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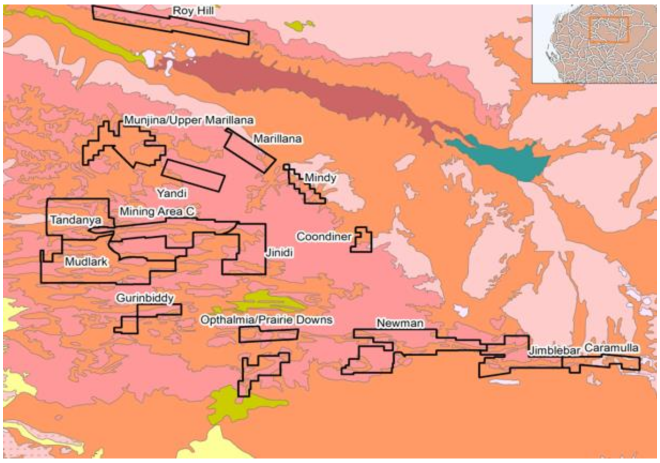


# BHP Pilbara Strategic Proposal

# INPUTS TO REHABILITATION REPORT

**February 2020**

**For BHP**

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# TABLE OF CONTENTS


| | | |
|---|---|---|
| **EXECUTIVE SUMMARY** | | **I** |
| **PART 1 REHABILITATION CONTEXT** | | **1** |
| **1.0** | **INTRODUCTION** | **1** |
| 1.1 | CONTEXT AND PURPOSE | 1 |
| 1.2 | CURRENT STATE OF PLAY | 1 |
| 1.3 | SCOPE OF REPORT | 3 |
| 1.4 | LINKS TO OTHER REHABILITATION REPORTS | 3 |
| **2.0** | **REHABILITATION IN THE PILBARA CONTEXT** | **8** |
| 2.1 | KEY CONCEPTS | 8 |
| 2.2 | REHABILITATION STANDARDS AND EXPECTATIONS | 10 |
| 2.2.1 | International Standards | 10 |
| 2.2.2 | National and State Standards | 11 |
| 2.2.3 | BHP WAIO Current Standards | 12 |
| 2.3 | FACTORS IMPACTING REHABILITATION SUCCESS IN THE PILBARA REGION | 12 |
| 2.3.1 | Macroscale Influences - Rainfall | 12 |
| 2.3.2 | Microscale Interactions – Vegetation Cover and Soil Moisture | 13 |
| 2.3.3 | Implications for Rehabilitation Success | 14 |
| **3.0** | **FINAL LAND USES, REHABILITATION GOAL & CLOSURE OBJECTIVES** | **15** |
| 3.1 | PROPOSED FINAL LAND-USES | 15 |
| 3.1.1 | Natural Environments for Managed Resource Protection (Primary Class 1) | 16 |
| 3.1.2 | Relatively Natural Environments for Pastoral Grazing Purposes (Primary Class 2) | 17 |
| 3.1.3 | Other Uses | 17 |
| 3.2 | REHABILITATION GOAL | 22 |
| 3.3 | CLOSURE OBJECTIVES | 22 |
| **PART 2 DERIVING CRITERIA** | | **23** |
| **4.0** | **APPROACH TO MEASURING SUCCESS** | **23** |
| 4.1 | SELECTION OF APPROPRIATE ATTRIBUTES (FLORISTIC) | 23 |
| 4.2 | TARGET ECOSYSTEMS AND VEGETATION TYPES | 25 |
| 4.2.1 | Ecosystem Types | 25 |
| 4.2.2 | Subregions | 25 |
| 4.2.3 | Vegetation | 26 |
| **5.0** | **INFLUENCE OF SCALE** | **30** |
| 5.1 | SITE SCALE | 30 |
| 5.2 | HUB SCALE | 32 |
| 5.3 | REGIONAL SCALE | 34 |
| 5.4 | VEGETATION TYPE (ECOSYSTEM) SCALE | 35 |
| 5.5 | SUMMARY | 37 |
| **6.0** | **INFLUENCE OF TIME** | **37** |

**7.0 FACTORS INFLUENCING WEED TYPE AND DISTRIBUTION 39**

**8.0 DEVELOPING COMPLETION CRITERIA 42**
8.1 SELECTION OF CRITERIA AND TARGETS 42
8.2 VARIATION IN TARGETS BASED ON FINAL LAND USE 44
8.3 REFINING AND VALIDATING COMPLETION CRITERIA 45

