive vibration analysis using multiple vibration monitoring stations in and around the F3 pit. The objective of this analysis is to determine if there is any directionality or magnification to the vibration waves from local conditions.
2. Deck loading has been initiated in F3 pit, which reduces the level of instantaneous charge by 50%. Initial results (February 2019 to present) indicate a substantial drop in monitored vibration levels.
3. Periodic testing of vibration monitors has been implemented to ensure that they are calibrated (to specifications) and properly fixed to competent material.
4. Implementation of discontinuity mapping to provide further understanding of transmission paths for vibrations.
5. Changes in mining methodology implemented, where subject to block model and drilling results, a larger buffer between the pit and the undisturbed/natural ground will be maintained.
6. Introduction of pre-split drilling and single hole split for the purpose of creating a barrier of broken material to prevent vibration and gas travelling back into the rear wall of the F3 pit.
7. Implementation of a shield shot (a combination of a pre-split, and trim shot surrounding the main production shot)
8. Continuation of the reverse firing method to produce broken buffers to prevent shock wave attenuation.

3.1.1. Non-Compliance Closeout

Following consultation with both the Department of Water and Environmental Regulation (DWER) and third party technical experts regarding vibration exceedances recorded in the 2019 reporting period, a Statement of Resolution (**Attachment 2**) was received from DWER (27 February 2020) indicating that YIPL had satisfactorily completed the actions required to address the vibration exceedances and that revised blast vibration mitigation measures (**Section 0**) were deemed satisfactory. As a requirement of the Statement, YIPL must report F-Deposit vibration results fortnightly to DWER until blasting operations cease. To date, fortnightly vibration results for F Deposit have been provided on:

- 24 February 2020
- 09 March 2020
- 24 March 2020
- 07 April 2020

4. DISCUSSION AND CONCLUSIONS

4.1. Environmental Impacts

An assessment of the F3 pit following the recorded exceedances has found no evidence of pit wall instability and/or signs of potential development of pit wall instability. These observations provide a high level of confidence in the Project's geotechnical stability predictions.

To date, the recorded vibration exceedances have not resulted in any observed adverse impacts to *Tetratheca erubescens* plants and/ or other environmental values located on the scarp of the southern wall of the F3 pit. In addition, no detrimental stability impacts to the rock mass on which *Tetratheca erubescens* plants are located has been recorded.

4.2. Ongoing Stability Monitoring

Implementation of the approved Stability Monitoring Program continued during 2019. An independent aeromechanical consultant (Peter O'Bryan &Associates 2019) was engaged to provide a geotechnical assessment of the F3 pit and mining operation, specifically to review the ground conditions exposed during active mining. This assessment was used to compare findings with predictions, based on drill hole data obtained and used for pre-mining pit wall stability assessment.

The monitoring program confirms the stability of the southern wall of F3 Pit and the scarp of the southern Koolyanobbing Range has not been impacted. The report, found wall conditions in F3 Pit to be good, with no obvious signs of potential for development of significant wall instability.

Due to the investigations into blast exceedance and implementation of corrective actions, YIPL has reduced the risk of vibration exceedances. To date, YIPL has been in full compliance with blast vibration Conditions of Ministerial Statement 1054 since the implementation of the corrective actions.

ATTACHMENTS

ATTACHMENT 1: RAW PPV DATA – 2019

Date	PPV (mm/s)	Date	PPV (mm/s)
7/01/2019	2.65	20/07/2019	0.59
7/01/2019	2.65	27/07/2019	0.79
13/01/2018	1.06	4/08/2019	0.63
13/01/2018	1.06	20/08/2019	**12.31**
18/01/2019	0.6	23/08/2019	1.8
28/01/2019	0.47	28/08/2019	1.08
10/02/2019	4.9	31/08/2019	0.63
17/02/2019	1.35	4/09/2019	0.52
17/02/2019	1.35	11/09/2019	0.77
22/02/2019	**17.01**	16/09/2019	0
3/03/2019	0.74	24/09/2019	7.06
8/03/2019	**18.78**	28/09/2019	0.57
10/03/2019	**30.93**	2/10/2019	0.486
13/03/2019	0.6	4/10/2019	1.65
16/03/2019	1.46	8/10/2019	0.297
20/03/2019	1.4	12/10/2019	5.67
25/03/2019	3.02	15/10/2019	1.11
30/03/2019	1.27	25/10/2019	0.82
6/04/2019	0.79	28/10/2019	0.86
22/04/2019	3.61	4/11/2019	0
22/04/2019	0.62	6/11/2019	0.88
26/04/2019	1.57	10/11/2019	8.04
29/04/2019	6.22	12/11/2019	0.77
4/05/2019	7.93	18/11/2019	4.46
8/05/2019	**15.49**	18/11/2019	0.25
17/05/2019	1.62	21/11/2019	1.1
19/05/2019	0.61	23/11/2019	9.48
22/05/2019	0.95	26/11/2019	0
26/05/2019	2.18	29/11/2019	1.45
1/06/2019	4.73	2/12/2019	4.58
4/06/2019	3.72	6/12/2019	0.96
7/06/2019	6.13	9/12/2019	1.15
11/06/2019	0.87	14/12/2019	0.69
20/06/2016	7.22	15/12/2019	0.98
23/06/2019	1.43	23/12/2019	0.91
25/06/2019	9.49	28/12/2019	0.54
30/06/2019	0.97	30/12/2019	2.48
16/07/2019	3.95		

ATTACHMENT 2: MS 1054 – RESOLUTION OF NON-COMPLIANCE

Government of **Western Australia**
Department of **Water and Environmental Regulation**

Your ref: Ministerial Statement 1054
Our ref: DWERA-000306
Enquiries: Jaala Ayliffe, Ph 6364 6743

Mr Tim Berryman
General Manager - Technical Services
Yilgarn Iron Pty Ltd
1 Sleat Road
APPLECROSS WA 6153

Dear Mr Berryman

STATEMENT 1054 – YILGARN OPERATIONS, KOOLYANOBBING RANGE F DEPOSIT – RESOLUTION OF NON-COMPLIANCE

Thank you for your response dated 17 January 2020 and 21 February 2020 to the Notice of Non-Compliance (NoNC) issued by the Department of Water and Environmental Regulation (the department) on 18 December 2019.

Resolution of non-compliance:
Following the department's site visit conducted on 29 January 2020, it has been determined that YIPL has satisfactorily completed the actions required to address the identified non-compliance, as detailed below:

Item (1) – On 17 January 2020, YIPL provided documentation regarding revised blast vibration mitigation measures being implemented by YIPL in the F3 Pit. The department has found these mitigation measures to be satisfactory and YIPL has demonstrated compliance can be achieved under Condition 7-7.

However, the department requests that YIPL provide blast vibration results, as measured under Condition 7-7, on a fortnightly basis to compliance@dwer.wa.gov.au, allowing the department timely oversight of the blast vibration results. Results are to be provided for the F3 Pit until blasting operations cease.

Item (2) – On 21 February 2020, YIPL submitted the "MRL (2020) Koolyanobbing F Deposit *Tetratheca erubescens* Monitoring Plot 11 Assessment" which provided a summary of historical monitoring results of the *Tetratheca erubescens* population at Plot 11 where the rockfall occurred.

The department has reviewed the report and has found it to be satisfactory in meeting the requirements of Item 2 of the NoNC.

YIPL is required to continue its monitoring in accordance with Condition 6 of the Statement and the approved Condition Environmental Management Plan.

Prime House, 8 Davidson Terrace Joondalup Western Australia 6027
Locked Bag 10 Joondalup DC WA 6919
Telephone: 08 6364 7000 Facsimile: 08 6364 7001
www.dwer.wa.gov.au

Item (3) – On 21 February 2020, YIPL submitted the "Peter O'Bryan & Associates (2020) F Deposit Natural Scarp Stability Technical Memorandum" which assessed the stability of the F3 Pit southern scarp.

The department has reviewed the report and has found it to be satisfactory in meeting the requirements of Item 3 of the NoNC.

The department notes that blasting within the F3 pit is due to be completed in May 2020.

The department considers the non-compliance to be resolved. Thank you for your cooperation in achieving this resolution in a timely fashion.

Yours sincerely

Stuart Cowie
Executive Director
Compliance and Enforcement
for the Chief Executive Officer
under Notice of Delegation date 3 July 2017

27 / 02 / 2020

Attachment 11: BGPA (2019) *Tetratheca erubescens* Translocation Annual Research Report 2 (Revision 0)

Department of **Biodiversity, Conservation and Attractions**

GOVERNMENT OF WESTERN AUSTRALIA

Biodiversity and Conservation Science

BOTANIC GARDENS & PARKS AUTHORITY

KINGS PARK SCIENCE

ABN 30 706 225 320

Tetratheca erubescens Translocation Annual Research Report 3

for

Mineral Resources Limited

March 2019 to March 2020

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Please cite this document under the following:

Elliott C, Lewandrowski W, Turner S, Krauss S, Merritt D, Miller B, Stevens J (2020) *Tetratheca erubescens* Translocation Annual Research Report 3. Prepared by Kings Park Science, Biodiversity and Conservation Science in the Department of Biodiversity, Conservation and Attractions for Mineral Resources Ltd.

EXECUTIVE SUMMARY

Kings Park Science's "*Tetratheca erubescens* Translocation Research Program" commenced in June 2017 and has been active for 34 months. The broad research objectives of the Program were to (i) develop methods to support translocation and restoration of *T. erubescens;* (ii) provide technical and scientific support for a five-year research program of field translocation; and (iii) to assess functional attributes within restored / translocated populations to determine their long-term sustainability compared with natural populations.

This report highlights new research findings (March 2019 – March 2020) and summarises ongoing research since project commencement (June 2017). The following has been achieved:

- Program 1: Seed Biology
  - Determined responses for germination under different light and dark regimes.
  - Continued 'best bet' approach for seed dormancy release and germination stimulation.
  - Profiled water stress responses from seeds across different temperatures.
  - Continued experiments for dormancy break focussing on water stress responses after optimal dormancy break.
  - Initiated priming approaches to enhance germination speed under controlled conditions.
  - Continued seed enhancement design (using priming and pelleting technology).
- Program 2: Translocation and monitoring
  - Conducted four monitoring events of seedling emergence and greenstock survival in 2017 translocation sites.
  - Conducted four monitoring events of seedling emergence and greenstock survival in 2018 translocation sites.
  - Established five translocation trial sites in 2019 that involved *in situ* placement of 2000 seed and 500 nursery propagated plants.
  - Quantified plant performance of cuttings under drought conditions.
  - Finalised collections of propagation material (seeds only) to be used in proposed 2020 translocations.
  - Monitored natural demographic sites four times to assess plant growth, health, ecophysiology and fecundity of adults, juveniles and seedlings.
- Program 3: Plant function, habitat and substrate interactions
  - Continued ecophysiological measurements of plant function in natural populations (four sites) with a focus on *Tetratheca erubescens* and co-occurring BIF species.
  - Compared plant function in natural and translocation sites with a focus on slope aspect of populations.
  - Reported the results from soils and plant material chemical (nutrient) and physical analysis.
  - Continued storage of soils for molecular analysis to understand niche level microbial processes underpinning ecosystem function.
  - Continued soil temperature and moisture data collection in three natural and two translocation sites to monitor environmental conditions.

BACKGROUND

Cliffs Asia Pacific Iron Ore (Cliffs) received conditional approval to develop a new mining area at F deposit in the southern Koolyanobbing Range (Ministerial Statement 1054). The development at F deposit involves the removal of individuals of the Declared Rare Flora species *Tetratheca erubescens*. The Ministerial Statement includes a requirement for a program of research and restoration as part of the Stage 1 *Tetratheca erubescens* Offsets Plan. Cliffs originally engaged with the Botanic Gardens and Parks Authority (BGPA, or 'Kings Park Science') and formed a partnership to deliver a translocation research program for *Tetratheca erubescens* that supports the Offsets Plan. In 2018, Mineral Resources Limited took over operation of the F Deposit project area and implementation of the Translocation Research Program (with Kings Park Science, a science program under Biodiversity and Conservation Science in the Department of Biodiversity, Conservation and Attractions).

Tetratheca erubescens occurs in the Koolyanobbing area, in the Coolgardie IBRA (Interim Biogeographic Regionalisation for Australia) bioregion of Western Australia. This species has Threatened flora status under the *Biodiversity Conservation Act* (WA) 2016 with a very narrow distribution associated with a single banded iron formation (BIF) range where it grows in rock fissures on cliff faces. This extreme habitat provides a number of specific challenges for restoration and translocation of populations. Effective, sustainable translocation of plant individuals and populations requires understanding of attributes of the species and its habitat, including population processes and interactions with the environment, as well as appropriate propagation and translocation techniques.

This translocation research program aims to:

- Develop methods to support the translocation and restoration of *T. erubescens.*
- Provide technical and scientific support for a five-year research program of field translocations of *T. erubescens*. MRL's objective is to establish a new self-sustaining population of at least 313 mature individuals of *Tetratheca erubescens* on suitable landform that is suitable for the species.
- Assess functional attributes within restored/translocated populations to determine their long-term sustainability through a comparison with natural populations.

This document outlines the progress and outcomes of the scientific approach from March 2019-March 2020 that aims to:

- Develop practical, effective and sustainable restoration of *Tetratheca erubescens.* This will be achieved through understanding and optimising their establishment ecology and environmental requirements.
- Determine how these can be effectively utilised or recreated in restored systems. Thus ensuring the long term persistence of the species and viability of disturbed populations.

The Kings Park Science research program addresses the science required to underpin and inform translocation efforts by MRL. Occurring concurrently is an Offset Plan, derived and agreed upon by MRL and relevant regulatory authorities. Although Kings Park Science was not involved in developing the Offset Plan and associated milestones *per se,* it is understood that the Kings Park Science program will assist MRL in the science investigations relevant to the Offset Plan.

RESEARCH PROGRAM

The translocation of species whose habitat is confined to narrow cracks in rock outcrops is a challenge that significantly exceeds the complexities of a normal translocation program. The general principles of effective and sustainable translocation involve:

1. Understanding a) the interactions between plants and the environment in their natural habitat and b) the ecological, genetic and demographic population processes that enable self-sustained growth and persistence of natural populations.
2. Selecting, modifying or creating an appropriate translocation site given 1a.
3. Selecting plant material and developing translocation techniques that will enable the number of individuals required given likely attrition rates, with the appropriate level of population genetic diversity and representation given 1b.
4. Implementing, maintaining and monitoring the translocation.
5. Typically, translocation research and translocation programs involve an iterative learning/adaptive management approach and a scaling-up from experimental to implementation phases.

We have adopted these principles and executed a research program to support practical, effective and sustainable restoration of *Tetratheca erubescens* through investigation in three key disciplines: seed biology and enhancement (Program 1); translocation and demographic studies (Program 2) and plant-substrate interactions (Program 3).

RESEARCH RESULTS

Program 1. Seed biology

1.1 *Dormancy and germination.*

1.1.1 Assess the sensitivity of seeds to constant and alternating incubation temperatures under differing light regimes.

Research outcomes:

- Optimal temperature for germination was between 15 - 20°C (even after breaking dormancy through warm stratification).
- Alternating temperatures (e.g. 20/10°C, or 25/15°C) did not support germination.
- There is no difference between alternating light/dark and constant dark conditions for seed germination.
- Details of research are in Annual Research Reports 1 and 2 respectively (Elliott *et al.* 2018; Elliott *et al.* 2019).

Alternating vs constant temperatures

Upon commencement of the program, there was no understanding into the requirements for seed germination in *T. erubescens.* Experiments were conducted at six constant incubation temperatures on water and karrikinolide (KAR_1) - a smoke related germination stimulant - to profile temperature requirements for fresh *T. erubescens* seeds. Previous findings from Elliott *et al.* (2019) showed that germination was limited to a narrow temperature envelope between 10 and 20°C (Figure 1.1.1a), with germination speed fastest between 15 and 20°C. KAR_1 was also found to stimulate faster germination at 20°C (Elliott *et al.* 2019). Taken together, this response suggests germination windows to occur during cool Autumn, Winter and/or Spring seasons, rather than Summer.

While seeds germinated at the highest proportions at a constant temperature of 20°C, germination did not occur at alternating 25/15°C (i.e. day/night; on water or KAR_1). Follow-up experiments testing alternating conditions of 20/10°C (day/night alternating conditions) demonstrated no germination from fresh seeds after 30 days. The absence of germination at alternating temperatures may be due to the following reasons:

1) The upper temperature limit of 25°C in the 25/15°C alternating regime likely exceeds the maximum germination temperature (as shown in Elliott *et al.* (2019) seeds were thermally suppressed at 25°C).
2) Alternating temperatures are more representative of those which occur above the exposed soil/substrate surface rather than within the soil matrix. As such, germination may be limited to more constant environmental conditions experienced by seeds that are buried or dispersed into more suitable micro-sites in the substrate.

Alternating light/dark vs constant dark

A pilot study on fresh and stratified seeds, incubated on water and KAR_1 demonstrated no differences in germination between alternating light/dark and constant dark conditions.

1.1.2 Profile the sensitivity of seeds to water stress during germination.

Current research outcomes:

- Water stress affects germination of *T. erubescens* seeds – with seeds requiring at least 14 days of optimal water availability (0 to -0.25 MPa) for germination.
- At higher water stress conditions (close to the permanent plant wilting point e.g. -1.0 to -1.5 MPa), germination capacity decreased and seeds took >24 days to germinate.
- Germination sensitivity to water stress changed between dormant and non-dormant seed batches. Stratifying seeds (as outline in Elliott *et al.* 2019), and pre-treating with KAR_1 increased germination (its range into water stress; germination speed).

Understanding seed germination responses to water stress is critical to quantify the effects of rainfall across summer and winter seasons, and to inform future seedling recruitment and proposed translocation activities. Additionally, quantifying the germination responses to water stress will help determine baseline germination information for future research outlined in "Program 1.2. Seed enhancement to improve seedling establishment" and for underpinning future recruitment events from translocated populations, should these establish and disperse seeds. Initial trials on a small subset of dormancy alleviated/stratified seeds demonstrated a wide water stress envelope for germination with germination decreasing by 50% from 0 MPa to -0.83 MPa (Elliott *et al.* 2019; Figure 1.1.2a). Stratifying seeds for six weeks was also identified as a critical treatment in order to alleviate dormancy – the condition that limits germination from newly dispersed seeds.

Profiling water stress sensitivity from fresh and stratified seeds.

- Dormancy was alleviated after a 6-week stratification period, by incubating seed at 30°C (as described in Elliott *et al.* 2019; Section 1.1.3).
- Stratified seeds were compared with fresh seeds that were left untreated, by incubating seeds on a gradient of water stress, simulated by varying temperature corrected concentrations of polyethylene glycol in water (Michel 1983), whereby 0 MPa reflects non-limiting water availability, and -1.5 MPa reflects the theoretical permanent plant wilting point, and the onset of drought.
- Water stress experiments were conducted at 5, 10, 15, 20 and 25°C and seeds treated with or without a germination stimulant (24 h soak in KAR_1). Despite fresh seeds failing to germinate at 5 and 25°C (see Elliott *et al.* 2019), alleviating dormancy through treatment has been reported to enhance the capacity for seeds to germinate into wider environmental conditions (Baskin and Baskin 2014). As such, a small subset of seeds were incubated at 5 and 25°C to account for possible germination responses following dormancy alleviation through stratification.
- Fresh and stratified seeds were still constrained to temperatures between 10 and 20°C for germination, further supporting findings from Section 1.1.1. Following dormancy alleviation, there were overall faster (Figure 1.1.2a) and wider modelled water stress envelopes (Figure 1.1.2b) for germination from stratified seeds (14-16 days to initial germination at non-limiting water stress of 0 MPa; germination into water stress limited to –1.10 and –1.71 MPa) compared to fresh seeds (>20 days to

initial germination at non-limiting water stress of 0 MPa; germination into water stress limited to -0.75 and -1.60 MPa).

- For both fresh and stratified seeds, the germination stimulant KAR_1 always improved germination into water stress across all temperatures, with the combination of KAR_1 and stratification proving the best treatment with the widest water stress envelope (e.g. seeds with this treatment capable of germinating at -1.5 MPa).
- At lower water potentials of -1.00 MPa, time to initial germination was 24 days for non-dormant/stratified seeds, compared to 28 days for dormant/fresh seeds. The results suggest water moisture needs to be available for a continuous and extended period in the soil profile in order to support germination processes. Taking into account that germination processes are slowed at low water potentials of -1.00 MPa, water would have to be available for at least 24-28 days under these conditions in order to support the germination of seeds.

Applications

- With initial germination occurring after 14-16 days under optimal temperature and moisture conditions, and 24-28 days under water stress conditions of -1.00 MPa, which is close to the theoretical permanent plant wilting point of -1.5 MPa (drought), frequent irrigation of seeds in the field could enhance recruitment in translocation sites. The irrigation treatment would need to be frequent, and supply moisture above limiting water stress thresholds for an extended period.
- The data generated can be incorporated into species distribution modelling in order to identify new translocation sites (e.g. Tomlinson *et al.* 2020), or to help predict recruitment timing from sown seeds.
- Quantified germination thresholds can be related to soil water potential thresholds following rainfall, which would help inform the magnitude and frequency of rainfall required to support seedling recruitment (e.g. Lewandrowski *et al.* 2017). This in turn can be used to inform soil treatments aimed to increase soil water retention (e.g. Merino-Martín *et al.* 2017) or seedling vigour (e.g. Erickson *et al.* 2017).
- Evaluate seed enhancement methodologies to increase germination speed, as outlined in "Program 1.2. Seed enhancement to improve seedling establishment". Of particular note are hydro- and osmo-priming experiments that aim to reduce the time required for seeds to germinate. An added benefit for priming can also be improved stress tolerance, which may further extend the capacity of seeds to germinate under water stress.

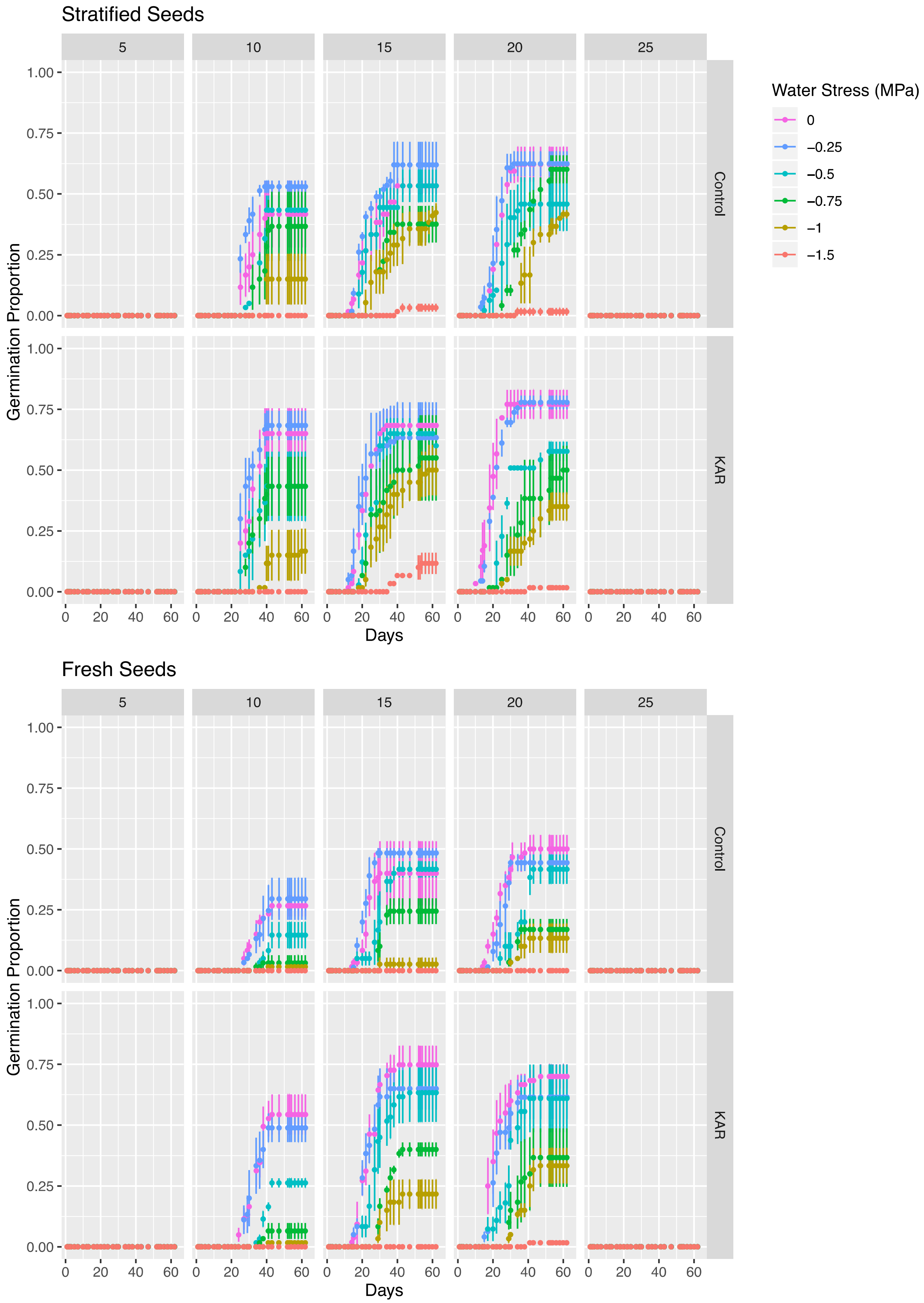


Figure 1.1.2a. Cumulative germination responses (mean ± standard error) over time from fresh and stratified seeds (with or without KAR_1) that were incubated at 5, 10, 15, 20, and 25°C on a water stress gradient between 0 MPa (non-limiting water availability) and -1.5 MPa (permanent plant wilting point).

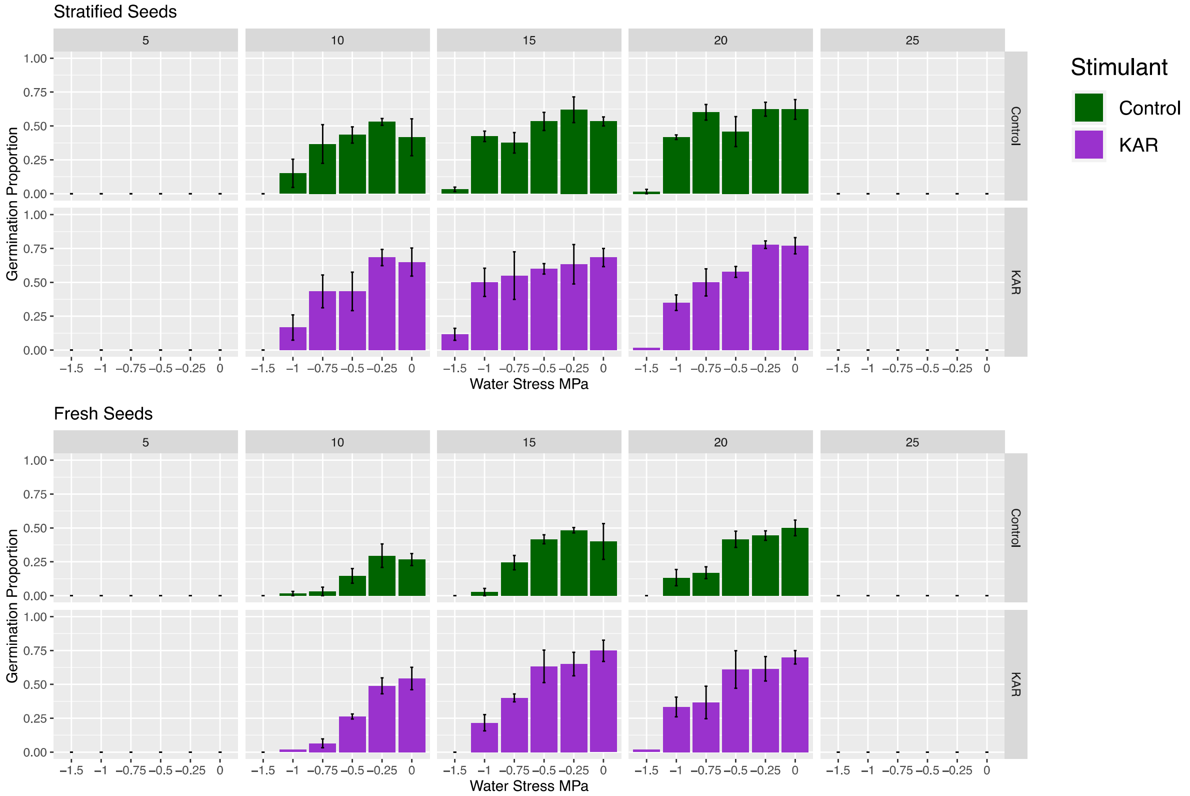


Figure 1.1.2b. Final germination responses (mean ± standard error) after 60 days from fresh and stratified seeds (with or without KAR_1) that were incubated at 5, 10, 15, 20, and 25°C on a water stress gradient between 0 MPa (non-limiting water availability) and -1.5 MPa (permanent plant wilting point).

1.1.3 Identify the optimal conditions required for promoting dormancy loss focussing on after-ripening, wet/dry cycling and stratification.

Research outcomes:

- Highest germination was achieved by stratifying seeds for 6 weeks.
- Application of a germination stimulant (KAR_1) further increased germination responses by 10-15%.
- Application of stratification treatment to water stress experiments demonstrate an increased capacity for seeds to germinate at lower water availabilities.
- Details of research are in Annual Research Reports 1 and 2 respectively (Elliott *et al.* 2018; Elliott *et al.* 2019).

1.1.4 Define the role of germination stimulants in promoting germination.

Research outcomes:

- The smoke related germination stimulant karrikinolide (KAR_1) significantly improves germination at temperatures between 10-20°C in fresh seeds and during dormancy loss following stratification, after-ripening and wet/dry cycling.
- KAR_1 increases the capacity for seeds to germinate into water stress (Section 1.1.2).
- Details of research are in Annual Research Reports 1 and 2 respectively (Elliott *et al.* 2018; Elliott *et al.* 2019).

1.2 *Seed enhancement to improve seedling establishment.*

1.2.1 Assess the potential of seed priming to enhance germination and seedling establishment in the field.

Current research outcomes:

- Preliminary results demonstrate faster time to initial germination following osmo-priming when compared to un-primed seeds.

To determine the effects of priming treatments, two methodologies are currently being tested on dormancy alleviated seeds (as determined in Section 1.1.1; see Elliott *et al.* 2018); using 1) hydropriming and 2) osmopriming methodologies. Hydropriming involves hydrating seeds in water (+/- stimulant, e.g. KAR_1) for different periods of time, while osmopriming, involves hydrating seeds in solutions containing different water potentials to regulate maximum water uptake (as determined from experiments conducted in Section 1.1.2).

1.2.2 Investigate seed coating and seed pelleting approaches for improving seed germination and establishment in the field.

Current research outcomes:

- The current pelleting technique was not suitable for *T. erubescens*.
- This was due to the impracticality of finding suitably sized cracks to accommodate a pellet with a greater diameter than what was previously tested.

The initial development of a pelleting approach to improve seedling establishment in the field tested a surrogate species (*Acacia hilliana*) that had similar seed characteristics to that of *T. erubescens* (see Elliott *et al*. 2019). However, this initial pelleting method was not optimal for *T. erubescens* because there was a ~30% loss of seed during the process of producing the pellets; and there was inconsistent incorporation of a predictable number of seeds into each pellet (see Elliott *et al*. 2019). Investigation into increasing the diameter of the pellet (to 10mm) to reduce the risk of seed wastage or damage was deemed impractical after preliminary observations of the translocation sites (May 2019) found that there were limited locations for which a pellet of this size could be placed within the cliff topography. An alternative to the pelleting approach may be the application of a 'slurry' soil matrix *in situ*, that may deliver the beneficial microbes, nutrient and growth factors with enhanced water holding capacity to promote and sustain germination, emergence and seedling establishment. A preliminary trial of this approach using *A. hilliana* was conducted in the glasshouse. The feasibility of the application of a 'slurry' soil matrix using an artificial propagation structure was positive, as there was germination of *A. hilliana*.

Future research:

We will modify the artificial propagation structure from the preliminary trial, where we used plastic and potting mix to constructing a brick, gravel and topsoil substrate. We will assess 1-2 different recipes of the soil matrix and apply the technique to *T. erubescens*, *A. hilliana* and *Androcalva perlaria* seed in the glasshouse before considering application in the field.

Program 2. Translocation and monitoring

2.1 *Optimising translocation approaches*

2.1.1 Assess the effectiveness of treated *in situ* sown seeds for undertaking translocations.

Current research outcomes:

- Seedling emergence was observed in August 2019 (total of 72 seedlings).
- This emergence was greater than August 2018 (29 seedlings); possibly due to the above average June and July rainfall in 2019.
- Seedling survival declined significantly over the summer period (2019/2020; three seedlings survived); possibly due to below average climate conditions in spring and summer.
- Survival rates, after their first summer, for 2018 and 2019 emergence events were similar and very poor.
- 2019/2020 collection of fresh seed was sourced from the natural population, however the number of collected seeds was lower compared to the previous years, possibly due to below average spring rainfall (2019).

Translocations – 2017, 2018 and 2019

The habitat characteristics and results from the 2017, 2018 and 2019 translocation sites are summarised in Table 2.1.1a. In late 2017, the immediate area of T19 became unstable and the presence of mining activities close to and above the T19 area presented unsafe conditions for personnel to conduct ongoing monitoring (monitoring February 2018 incomplete). An additional translocation site (T24) was approved for use as a translocation site in 2018 and 2019 (Table 2.1.1a).

Details of these locations and the overall numbers of seed and greenstock trialled at each location for the 2019 translocation is summarised in Table 2.1.1b. Further details of the treatment design for the direct seeding are in Table 2.1.1f and for the greenstock planting are in Table 2.1.1g. Details of the 2017 and 2018 translocation trials are in Annual Research Reports 1 and 2 respectively (Elliott *et al.* 2018; Elliott *et al.* 2019).

Table 2.1.1a. Summary of specific habitat details for each translocation site.

Site	Latitude	Longitude	Geology	Translocation potential (no. plants)	Distance to extant plants	Model strength (BGPA 2015)*
T6	-30.87245	119.60269	Canga/weathered haematite	<300	<0.1km	<0.3
T18	-30.88656	119.61919	BIF (high iron)	<200	0.7km	0.45-0.5
T19	-30.87145	119.60642	-	50	<0.1km	<0.3
T21	-30.87394	119.60513	BIF (20% iron)	75	<0.1km	0.55-0.6
T23	-30.87150	119.60637	BIF (20% iron)	150	<0.1km	<0.3
T24	-30.87417	119.61111	Canga	150	0.18km	0.3-0.5

* the higher the number the higher the predicted likelihood of habitat matching by the model for *Tetratheca erubescens* (Miller 2015)

Table 2.1.1b. Summary of the number of seed sown and greenstock planted for each translocation site (2019).

Site	Latitude	Longitude	Seed sown	Greenstock
T6	-30.87245	119.60269	400	99
T18	-30.88656	119.61919	800	255
T21	-30.87394	119.60513	400	57
T23	-30.87150	119.60637	400	47
T24	-30.87417	119.61111	-	42
Total			2000	500

Monitoring schedule for 2017, 2018 and 2019 translocations were as follows:

Table 2.1.1c. Summary of installation and monitoring periods for each translocation site (Translocation 2017). Translocation site T19 only had the first monitoring assessment and none afterwards (see above).

				Monitoring							
Site	**Latitude**	**Longitude**	**Installed**	**1st**	**2nd**	**3rd**	**4th**	**5th**	**6th**	**7th**	**8th**
T6	-30.87245	119.60269	9-16th August 2017	18-25th October 2017	8-15th February 2018	16-23rd August 2018	21-28th October 2018	12-20th February 2019	22-30th August 2019	30-7th November 2019	14-26th February 2020
T18	-30.88656	119.61919									
T19	-30.87145	119.60642									
T21	-30.87394	119.60513									
T23	-30.87150	119.60637	Late Winter	9 wks	25 wks	51 wks	61 wks	77 wks	97 wks	107 wks	117 wks

Table 2.1.1d. Summary of installation and monitoring periods for each translocation site (Translocation 2018).

				Monitoring					
Site	**Latitude**	**Longitude**	**Installed**	**1st**	**2nd**	**3rd**	**4th**	**5th**	**6th**
T6	-30.87245	119.60269	14-21st June 2018	16-23rd August 2018	21-28th October 2018	12-20th February 2019	22-30th August 2019	30-7th November 2019	14-26th February 2020
T18	-30.88656	119.61919							
T21	-30.87394	119.60513							
T23	-30.87150	119.60637							
T24	-30.87417	119.61111	Early Winter	8 weeks	18 weeks	34 weeks	54 weeks	64 weeks	74 wks

Table 2.1.1e. Summary of installation and monitoring periods for each translocation site (Translocation 2019).

				Monitoring		
Site	**Latitude**	**Longitude**	**Installed**	**1st**	**2nd**	**3rd**
T6	-30.87245	119.60269	13-23rd June 2019 Early Winter	22-30th August 2019 8 weeks	30-7th November 2019 18 weeks	14-26th February 2020 28 wks
T18	-30.88656	119.61919				
T21	-30.87394	119.60513				
T23	-30.87150	119.60637				
T24	-30.87417	119.61111				

Table 2.1.1f. Summary of the 2019 translocation site, source of seed, treatment tested, location of seed line, number of seeds sown and the total number of seedlings emerged over the monitoring period (at 8 weeks; see Table 2.1.1e).

Site	Latitude	Longitude	Source of seed	Treatment tested	Seeding location	Number of seeds sown	Number of emergents
T6	-30.87245	119.60269	2017/2018	Stratified	Drill hole	200	5
					Fissure/crack	200	1
T18	-30.88656	119.61919	2017/2018	Controls	Drill hole	200	0
					Fissure/crack	200	1
				Stratified	Drill hole	200	14
					Fissure/crack	200	3
T21	-30.87394	119.60513	2017/2018	Stratified	Drill hole	200	2
					Fissure/crack	200	0
T23	-30.87150	119.60637	2017/2018	Stratified	Drill hole	200	0
					Fissure/crack	200	0
Total						**2000**	**31**

Table 2.1.1g. Summary of the 2019 translocation site, source of greenstock or whether water crystals (Hydro-beads, Advanced Fertilising Technology Pty Ltd.) was added to the planting hole and the total number of planted at each site.

Site	Latitude	Longitude	Greenstock source	Water crystal	Number planted June 2019
T6	-30.87245	119.60269	Cutting	Yes	34
			Cutting	No	33
			Seedling	Yes	-
			Seedling	No	32
T18	-30.88656	119.61919	Cutting	Yes	78
			Cutting	No	77
			Seedling	Yes	51
			Seedling	No	49
T21	-30.87394	119.60513	Cutting	Yes	17
			Cutting	No	15
			Seedling	Yes	-
			Seedling	No	25
T23	-30.87150	119.60637	Cutting	Yes	15
			Cutting	No	15
			Seedling	Yes	-
			Seedling	No	17
T24	-30.87417	119.61111	Cutting	Yes	15
			Cutting	No	15
			Seedling	Yes	-
			Seedling	No	12
Total					**500**

Direct seed sowing in 2017, 2018 and 2019 translocations

Seeds collected from natural plants in 2016/2017 (Elliott *et al.* 2017) were used in the direct seeding experiments in the 2017 and 2018 translocation trials. Due to limited seed availability from this initial collection, seeds for the 2019 translocation trial were sourced from the more recent 2017/2018 collection. The development and implementation of the translocation design for the *in situ* sown seeds, including the seed treatments, the number of replicates implemented, and the number of emergents counted within each translocation site, are summarised in Table 2.1.1f for the 2019 translocation.

Seeds that were sown in the 2019 translocation were placed within available natural cracks within the site and covered with topsoil (0.5-1cm) or drill holes, by placing topsoil halfway up the drill hole, sowing seeds and covering seeds with a layer of topsoil (~1cm). To monitor the impacts of surface water runoff washing seeding lines away, photos were taken of each sowing location at installation and each subsequent monitoring period (as per the previous translocations). The seeding lines showed no evidence of washout 8 weeks after sowing in the drill holes and only 0.03% of cracks showed evidence of washout. This indicated that natural rainfall during this period was not flushing soil from the 2019 seeding line locations.

Seedling emergence from our direct sowing lines was detected in August 2019, for all three years of direct seeding (2017: 1 seedling; 2018: 40 seedlings; 2019: 31 seedlings; and total of 72 seedlings). This was a greater emergence response than 2018 (29 seedlings in total; Elliott et al 2019). Winter 2019 had 88.5mm of rainfall (1 June to 10 August), whereas the 2018 winter only had 79.2mm of rainfall over the same period, suggesting that the higher rainfall during the 2019 winter stimulated a greater germination response in all translocation trials.

However, seedling survival declined to almost zero over the summer period (2019/2020), with a total of three seedlings surviving (4% of total; 2017: 0 seedlings; 2018: 2 seedlings; and 2019: 1 seedling). This survival rate after their first summer was similar to 2018 (1-2 seedlings; Elliott et al 2019). Of the two surviving seedlings from summer 2018/2019, only one survived its second summer (2019/2020; at T21).

Rainfall over summer 2018/2019 was 47% below average for this period (1 Dec 2018 - 28 Feb 2019; BOM, 2019). Rainfall over summer 2019/2020 was 42% above average for the same period, however, the late summer rain from the 24-29 Feb may have been too late for most seedlings (excluding this equates to 46% below average rain for 1 Dec – 23 Feb 2020; BOM, 2020). In addition to understanding that summer rains may be an important part of sustaining seedling survival from the 2018 emergence data, it is now apparent that the timing of these rainfall events is also critical to seedling survival, at least, in their first year.

Future research:

Given the low survival from emergence lines, future research will aim to understand if the low survival is a result of the growth environment, or possibly a natural occurrence in the system. In order to address this issue, habitat characteristics will be measured on seedlings recruiting and surviving in natural sites, and compared with seedlings recruiting and surviving in translocation sites. A broad species comparison was undertaken during the 2019 translocation trial at T18, whereby a range of BIF species were sown into rock and ground strata. Data are currently being analysed and responses will be compared to *T. erubescens* germination and emergence results. Findings will be reported in the next annual report.

Fresh seed collections (2019/2020)

Tetratheca erubescens plants that were fruiting during spring 2019 (November) had organza bags placed over stems or custom-made baskets suspended beneath large plants (>30 cm diameter) that passively collected <15% of a plants' seed crop as fruit/seeds matured and dropped off the plant in summer 2020 (February). Table 2.1.1h summarises the number of plants sampled in each plot, the total number of seeds collected, the average seed weight and the proportion of viable seeds for each. As per permit to take license conditions (136-1718), 20% of the total amount of seeds collected (20% of 8027 = 1606 seeds) will be sent to the DBCA Threatened Flora Seed Centre in April 2020. All collected material has been separately labelled at the plant level, with plot locality data to ensure precise records of source provenance of all translocated material (Figure 2.1.1b). Compared to previous years, the limited seed quantity of the 2019/2020 summer collection was either a result of below average rainfall conditions over the 2019 spring and summer (19% below average for the calendar year; BOM, 2020) or changes to the pollination system (e.g. pollen limitation).

Despite fewer seeds collected in the 2019/2020 collection season, seed fill was 90.8% and slightly higher compared to 2017/2018 and 2018/2019 seed collection seasons. Highest fill was determined from 2016/2017 seed collections, although a lower proportion of seeds were assessed from this collection compared to the subsequent years (Figure 2.1.1a). Seed mass varied among collections, with lowest from 2017/2018 and highest from 2019/2020 collections (Figure 2.1.1a).

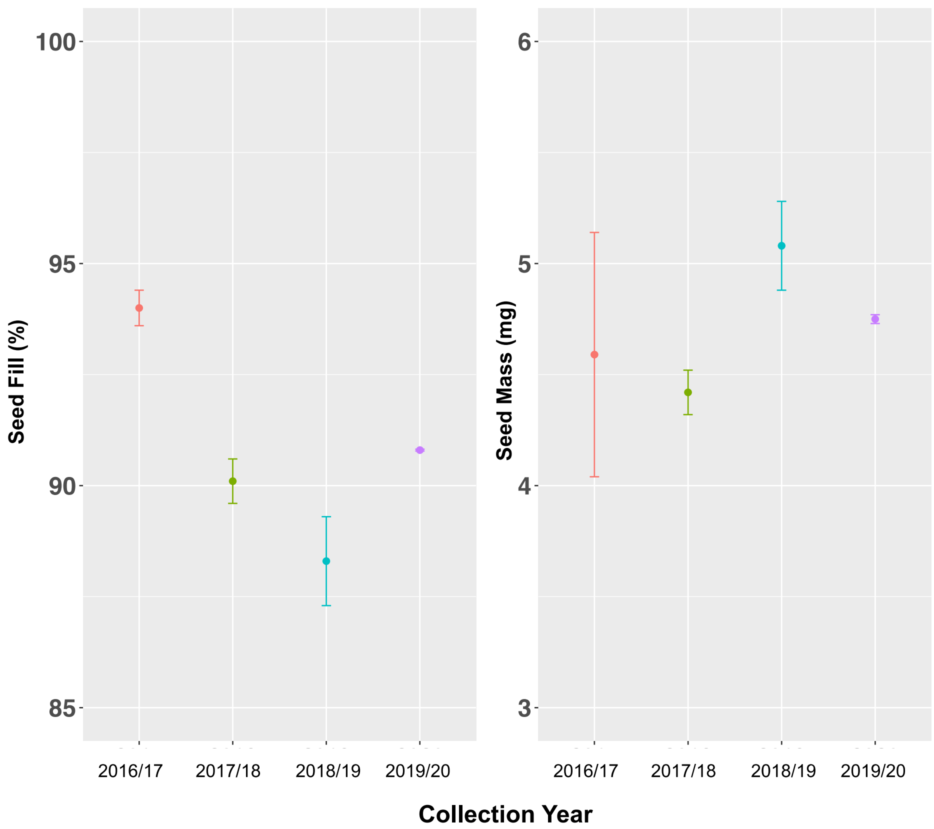


Figure 2.1.1a. Comparison of seed fill (%) and seed mass (mg) between the different collection years in the natural population (2016/2017, Elliott *et al.* 2017; 2017/2018, Elliott *et al.* 2018; 2018/2019, Elliott *et al.* 2019; 2019/2020). Figure contains mean ± standard error.

Table 2.1.1h. Summary of the amount of seed collected from *T. erubescens* within the natural population during the 2019/2020 season (Plot 1 – 26; Figure 2.1.1b).

FIELD COLLECTION	**General Easting**	**General Northing**	**No. plants**	**No. seeds**	**Ave seed weight (mg)**	**Ave seed fill (%)**
Plot 1	748880	6581641	19	722	4.19	91.4
Plot 2	748968	6581574	19	290	4.98	83.8
Plot 3 & 4	749028	6581554	23	518	3.74	84.5
Plot 5	749048	6581507	16	370	4.55	94.2
Plot 6	749071	6581488	12	151	4.48	83.1
Plot 7 & 25	749260	6581695	17	589	5.46	91.8
Plot 8 & 9	749433	6581518	12	301	4.98	93.4
Plot 10	749531	6581119	25	607	4.62	86.8
Plot 11	749628	6581109	5	317	5.03	95.0
Plot 12	749701	6581068	19	713	5.76	94.7
Plot 13	749702	6581074	24	349	4.84	94.4
Plot 14	749963	6581008	4	56	4.60	90.6
Plot 15	749990	6580963	21	450	5.58	98.9
Plot 16	750011	6580924	8	42	4.56	91.0
Plot 17	749996	6580911	24	387	4.44	91.0
Plot 18	749987	6580874	18	162	4.68	96.3
Plot 19	750006	6580817	6	29	5.00	95.0
Plot 20 & 21	750008	6580775	4	158	4.20	81.2
Plot 22	749993	6580744	13	340	5.25	86.6
Plot 23 & 24	749988	6580736	31	909	4.40	87.0
Plot 26	749000	6581900	15	567	4.52	95.1
					Average	Average
		Total	335	8027	4.75	90.8

Future research:

Further investigation will be conducted on these seed collections to determine if there are additional environmental variables, such as genetic groups (as determined in Krauss and Anthony 2019), NE- and SW-facing aspects, or on a plot level to understand the variation in seed quality among locations on the ridge, in different years.

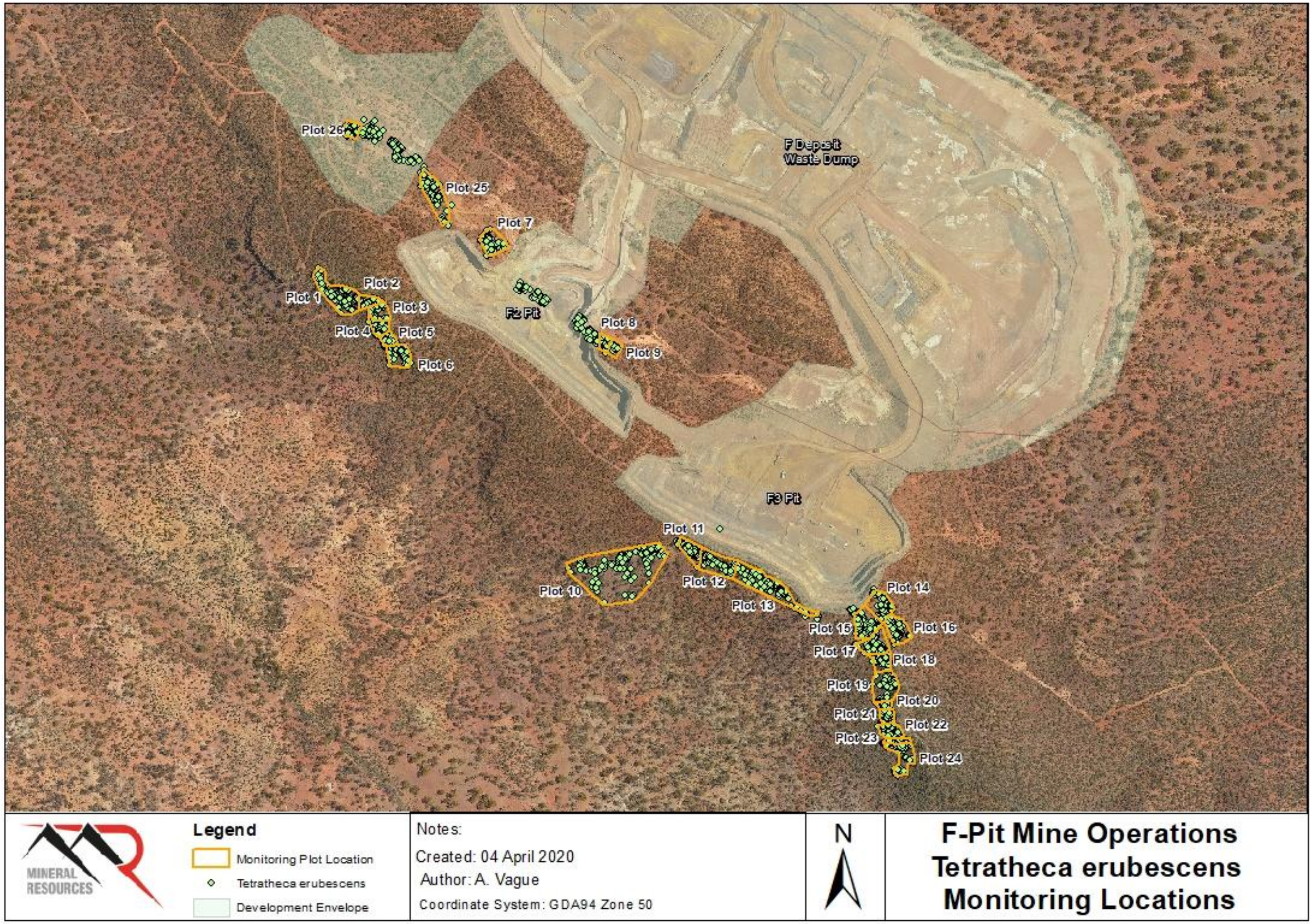


Figure 2.1.1b. Locations of the monitoring plots of *T. erubescens* indicating where seeds were collected during spring/summer 2019/20.

2.1.2 Assess the feasibility of using greenstock derived from different sources (seeds, vs cuttings) for establishing new plants *in situ*.

Current research outcomes:

- It is feasible to derive greenstock from cuttings or seeds to establish plants in the field, based on the 2019 translocation.