**9.0 DEVELOPING PROGRESSIVE CRITERIA 50**
9.1 AGE CATEGORIES 50
9.2 KEY PRINCIPLES 51
9.3 DERIVING PROGRESSIVE CRITERIA 52
9.3.1 Research Base for Setting Threshold Criteria 52
9.3.2 Statistical Analysis of BHP Rehabilitation Data 53
9.3.3 Summary and Implications for Threshold Criteria 56
9.4 DETERMINING THE TARGETS 56
9.5 PROPOSED TRAJECTORY TARGETS 58

**PART 3 REHABILITATION SUCCESS 59**

**10.0 BRIEF HISTORY OF BHP WAIO REHABILITATION PRACTICES 59**

**11.0 METHODOLOGY FOR ASSESSING REHABILITATION SUCCESS 62**
11.1 SEQUENCE OF ANALYSIS 62
11.2 ASSIGNING TARGET VEGETATION TYPES 62

**12.0 ANALYSIS OF 2011 – 2016 REHABILITATION DATA 64**
12.1 ANALYSIS OF COVER BY HUB & REGION 64
12.2 ASSESSMENT OF HUBS AGAINST COMPLETION CRITERIA 69
12.3 INFLUENCE OF AGE OF REHABILITATION ON REHABILITATION PERFORMANCE 91

**13.0 ANALYSIS OF 2017-2018 REHABILITATION DATA 93**
13.1 OBJECTIVES 93
13.2 LAND STATUS CATEGORIES AND SCALE OF ASSESSMENT 93
13.3 ASSESSMENT OF HUBS AGAINST COMPLETION CRITERIA 96

**14.0 PREDICTING FUTURE REHABILITATION SUCCESS 110**

**REFERENCES 113**

**APPENDICES 117**

# LIST OF TABLES


Table 1. Major hubs and existing operations. 4

Table 2. Summary of Australian Land Use and Management (ALUM) classification (ABARES 2016) and relevance of classes to BHP WAIO closure* 16

Table 3. Current proportion of land tenures within individual hubs and sites. 18

Table 4. Influence of the sampling method on some key assessment metrics. 31

Table 5. Frequency of buffel grass within plots in different landforms (BHP data) 41

Table 6. Completion criteria (attributes, criteria and metrics) 46

Table 7. Targets for individual attributes – Land Use: Natural Environments for Managed Resource Protection. 47

Table 8. Targets for individual attributes – Land Use: Relatively Natural Environments for Pastoral Grazing Purposes. 48

Table 9. Correlations (r values) between *Triodia* cover & selected parameters vs age of rehabilitation. 54

Table 10. Relative abundance correlations (r values) for reference sites. 54

Table 11. Proposed Ecological Trajectory Criteria for Assessing Young & Progressive Rehabilitation. 58

Table 12. Changes in Practices and Evidence of Improved Outcomes. 60

Table 13 Yandi hub historical rehabilitation (2011-2016) - assessment of rehabilitation success. 70

Table 14 . Yandi hub historical rehabilitation (2011-2016) – performance of individual plots for vegetation cover criteria. 71

Table 15. Yandi sites compared against presence/absence of indicator species from each stratum. 72

Table 16. Area C hub historical rehabilitation (2011-2016) - assessment of rehabilitation success. 74

Table 17. Area C hub historical rehabilitation (2011-2016) – performance of individual plots for vegetation cover criteria. 75

Table 18. Yarrie hub historical rehabilitation (2011-2016) - assessment of rehabilitation success. 77

Table 19. Yarrie hub historical rehabilitation(2011-2016) – performance of individual plots for vegetation cover criteria. 78

Table 20 Yarrie sites compared against presence/absence of indicator species from each stratum. 80

Table 21. Goldsworthy hub historical rehabilitation (2011-2016) - assessment of rehabilitation success. 82

Table 22. Goldsworthy hub historical rehabilitation (2011-2016) – performance of individual plots for vegetation cover criteria. 83

Table 23. Jimblebar hub historical rehabilitation (2011-2016) - assessment of rehabilitation success. 86

Table 24. Jimblebar hub historical rehabilitation (2011-2016) – performance of individual plots for vegetation cover criteria. 87

Table 25. Newman hub historical rehabilitation (2011-2016) - assessment of rehabilitation success. 89

Table 26. Newman hub historical rehabilitation (2011-2016) – performance of individual plots for vegetation cover criteria. 90

Table 27. Comparison of individual hubs based on age post rehabilitation - Central Region. 91

Table 28. Comparison of individual hubs based on age post rehabilitation - Northern Region. 92

Table 29. Comparison of individual hubs based on age post rehabilitation - Eastern Region. 92

Table 30. Assessment of Progressive rehabilitation sites at Area C Hub. 97

Table 31. Assessment against Completion Criteria at Yandi Hub. 98

Table 32. Assessment of Young & Progressive rehabilitation sites at Yandi hub. 100