Greenstock for the 2019 translocation trial were sourced from cutting material collected and propagated in 2017 (Elliott *et al.* 2018) and seedlings generated from laboratory trials. We planted 186 seedlings in the 2019 translocation across the five sites (Table 2.1.1g) to compare seed derived greenstock to cutting derived greenstock. Seedlings were able to be planted in the field and overall we had some survival of seedlings, even though rainfall was 19% below average rainfall for the calendar year (see Section 2.2).

Future research:

Currently, Kings Park Science has ~588 seedlings in propagation (sourced from past laboratory experiments) that will be part of the 2020 translocation trials, provided they are developed enough for translocation (Figure 2.1.2a).

Figure 2.1.2a. Seedlings to be used in the 2020 translocation. A) potted into biodegradable pots (Fertil pots); B) seedling collection in glasshouse; C) one week old seedling; and D) seven week old seedling. Images C. Elliott.

2.1.3 Determine the environmental requirements (crack attributes, aspect, temperature and moisture) for establishing plants *in situ*.

Current research outcomes:

- Measured habitat characteristics at individual planting locations of translocated greenstock in all five translocation sites in 2019.
- The choices of greenstock locations were considered water capturing slope types.
- Greenstock survival was less variable in water capturing locations.
- Preliminary review suggests that greenstock planting locations reflect the locations of natural plants (on local geomorphologic features and local slope type only).
- Measured habitat characteristics on seedlings that recruited in monitored plots of the natural population in 2019.
- Natural recruitment and survival of these seedlings was greatest in water capturing locations.
- Peak soil temperatures were >60°C in summer 2017/2018, and <60°C in 2018/2019 and 2019/2020 summers.
- Rainfall was 19% below average in 2019.

Habitat characteristics

Translocated greenstock

Locations of all greenstock planted at all five translocation sites (Table 2.1.1a, except T19) for the 2017 & 2018 & 2019 translocations were assessed for the 20 habitat characters defined in Miller (2015) and Elliott *et al*. (2019). In total, 1272 locations of planted greenstock were measured in translocation sites. Preliminary analysis on a subset of 345 locations showed that greenstock was planted in all local geomorphologic features (rock, ground, rock bench). The majority of greenstock was planted in rock (66%) and the survival of greenstock located in this feature was similar to the other features (9-10% survival after the first summer). Preliminary analysis (on the same subset of data) showed that greenstock was planted in all categories of local slope trend (Section 2.1.3 in Elliott *et al*. 2019). The majority of greenstock were planted where the local slope was considered water capturing (waning, minimal or depression; 82% of greenstock) and the survival of plants with this local slope was less variable across the three types than the water shedding slopes (9-10% survival after the first summer, compared to 0-25% survival of plants located with a water shedding slope). However, this was a preliminary analysis on a subset of the data at the time.

Review of planting locations

The choice of greenstock locations in the translocation sites reflected the breath of habitat characteristics where adult plants of *T. erubescens* occur (see Miller 2015). The majority of greenstock were planted in water capturing locations, where naturally occurring plants were 2.4 times more likely to occur (Miller 2015).

Natural recruitment

There was natural recruitment in the *T. erubescens* population in winter of 2018. Taking advantage of this natural event, we assessed the same 20 habitat characteristics (outlined above for the greenstock) on the new seedlings in the natural population in 2019. Seedling survival was tracked over the season to determine if any characteristics correlated to seedling survival. In total, 102 locations of naturally recruited seedlings were measured in monitored plots described in the previous report (Section 2.2.1 in Elliott *et al*. 2019). Preliminary analysis showed that seedlings recruited in all local geomorphologic features (rock, ground, rock bench or ground/rock bench). The majority of seedlings emerged from rock (51%) and the survival of seedlings located in this feature was greatest (25% of seedlings in rock were alive after the first summer, compared to the ground at 15% survival). Preliminary analysis showed that seedlings recruited in all categories of local slope trend (Section 2.1.3 in Elliott *et al*. 2019). The majority of seedlings emerged where the local slope was considered water capturing (waning, minimal or depression; 73% of seedlings) and the survival of seedlings with this local slope was higher (23-28% survival of seedlings after the first summer, compared to 0-10% survival of seedlings located with a water shedding slope).

Future research:

Kings Park Science will measure these habitat characteristics on individual seeding line locations within translocation sites in 2020/2021 and any additional seedlings that emerge from recruitment events in the natural population, to determine if patterns of survival and growth can be better predicted by fine-scale assessment of individual sowing locations across multiple years.

Soil characteristics

Soil moisture and temperature loggers were installed in five sites (two translocation sites: T6 and T18; three natural sites: P5, P7 and P25) across northeast (NE) and southwest (SW) slope aspects. Composite soil samples were collected from 0-5 cm depth at each site and used to determine soil water retention curves. The retention curves will help describe seed and plant available water calculations and site environmental effects on plant establishment and function in Programs 1, 2 and 3. Additionally, the retention curves help to described soil moisture availability ranging between field capacity (e.g. 100% = -0.01 MPa) and dry soil (e.g. 0 % < -10 MPa).

In each site, logger stations were installed with three moisture probes and one temperature probe. The moisture probes were buried at soil depths of 1-5 cm adjacent to rock sites in natural and translocation sites. Soil moisture and temperature logging was set at 15 min intervals. Prior to instalment, each probe was calibrated with field soil (sieved at 2 mm) collected during the plant-excavation trip in July 2017 (see section 3.1.3), using soil at field capacity moisture availability (e.g. -0.01 MPa), and oven dried soil (24 hour drying, 105^{o}C) to determine wet and dry ranges. During the field installation, each soil moisture and temperature probe was buried at a depth of 5cm. The loggers were installed at different times: August 2017 (T6, T18 and Plot 5), and October 2017 (Plot 7 and Plot 25). Only one logger was reported faulty (T18) and did not have data available from November 2017 to

February 2018. Overall, the soil moisture probes were sensitive to rainfall events of 0.2 mm events, with higher resolution evident to rainfall events >1 mm.

Across all sites, natural rainfall events of 5 mm were correlated with raising the soil water content to ~50% field capacity (Figure 2.1.3a), while rainfall events of 10 mm elevates the soil moisture content to >75% field capacity, though soil type, particle size and underlying substrate will influence moisture retention following rainfall. Higher soil moisture content was generally related to cooler periods (August- September), with higher soil temperature related with quicker soil drying events (e.g. November - January). During the warmer months, soil water content depleted to drier ranges 0-7% field-capacity (Figure 2.1.3a).

Overall, 2017 soil temperatures were consistently hotter compared to 2018 and 2019. Due to the lower total rainfall in 2019 (212 mm, compared to >300 mm in 2017 and 2018), soil moisture availability was consistently the lowest across all sites (Figure 2.1.3a and Figure 2.1.3b).

In translocation sites, T6 was consistently wetter than T18, which is due to the majority of the site being shaded during the morning and having a SW-facing aspect. Despite having higher wetting profiles, T6 measured higher temperatures during summer, but not during late autumn, winter and early spring periods. Natural populations with NE-facing aspects (P7 and P25) were consistently hotter (max temperatures: 55-69°C, Figure 2.1.3a) than SW-facing aspects (e.g. P5, max temperatures: 48-56°C; Figure 2.1.3a) between 2017 and 2019.

A moisture window was evident during autumn, winter and spring months (May - November) – where soil moisture levels were elevated (5-80%) and never completely dried (e.g. 0%). This is a likely result of lower evaporation rates evident from the soil profile due to cooler soil temperatures. For both translocation trials, planting and sowing seeds during this period coincided with the period of highest moisture availability. Interestingly, soil moisture peaks were higher in the translocation sites when compared to natural sites. On inspection, moisture windows were similar, and further investigation will examine soil moisture dynamics in finer detail. A likely driver of this variation could be the particle size composition of the substrate, surrounding vegetation shading the site and availability of hydrological zones in the BIF that may be retaining greater moisture than zones that are exposed.

Future research:
Future investigation will include installing probes directly into the rock substrate, into holes and cracks reminiscent of *T. erubescens* planting and seeding locations, and characterising light-levels (by measuring photosynthetic active radiation- PAR) during different seasons. Soil moisture and temperature logging will continue throughout the project to determine environmental requirements for natural and translocated *T. erubescens* populations.

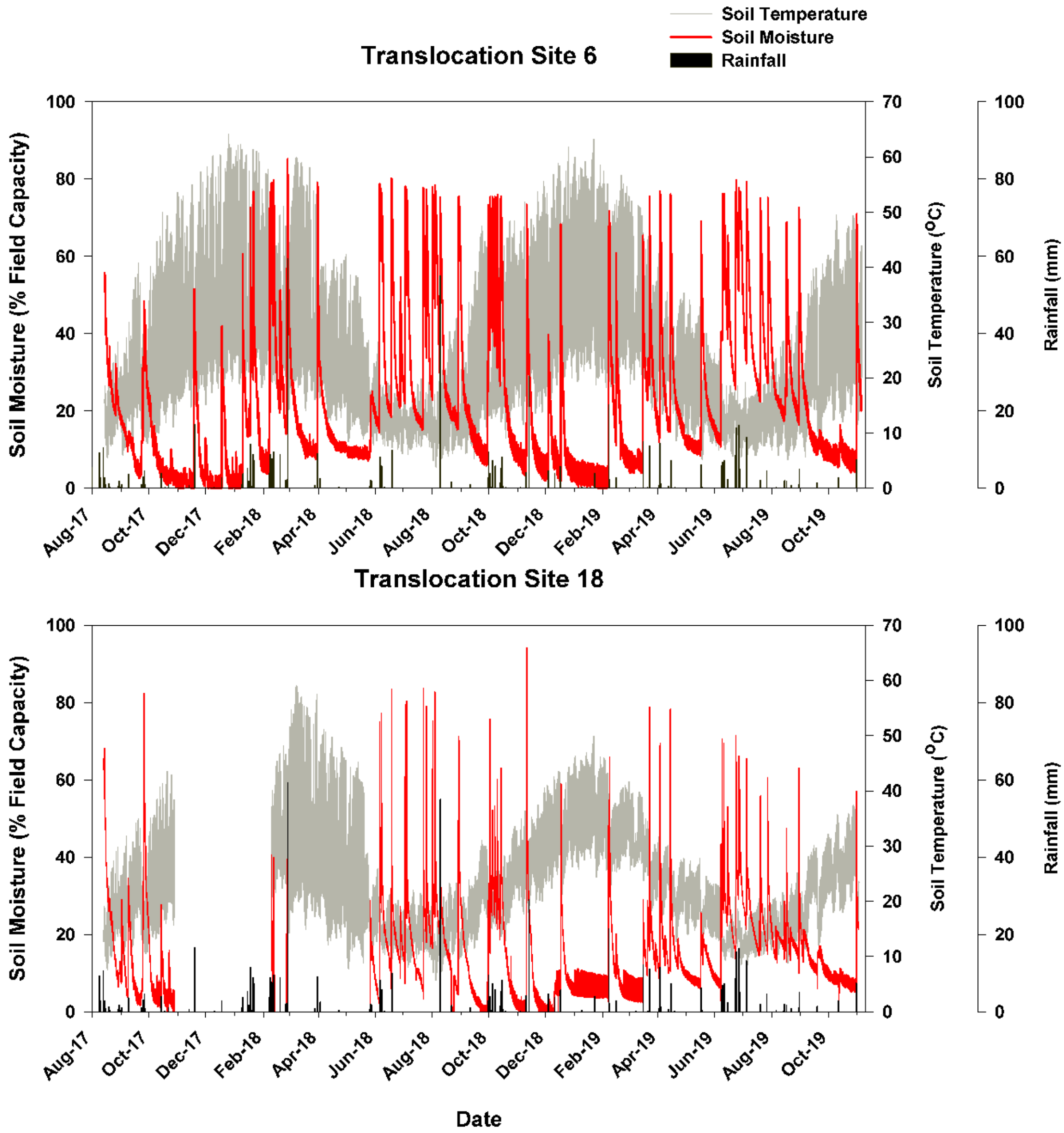


Figure 2.1.3a Soil moisture, soil temperature and total daily rainfall for translocation sites T6 and T18 from August 2017 to February 2019. Soil moisture is shown as % Field capacity, with 100% indicating field capacity = -0.01 MPa, and dry 0% < -10 MPa. Rainfall data available from BOM, 2019 - Koolyanobbing, Site 12227.

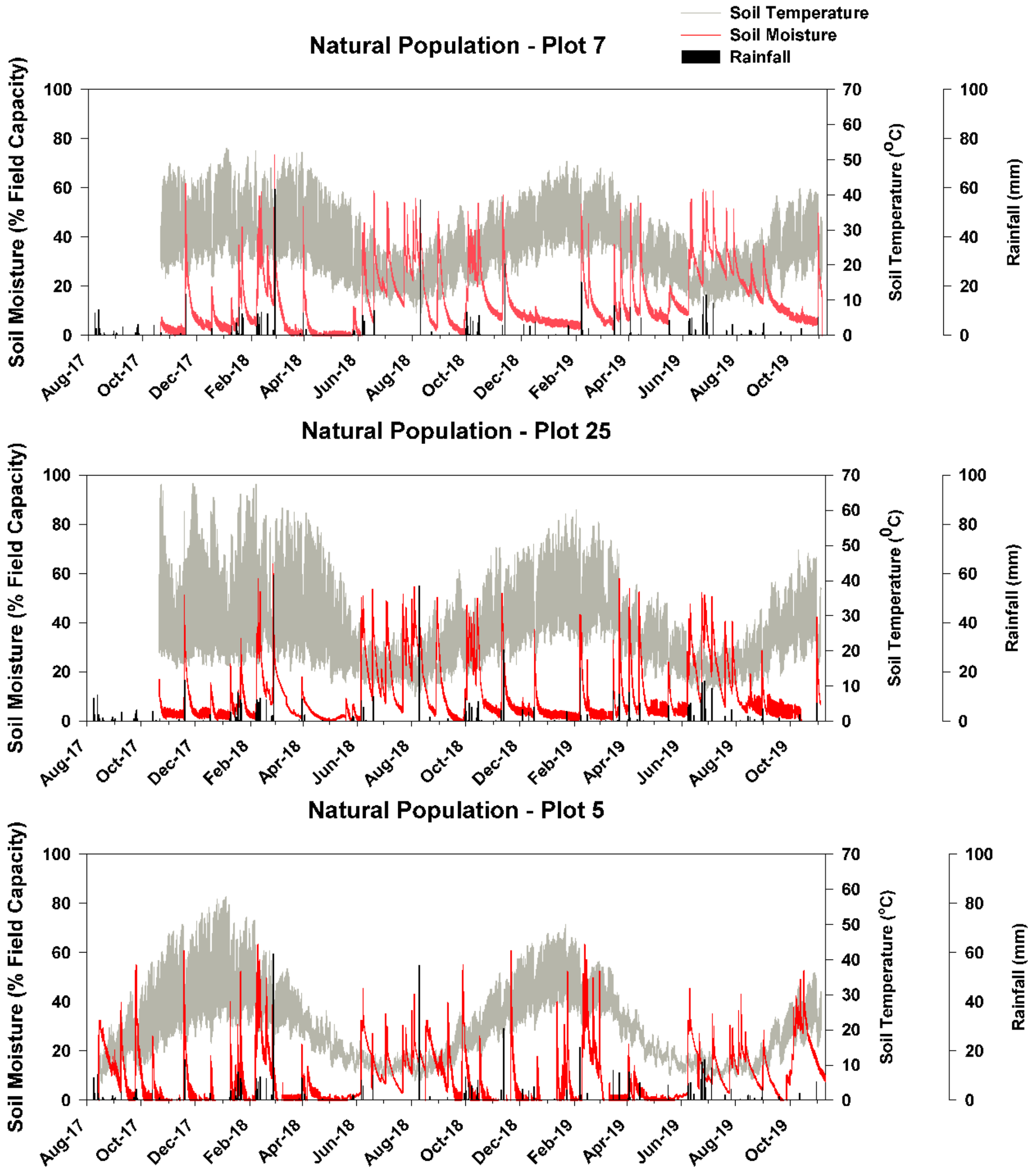


Figure 2.1.3a continued. Soil moisture, soil temperature and total daily rainfall for plots P5, P7 and P25 from August 2017 to February 2019.

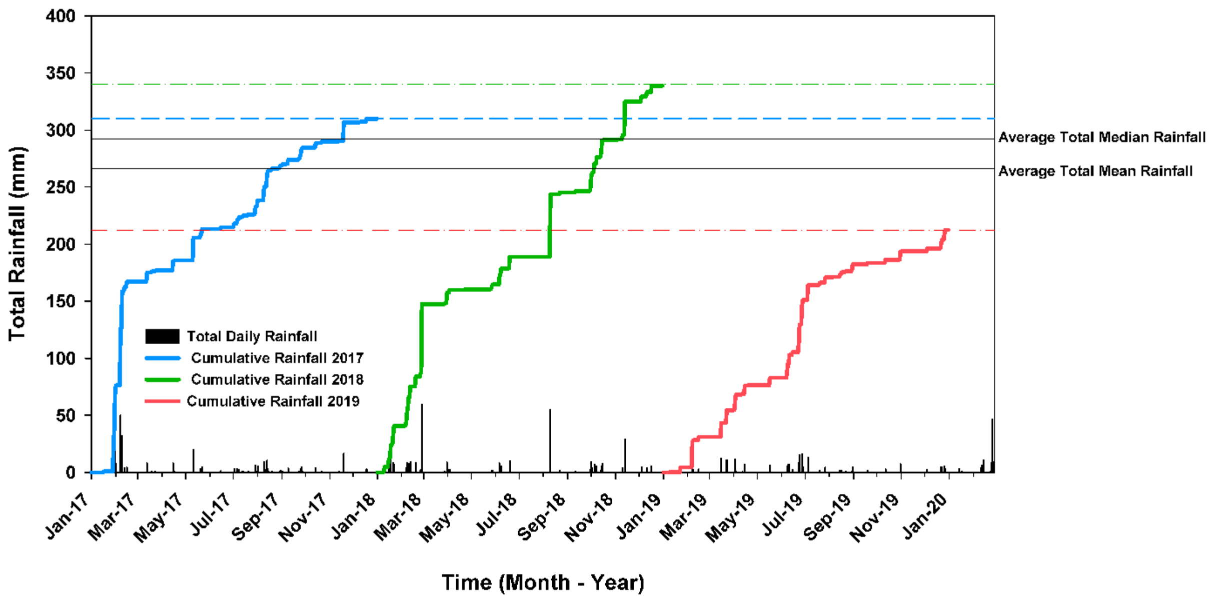


Figure 2.1.3b Cumulative rainfall for 2017 (blue line), 2018 (green line) and 2019 (red line) between January 2017 and February 2020. The dashed horizontal lines indicate total yearly rainfall (2017: dashed blue line; 2018: dashed green line; and 2019: dashed red line). Total rainfall over a period of 365 days is reported in Figure 2.1.3b. Rainfall data available from BOM, 2020 – Koolyanobbing, Site 12227, with the average total mean and medium rainfall for Koolyanobbing represented as the black lines.

2.1.4 Compare the responses of plants when placed *in situ* into different locations including within, adjacent and outside of known *T. erubescens* populations, and into artificial sites created as a consequence of mining.

Current research outcomes:

- Plant responses (i.e. survival) to *in situ* locations were similar among most translocation sites, except one located adjacent to natural populations on the northern side of the ridge where survival was noticeably higher (T23).
- Pre-planting performance of greenstock was similar among treatments.
- Baseline (*ex situ*) plant function responses to drought declined after three days and plants significantly deteriorate after ten days.

Greenstock survival was similar among most translocation sites in the initial stages at all three translocation sites (Elliott *et al.* 2018; Elliott *et al.* 2019; Table 2.1.4a), but the survival over multiple summers has showed a varied temporal response among sites. Despite the low survival, the best performing site was an adjacent site (T23) in all three translocation years (See Section 2.2 for further details).

Table 2.1.4a. Summary of greenstock survival for each trial in each translocation site and their spatial location. Table represents cumulative survival of greenstock that are 27 months (2017), 17 months (2018) and 5 months (2019) as of November 2019 (i.e. pre-summer). Note: greenstock survival after summer 2019/2020 has declined significantly, see Section 2.2. Location was classed according to distance to the natural population (Elliott *et al*. 2018).

Site	Latitude	Longitude	Location class	Distance to population	Greenstock survival		
					2017	2018	2019
T6	-30.87245	119.60269	Outside	<0.1km	0.4%	7.5%	19.2%
T18	-30.88656	119.61919	Outside	0.7km	3.5%	6.2%	32.0%
T19	-30.87145	119.60642	Artificial	<0.05km	0%	na	na
T21	-30.87394	119.60513	Adjacent	<0.01km	na	2.8%	29.8%
T23	-30.87150	119.60637	Adjacent	<0.02km	5.1%	15.0%	34.0%
T24	-30.87417	119.61111	Outside	<0.1km	na	4.6%	9.5%

na = not applicable due to no greenstock planting at location

Plants were translocated into five locations with different underlying substrate and context (i.e. distance to nearest *Tetratheca* population; Table 2.1.1a). The pre-planting performance of greenstock was measured to provide a baseline to compare the future growth of translocated plants (average height, shoot mass, stem count, root mass).

Growth assessment

The baseline results show that cuttings were similar for seedlings grown with and without Fe-fertilizer in both 2018 and 2019 translocation trials, respectively (i.e. all started with similar sized plants; Figure 2.1.4a). Despite there being no difference following fertilizer application, the cuttings that were planted in the 2019 translocation trial were overall marginally larger, in terms of their height and shoot mass than 2018 cuttings (Figure 2.1.4a). Despite investing more biomass into shoots, the root mass was highly variable from 2019 cuttings compared to 2018 cuttings.

Understanding drought responses from cuttings

A drought trial was conducted on cuttings from the 2018 translocation trial in winter 2018, shortly after the translocation in order to determine drought responses. Despite cuttings showing similar plant growth performance, cuttings grown with Fe-fertilizer for the 2018 translocation trial demonstrated slightly higher stomatal conductance (112.2 $\pm$ 5.1 mmol $m^{-2}.s^{-1}$) compared to cuttings grown without any fertilizer (90.7 $\pm$ 3.1 mmol $m^{-2}.s^{-1}$). There was a significant decline in performance at soil water potentials -0.91 $\pm$ 0.22 MPa and -1.34 $\pm$ 0.35 MPa for Fe and Control nursery-treatments and prior to the plant wilting point at -1.5 MPa (Figure 2.1.4b), when water was withheld for at least 3 days. For cuttings that were fertilized with Fe, a more rapid decline in function by 75% occurred after 6 days, while unfertilized seedlings declined by 75% in their function after 10 days of drought (Figure 2.1.4b).

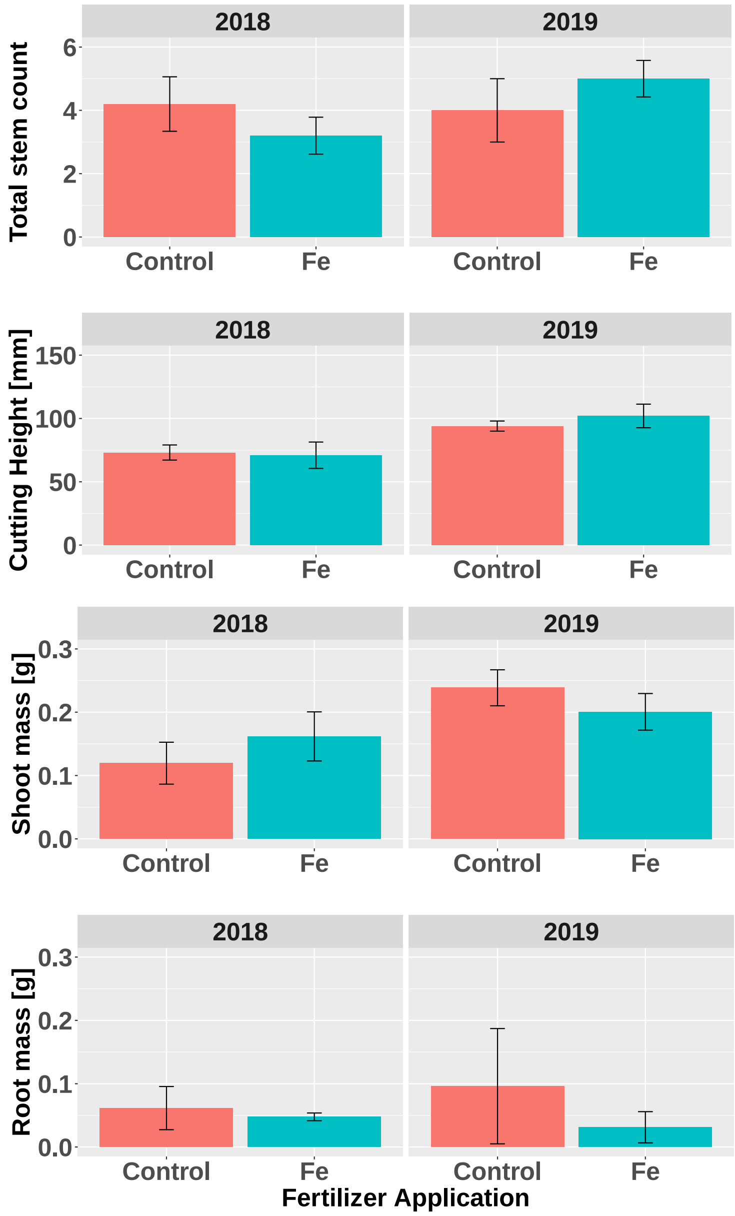


Figure 2.1.4a. Growth performance (live stem count, cutting height, shoot mass and root mass; n = 5) of greenstock grown with an iron supplement (Fetrilon Combi2; blue columns) and without an iron supplement (red columns) prior to planting in the 2018 translocation. Figure represents mean ± standard error.

Plant health measurements (detected through chlorophyll fluorescence assessment) indicated that cuttings were generally considered capable of photosynthesising for at least 10 days when water was withheld. Rapid declines in plant health were first detected between 13-14 days (slope 5.5-7.3), with lowest fluorescence measured after 16 days for both treatments (Figure 2.1.4b). When chlorophyll fluorescence measures were <0.05 at 17 days, all cuttings that were exposed to drought were re-irrigated daily for a week, but no increases in stomatal conductance and chlorophyll fluorescence were detected.