Table 33. Assessment of Young & Progressive rehabilitation sites at Jimblebar Hub. 101

Table 34. Assessment against Completion Criteria at Newman Hub. 102

Table 35. Assessment of Young & Progressive rehabilitation sites at Newman Hub. 104

Table 36. Assessment against Completion Criteria at Goldsworthy. 105

Table 37. Assessment against Completion Criteria at Yarrie. 107

Table 38. Assessment of Young & Progressive rehabilitation sites at Yarrie Hub. 109

Table 39. Comparison of % *Triodia* cover for young sites (<4 years post rehab) at Yarrie Hub. 111

Table 40. BHP current and completed research projects. 112

## LIST OF FIGURES

Figure 1. Mining hubs and existing operations. 5

Figure 2. Strategic Proposal Boundary in relation to IBRA regions and subregions 6

Figure 3. Proposed Mining Operations in the Strategic Proposal. 7

Figure 4. Key concepts. 9

Figure 5. Current land tenure distribution in the Pilbara (Hamersley and Fortescue subregions) (DPIRD 2018). 19

Figure 6. Current land tenure distribution in the Pilbara (Chichester subregion) (DPIRD 2018). 20

Figure 7. BHP current tenure overlaid on lands considered suitable for pastoral grazing (DPIRD 2018) 21

Figure 8. Major vegetation types in the Pilbara (Hamersley and Fortescue subregions) (Beard *et al*, 2013). 28

Figure 9. Major vegetation types in the Pilbara (Chichester subregion) (Beard *et al*, 2013). 29

Figure 10. Comparison of cover of *Triodia*, shrubs and herbs separated by crests, slopes and flats. 32

Figure 11. Comparison of hubs for *Triodia* and shrub cover. 33

Figure 12. Comparison of hubs for native perennial and annual richness. 33

Figure 13. Comparison of geographic regions for *Triodia*, shrub, and herb cover .

Figure 14. Comparison of geographic regions for native perennial and annual species richness. 35
Figure 15. Comparison of *Triodia*, shrub, herb and other grasses cover by major vegetation type. 36
Figure 16. Comparison of native perennial and annual species richness by major vegetation type. 36
Figure 17. Influence of time post rehabilitation on *Triodia* cover in rehabilitation sites using aggregated 2018 data (A) and 2011-2016 data (B). 38
Figure 18. Presence of buffel grass in Pilbara (from aggregated Pilbara database, Webber *et al* 2016). 39
Figure 19. Extent of buffel grass (blue) and probable frequency (average 16% of area) within minor drainage lines in selected central tenements. 40
Figure 20. Weed cover in BHP rehabilitation sites (historic data 2011-2016). 41
Figure 21. The interquartile range (IQR) statistical approach adopted for setting cover targets. 44
Figure 22. Weed cover targets for different final land uses and landforms. 49
Figure 23. Comparison of individual hubs for % cover in reference sites (2011-2016 data). 65
Figure 24. Comparison of individual hubs for % cover in rehabilitated sites (2011-2016 data) for Central Region. 66
Figure 25. Comparison of individual hubs for % cover in rehabilitated sites (2011-2016 data) for Northern Region. 67
Figure 26. Comparison of individual hubs for % cover in rehabilitated sites (2011-2016 data) for Eastern Region. 68
Figure 27. Yandi hub– performance of individual plots for *Triodia* cover criteria. 71
Figure 28. Impact of age post rehabilitation on % *Triodia* cover at three Yandi plots. 72
Figure 29. Area C hub – performance of individual plots for *Triodia* cover criteria. 75
Figure 30. Yarrie hub – performance of individual plots for *Triodia* cover criteria. 79
Figure 31. Goldsworthy Hub– performance of individual plots for Triodia cover criteria. 84
Figure 32. Jimblebar Hub– performance of individual plots for *Triodia* cover criteria. 87
Figure 33. Newman Hub– performance of individual plots for *Triodia* cover criteria. 90
Figure 34. Hypothetical mine / hub rehabilitation completion assessment. 95

## LIST OF APPENDICES

APPENDIX 1 ANALYSIS OF SUCCESS OF HISTORICAL REHABILITATION 117

# EXECUTIVE SUMMARY

***PURPOSE OF REPORT***

This report has been prepared for BHP WAIO, to assist in the preparation of Rehabilitation Reports, which:

- Are required under the Pilbara Expansion Strategic Proposal Ministerial Statement 1105 - Guidelines for submitting a derived proposal 1(c); and
- Are to be submitted when BHP submits a request to the EPA to declare a referred proposal to be a derived proposal.

In order to develop an appropriate reporting framework for these reports, this document specifically focusses on i) providing the context (of the Pilbara and iron ore mining plans), ii) analysis of existing data for baseline (reference sites) and rehabilitation sites across WAIO, and iii) measurements and forecasts of rehabilitation success. A key component of the document is the development of final land uses for mine closure, and ecological completion criteria that best apply to the setting.

***KEY FACTORS INFLUENCING REHABILITATION SUCCESS***

The analysis of the current scientific literature pertaining to natural ecological processes characterising the Pilbara (and comparable arid regions elsewhere) show that plant-soil-climate interactions are complex in arid environments. From a rehabilitation perspective, climate and soils influence vegetation cover and species distributions, however plants are significant in influencing soil moisture and microclimates, in increasing soil mineralisation, and in determining vegetation pattern. In general, vegetation cover is a key determinant of soil moisture, as is diversity of species and lifeforms with differing capabilities to germinate and grow in responses to smaller or larger rainfall events, as is vegetation structure (or at least diversity of species with variable root depths that can access different fractions of the soil profile). Vegetation cover and density are important to the evolution of soil carbon. Annuals in particular have rapid growth cycles and add soil carbon in early rehabilitation stages, which improves moisture retention and is critical to the support of later successional species, including the ubiquitous hummock grasses (*Triodia*). Therefore, forming soil carbon and supporting the appropriate sequence of species in time to provide vegetation cover and trap and retain moisture, are the key initial steps to rehabilitation success.

***END USE GOALS***

The first (obvious) factor that needs to be resolved in assessing whether (or not) a site has been successfully rehabilitated is stakeholder agreement of the final land use of a site.

In terms of possible land uses, the dominant current land uses within the Pilbara are considered the most suitable base for post-mining, given the limitations of alternative land uses in this arid and predominantly remote zone. The Australian Land Use and Management (ALUM) classification system was used to determine appropriate final land uses and to maintain consistent terminology across Australia and with the Western Australian Biodiversity Science Institute (WABSI) Draft Rehabilitation Framework.

For the purpose of this report and reflecting the current and future known proposals, the adopted final land uses are proposed to be:

1. *Natural Environments for managed resource protection (Primary Class 1); and*
2. *Relatively Natural Environments for pastoral grazing purposes (Primary Class 2).*

Not all WAIO sites are suited to managed resource protection (Primary Class 1). Sites already within a pastoral grazing tenure are assumed to most likely return to this final land use after mining. BHP could enhance the pastoral value of some sites after mining, if pastoral grazing is adopted as the preferred final land use (e.g. targeted rehabilitation of tussock grasses).

### *TARGET ECOSYSTEMS AND VEGETATION TYPES*

Once a final land use is agreed, defining the type of metrics and scales of assessment suited to the Pilbara setting is critical. BHP WAIO has traditionally used Ecosystem Function Analysis (EFA) and compared rehabilitation plots to adjacent undisturbed reference plots, for each landform position (crest, slope, flats). Little work has been done previously on analysing what the appropriate scale of assessment is and what the appropriate basis for comparison is.

Analysis of data for reference sites across various spatial scales (region, mining hubs, broad vegetation types, landform position) indicates that whilst there are regional patterns between northern, central, and eastern regions the underlying factor influencing vegetation cover, species richness (and density) is in fact Vegetation Type. The broad vegetation types defined within the Beard *et al* (2013) revised State mapping (which reflect the common ecosystems present) are sufficient to separate areas within the Strategic Proposal Boundary, based on vegetation structure, dominant species, vegetation cover and species richness. As such, these provide a meaningful basis for deriving target vegetation (ecosystem) types and in the setting of completion targets.

The key vegetation types present within the Strategic Proposal Boundary and proposed as 'Target Vegetation Types' in the completion criteria are:

1. Spinifex Grassland Ecosystems
    a. Low-tree steppe
    b. Shrub steppe
    c. Grass steppe
2. Low Woodland Ecosystems
    a. Low woodland, open low woodland and sparse woodland: mulga
3. Bunch Grassland Ecosystems
    a. Riverine sedgeland/grassland with trees

***MEASURING SUCCESS***

*Completion Criteria*

Draft completion criteria for BHP WAIO have been developed in previous years, however, ecological criteria have been difficult because of the fact these have been developed without first defining a probable final land use and/or because the methodology has not been derived from the Pilbara context. The completion criteria proposed in this report are based on an analysis of data that considered scale, time and the metrics most suited to representing success in a Pilbara context. Importantly, a distinction is made between rehabilitation criteria (i.e. those that assist the trajectory towards completion, but are process based – how to achieve), and completion criteria (i.e. those that can be used to measure success – what was achieved).