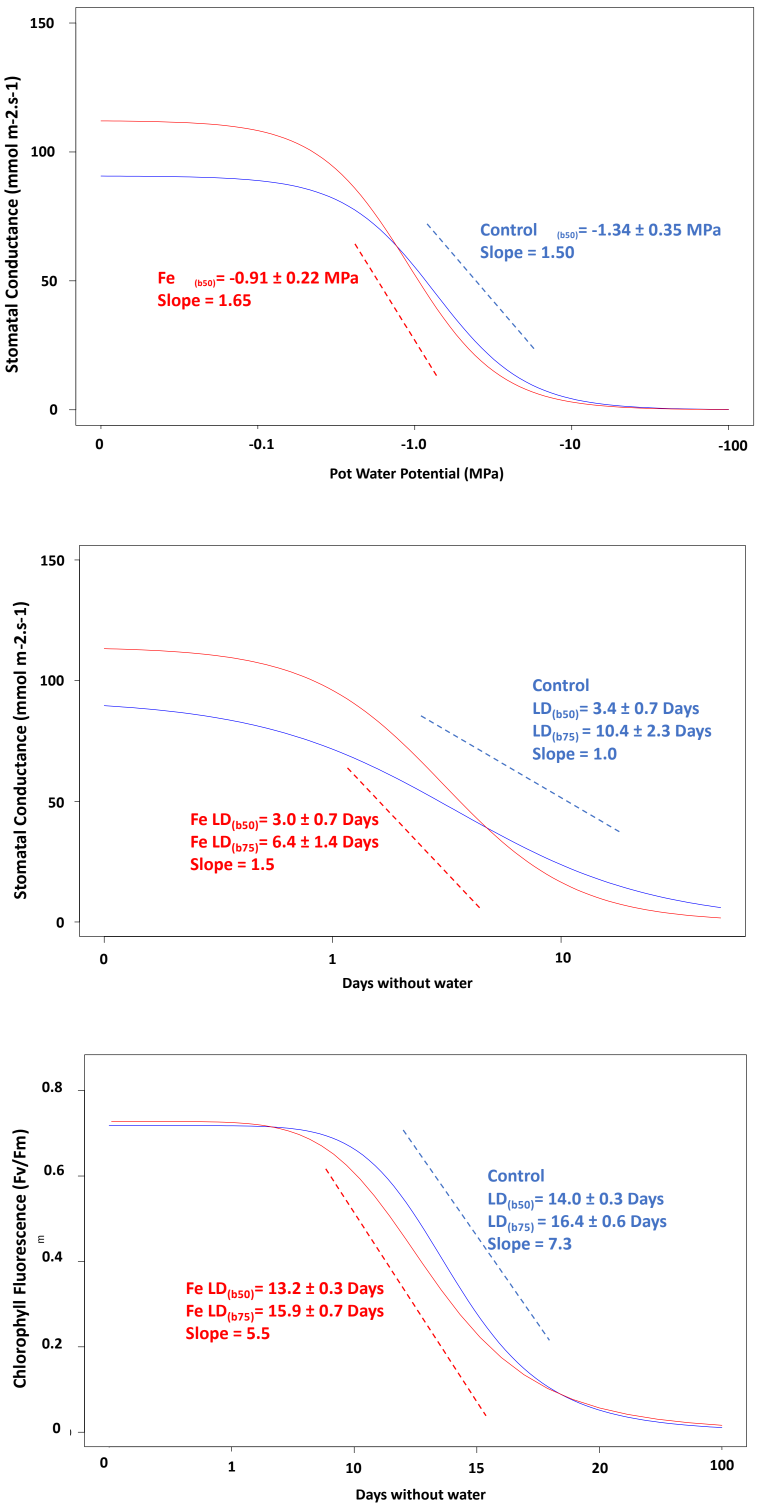


Figure 2.1.4b. Ecophysiological performance curves for stomatal conductance and chlorophyll fluorescence of cuttings that were grown with (red line) and without (blue line) Fe-fertiliser (*n* = 5) under drought and used in translocation in June, 2018. Drought experiments were conducted under glasshouse conditions in 2019.

Applications

- Results demonstrate how cuttings function in response to drought: plant water-use through stomatal conductance is decreased at soil water potentials between -0.91 and -1.34 MPa, which occurred after a period of three days after withholding water.
- Plant health decreased significantly after 13-14 days of withholding water, with no recovery possible after rehydrating cuttings.
- While the experiment was conducted in a warm glasshouse (ambient temperatures of 23-28^{o}C), it is anticipated that field conditions may be more exposed and hotter, which could increase soil drying rates and exacerbate drought stress on cuttings. The severity of field conditions is therefore expected to decrease plant performance at much higher rates than observations in the glasshouse.
- For translocation efforts concerned with applying irrigation, the rehydration of cuttings would have to occur prior to deterioration of plant health. The results demonstrate that this could occur within a window of 10 days.
- Frequent irrigation would therefore be necessary to improve establishment and mitigate drought stress.
- Frequent irrigation however could also lead to over-watering of establishing cuttings. As such, research is necessary to determine frequency and amount effects on plant growth and establishment under controlled and field conditions.

2.2 *Survival, growth and reproduction in restored and natural populations.*

2.2.1 Develop baseline data on the growth, survival, flowering and seed production of seedlings, juveniles and mature plants.

Natural population

Current research outcomes:

- Adult plant mortality was recorded (one plant).
- Floral and fruiting phenology differed to previous seasons for adult plants located on the north or south side of the range.
- Growth rates of adult plants on the northern side were similar, relative to their size, in comparison to plants on the southern side.
- Growth rates in 2019 were >30% and this was lower than 2018.
- Natural recruitment (252 seedlings) was two-fold higher than 2018 (121 seedlings).
- Survival of naturally recruited seedlings was only 5.6% post-summer 2019/2020.

Translocated populations

Current research outcomes:

- 2017 translocation greenstock survival (derived from cuttings) overall was 2.1% after three summers (15 greenstock plants).
- 2018 translocation greenstock survival (derived from cuttings) overall was 5.3% after two summers (57 greenstock plants).
- 2019 translocation greenstock (derived from cuttings and seed) overall was 2.0% after one summer (10 plants).
- 2019/2020 summer declines of *in situ* greenstock were greater in young greenstock (i.e. 8 months established) than older greenstock (i.e. 30 months established).
- Greenstock survival patterns were similar amongst all translocation sites (within the same year).
- See Section 2.1.1 for current research outcomes for direct seed sowing.

Natural population

In October 2017, mature plants were initially tagged and measured for ongoing reproductive monitoring (plant size, plant health, flower production, fruit production). Table 2.2.1a summarises the number of adult plants tagged for survival, growth and reproductive monitoring and the number that are also being measured for ecophysiology parameters. We recorded no above-ground green foliage for one plant (P9) for 12 months (Feb 2019 – Feb 2020), and suspect this plant has died. Monitoring should continue to determine if this species can recover after this period of no photosynthetic material, given future rainfall conditions in 2020. This will also assess if below-ground tissues are still viable and capable of regenerating new shoots after this length of time.

Table 2.2.1a. Summary of the number of mature plants in the natural population that were tagged for monitoring in each plot.

Site	General Easting	General Northing	Location on range	No. of plants for demography	No. of plants for ecophysiology
Plot 3	749028	6581554	South	20	4-6
Plot 5	749048	6581507	South	21	4-6
Plot 7	749260	6581695	North	20	4-6
Plot 9	749433	6581518	North	20	-
Plot 10	749531	6581119	South	20	-
Plot 11	749628	6581109	South	20	-
Plot 13	749702	6581074	South	20	-
Plot 16	750011	6580924	North	20	-
Plot 25	749117	6581805	North	20	4-6
Total				**181**	**16-24**

Monitoring schedule for demographic plants was as follows:

Table 2.2.1b. Summary of set-up and monitoring periods for tagged plants in each plot in the natural population at Koolyanobbing Range.

		Monitoring							
Site	**Set-up**	**1st**	**2nd**	**3rd**	**4th**	**5th**	**6th**	**7th**	**8th**
P3 P5 P7 P9 P10 P11 P13 P16 P25	18-25th Oct 2017 Mid Spring	18-21st May 2018	16-23rd Aug 2018	21-28th Oct 2018 12 months	12-20th Feb 2019	7-16th May 2019	22-30th Aug 2019	30-7th Nov 2019 24 months	14-26th Feb 2020

Floral and fruiting phenology

The average number of floral units (e.g. buds + flowers + fruit) was lower in 2019 than 2018 (Figure 2.2.1a), and corresponds to the pattern of rainfall that occurred in both years (see Elliott *et al*. 2019 and Figure 2.2.1i). The stage of floral development showed that the phenology of bud, flower or fruit production had similar responses between the years (i.e. skewed in one direction, and different between the northern and southern sides; Figure 2.2.1a). However, unlike 2018 there was not an increase in floral units in October as expected for spring peak flowering, due to the 78% below average rainfall that did not sustain the flowering season for plants in 2019 (i.e. premature end).

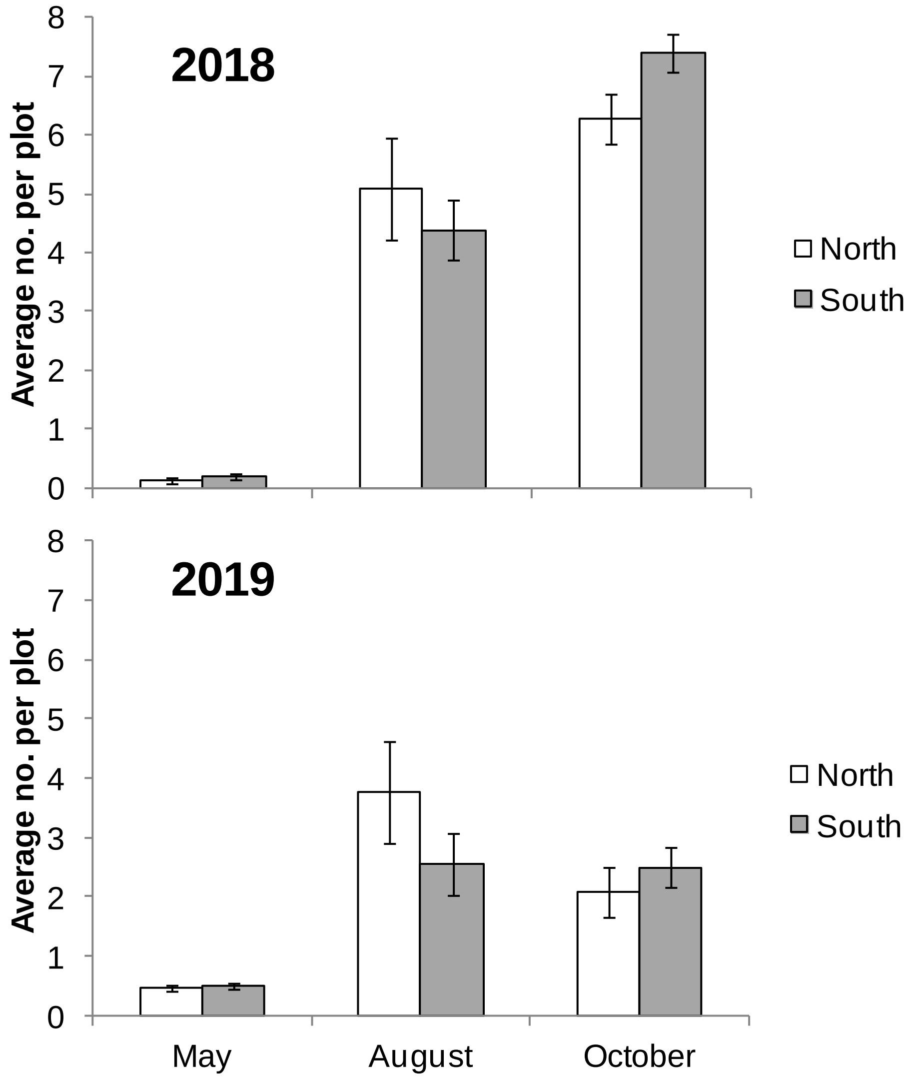


Figure 2.2.1a. Reproductive phenology (mean ± standard error) of plants (n = 20 per plot; Table 2.2.1a) in the natural population located on the northern or the southern side of the Koolyanobbing Range. Reproductive phenology represents the average number of floral units (e.g. buds + flowers + fruit) recorded for each month (average number of floral units per branch). Top chart is the 2018 flowering season (Elliott *et al*. 2018) and the bottom chart is the 2019 season.

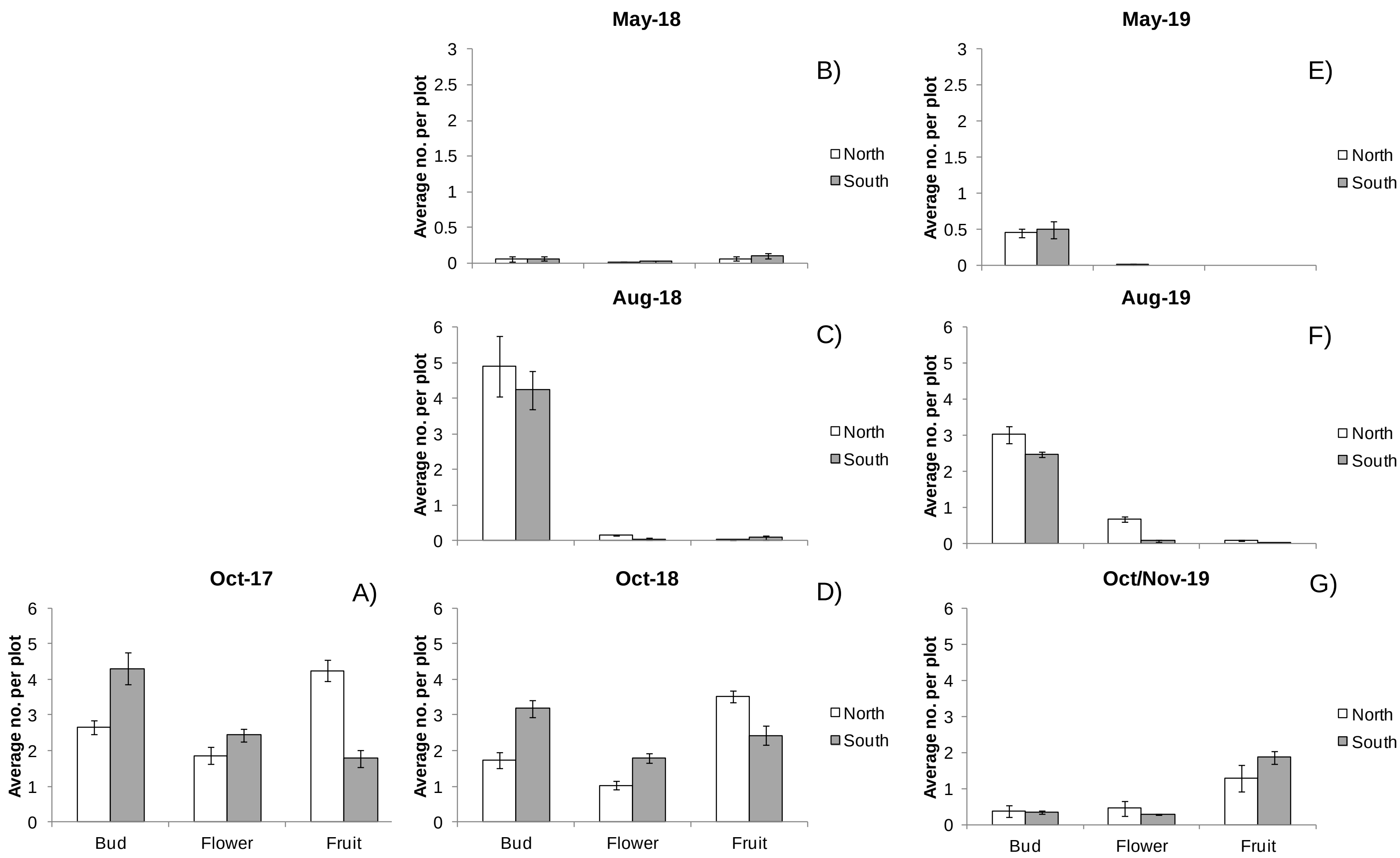


Figure 2.2.1b. Floral and fruiting phenology (mean ± standard error) of plants (n = 20 per plot; Table 2.2.1a) located on the northern side (white) or the southern (grey) side of Koolyanobbing Range. The average number of buds, flowers or fruit on plants during A) October 2017; B) May 2018; C) August 2018; D) October 2018; E) May 2019; F) Aug 2019; and G) October/November 2019 (average number of floral units per branch).

The peak production of buds in 2019 was higher on the northern side of the range and occurred during late winter (Figure 2.2.1.1b.f) and by mid-spring plants had a combination of buds (e.g. late flowering), flowers or fruits (e.g. early flowering). However, the mid-spring pattern of reproductive phenology was different in 2019 compared to 2018 patterns. Besides being lower in quantity, the amount of buds and flowers were similar on both sides and the amount of fruit was higher on the south side than the north side (Figure 2.2.1g). This difference demonstrates that plants on either side responded differently in a poor rainfall season than an average one (Elliott *et al*. 2019).

In summary, this data indicates that floral phenology differed between the northern and southern sides of the range, perhaps due to differences in environmental conditions (e.g. temperature, moisture) on northern versus southern facing aspects. In addition, this pattern of reproductive phenology, both the spread of floral units and specific differences between north and south, was different among monitoring years, depending on climate (October 2017 Figure 2.2.1b.a; October 2018 Figure 2.2.1b.d; and October 2019 Figure 2.2.1b.g).

Plant size and growth

The plant sizes and growth of adult plants in the natural population were assessed to establish the baseline physical attributes of plants. Adult plants on the northern side were smaller on average than those on the southern side (see Elliott *et al*. 2019 for details). New plant growth (new stems) of monitored plants occurred mainly between May and August (Figure 2.2.1c). Plants on the northern side produced similar (or slightly higher) amounts of new growth, relative to their size, in comparison to plants on the southern side (Figure 2.2.1c.a). Each plot performed similarly, except for P9, with a greater proportion of new growth occurring in May before it reached a plateau in August (Figure 2.2.1c.b). In comparison to the 2018 growing season, the proportion of new growth relative to plant size was less by >30%. Overall growth in 2019 was 35-40% compared to 60-70% in 2018 (Elliott *et al*. 2019).

Natural population recruitment

In August 2019, recruitment of *T. erubescens* seedlings occurred in many of the established monitoring plots in the natural population. These seedlings or existing juveniles were tagged and monitored to establish baseline survivorships of this age cohort in the population. At the time of measurements, seedlings and some juvenile plants were sensitive to assessments due to their low abundance, location accessibility and very small size, therefore, a limited number of measurements were taken to minimise any impact to their survival.

In eight of nine monitoring plots (Table 2.2.1a; excluding P25) seedlings were observed in plots, ranging from 4-71 seedlings per plot. Seedlings were also detected in an additional two plots (P6 and P18: 5 seedlings per plot). In total, 252 seedlings were monitored for growth and survival, which was two-fold higher than 2018 natural recruitment. In terms of winter average rainfall, 2019 was 31% above average whereas 2018 was 3% above average. Monitoring in February 2020 (post-summer) found that only 5.6% of these new seedlings had survived. These seedlings emerged and died across a broad range of habitat types, including cliff cracks, rock benches, under adult plants (or not) and deeper soils at the cliff foot-slope. The survival of the 2018 recruits was 20.5% after their first summer and declined to 9.8% after their second summer.

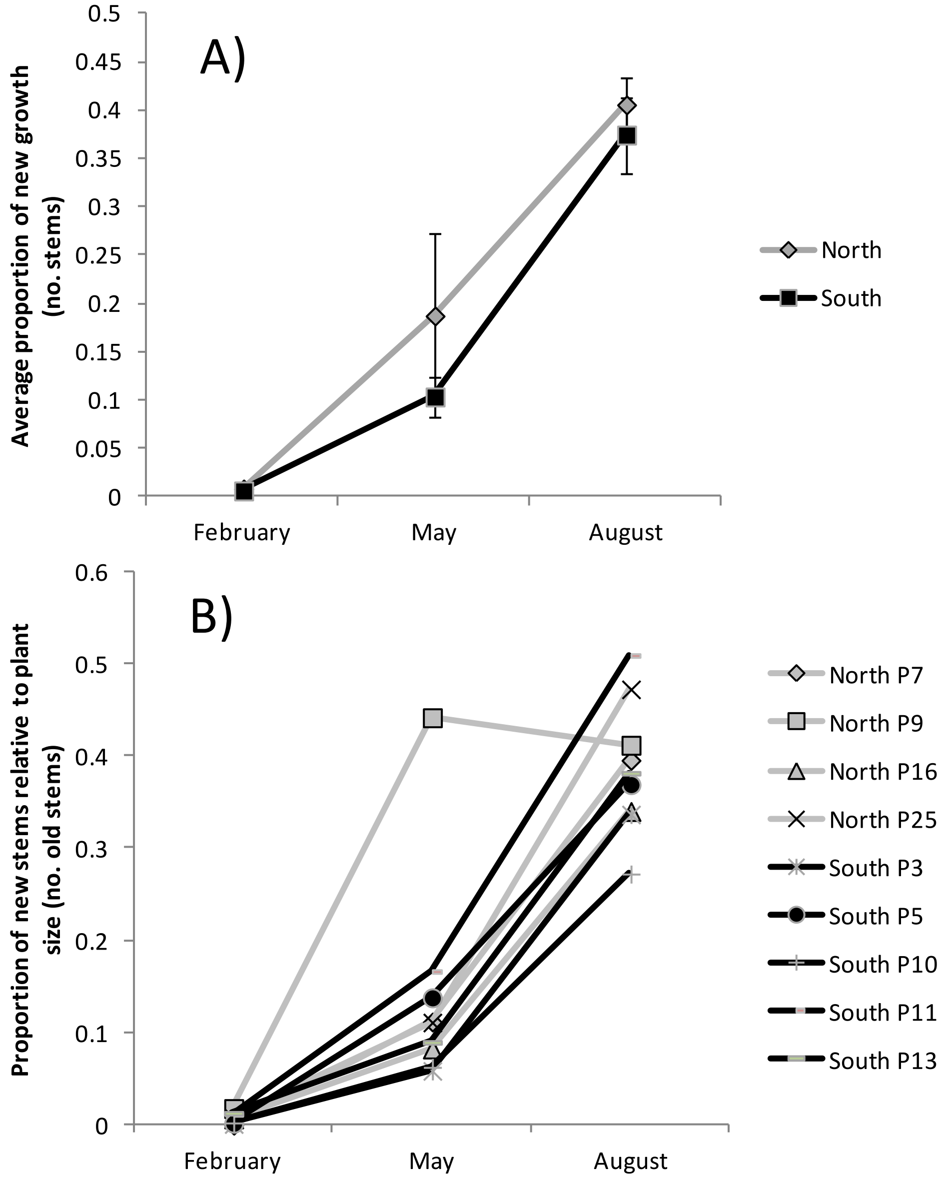


Figure 2.2.1c. Growth of adult plants in the natural population (*n* = 20 plants per plot; Table 2.2.1a), as measured by the number of new stems relative to the number of old stems on each plant over time (February – August 2019). A) overall plant growth (mean ± standard error) for the northern or southern side and B) growth rates (mean ± standard error) within each individual plot, on the northern or southern side.

Translocated populations

See section 2.1.1 for details on translocation site details, including location, characteristics, number of seed sown per translocation and number of greenstock planted per translocation. Details on direct seeding responses and survival is also summarised in this section.

Greenstock planting in 2017 translocation

The survival of greenstock (i.e. at least one cutting per planting unit still alive) declined again after their third summer for two sites (T6, T18), while one site held steady (T23; Figure 2.2.1f). Survival after 30 months ranged from 0.4 – 5.1% per site, of the original planting (overall = 2.1% or 15 plants).

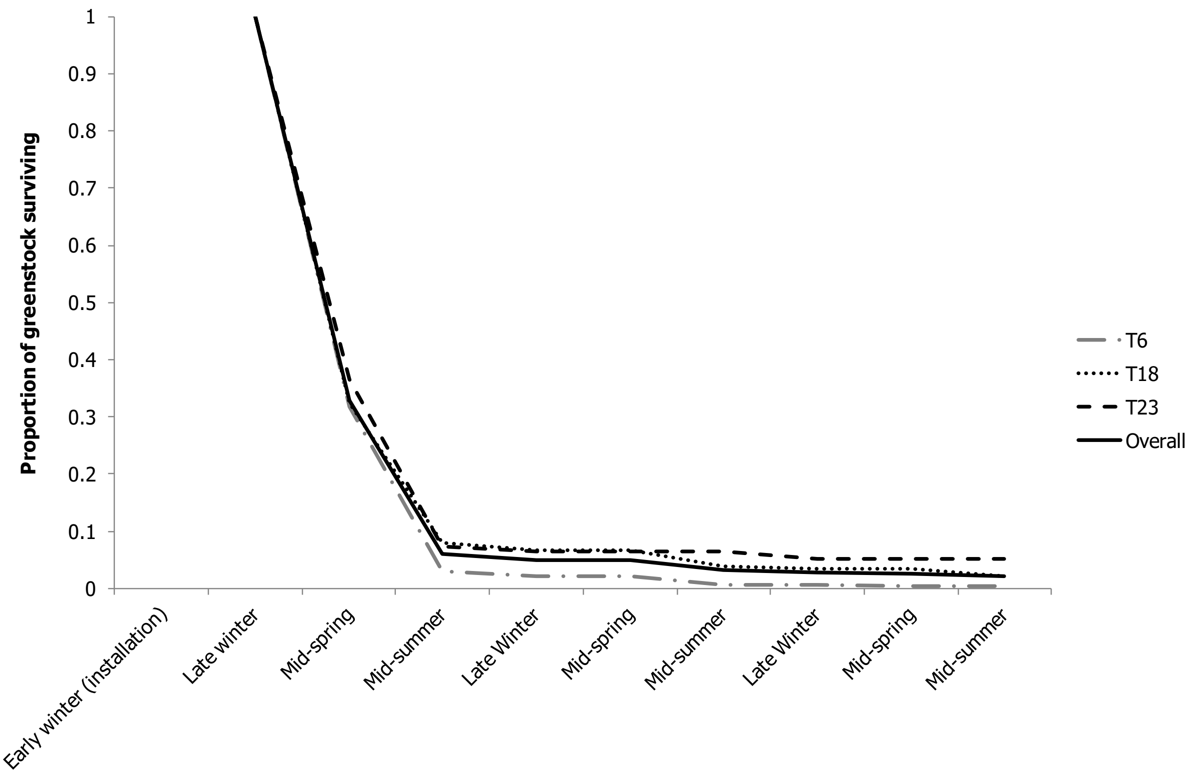


Figure 2.2.1f. Survival of 2017 translocation greenstock from installation (August 2017) to their third summer of monitoring (February 2020). Data represents the three translocation sites (T6, T18 and T23) and a combined overall survival rate.

Greenstock planting in 2018 translocation

The survival of greenstock (i.e. at least one cutting per planting unit still alive) declined again after their second summer (Figure 2.2.1g). A loss of half the previous 2018/2019 summer survivors was observed, with declines between the end of summer and winter, and the end of spring and summer 2019/2020. Survival after 20 months ranged from 1.9 – 10.8% per site, of the original planting (overall = 5.3% or 57 plants).

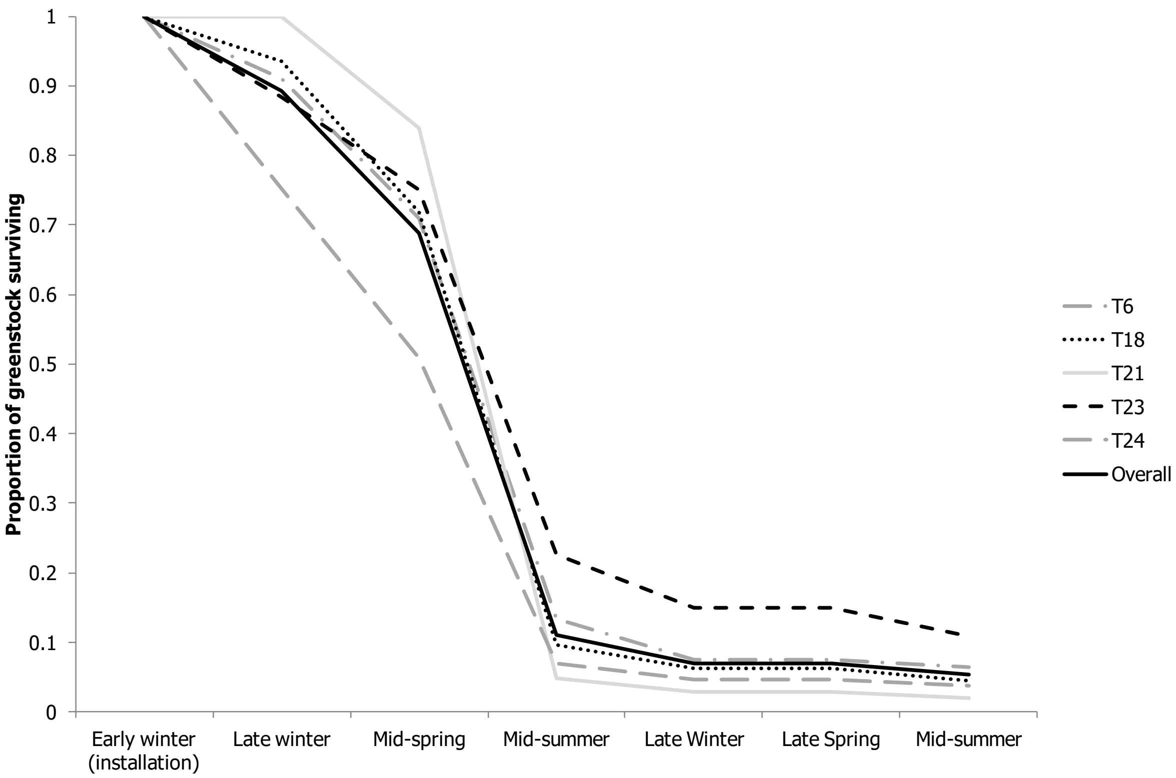


Figure 2.2.1g. Survival of 2018 translocation greenstock from installation (June 2018) to their second summer of monitoring (February 2020). Data represents the five translocation sites (T6, T18, T21, T23 and T24) and a combined overall survival rate.

Greenstock planting in 2019 translocation

Cuttings collected from plants in 2017, propagated at Kings Park and then sent to Natural Area Resource Management for the final propagation phase (Elliott *et al*. 2018), were planted in the five translocation sites in 2019 (Table 2.1.1b; Figure 2.2.1j). Each planting unit had 1-4 cuttings as previously outlined for the 2017 translocation (Elliott *et al*. 2018). The treatments tested on the planted greenstock and the number of replicates implemented within each translocation site are summarised in Table 2.1.1g.

The survival of greenstock (i.e. at least one cutting per planting unit still alive) declined significantly after their first summer (Figure 2.2.1h). Survival after 8 month ranged from 0 – 3.1% per site, of the original planting (overall = 2.0% or 10 plants).

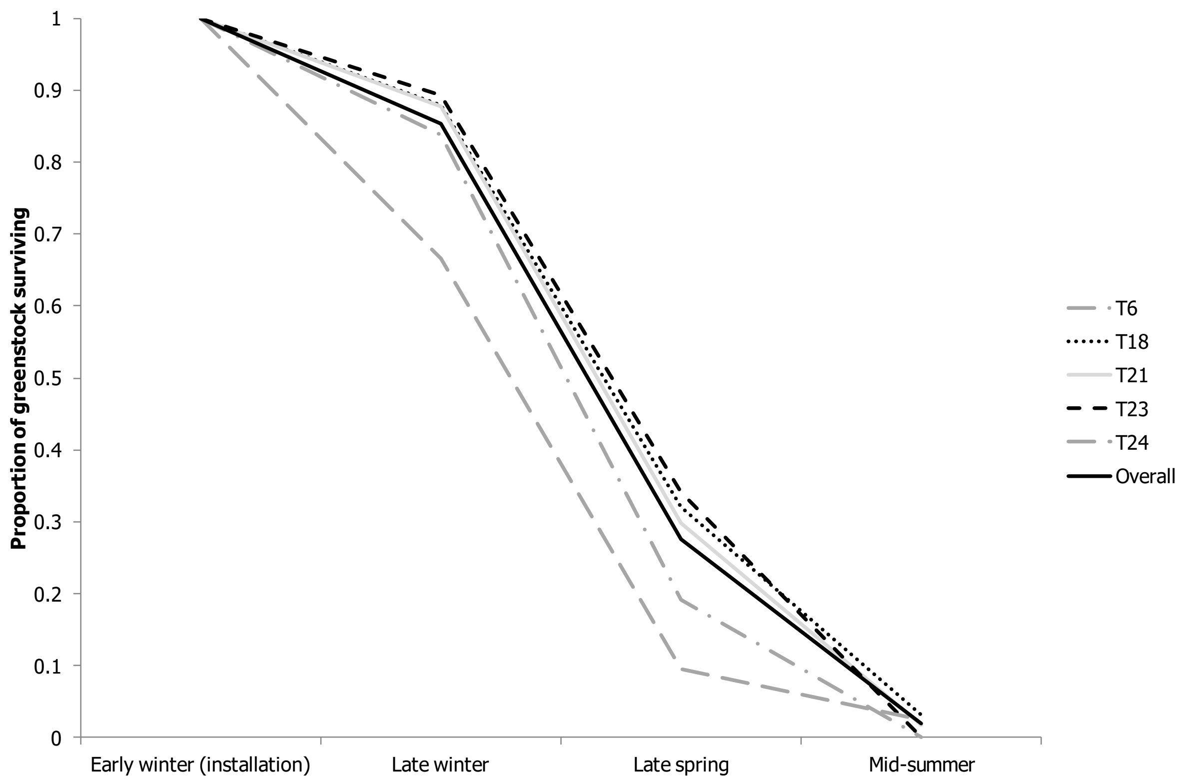
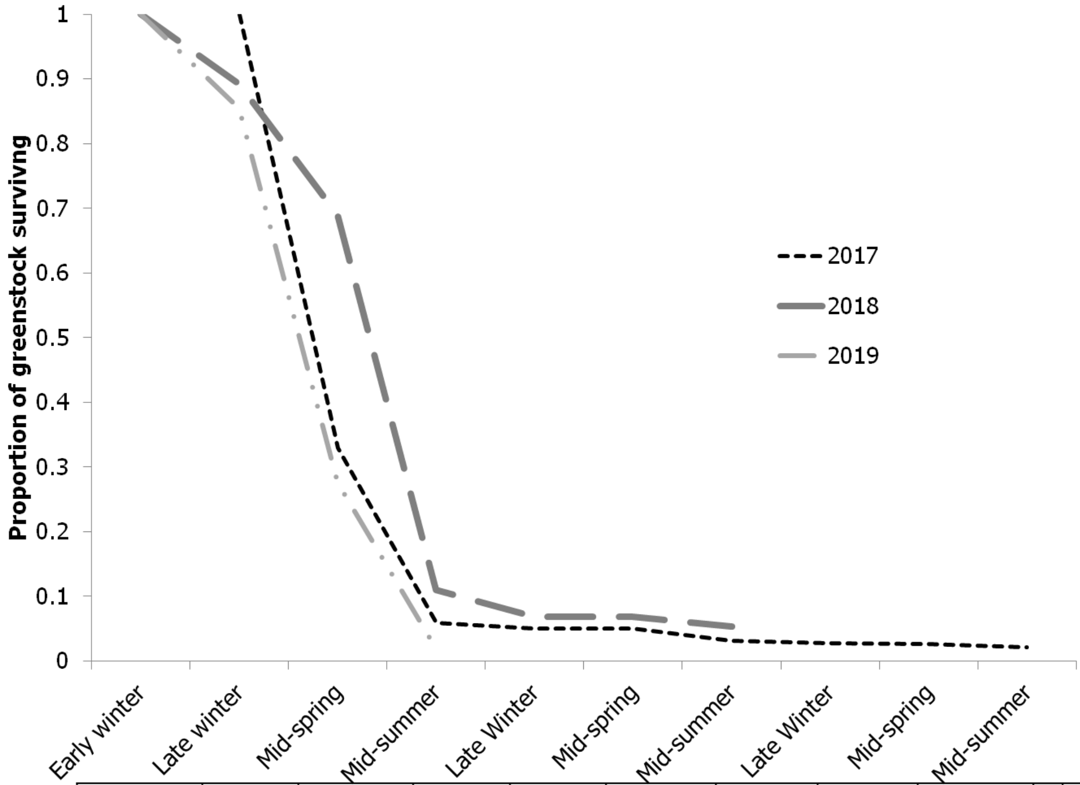


Figure 2.2.1h. Survival of 2019 translocation greenstock from installation (June 2019), late winter (8 weeks; August 2019), mid-spring (18 weeks; October 2019) and after their first summer of monitoring (34 weeks; February 2020). Data represents the five translocation sites (T6, T18, T21, T23 and T24) and a combined overall survival rate.

Year to year comparison

In summary:

- Late winter planting with below average winter rainfall can result in poorer survival, particularly after summer (i.e. 2017 vs 2018).
- Above average winter rainfall but below average spring rainfall (78%) can result in poorer survival, equivalent to a "late winter planting with below average winter rainfall" response in survival (i.e. 2017 vs 2019).
- Below average spring rainfall (78%); late summer rains (Feb rain event of >45mm); and effectively only 19 rainfall events (between 1-10mm) over 6 months post-planting (or 65% below average rainfall) can result in extremely limited survival (2% in 2019; Figure 2.2.1i).
- 2019/2020 summer declines of greenstock were greater in young greenstock (i.e. planted in 2019 and 8 months established) than older greenstock (i.e. planted in 2017 and 30 months established).



										% above or below seasonal rainfall
29%	29%	85%*	3%	48%	45%	31%	78%	45%*		2017
3%	48%	45%	31%	78%	45%*					2018
31%	78%	45%*					*Late rains			2019

Figure 2.2.1i. Overall survival of greenstock planted (2017, 2018, 2019 translocations) from installation, late winter, mid-spring and summer. Data represents five translocation sites (T6, T18, T21, T23 and T24) in a combined overall survival rate. Table presents the amount of above (blue) or below (red) average rainfall for that specific period of season (BOM, 2020).

Future research:

Natural population and translocated populations

Ongoing development of baseline data on the growth, survival, flowering and seed production of seedlings, juveniles and mature plants in natural and translocated sites will occur to quantify spatiotemporal variation (and any treatment effects). Characterisation of habitat types where these seedlings emerged and survived (or did not) will occur to determine what role it plays in the ongoing survival of seedlings under natural conditions (See Section 2.1.3).

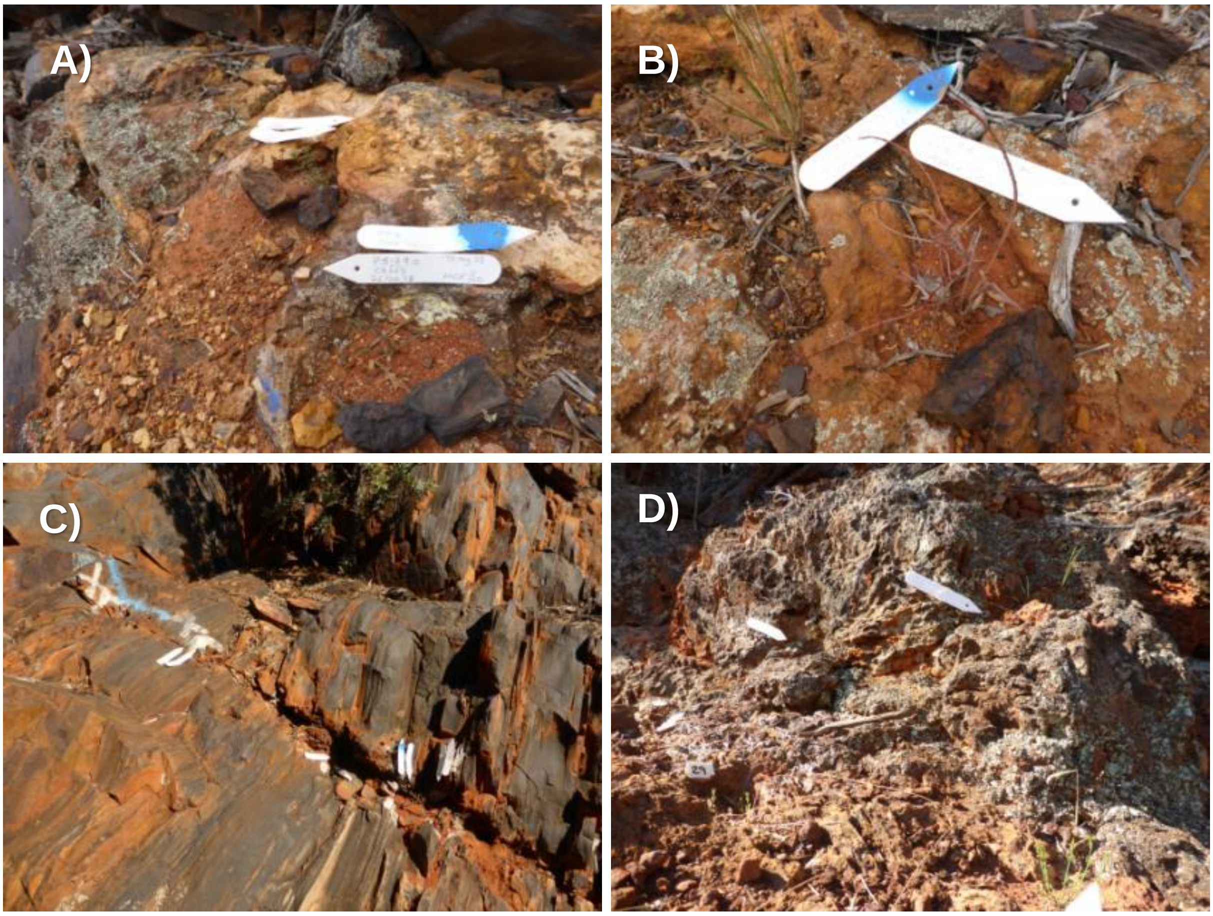


Figure 2.2.1j. Images of the 2019 translocation of greenstock. A) T18 locations of seedling derived greenstock; B) close-up of a planted cutting derived greenstock that died pre-summer; C) T18 locations of cutting and seedling derived greenstock; and D) T21 locations of seedling greenstock (bottom right), cutting greenstock (top left and right) and emerged seedlings (bottom left). Images C. Elliott.

2.2.2 Develop understanding of the importance of spatiotemporal environmental factors that drive variation in these population parameters.

Seasonal monitoring will continue across sites and will be paired with environmental data gathered from data loggers (currently at five translocation sites). Kings Park Science will also be using accurate rainfall, wind and temperature data provided by MRL from their weather stations on the top of Koolyanobbing Range. Multiple seasons are required to determine spatiotemporal variation and will be concluded at the end of the project. We anticipate reporting preliminary findings following the 2021 data collection.

2.2.3 Model the dynamics of *T. erubescens* populations to increase understanding of parameters such as expected longevity and time to maturity.

Data are being collected from demographic studies outlined in 2.2 for demographic modelling. This modelling is scheduled for summer 2022.

2.2.4 Compare performance of plants (growth, survival, flowering and seed production) in natural and translocated sites.

Current research outcomes:

- Survival of translocated greenstock (2.0 - 5.3%) was lower than the survival of monitored adult plants (99%; one plant dead in P9).
- The quantity of flowering and seeding of greenstock plants (8-30 months old) was lower than natural adult plants.
- Poor seedling survival from emergents in translocations and natural recruitment was similar (4.2% compared to 5.6% survival; August 2019 – February 2020).
- Disturbance events (e.g. herbivory, environmental disturbance such as substrate movement) negatively impacted the health and survival of plants in translocated and natural sites.

The comparative performance of adult plants in the natural population to the greenstock of the 2017 (30 months old), 2018 (20 months old) or 2019 (8 months old) translocation plants was difficult to make for some measures due to the young age and poor survival of greenstock. For example, survival or growth of adults was not a realistic comparison to make to greenstock, as almost all monitored natural plants remained alive for the duration of the monitoring unlike the translocated greenstock, where significant mortality was recorded (see Section 2.1.4 and 2.2.1). Flowering and seed production was quantifiable for translocated plants for the first time. Although not comparable to adults in the natural population (i.e. size, maturity etc.), greenstock plants produced 1-26 flowers per greenstock plant (of those that flowered). Developing fruits were observed, but were immature at the time and could not be collected and the plants too fragile to place organza bags on them. Some (very few) late maturing fruit was collected from plants that did contain seed. Quality and viability assessments of this seed will be completed. Maturity and ongoing survival of greenstock plants will ensure comparative performance measures can occur in future seasons. Survival of seedlings that emerged from direct seeding lines in the translocations was similar (or slightly poorer at 4.2%) than the survival of seedlings monitored as a recruitment event in the natural population (5.6%).

There was evidence of disturbance events impacting plant health or mortality in both the translocated and natural sites. These were either herbivory (removal of 75-100% of foliage on plant) or environmental disturbance, like soil or rock movement (plant roots exposed or whole plant, including roots, not in original location). Observations of increased evidence of mammals (i.e. fresh scats) and soil around established greenstock being 'washed away' at most translocated sites. Observations of the impact of two separate rockfall events (Jan/Feb 2019 and Aug 2019) in the natural population on plants were recorded. A brief report submitted to MRL Environment for the second rockfall event (August, 2019).

<u>Herbivory</u>

- 2017 translocation: One site impacted (T18 = 31%), of mid-spring surviving greenstock post-summer, and may have contributed to 21% of greenstock mortality.
- 2018 translocation: Three sites impacted (T6 = 21.4%; T18 = 12.5%; T23 = 28%) of mid-spring surviving greenstock post-summer, and may have contributed to some greenstock mortality.
- 2019 translocation: Two sites impacted (T18 = 3.5%; T23 = 11%) and these greenstock died.
- Natural population: none observed during monitoring of demographic plots (Table 2.2.1a).

<u>Environmental disturbance – soil movement</u>

- 2018 translocation: Two sites impacted (T21 = 25%; T24 = 9.1%) of mid-spring surviving greenstock post-summer, and these greenstock died.
- 2019 translocation: One site impacted (T18 = 2.4%) and these greenstock died.

<u>Environmental disturbance – rock movement</u>

- Natural population: Observations of adult plants impacted by large sections of rock that fell on top of them from higher up on the cliff.
- Summary of impact to a total of five (possibly six) adult plants in Plot 11:
    - immediate mortality (one plant)
    - complete loss of above ground biomass (one plant)
    - partial loss of above ground biomass (two plants, possibly three)
    - root disturbance (two plants)

Future research:
Ongoing comparative performance between plants in natural and translocated sites will occur to quantify spatiotemporal variation for natural adult plants across seasons, greenstock across seasons, as greenstock matures in translocations and comparisons between both groups (and any treatment effects). Ongoing monitoring of plants impacted by disturbance events is necessary to determine survival/recovery outcomes and/or initiate management actions to ensure survival.

Program 3. Plant function, habitat and substrate interactions

3.1 *Plant function, condition and water usage*

3.1.1 Develop baseline data on the physiology and function of *T. erubescens* plants at seedling, juvenile and adult stages in natural populations.

Current research outcomes:

- Ecophysiological performance was similar between juvenile and adult plants in the natural population.
- Plant condition of those in the natural population, as measured by the proportion of a plant that had recently died, did not peak during winter (May) as expected overall.
- Each plot responded differently to 2019 conditions, with some plots showing peak conditioning and other worse conditioning in winter (May; both sides of the ridge).
- Plants in the natural population on the southern side of the ridge were similar in condition (or slightly better), to plants on the northern side of the ridge.

Plant health, measured by assessing chlorophyll fluorescence (Fv/Fm) on dark adapted leaves on plants in the natural population during late winter (August 2019) and late spring (November 2019) showed that juvenile plants performed to a similar or higher level as that of adult plants (i.e. on the same side of the range; Figure 3.1.1a). This was consistent with the performance of juveniles and adults in 2018 (Elliott *et al*. 2019).

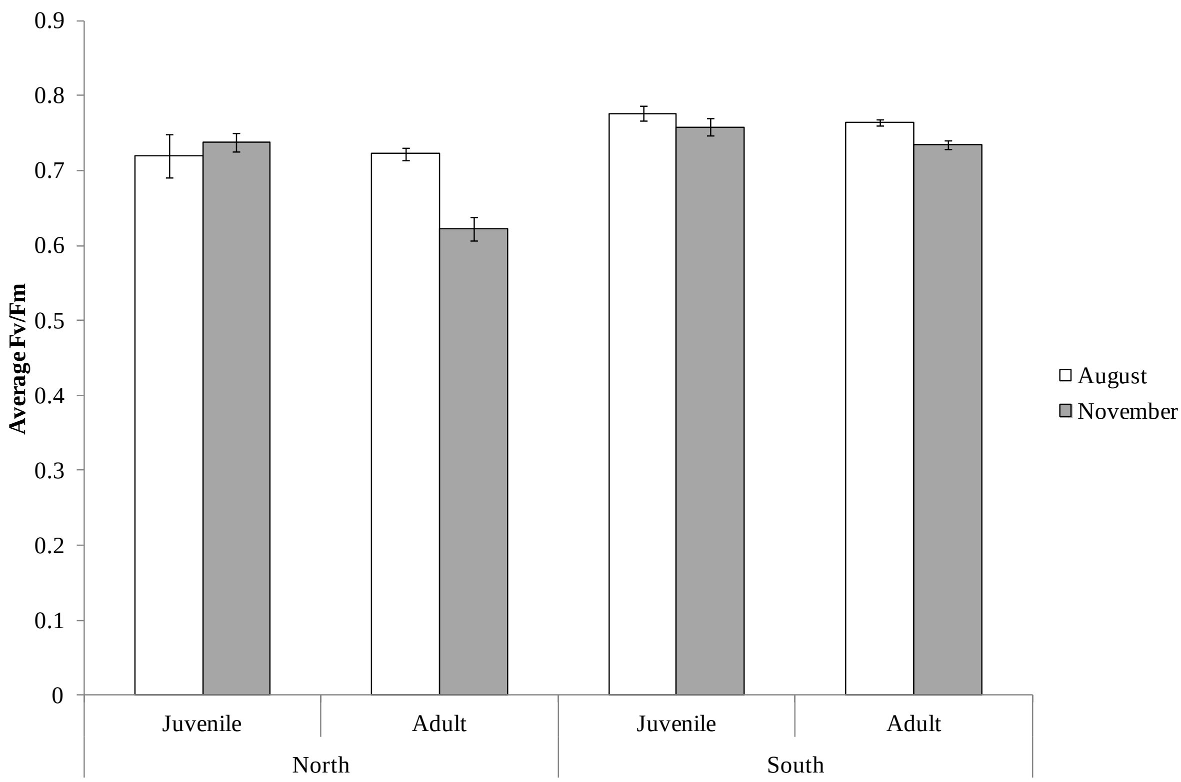


Figure 3.1.1a. Average Fv/Fm measurements of adult plants (*n* = 66-84 plants) and juveniles (*n* = 6 plants) in the natural population during two periods in 2019.