The proposed completion criteria cover the key concepts of naturalness (does it tie into the Pilbara setting?), resilience (can it recover from fire, drought?) and habitat connectivity (can it support key fauna movements?).

The approach to the setting of specific criteria was based on the following principles:

1. The closure objectives, which are not seeking replication of nature, but conformity with naturalness, resilience of rehabilitated landscapes, and habitat connectivity.

2. The attributes shown to best capture the objectives, based on analysis of reference data and the literature.

3. The variability within the Pilbara, which does not favour the use of averages for ecological targets, but ranges that capture the typical variability based on bioregions, vegetation types and landforms (weeds attributes).

4. Disturbance impacts, such as from existing pastoral activities, road and rail corridors, townships etc, as well as wider climate influences, that have resulted in modifications to the pre-European condition.

The selected attributes that guided the development of the criteria are as follows:

- Bare Ground;
- Vegetation Types;
- Indicator Species;
- Plant Cover;
- Species Richness;
- Reproductive Capacity (Resilience);
- Weed Invasiveness; and
- Feral Animals.

*Time*

Analysis of historic rehabilitation data indicates that time is critical to the achievement of completion criteria in the Pilbara context. The measurement of a site against completion criteria does not seem sensible before 15 years after rehabilitation commences (sites will generally fail one or more criteria), and 20 years would not be an unreasonable time point for final assessment. Even with a sequence of good rainfall years and improvements in rehabilitation methods, it is unlikely that any site will be ready for assessment against completion criteria before 10 years, since even if some areas do attain the required metrics at this time, the site would need to sustain this during a poor climatic period and fire event to demonstrate resilience of the rehabilitation.

*Historical Performance*

A comprehensive analysis of the historic rehabilitation data showed the following outcomes:

1. Where data was compared against the traditional reference plots (in this case aggregated) per hub, where the assumption is to return the site to pre-mined vegetation communities, all sites and most plots fall short of demonstrating success for at least one key attribute (usually vegetation cover).

2. Where data is assessed against the proposed revised completion criteria and methods of assessment, most hubs (e.g. Yandi, Yarrie), are not too far off achieving targets, and plots older than 20 years post-rehabilitation generally comply with all criteria for which data is available.

3. There are individual plots that capture areas that may not be acceptable without some intervention to improve outcomes.

*Future Prognosis*

The future for rehabilitation success in the Pilbara seems contingent on time, and the roll out of the current knowledge around successful rehabilitation methods, along with continuing targeted research programs. Newer rehabilitated sites indicate a trend of improvement in some key metrics (e.g. *Triodia* cover), which suggest research outcomes are being applied, at least at some sites. For example, at Yarrie Hub, sites that were rehabilitated in 2016 already have 8-9% *Triodia* cover, which is significantly higher than the average of plots at this site at the same age (4 plots, rehabilitated in 2011, with 0.5 – 2.5%). Progressive rehabilitation, combined with the proposed new approaches to completion criteria and monitoring methods, are likely to support a positive future in terms of rehabilitation outcomes.

# PART 1 REHABILITATION CONTEXT

## 1.0 INTRODUCTION

### 1.1 CONTEXT AND PURPOSE

This document is for the purpose of supporting a report on rehabilitation under the Pilbara Expansion Strategic Proposal MS1105 - Guidelines for submitting a Derived Proposal 1(c).

Specifically, the requirement under Ministerial Statement 1105 is a report from BHP that details the following:

1. The types of ecosystems and total area of rehabilitation that BHP will be required to rehabilitate across their WAIO tenure, including the derived proposal.
2. An analysis of the history of rehabilitation that BHP has undertaken in the Pilbara and the demonstrated success of this rehabilitation.
3. The likely success of future rehabilitation activities in establishing self-sustaining areas of rehabilitation, taking into account:
   - Relevant contemporary scientific evidence;
   - The types of areas to be rehabilitated; and
   - The scale of the rehabilitation activities.

This document focuses on data analysis and the supporting evidence base for historical and future rehabilitation, and the development of completion criteria to be used in future assessments, to support rehabilitation reports required for derived proposals. The report focuses on revegetation only.

### 1.2 CURRENT STATE OF PLAY

Delivering successful rehabilitation in the Pilbara is widely acknowledged as challenging, which reflects the climatic and remote nature of the region, the relatively young knowledge base covering natural systems and rehabilitation, the fast pace and scale of mining, and changing stakeholder expectations.