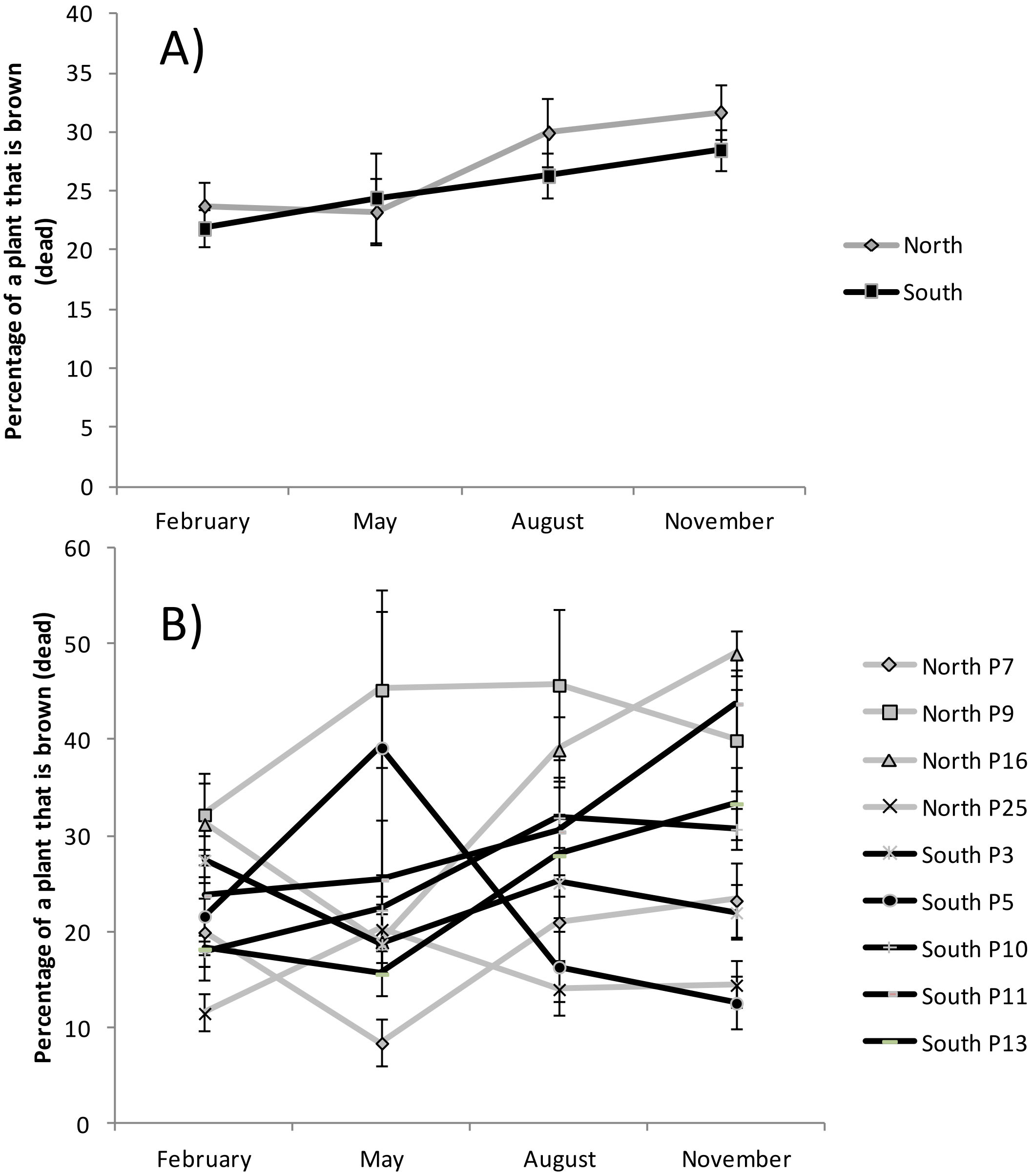


Figure 3.1.1b. Condition (mean ± standard error) of adults plants (n = 20 per plot; Table 2.2.1a) in the natural population, as measured by the proportion of an adult plant that is brown (i.e. newly dead plant tissue less than six months is a rich brown, not faded grey/white) over time (February – November 2019). A) overall plant condition averages (% plant brown) for the northern or southern side and B) average condition of plants within each individual plot, on the northern or southern side.

The peak condition of monitored plants (i.e. majority of the plant was green) occurred mainly during May in 2018 (see Elliott *et al*. 2019), but in 2019 there was no apparent peak overall, as plant condition showed a steady and stable decline in health from summer to summer (Figure 3.1.1b.a). Unlike 2019, plants on the northern side had similar plant condition (or slightly poorer), in comparison to plants on the southern side (Figure 3.1.1b.a). However, each individual plot responded differently to 2019 conditions (Figure 3.1.1b.b), with some plots showing peak conditioning in May (e.g. P7) and other worse conditioning in May (e.g. P9), and no discernible pattern between either side of the ridge. Plot 9 is located within an island of native vegetation, surrounded by mining activities, and had the worst condition in 2018 as well (Elliott *et al*. 2019). Ongoing monitoring of these plots during this time (winter) will determine if this is an ongoing pattern that requires further investigation into plant health and function.

Future research:
To understand plant function at different ages, plants will need to be propagated from seed and grown to seedling, juvenile and adult plant stages. The source material will be generated from seed experiments outlined in Program 1. Germinated seeds will be propagated into large pots and grown to different stages over two years. At each growth stage, a subset of plants (8-16 samples/treatment) will be used to understand drought-response, gas exchange (photosynthesis, transpiration and stomatal conductance) and chlorophyll fluorescence. Plant function and condition of those tagged in the natural population will continue to be monitored to determine the magnitude of variation in their responses to seasonal changes.

3.1.2 Assess the impact of spatiotemporal variation in the environment (years, seasons, sites, habitat characteristics) on plant function

Current research outcomes:
- Stomatal conductance varied among seasons and between aspects, most likely driven by soil water availability and temperature/site exposure.
- *Tetratheca erubescens* plants on NE-facing aspects have consistently lower performance during autumn, winter and spring, but slightly elevated responses during summer than plants on SW-facing aspects.
- Leaf temperatures were higher in NE-facing sites indicating hotter site temperatures.
- Chlorophyll fluorescence declined between spring and summer periods and recovered between autumn and winter periods. Further corroborating stomatal conductance and leaf temperature measurements, NE-facing sites are generally showing lower Fv/Fm ratios suggesting an increased stress risk to environmental conditions.

Methods and Results
Previous ecophysiological assessments were quantified using a LI-COR 6400XT gas exchange system. While providing high quality data, measurements were constrained by the mobility of device, accessibility to plants on rocky locations and measurement durations. As an alternative to the LI-COR 6400XT, porometer measurements (SC-1 Leaf Porometer, Decagon Devices Inc. Pullman) were conducted to increase the sample size and the spatial resolution of plants measured across sites. While only providing measurements for stomatal conductance and leaf temperature, the porometer is more mobile across the landscape and measurements are more rapid, thus increasing the sample size. Measurements were conducted in four natural *T. erubescens* populations (NE Plots: 7 and 25; SW Plots: 3 and 5) in spring, summer, autumn and winter seasons in 2018 and 2019 on 8-12 adult *T. erubescens* plants per plot (*n* =16-24 plants per NE and SW aspect) on green new/fully developed phyllodes. All measurements were conducted in the morning between 0700-

1130am. Leaf temperature was quantified simultaneously with stomatal conductance measurements to determine how effective plants were regulating their stomata relative to the environment. Chlorophyll fluorescence was measured after dark adapting the same leaf for 10 minutes. These measurements were conducted on 4-6 *Banksia arborea* and *Eremophila decipiens* plants per plot (*n* = 8-12 plants per NE and SW aspect) that co-occur with *T. erubescens*, to quantify environmental variation on a species-level across natural populations. In total, nine measurement blocks have been completed since summer, 2017.

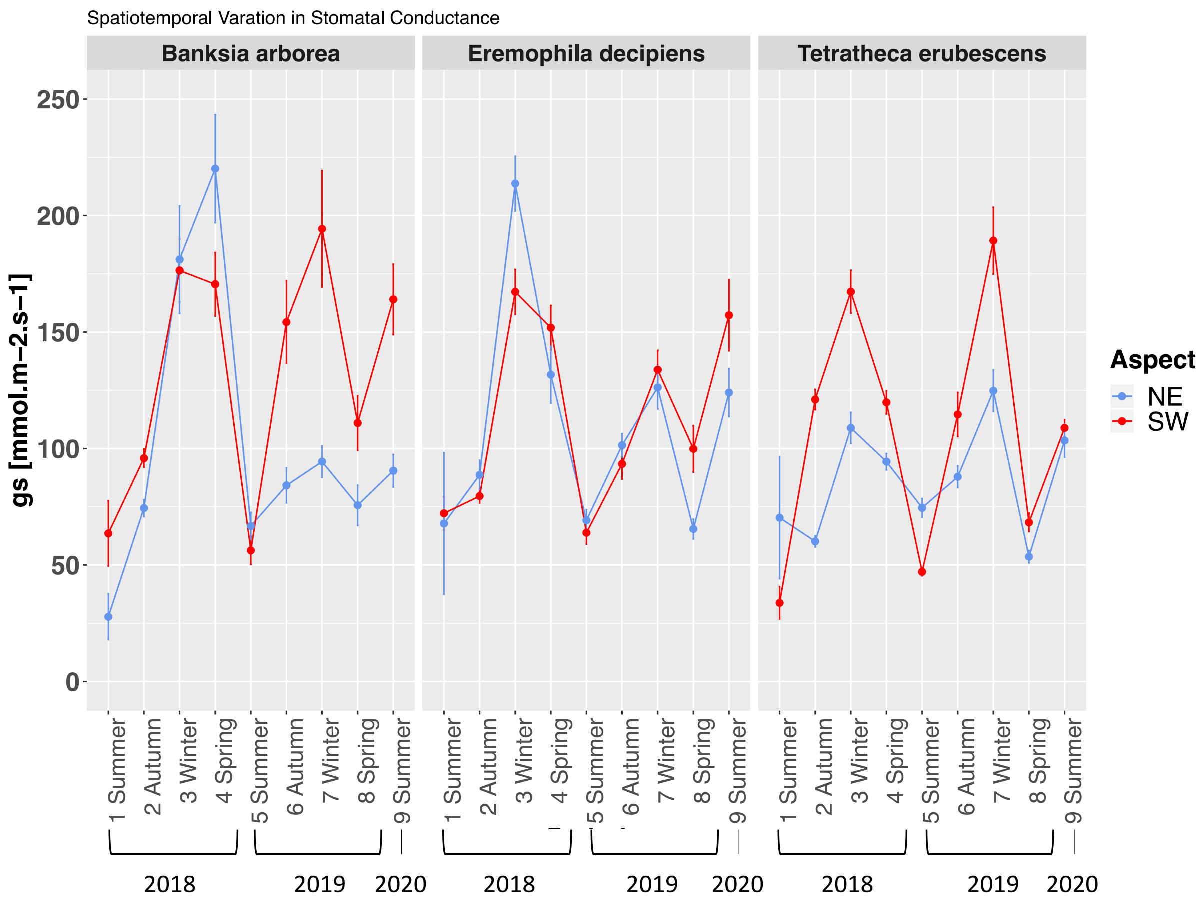


Figure 3.1.2a. Stomatal conductance (mean ± standard error) of *Tetratheca erubescens* (*n* = 16-24) and two common BIF species (*Banksia arborea* and *Eremophila decipiens*; *n* = 8-12) in NE-facing sites (P7 and P25) and SW-facing sites (P3 and P5).

There was seasonal variation in stomatal conductance between NE- (P7 and P25) and SW-facing (P3 and P5) sites (Figure 3.1.2a). As demonstrated by winter measurements that were always characterised by highest plant performance, and summer characterised by lowest plant performance (with exception to the summer period of 2020 as measurements coincided with >50 mm rainfall event). For T. *erubescens,* there was much lower stomatal conductance in NE-facing sites compared to SW-facing sites. Compared to the other two species, measurements in 2019 for *T. erubescens* were consistent with measurements from 2018. Both *Banksia arborea* and *Eremophila decipiens* demonstrated higher performance values in 2018 compared to 2019. This response is likely a result of lower rainfall observed in 2019 (see Figure 2.1.3b). For *T. erubescens,* despite the SW-facing sites having higher stomatal conductance responses across autumn, winter and spring seasons, both summer 2018 and 2019 measurement points were lower than NE-facing sites. The summer measurements in 2020 demonstrated much higher responses, due to greater plant available water in the BIF substrate, due to rainfall during the measurement period. For all species there were increases in stomatal conductance compared to the previous spring measurement.

Leaf temperatures were consistently higher for all species in NE-plots than in SW-plots (Figure 3.1.2b). Higher leaf temperatures were matched by lower stomatal conductance – indicating summer to be periods of decreased water-use and ecophysiological function for all species. For all species, leaf temperatures in spring 2019 were similar to leaf temperatures measured in the previous two summer periods, indicating a hot and dry spring period in 2019, had elicited a summer response in plants. These conditions are likely contributing to the decreased stomatal conductance measurements reported in spring 2019 (Figure 3.1.2a).

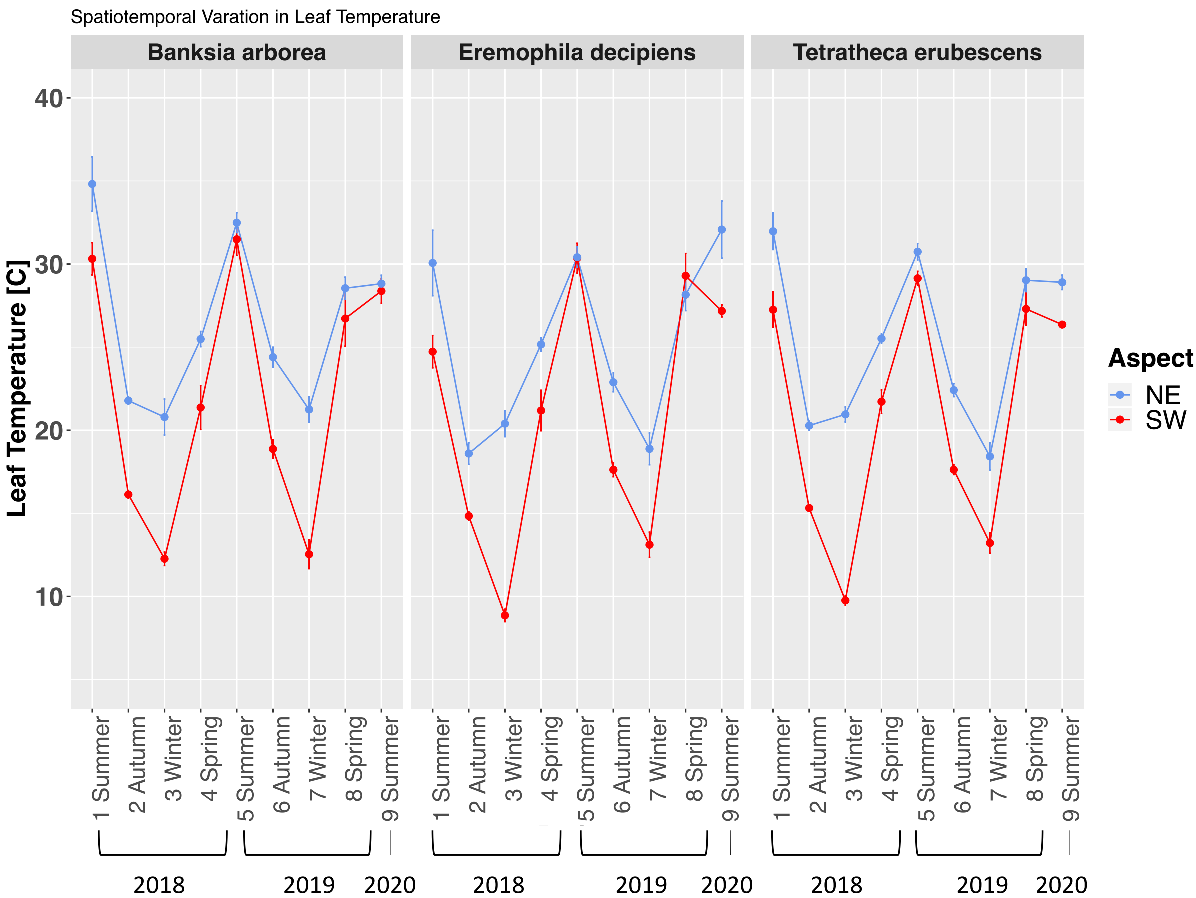


Figure 3.1.2b. Leaf temperatures (mean ± standard error) of *Tetratheca erubescens* (*n* = 16-24) and two common BIF species (*Banksia arborea* and *Eremophila decipiens*; *n* = 8-12) in NE-facing sites (P7 and P25) and SW-facing (P3 and P5) sites.

Chlorophyll fluorescence generally declined between spring and summer periods, with recovery observed between autumn and winter. For all species, lower chlorophyll fluorescence coincided with higher leaf temperatures in NE-facing plots (Figure 3.1.2c). Further corroborating the low stomatal conductance and high leaf temperatures measures during summer, low chlorophyll fluorescence values during summer indicate declines in stem health. The increased chlorophyll fluorescence measurements in summer 2020, demonstrate recovery following the spring 2019 senescence.

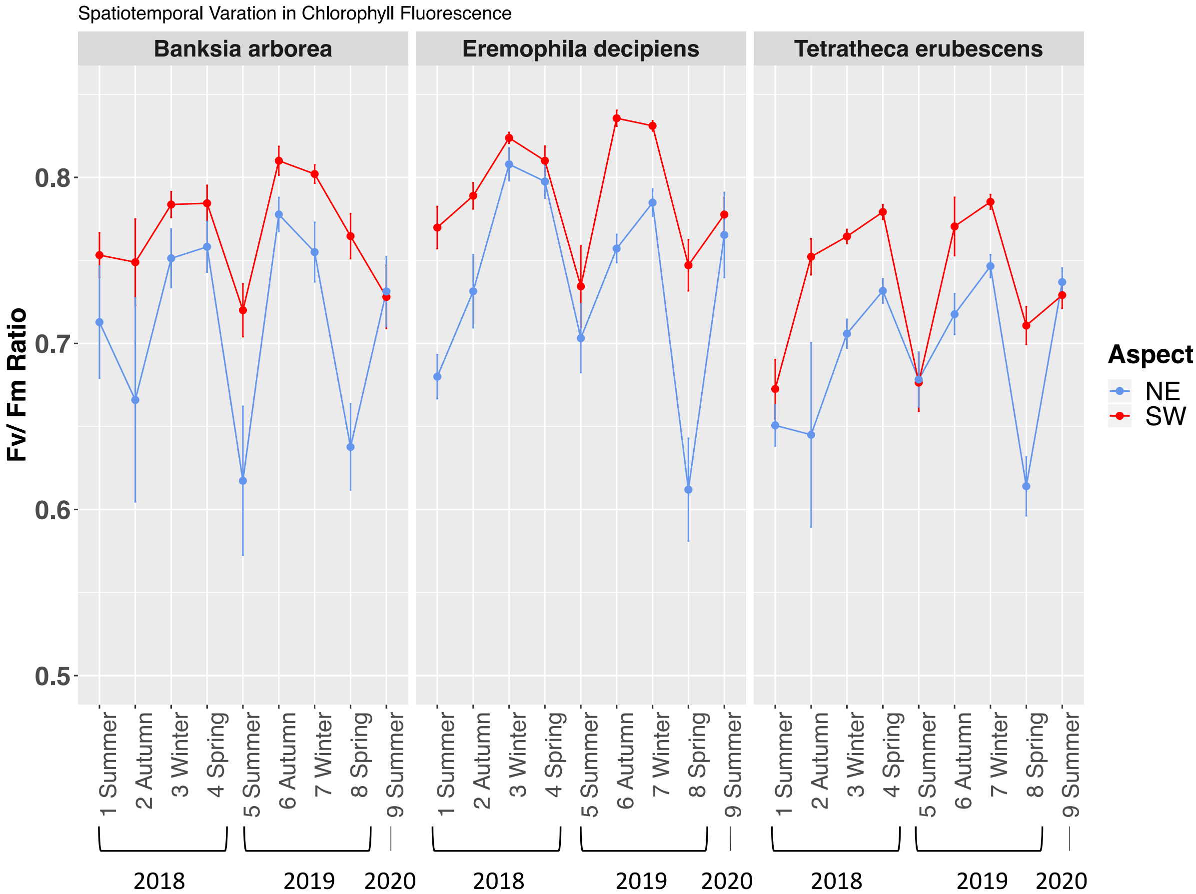


Figure 3.1.2c. Chlorophyll fluorescence (mean ± standard error) of *Tetratheca erubescens* (*n* = 16-24) and two common BIF species (*Banksia arborea* and *Eremophila decipiens*, *n* = 8-12) in NE-facing sites (P7 and P25) and SW-facing (P3 and P5) sites.

Applications

- The data demonstrate seasonal changes in plant performance between summer and winter periods – these conform to the active plant growth and senescence cycles (reported in Section 2.2).
- The common species, *B. arborea* and *E. decipiens*, demonstrate similar patterns, with reduced plant performance observed during summer. The ridge aspect showed strongest variation, with NE-facing sites generally more exposed to direct sun-light and thus hotter leaf temperatures, lower stomatal conductance and chlorophyll fluorescence compared to the shaded SW-facing sites.
- In summary, plants (*T. erubescens, B. arborea* and *E. decipiens*) growing in NE-facing sites appeared functionally more stressed. This may have implications for future translocation designs, as NE-facing sites may expose cuttings to greater environmental stress.

- The rainfall that coincided with the measurements in summer 2020 increased soil water availability, which increased plant performance across both NE- and SW-facing aspects.

Future research:
Ongoing measurements will occur over the next year to quantify spatiotemporal variation for plants of *Tetratheca erubescens* (and the two common species) to confirm that plant function is responding differently than other more common species in the same habitat, during the same season.

3.1.3 Identify the ecophysiological strategies employed by plants that enable them to survive and grow in rock fissures in a semi-arid environment

Current research outcomes:
- Rock strata contain potential pockets of accessible moisture for roots (as outlined in Elliott et al 2019).

Ongoing analysis of the materials collected for this objective is required before an identification of the ecophysiological strategies employed by plants on banded ironstone ranges can be reasonable made. Additional sampling may be required to improve the resolution of the analysis, should the opportunity occur to collect more samples.

3.1.4 Develop understanding of the environmental factors that underpin variation in plant function

Investigations in Sections 3.1.1 and 3.1.2 are currently in progress and will contribute towards underpinning variation in plant function. Kings Park Science will report findings following the 2020 data collection. Current investigations for environmental factors include leaf temperature, ambient temperature, soil temperature, evaporation, rainfall and aspect.

3.1.5 Compare plant function (chlorophyll fluorometry, leaf gas exchange, and plant water status) of plants growing in natural and translocated sites.

Current research outcomes:
- There is variation in plant performance between natural and translocation sites, and populations in planted facing northeast and southwest aspects.
- As cuttings establish over time, they perform similarly to plants in natural reference sites.
- Lowest performance indicators are measured from more recent translocation trials, as populations are experiencing highest mortality rates.

Natural vs translocation performance
Ecophysiological assessments were conducted on cuttings that were planted in 2017, 2018 and 2019 translocation trials with the aim to compare plant function from establishing plants

with plants in natural sites. Measurements were quantified in winter and spring in 2019, and during summer in 2020, using the same approach as outlined in Section 3.1.2.

There is a seasonal trend in plant performance from plants in natural reference sites in translocation sites, with winter measurements demonstrating increased stomatal conductance than spring measurements. Given the rainfall in summer that coincided with ecophysiological assessments, there were elevated stomatal conductance responses from cuttings in SW-facing translocation site that were consistent with measurements from plants in natural reference sites. This pattern, however, was not matched by plants in NE-facing aspects, with only elevated responses in stomatal conductance observed in natural sites. These low responses are corroborated by increased leaf temperature measurements observed in the NE-facing translocation site compared to natural reference sites.

Chlorophyll fluorescence measurements were decreased in both translocation sites (NE- and SW-facing aspects) in contrast to natural reference sites. The decreased fluorescence was matched by higher mortality rates measured during spring and summer periods.

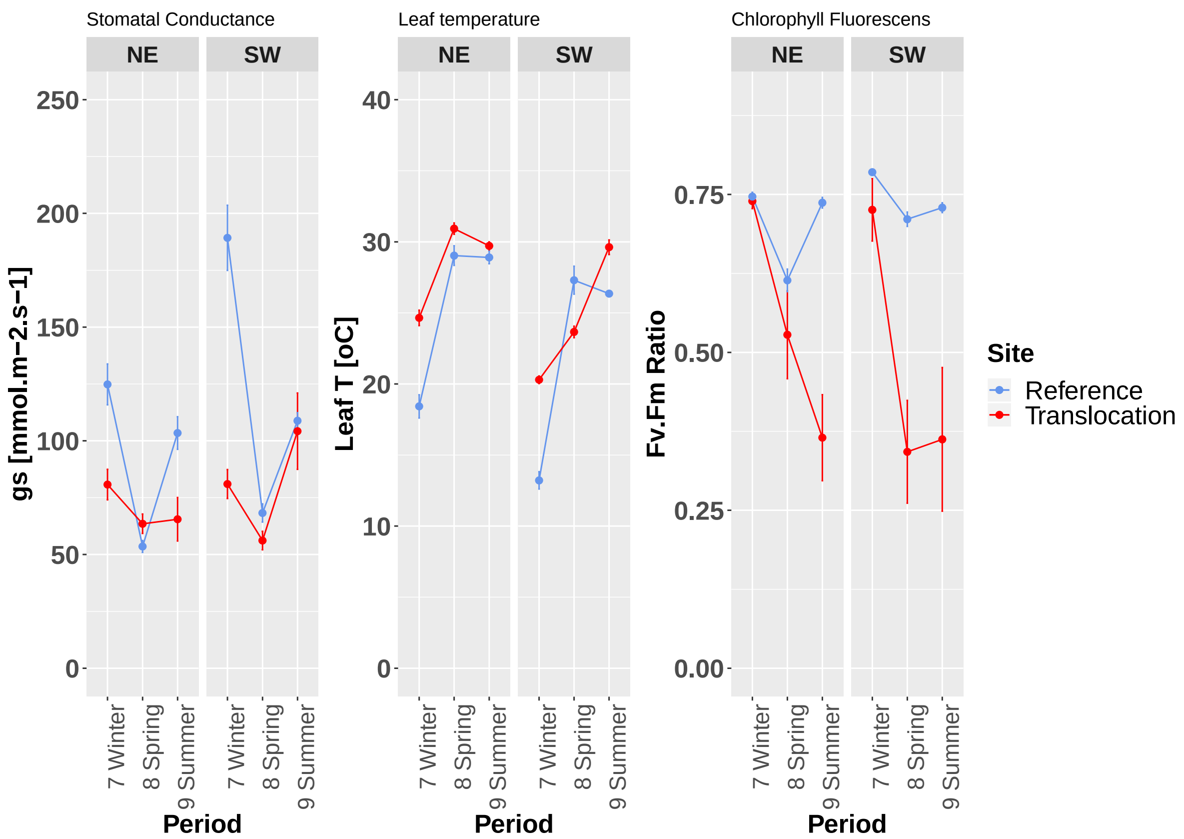


Figure 3.1.5a. Ecophysiological performance of *Tetratheca erubescens* in natural (reference) sites (adult plants) and translocation sites (tubestock). The performance from cuttings was averaged across 2017, 2018 and 2019 translocation trial years (mean ± standard error). The northeast (NE) aspect are natural reference plots P7 and P25, and translocation site T23; and southwest (SW) aspect are natural reference plots P3 and P5 and translocation site T6. The measurements blocks coincide with winter and spring in 2019, and summer in 2020.

Performance of cuttings planted in 2017, 2018 and 2019 trials

When comparing between different ages of cutting establishment, stomatal conductance responses from the more recent translocation trial in 2019 were consistently the lowest, which was matched by increased leaf temperatures and decreased chlorophyll fluorescence (see Figure 3.1.5b). These measurements indicate decreased plant-function of recently planted greenstock compared to older greenstock from previous translocation trials. A possible explanation for this is that greenstock from 2017 and 2018 trials have established through their first summer and likely developed more extensive or mature root systems in the BIF-substrate. As greenstock establish, their performance becomes more similar to adult plants in natural reference sites (compare 2017 greenstock with reference values in Figure 3.1.5a).

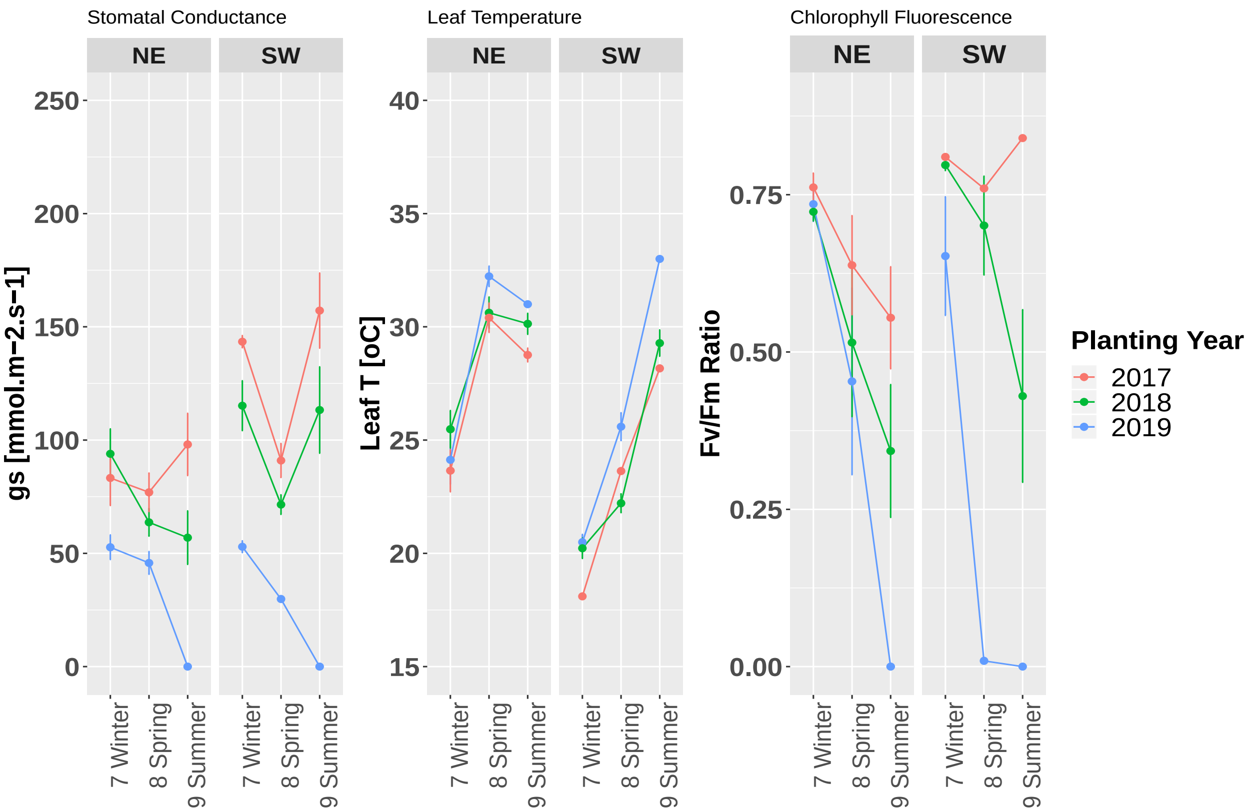


Figure 3.1.5b. Ecophysiological performance of greenstock that were planted in 2017 (red), 2018 (green) and 2019 (blue). The northeast (NE) and southwest (SW) aspects are translocation sites T23 and T6, respectively. The measurements blocks coincide with winter and spring in 2019, and summer in 2020.

3.2 *Soil - nutrient acquisition interactions*

3.2.1 Assess the chemical and physical properties of soils from within natural *T. erubescens* populations.

Current research outcomes:

- Initial assessment of soil chemical and physical composition analyses show similar physical structure, but dissimilar chemical composition among locations.
- Ridge top soils were generally associated with higher calcium (Ca) and magnesium (Mg) cations and nutrients, while BIF soils sampled underneath and adjacent to *T. erubescens* plants were associated with higher iron (Fe) and boron (B) concentrations.
- Investigations are based on low resolution of samples (see Table 3.2.1a), and thus only present limited assessments of underlying soil chemical and physical composition.

Soils were collected within Stage 1 (SE) of the proposed disturbance area in July 2017, from soil depths of 5-30 mm. Further collections were made in October 2017 to increase the soil volume for analysis. The samples were sent to SESL Australia for a comprehensive soil chemical and physical analysis and returned to Kings Park Science for reporting. Table 3.2.1a summarises the total number of samples taken from each site for chemical and physical analysis.

The samples were separated analysed based on the niche of the sampling site, which were broadly categorised as BIF (locations 1 and 4) where *T. erubescens* occurs, slope (Locations 2 and 3) or ridge (location 5). Samples from BIF substrates were furthermore sub-categorised based on whether the sample was located from underneath a *T. erubescens* plant (sample in Location 1), or from adjacent surrounding BIF substrates. All substrates were bulked based on the location in order to satisfy the minimum sampling threshold for chemical and physical analyses, hence replication within the BIF, slope and ridge niche sites were low (n = 2). The reason for the low replication was overall related to the shallow and limited soil available within locations.

Table 3.2.1a. Summary of the total number of soil samples collected for chemical and physical analysis, and biological function (see Section 3.3 Elliott *et al*. 2019). All analyses were analysed by SESL Australia and results sent to Kings Park Science for reporting.

Site	Latitude	Longitude	Soil Analysis	Location No.	Niche	No. of samples
Stage 1 (SE)	-30.87244	119.60728	Chemical and physical	1	BIF	26
				2	Slope	1
				3	Slope	1
				4	BIF	1
			Biological	1	BIF	39
				2	Slope	2
				3	Slope	2
				4	BIF	2
Top of the ridge W-NW of Stage 1	-30.87313	119.60601	Chemical and physical	5	Ridge Top	5
			Biological	5	Ridge Top	10
Top of ridge W of Stage 1	-30.87656	119.60139	Biological	5	Ridge Top	9

Insights from the analysis

- Principal component analysis (PCA) was used on soil chemical data to determine which variables contributed significant variation in the data set. Physical properties (see Table 3.2.1b in Elliott *et al*. 2019) generally were homogenous across samples and thus were not considered for these analyses.
- Dimensions 1 and 2 from the PCA-results explained 47 and 18% of the variation from the soil chemical data, with plant available nutrients such as Ca, Mg, Fe and Mn, soil conductivity variables and exchangeable cations contributing to this variation (see Figure 3.2.1a).
- All soils sampled from the different locations were generally considered infertile and acidic (see Table 3.2.1b in Elliott *et al*. 2019) and associated with higher Al, H, Na, NO_3, Mn and Fe (Figure 3.2.1a).
- The P-levels overall appear to be poor across all soils (Figure 3.2.1a), however, slope and ridge top soils were generally lowest in P concentrations, while higher levels were measured from BIF-soils underneath and adjacent to *T. erubescens* plants (see Table 3.2.1b in Elliott *et al*. 2019).
- Soils sampled from directly underneath *T. erubescens* were more associated with increased levels of Fe and B, than soils from adjacent locations on the BIF near *T. erubescens* plants (Figure 3.2.1a).
- The investigations are based on low resolution of samples (see Table 3.2.1a), and thus only present limited investigations of the underlying soil chemical and physical composition.

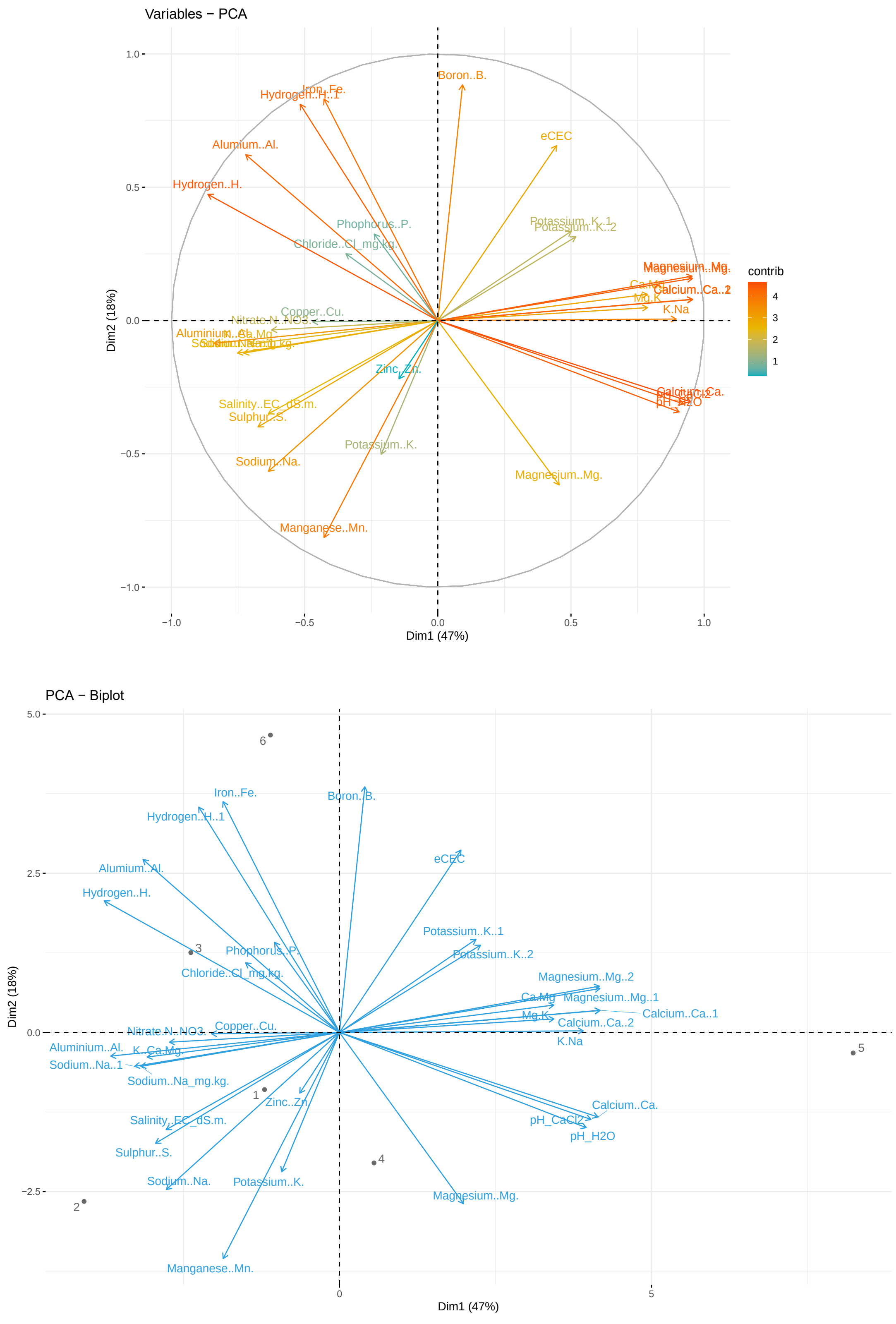


Figure 3.2.1a PCA - variables (top chart) including relative contribution (%) of soil chemical variables and PCA – biplot (bottom chart) of soil chemical variables and soil samples are numbered as follows: 1 and 4 - BIF locations containing *T. erubescens* plants; 2 and 3 - slope sites without *T. erubescens* present; 5 - ridge top site without *T. erubescens* present; and 6 – soils sampled from underneath *T. erubescens* in location 1.

3.2.2 Develop understanding of the importance of varying soil properties on plant survival and growth

Current research outcomes:

- Lower total N, P, K and Ca composition in leaves of *T. erubescens* and *B. arborea* compared to other species.
- Based on the sampling, there was separation of species sampled from the ridge top and slope locations, with BIF classified as overlapping due to sharing similar leaf tissue composition traits with both the ridge top and slope locations.
- Investigations are based on low resolution of samples (see Table 3.2.2a), and thus only present limited assessments of underlying plant leaf tissue composition.

Leaf material was collected from six species that were located within Stage 1 and a further seven species located near the west-northwest corner of the Stage 1 site in July 2017. A further collection was made to supplement the original material (Stage 1 sites only). To avoid oversampling *Tetratheca erubescens*, *Beyeria rostellata*, *Lepidosperma ferricola* and *Stenanthemum newbeyi* plants, small samples were taken from each plant to meet the minimum criteria for leaf tissue analysis and therefore, were bulked into one sample for each location. After collection, all leaf tissue samples were sent to SESL Australia for a comprehensive plant leaf tissue analysis and returned to Kings Park Science for reporting. Table 3.2.2a summarises the total number of plant samples taken from each site for analysis. The reason for the low replication was overall related to the amount of material permitted to collect from plant species within locations.

Table 3.2.2a. Summary of the total number of leaf samples collected for nutrient and stem isotope analysis for each species. Leaf tissue samples were sent to SESL Australia for a comprehensive chemical analysis and returned to Kings Park Science for reporting.

Site	Latitude	Longitude	Species	Niche	Sample Location No.	No. of samples
Stage 1 (SE)	-30.87244	119.60728	*Tetratheca erubescens*	BIF	1 and 4	31
			Banksia arborea	BIF and Slope	1 and 4	13
			Eremophila decipiens	BIF and Slope	1-4	12
			Dodonaea inaequifolia	BIF and Slope	1-4	11
			Ptilotus obovatus	BIF and Slope	1-4	15
			Acacia acuminata	BIF and Slope	1-4	10
Top of the ridge next to Stage 1	-30.87313	119.60601	*Banksia arborea*	Ridge Top	5	5
			Eremophila decipiens	Ridge Top	5	5
			Dodonaea inaequifolia	Ridge Top	5	5
			Acacia acuminata	Ridge Top	5	5
			Beyeria rostellata	Ridge Top	5	6
			Stenanthemum newbeyi	Ridge Top	5	5
			Lepidosperma ferricola	Ridge Top	5	5

Insights from the analysis

- Principal component analysis (PCA) demonstrated low explanatory power on the first (23.3%) and second dimensions (16.5%), which was a result of low replication within the sampling location. Despite this limitation, the findings demonstrate differences of leaf tissue analyses to be largely driven by total N, P, K, Fe and Ca (Figure 3.2.2a). These variables are associated with species such as *P. obovatus*, *D. inaequifolia*, *E. decipiens* and *A. acuminata* that are more broadly distributed across BIF, slope and ridge top sites, compared to the restricted *T. erubescens* (only found on BIF), and *B. rostellata*, *L. ferricola* and *S. newbeyi* (ridge top species).
- Despite *B. arborea* sharing a wider distribution across the different locations, its frequency of occurrence is comparatively low, and generally associated with rockier substrate.
- *Ptilotus obovatus* strongly separated from the other species, which was explained by increased Fe-levels compared to the other species (Figure 3.2.2a and 3.2.2b; see Table 3.2.1b in Elliott *et al.* 2019).
- Out of all species, *T. erubescens* (individuals 6 and 22 in bi-plot), *B. arborea* (individuals 2, 8, 13, 18 and 24 in bi-plot) and *L. ferricola* (individual 28 in biplot) did not group with other species in the PCA - analyses (Figures 3.2.2a and 3.2.2b). There were weak associations found with elemental ratios (see Figure 3.2.2a), however the mechanism and association with these elemental ratios is unknown for these species.
- Overall, there was no separation between leaf tissue composition results between sites with and without *T. erubescens,* however, there was a separation between ridge top and slope locations, with the BIF location overlapping both in the middle, grouping both with the ridge top and slope locations based on leaf tissue composition of species (Figure 3.2.2b).

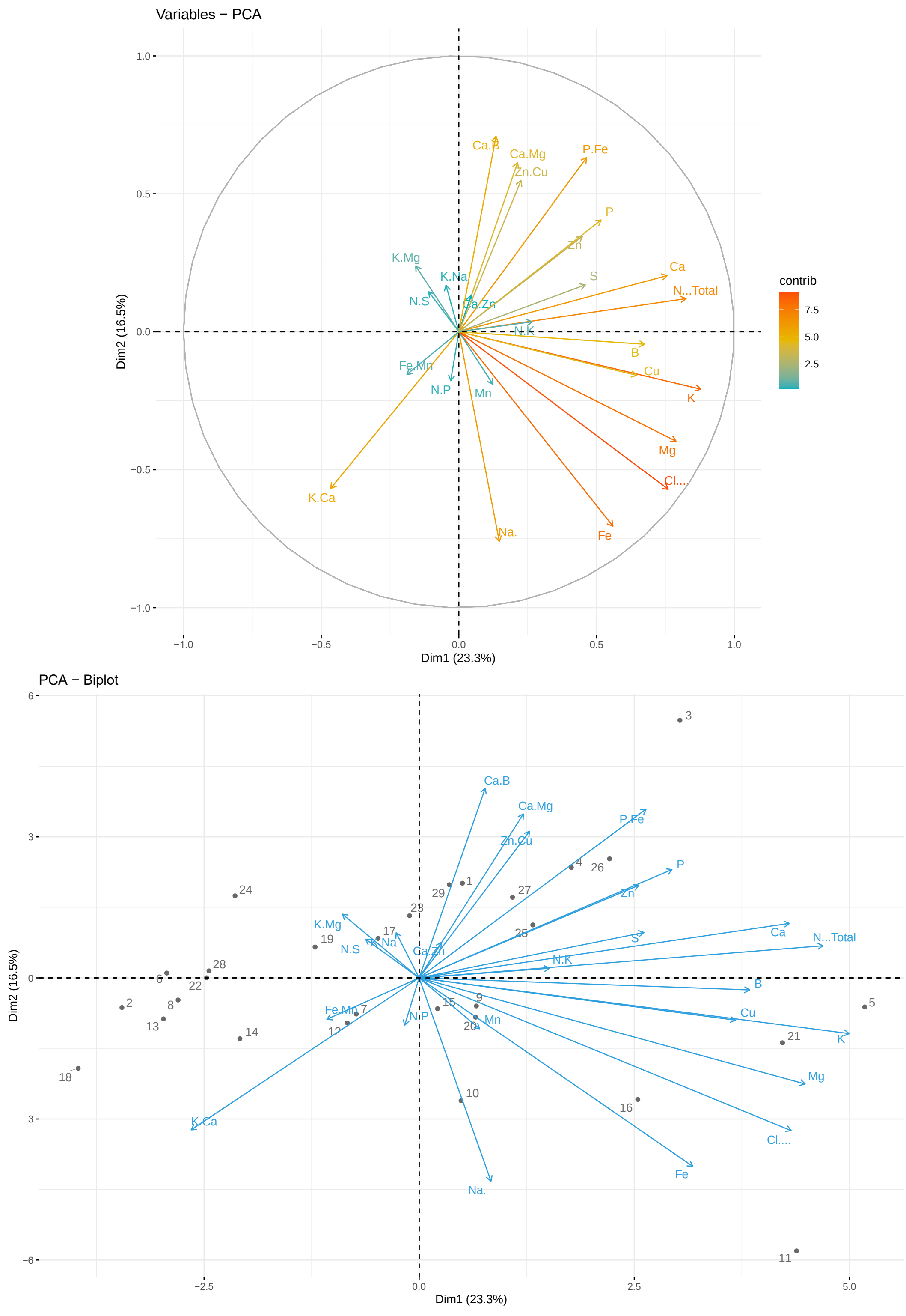


Figure 3.2.2a PCA-results including relative contribution % of variables (top) and PCA-biplot of variables and species individuals (bottom) from leaf tissue analyses of eight ridge species – *Acacia acuminata* (individuals 1, 7, 12, 17 and 23), *Banksia arborea* (individuals 2, 8, 13, 18 and 24), *Beyeria rostellata* (individual 25), *Dodonaea inaequifolia* (individuals 3, 9, 14, 19 and 26), *Eremophila decipiens* (individuals 4, 10, 15, 20 and 27), *Lepidosperma ferricola* (individual 28), *Ptilotus obovatus* (individuals 5, 11, 16 and 21) and *Stenanthemum newbeyi* (individual 29) occurring on sites with *Tetratheca erubescens* (individuals 6 and 22) present and absent.

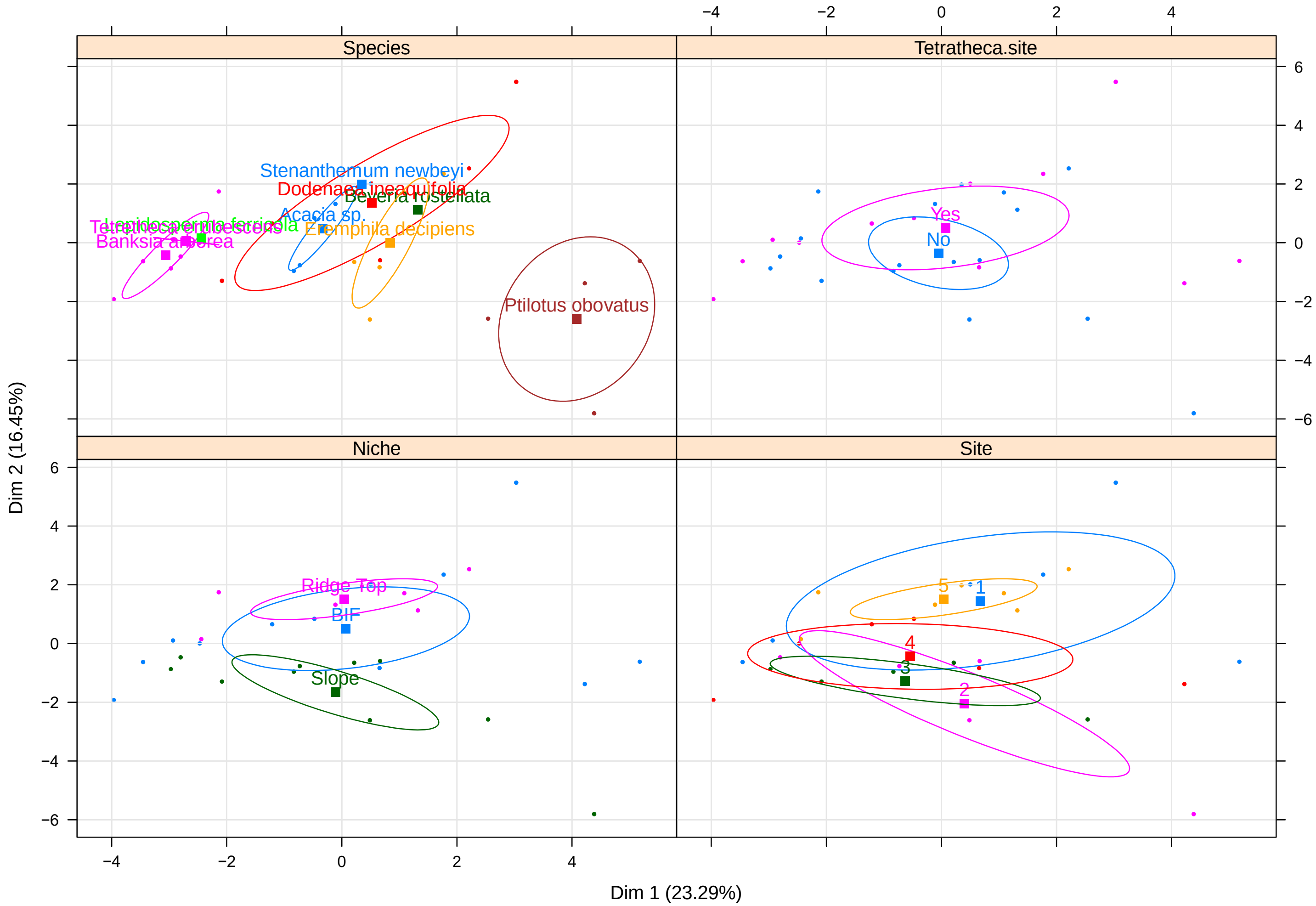


Figure 3.2.2b PCA-results of individuals (including 95% ellipses around the centroid) grouped by: species (top left; *Acacia acuminata*, *Banksia arborea*, *Beyeria rostellata*, *Dodonaea inaequifolia*, *Eremophila decipiens*, *Lepidosperma ferricola*, *Stenanthemum newbeyi*, *Ptilotus obovatus* and *Tetratheca erubescens*); presence or absence of *Tetratheca* at the site (top right); type of niche habitat location (bottom left; ridge top, BIF, slope); and sample site number (1 and 4: *T. erubescens* present; 2, 3 and 5: *T. erubescens* absent).

3.2.3 Provide data to support soil treatments aiming to improve the establishment and growth of plants in translocated sites.

Research outcomes:

- Soil treatments (as outlined in Elliott et al 2018, 2019), did not show improved establishment due to poor survival rates observed in Summer 2018 or Summer 2019.
- Two types of iron fertilizer were tested as soil treatments (2017 translocation: iron chelate supplement; 2018 translocation: Fetrilon Combi2).
- Details of research are in Annual Research Reports 1 and 2 respectively (Elliott *et al.* 2018; Elliott *et al.* 2019).

3.3 *Soil biological function in natural and translocation sites.*

3.3.1 Assess biological communities of soils where *T. erubescens* grow

Soils were sampled in July 2017 and October 2017 from three locations and have been stored for assessment. Unforeseen circumstances have delayed the timeline for analysis, while an alternate service provider and their requirements for sample submission are confirmed. The continuation of this objective has been delayed and the revised timeline for analysis is Autumn 2021 (see Elliott et al 2019 for details).

3.3.2 Assess the frequency and type of mycorrhizal associations of *T. erubescens*

Soils were sampled in July 2017 and stored for assessment (as described in Elliott *et al*. 2019). The continuation of this objective has been delayed and the revised timeline for analysis is in Spring 2020.