In 2010, BHP noted that while demonstrable progress had been made (by BHP) in achieving robust rehabilitation outcomes, step changes were needed to improve future outcomes. A range of commitments were made and endorsed within a Rehabilitation Strategy (BHP Billiton 2010), which sought to deliver a step change in the quantum and the business capability to rehabilitate land to meet future requirements at closure sites, operating sites and new sites being planned.

A range of commitments were endorsed by the business at the executive level, which have all been implemented and are tracked as part of BHP's continuous improvement practices. These commitments and progress to date are summarised below:

1. Sufficient rehabilitation undertaken mid-term (by 2020) to develop and embed low cost technologies that demonstrate capacity to rehabilitate the whole disturbed footprint over the life of the asset.

   *Considerable rehabilitation investments (research, active works, monitoring, altered practices) have been made to demonstrate that BHP has the capacity and evidence base to undertake rehabilitation. Rehabilitation performance is discussed in Part 3 of this report.*

2. Specialist capability provided to effectively deliver the plan including defined responsibilities/roles across accountability streams and a comprehensive GIS based system to capture data and learnings.

   *A dedicated Environment team from executive to site level has been established with clear accountabilities. A comprehensive GIS system is used to capture and host biodiversity survey and rehabilitation data.*

3. Monitoring and verification of rehabilitation to schedule and to completion criteria.

   *Rehabilitation monitoring is currently scheduled and reported against analogue sites on a two-yearly basis against draft completion criteria and targets. This report details the revised and final proposed criteria and provides a summary of performance to date (Section 11.0).*

4. A Research and Development (R&D) program defined, and budget established for approval to address key technological deficiencies.

   *A 5-year R&D Plan was adopted in 2012, which is reviewed and revised annually to ensure learnings are adopted and priorities revisited (last revision was in 2019).*

5. Closure action gaps filled, including the following high priorities:

   - Translating Life of Asset targets into the 5 year and 2-year functional plans.
   - Defining the process for annual planning and execution.
   - Finalising and obtaining regulatory approval for completion criteria for land rehabilitation.
   - Conducting an audit across all sites to determine status against draft completion criteria.

   *All actions are completed, except for regulatory approval of completion criteria. Final proposed completion criteria form part of this current document.*

6. Ownership/management responsibilities defined and improvement actions for closed sites and active sites with legacy issues, including:

   - Goldsworthy (closed site) where land disturbance and mining operations have effectively ceased with a range of legacy issues. These sites could effectively be used as the pilot for larger scale rehabilitation aimed at experimentation and technology development.
   - Newman Joint Venture (NJV), Yandi and Area C Mine (active sites) where topsoil shortage and ARD need to be effectively managed and opportunities for improved integration (e.g. top soil management) be effectively explored.

*Active mine areas are currently subject to various and ongoing trials as part of the (previous) Restoration Seed Bank Initiative Research Project and current Global Innovation Linkage project: Remote sensing phase 3.*

7. Identification of future areas (e.g. within the Jimblebar hub) where opportunities for excellence in mine planning and execution can be put in place.

   *Proposals for leading practice rehabilitation in new mine areas is currently being developed as part of a new Rehabilitation Research Strategy and the revised R&D Plan.*

## 1.3 SCOPE OF REPORT

The scope of this report is revegetation only. It includes disturbed areas requiring rehabilitation under Part IV and Part V of the EP Act, and State Agreement approvals on BHP's WAIO tenure (Figure 1).

It covers:

- All mining related disturbance (overburden storage areas (OSAs), waste dumps, borrow pits).
- All infrastructure types (laydown areas, buildings, towns, power lines, pipelines, accommodation camps, access roads, conveyors and airports etc).
- Rail (spurs connecting the new mining operations to existing rail infrastructure, loops within each mining operation to enable ore loading and potential expanded rail capacity of the Newman to Port Hedland rail line.

It excludes:

- Pits (mine voids).
- Landforming and all activities associated with post-mined earthworks to form final rehabilitation landform – these are covered in other regulatory reporting documents.

The major hubs and current operations covered by this report are as shown in Table 1.

Expansions to existing operations at the Jimblebar, Mining Area C, Newman and Yandi mining hubs are within the Strategic Proposal (Ministerial Statement 1105). Although Goldsworthy and Yarrie mining hubs are outside of the Strategic Proposal Boundary (Figure 2), these have been included for the purposes of reviewing rehabilitation success, as they are part of BHP's iron ore tenure. Some analyses of rail rehabilitation (Chichester Rail) have also been included, but the focus is on rehabilitation at mine sites.

## 1.4 LINKS TO OTHER REHABILITATION REPORTS

This document links to other BHP reports which includes, but is not limited to, the following documents:

- Mine Closure Plans;

- Annual Environmental Reports;
- Impact Reconciliation Reports (Offsets); and
- Mining Rehabilitation Fund.