3.3.3 Compare soil biological diversity and function between natural and translocated sites.

Soils have only been collected from natural sites (as described in Elliott *et al*. 2019) and stored for assessment. The collection of soils from translocated sites will occur later in the project as translocations mature (see Table 4 of the Program Schedule).

3.3.4 Provide data to support soil inoculation aiming to improve the establishment and growth of plants in translocated sites.

Research outcomes:

- Initial soil inoculation trials in the 2017 translocation experiment did not support improved establishment and growth of planted cuttings in the different translocation sites.
- Details of research are in Annual Research Report 1 (Elliott *et al.* 2018).

PROGRAM SCHEDULE

Project management schedule

A five-year project is underway, with components varying in start date and period as described in Table 4. Translocation and monitoring, and plant function analysis are proposed for each year, with seed biology concentrated in the first years and soil nutrition and biological function studies both at the start and towards the end – reflecting their focus on initial conditions and on conditions in developing translocated populations.

Table 4 Program schedule.

	2017/18				2018/19				2019/20				2020/21				2021/22			
	W	S	S	A	W	S	S	A	W	S	S	A	W	S	S	A	W	S	S	A
Pr.1 Seed biology																				
1.1 Dormancy and germination																				
test 'best bet' dormancy mode & germination																				
Refine tests: wet/dry cycling																				
temperature and water potential tests																				
1.2 Seed enhancement																				
Priming																				
develop pellet design																				
preliminary pelleting field trials																				
refine pellet design																				
test pelleting in field																				
Pr.2 Translocation and monitoring																				
2.1 Optimising translocation approaches																				
establish initial translocation sites																				
collect seed and propagate material for Y2																				
develop sites for Y2 trial																				
2nd year translocation																				
preliminary pelleting field trials																				
3rd year translocation: test pelleting in field																				
4th year translocation																				
Monitor translocation																				
2.2 Survival, growth and reproduction																				
Demographic survey																				
demographic modelling																				
Pr.3 Plant function, habitat and substrate interactions																				
3.1 Plant function, condition and water use																				
regular plant function monitoring: in natural systems																				
in translocation																				
3.2 Soil - nutrient acquisition interactions																				
collect and analyse soils: in natural sites																				
in translocation																				
3.3 Soil biological function																				
collect materials and undertake molecular analysis: in natural system																				
in translocation																				
mycorrhizal assessment																				

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APPENDIX 1

Items for Stage 1 Offset Plan

Table S1.1. Items from the Stage 1 *Tetratheca erubescens* Offsets Plan August 2017, Cliffs Asia Pacific Iron Ore.

Table 3-9 Stage 1 *Tetratheca erubescens* Offsets Plan implementation schedule.

YEAR	TIMING	ACTION	DELIVERY	PURPOSE/OUTCOME		
2016	November (completed)	Seed collections (soil vacuuming, placement of collection nets beneath plants and bags on developing fruit clusters).	BGPA	Soil-stored seed collection from Stage 1 area approved for mining. For use in research and/or field translocations.		
	November (completed)	Cuttings collections and establishment of greenstock.	BGPA	Potted greenstock for use in field translocations.		
	September – March 2017	Review relevant Tetratheca restoration knowledge.	Cliffs/BGPA	Incorporation learnings into the design of the *Tetratheca erubescens* research program and translocation design.	Completed (2017 report)	
	December – January 2017	Field assessments of potential translocation sites and selection of preferred sites.	BGPA/Cliffs	Assessment and suitability ranking of potential translocation sites.	Completed (2017 report)	
2017	January	Retrieval of seed collection nets and bags and seed cleaning.	BGPA	Seed collections from locations across the geographic range of *Tetratheca erubescens*.	Completed (2017 report)	
	January - February	Seed viability assessments.	BGPA	Determine the seed resource available for 2017 research and translocations.	Completed (2017 report)	
	January - June	Maintenance and potting-on of greenstock.	BGPA and Natural Area Holdings Pty Ltd	Establishment of greenstock into narrow pots suitable for planting out.	Completed (2017 report)	
	March	Detailed design of 2017 field translocations.	BGPA/Cliffs	2017 translocation design.	Completed	
	March - April	Apply treatments to seed.	BGPA	Treated seed of adequate numbers as required by the field translocation design.	Completed (2017 report)	
	May	Prepare tubestock planting niches at translocation sites	Cliffs/BGPA	Adequate numbers of planting niches as per translocation design.	Completed (2017 report)	
	June	Transfer tubestock from NAM Perth to Koolyanobbing and maintain 2-3 weeks for hardening-off.	Cliffs/NAM	Adequate numbers of hardened-off tubestock held on site as per translocation design.		
	July-August	Implementation of 2017 field translocations.	BGPA/Cliffs	Translocations established as per translocation design.	Completed (2018 report)	
	July 2017 – March 2018	Maintenance of 2017 field translocations.	Cliffs/BGPA	Information obtained on the germination, survival and growth of translocated *Tetratheca erubescens*. Supplemental watering treatments applied initially as per 2017 translocation design.	Completed (2018 report)	
	July - August	Molecular analysis of soils within *Tetratheca erubescens* occupied sites.	BGPA	Soil biota characterisation within natural populations.	In progress (Collected only)	Section 3 pp. 64
	September 2017 - March 2018	Research and testing of seed priming and pelleting.	BGPA	Development of techniques for potential application in 2018 translocations.	Complete (2017 report)	
	October - November	Monitoring of 2017 field translocations.	Cliffs/BGPA	Information obtained on the germination, survival and growth of translocated *Tetratheca erubescens*.	Completed (2018 report)	

	October - November	Population demographic survey	BGPA	Obtain annual population demographic information for *Tetratheca erubescens*	Completed (2018 report)	
	October 2017 - January 2018	Seed and cuttings collections.	BGPA	Obtain adequate viable seed and cuttings for 2018 research and translocations.	Completed (2018 report)	
	October 2017 - February 2018	Root rhizosphere soil investigations and *Tetratheca erubescens* tissue analysis.	BGPA	Information on soil characteristics and *Tetratheca erubescens* nutrie acquisition strategies within natural populations.	Completed (2020 report)	Section 3 pp. 56-63
	December 2017 - December 2021	Monitoring of plant physiology and function in natural and restored populations	BGPA/Cliffs	Build a profile of physiological functioning across life stages of *Tetratheca erubescens* and compare with translocated individuals.	In progress (2020 report)	Section 3 pp. 47-55
2018	January 2018 – May 2019	Development and testing of seed priming, coating and pelleting methods.	BGPA/Cliffs	Determine suitable methods and complete laboratory/greenhouse testing.	In progress (2020 report)	Section 1 pp. 12
	February	Review and report results.	Cliffs/BGPA	Report describing results to date and assessing results against succe criteria.	Complete	
	February-March	Consult with technical specialists, OEPA and DBCA regarding results and 2018 research and translocation plans.	Cliffs	Recommendations regarding 2018 program.		
	February - March	Evaluate potential translocation sites for 2018 translocations.	BGPA/Cliffs	Preferred translocation sites for 2018.	Complete	
	February - May	Follow-up research and testing of methods to refine direct seeding and/or greenstock translocation methods.	BGPA/Cliffs	Refined translocation methods available for application in 2018.	Complete (2019 report)	
	March - April	Detailed design of 2018 field translocations.	BGPA/Cliffs	Approved translocation proposal for 2018 translocations.	Complete	
	April-May	Monitoring of 2017 field translocations.	Cliffs/BGPA	Information obtained on the germination, survival and growth of translocated *Tetratheca erubescens*.	Complete (2019 report)	
	April	Annual reporting	Cliffs	Report to OEPA and DBCA on results and progress against plan.		
	May - June	Implementation of 2018 field translocations.	BGPA/Cliffs	Translocations established as per translocation design.	Complete (2019 report)	
	June 2018 – March 2019	Maintenance of 2018 field translocations.	Cliffs/BGPA	Information obtained on the germination, survival and growth of translocated *Tetratheca erubescens*. Supplemental watering treatments applied initially as per 2017 translocation design.	Part complete (2019 report)	
	June - November	Preliminary field testing of pelleting methods.	BGPA	Determine if pelleting is likely to be suitable for field applications.	In progress	Section 1 pp. 12
	October - November	Monitoring of 2017 and 2018 field translocations.	Cliffs/BGPA	Information obtained on the germination, survival and growth of translocated *Tetratheca erubescens*.	Complete (2019 report)	
	October - November	Population demographic survey	BGPA	Obtain annual population demographic information for *Tetratheca erubescens*	Complete (2019 report)	
	October – January 2019	Seed temperature and water potential testing.	BGPA	Information to refine optimal seed pre-treatments.	Complete (2020 report)	Section 1 pp. 8-12
	October – January 2019	Seed and cuttings collections.	BGPA	Obtain seed and cuttings for 2019 translocations.	Complete (2020 report)	Section 2 pp. 21

	October – January 2019	Mycorrhizal assessment of *Tetratheca erubescens* roots	BGPA		Incomplete	Section 3 pp. 64
	December - February 2018	Refine seed pellet design.	BGPA/Cliffs	Pellet design suitable for scaled-up application in 2019 translocations	In progress (2020 report)	Section 1 pp. 12
2019	March - April	Review and report results.	Cliffs (BGPA/CMSR)	Report describing results to date and assessing results against succes criteria.	Complete	
	March - April	If success criteria not yet achieved, consult with OEPA and DBCA, review, revise and extend Stage 1 Offsets Plan. Seek approval of revised Stage 1 Offsets Plan.	Cliffs	Approval of revised Stage 1 Offsets Plan.		
	March - April	Detailed design of 2019 field translocations, including the testing of pelleting.	BGPA/Cliffs	Approved translocation proposal for 2019 translocations.	Complete	
	April - May	Monitoring of 2018 field translocations.	Cliffs/BGPA	Information obtained on the germination, survival and growth of translocated *Tetratheca erubescens*.	Complete (2020 report)	
	April	Annual reporting	Cliffs	Report to OEPA and DBCA on results and progress against plan.		
	May - June	Implementation of 2019 field translocations.	BGPA/Cliffs	Translocations established as per translocation design.	Complete (2020 report)	Section 2 pp. 13-19
	June 2019 – March 2020	Maintenance of 2019 field translocations.	Cliffs/BGPA	Information obtained on the germination, survival and growth of translocated *Tetratheca erubescens*. Supplemental watering treatments applied initially as per 2017 translocation design.	Part complete (2020 report)	Section 2 pp. 13-19
	October - November	Monitoring of 2017, 2018 and 2019 field translocations.	Cliffs/BGPA	Information obtained on the germination, survival and growth of translocated *Tetratheca erubescens*.	Complete (2020 report)	Section 2 pp. 40-43
	October - November	Population demographic survey	BGPA	Obtain annual population demographic information for *Tetratheca erubescens*.	Complete (2020 report)	Section 2 pp. 34-39
2020	March - April	Detailed design of 2020 field translocations.	BGPA/Cliffs	Approved translocation proposal for 2018 translocations.	Incomplete	
	April	Annual reporting	Cliffs	Report to OEPA and DBCA on results and progress against plan.		
	April - May	Monitoring of 2019 field translocations.	Cliffs/BGPA	Information obtained on the germination, survival and growth of translocated *Tetratheca erubescens*.		
	May - June	Implementation of 2020 field translocations.	BGPA/Cliffs	Translocations established as per translocation design.		
	June 2020 – March 2021	Maintenance of 2020 field translocations.	Cliffs/BGPA	Information obtained on the germination, survival and growth of translocated *Tetratheca erubescens*.		
	October 2020 - February 2021	Root rhizosphere soil investigations and *Tetratheca erubescens* tissue analysis.	BGPA	Information on soil characteristics and *Tetratheca erubescens* nutrien acquisition strategies within translocation populations.		
	October – November	Monitoring of 2017, 2018, 2019 and 2020 field translocations.	Cliffs/BGPA	Information obtained on the germination, survival and growth of translocated *Tetratheca erubescens*.		

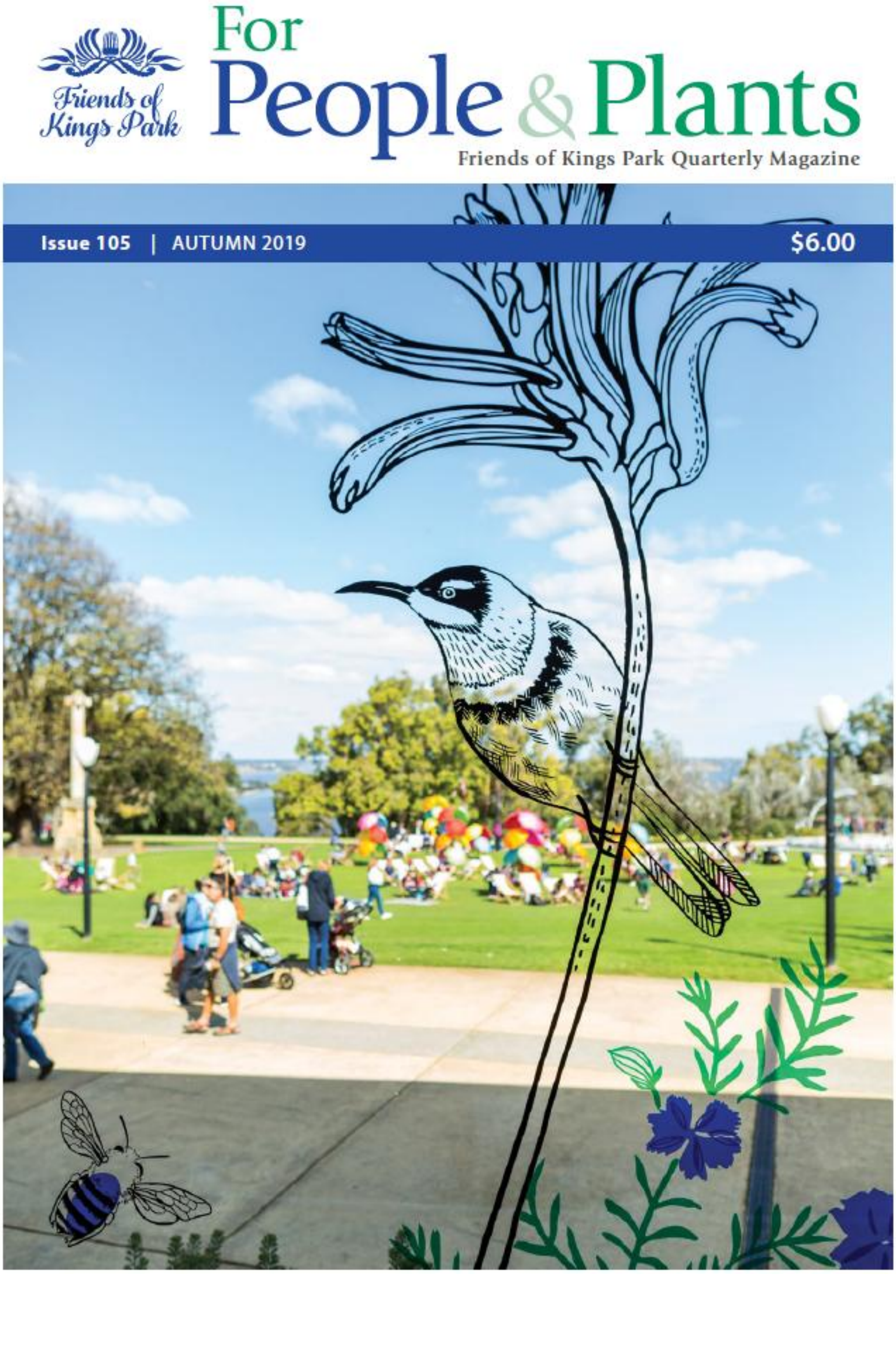
	October - November	Population demographic survey	BGPA	Obtain annual population demographic information for *Tetratheca erubescens*.
2021	April	Annual reporting	Cliffs	Report to OEPA and DBCA on results and progress against plan.
	April - May	Monitoring of 2020 field translocations.	Cliffs/BGPA	Information obtained on the germination, survival and growth of translocated *Tetratheca erubescens*.
	July - August	Molecular analysis of soils within *Tetratheca erubescens* translocation sites.	BGPA	Soil biota characterisation within translocation populations and comparison with the population in natural sites.
	October - November	Monitoring of 2017, 2018, 2019 and 2020 field translocations.	Cliffs/BGPA	Information obtained on the germination, survival and growth of translocated *Tetratheca erubescens*.
	October - November	Population demographic survey	BGPA	Obtain annual population demographic information for *Tetratheca erubescens*.
	November - December	Complete population demographic modelling.	BGPA	Long-term population demographic model for *Tetratheca erubescens*.
2022	April	Prepare and submit a final report providing the results and outcomes of the Stage 1 *Tetratheca erubescens* Offsets Plan.	Cliffs/BGPA	Summary report capturing the results and outcomes of the five-year offsets plan.
	April - May	Undertake a review of the offsets plan in consultation with OEPA and DBCA and prepare and submit a revised offsets plan, if required.	Cliffs	Results of the five-year offsets plan considered in detail and decisions made around the needs and content of a revised offsets plan. A revised offsets plan developed and submitted to OEPA for approval, if required.

APPENDIX 2

Publications, conferences, workshops, requested reports or project publicity associated with the research program.

Table S2.1. Date, type of activity and details of activity that relates to the publicity of the *Tetratheca* research program.

Date	**Activity**	**Details**
March 2019	Publication: in 'For People and Plants'	"Out of rock they emerge: Recruitment of rare *Tetratheca erubescens* from banded ironstone ranges" (pg. 27-29)
March 2019	Workshop: ANPC Threatened Species Translocation Workshop	"Case studies of translocation in the mining sector"
April 219	Presentation: Project update	Update on the status of the *Tetratheca erubescens* project provided to MRL, Strategen Environmental, Species and Communities Branch (DBCA), Environmental Management Branch (DBCA).
August 2019	Short report: Recruitment data	Update on the recruitment status of *Tetratheca erubescens* in translocations and natural population provided to MRL for a meeting with the EPA.
	Short report: Rockfall observations	Report on observations of the immediate physical impact to *Tetratheca erubescens* plants following a rockfall in the natural population, as requested by MRL.
September 2019	Publication: in 'Hort Journal Australia'	"Translocation of a threatened cliff-dwelling species" (pg. 66-17)
September 2019	Conference: Society for Ecological Restoration	"Integrated scientific approaches to rare species restoration: Lessons learnt from Western Australia's Kings Park and Botanic Gardens"
November 2019	Short report: for Goldfields Threatened Species Recovery Team	Update on the monitoring of *Tetratheca erubescens* and *Ricinocarpos brevis* translocations provided to MRL for the Goldfields Threatened Species Recovery Team meeting
February 2020	Short report: Seed biology data	Update on the seed biology of *Tetratheca erubescens* provided to MRL and Strategen-JBS&G


Friends of Kings Park
For People & Plants
Friends of Kings Park Quarterly Magazine
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Out of rock they emerge
Recruitment of rare *Tetratheca erubescens* from banded ironstone ranges

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All Photos by **Wolfgang Lewandrowski**

Seeds play an important role in the conservation and restoration of our unique and biodiverse Western Australian flora. However, for many of our rare and threatened species our knowledge on seed biology and recruitment dynamics pales in comparison to the large number of species that require this type of attention.

For threatened plants, particularly those with highly specific habitat requirements like those on banded ironstone formations (BIF) in arid landscapes, understanding the triggers and environmental envelopes for establishment is integral for their ongoing conservation and management.

Our translocation project in the Yilgarn Craton, has gained insights into the seedling establishment of the threatened *Tetratheca erubescens* (Blushing Tetratheca) through experiments carried out at Kings Park and also in its natural habitat.

Tetratheca erubescens growing on a banded ironstone ridge on the Koolyanobbing range.

Tetratheca erubescens is a cliff dwelling BIF endemic with a global distribution of 3.5ha on a single range (Koolyanobbing Range), approximately 50 km north-east of Southern Cross.

Just how a *Tetratheca* ends up on cliff rock faces is a puzzle. Seeds dispersed from the parent plant find their way into safe sites within the rock – moved either by gravity (pure luck!) or by insects such as ants.

One of the challenges is to understand how seedlings of this fascinating species establish in the cracks or holes in the rock face – the primary habitat of adult *Tetratheca*'s.

Tetratheca erubescens seedling emerging out of a rock crack in a natural population.

Tetratheca erubescens seedling emerging from leaf litter on the ground underneath a *Tetratheca* plant.

Once located in a safe site, the conditions have to be optimal to break dormancy and support germination, growth and establishment. This is truly an unusual niche for recruitment and one that we hope to characterise.

From a previous expedition, (see Elliott et al. *For People and Plants*, Issue 104, pages 26-29), we learnt that BIF outcrops can retain moisture within shallow niches in the rock containing soil for up to three weeks – providing microsites for moisture supporting germination. Three weeks-worth of water seems a relatively long period, when considering the arid climate and unpredictable rainfall in the Coolgardie bioregion.

Few rainfall events rarely occur in close sequence leading to quickly depleting moisture reserves after rainfall, particularly during the hot summer months where average ambient temperatures exceed 35ºC. The rocky substrate furthermore amplifies these conditions, with our data loggers frequently reporting temperatures of up to 67ºC on the rock surface. It is not surprising that summer is likely to be too hostile for successful establishment.

To underpin our knowledge of germination requirements, we conducted rigorous experimentation focussed on characterising the physiological requirements limiting seed germination.

Our research has found that seeds of *T. erubescens* take a long time to germinate – in some cases, up to 10 weeks. One of the major blocks to germination of this species is seed dormancy – with freshly dispersed seeds typically requiring prolonged periods of after-ripening (warm and dry conditions) in the soil seedbank or on the rock face itself. After dormancy release, germination may only occur provided moisture is sufficiently available.

While summer conditions prove to be hostile, we recently observed a flush or *Tetratheca* recruitment after winter 2018 across the natural population. To understand recruitment responses, we surveyed a number of different sites across the range. The locations varied significantly, with a number of seedlings emerging out of the rock – from holes or cracks, rocky slopes and also the ground beneath *Tetratheca* plants.

Tetratheca erubescens seedling emerging from a rock crack in a translocation site.

Tetratheca erubescens seedlings emerging from pre-drilled holes on rock in a translocation site.

Just how long seedlings will survive across these different locations and to what degree other factors such as competition with other plants species will affect establishment, is yet to be determined.

It is not surprising that recruitment favours winter conditions – temperatures are low and moisture from rainfall is retained in the substrate for longer periods. However, winter-recruitment often comes with slower growth rates and seedlings must establish extensive root systems in order to access vital resources.

We also observed our first recruitment event in recently established translocation sites, where we planted seeds into shallow rock cracks or pre-drilled holes.

We hope to gain a deeper understanding of the attrition rates across the different locations after this summer to underpin habitat preferences for survival, in both natural and translocation sites.

These valuable insights into the suitability of sites for germination, growth and establishment will help to fine-tune the necessary requirements for the re-introduction of threatened plant species in BIF habitats to be more successful. ■

Reference

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Botanic Gardens

Translocation of a threatened cliff-dwelling species

By Carole Elliott, Wolfgang Lewandrowski and Jason Stevens

Translocations of threatened plant species are one option for conserving plant species and establishing self-sustainable populations capable of surviving in the longer term (Commander et al., 2018). The challenge of conserving threatened plant species lies at the heart of their breadth of diversity – there is no one solution for all.

Take the case of The Blushing Tetratheca (*Tetratheca erubescens* J.P. Bull) as an example. The species has a global distribution of 3.5 ha and only lives on cliffs that occur on banded ironstone outcrops in the Goldfields region of Western Australia. These plants put their roots down into cracks and fissures on rocky cliffs, in an arid environment where receiving less than 300mm of rain a year is an average expectation.

There are many threats facing this species, such as mining and exploration (direct removal, indirect effects), limited habitat (restricted to steep cliffs), weed invasion, potential predation (foliage and seed), and inappropriate fire regimes. Mining activities in particular, have instigated the need for research into the development of appropriate translocation protocols.

How do you go about translocating a plant species that grows on cliff faces in a water-limiting environment? By understanding the where, how, when and why of the unique, and highly evolved lifestyle of *Tetratheca erubescens*.

A comprehensive and integrated research program addressing this question commenced at Kings Park Science, located at the Western Australia's State Botanic Garden, in 2016 that has involved:

- understanding where the species grows (species habitat modelling),
- finding similar growing areas for the translocation (site selection),
- consideration of provenancing guidelines (genetic structure),
- development of propagation protocols and nursery practices (horticulture),
- preparation, design, installation and ongoing maintenance of the translocation and
- monitoring the translocation against established benchmarks (comparing performance of naturally occurring plants with translocated plants).

As you would expect from a species that enjoys a stunning vista, it is all about location. This species requires an elevated rock substrate, with a specific position that collects water when it rains, like a bowl or deep fissure (Miller, 2015). This type of position was found on cliff faces outside the existing population and holes were drilled directly into the rock. These holes were large enough to fit tubestock that had been grown in biodegradable pots for 6-9 months.

Mature *Tetratheca erubescens* plant located on a cliff face in the natural population at Koolyanobbing Range, Western Australia (Image: Carole Elliott)

Buzz-pollinated flower of *Tetratheca erubescens* (Image: Carole Elliott)

Testing of various treatments is essential for developing successful translocation protocols and for *T. erubescens* this included assessing the results of planting substrate (cliff or scree slope), field soil inoculation in the nursery, supplemental iron-rich fertiliser, irrigation and biodegradable pots. For direct seeding, we tested the effects of irrigation and dormancy alleviation on the emergence and survival of seedlings, whereby seeds were sown into rock cracks or pre-drilled holes.

The buzz-pollination and ant-dispersed seed may have contributed to the species pattern of genetic structure, therefore provenancing guidelines were followed. Provenancing involved strict database curation (collection, propagation, transportation, labelling, translocation) and licensing conditions, which meant that tubestock and seeding locations were mapped with meticulous continuity of records, to ensure source and destination of material was known.

Resolving the horticultural production systems has allowed Kings Park to install three translocation trials on the rocky ridges of Koolyanobbing Range. The early stages indicate that cliff position, seasonal rainfall and access to supplementary water (irrigation) are essential for translocation success of this endemic cliff-dwelling species. We are only half way through our journey and hope to uncover more about this plant to increase its translocation success.

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Translocation location of *Tetratheca erubescens* tubestock that have been planted into a drill hole on the cliff face, as shown by the white tags (Image: Carole Elliott)