**Table 1. Major hubs and existing operations.**

| HUB | OPERATION<br>(Map presentation) | IBRA SUBREAGION | GEOGRAPHIC REGION |
|---|---|---|---|
| **Jimblebar** | Jimblebar<br>Orebody 31<br>Orebody 17<br>Orebody 18 | Hamersley, Fortescue, Augustus | Eastern Pilbara, Northern Gascoyne |
| **Newman** | Whaleback<br>Orebody 29<br>Orebody 30<br>Orebody 35<br>Eastern Ridge<br>Orebody 23 | Hamersley | Eastern Pilbara |
| **Yandi** | Yandi | Hamersley, Fortescue | Central Pilbara |
| **Mining Area C** | Mining Area C | Hamersley | Central Pilbara |
| **Goldsworthy^** | Goldsworthy | Chichester | Northern Pilbara |
| **Yarrie^** | Yarrie<br>Cundaline<br>Callawa<br>Nimingarra | Chichester | Northern Pilbara |
| **Chichester Rail** | | Chichester | Central and Northern Pilbara |

** As at December 2019.*

*^ Yarrie and Goldsworthy are outside the Strategic Proposal Boundary.*

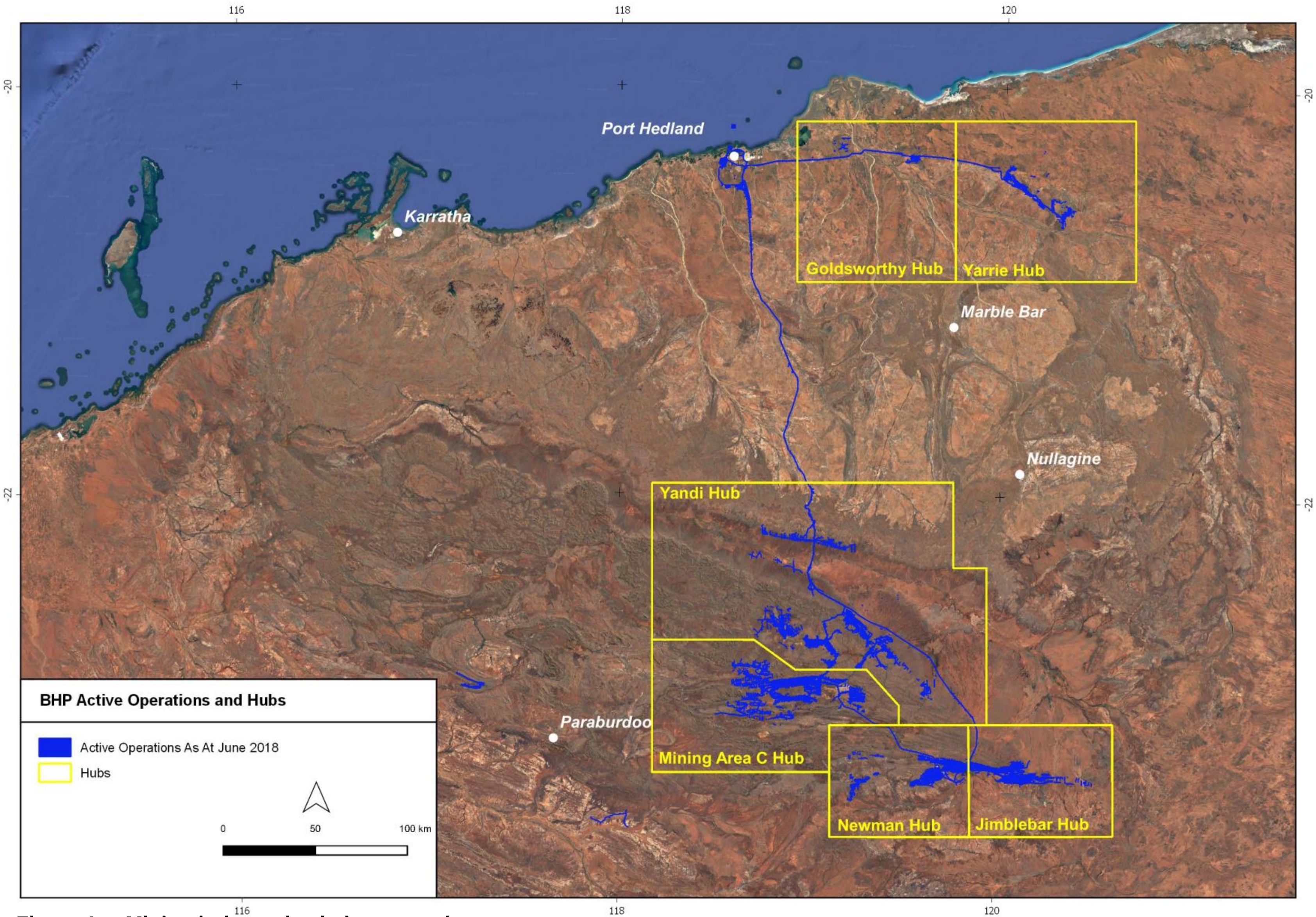



**Figure 1. Mining hubs and existing operations.**

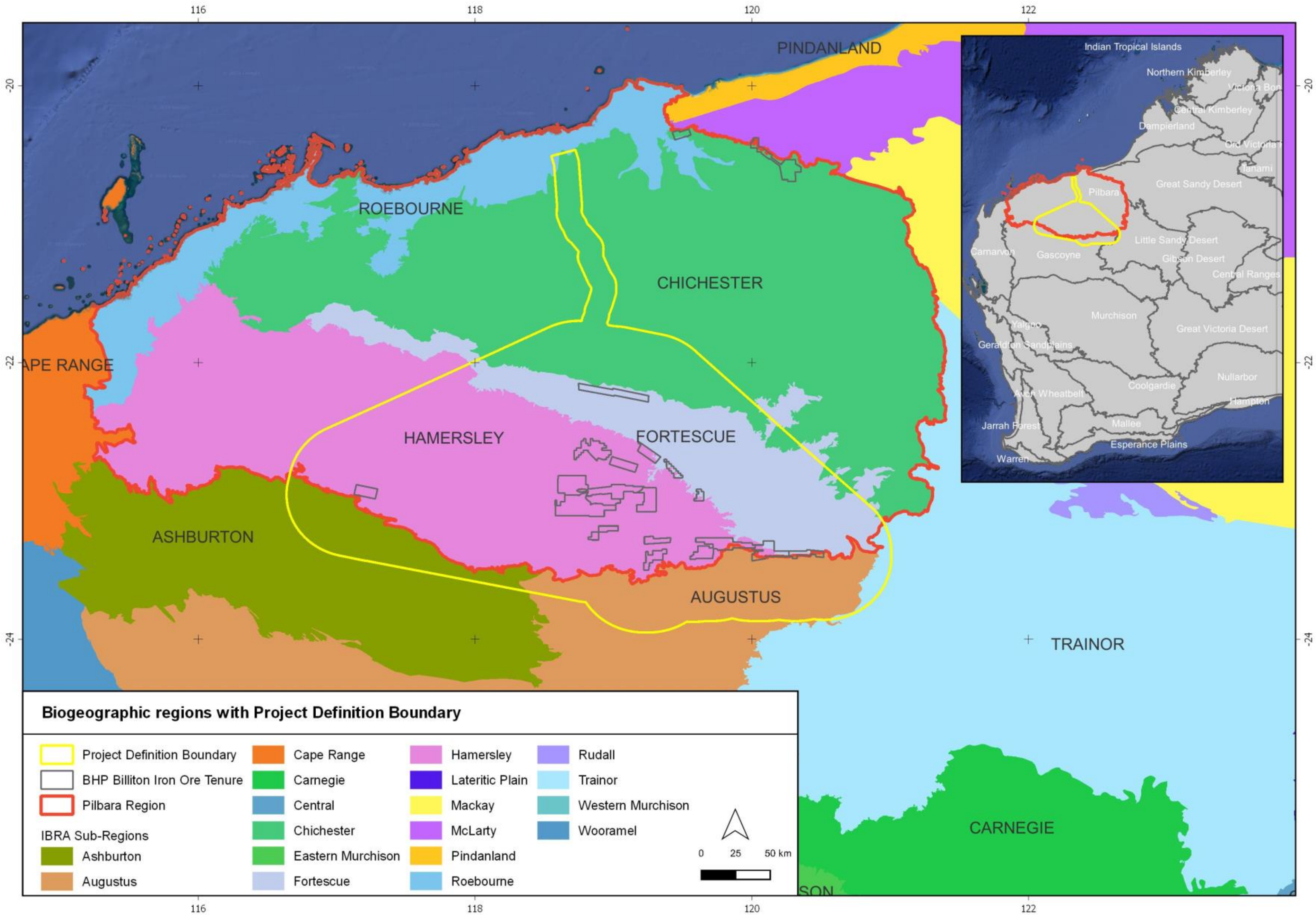



Figure 2. Strategic Proposal Boundary in relation to IBRA regions and subregions.

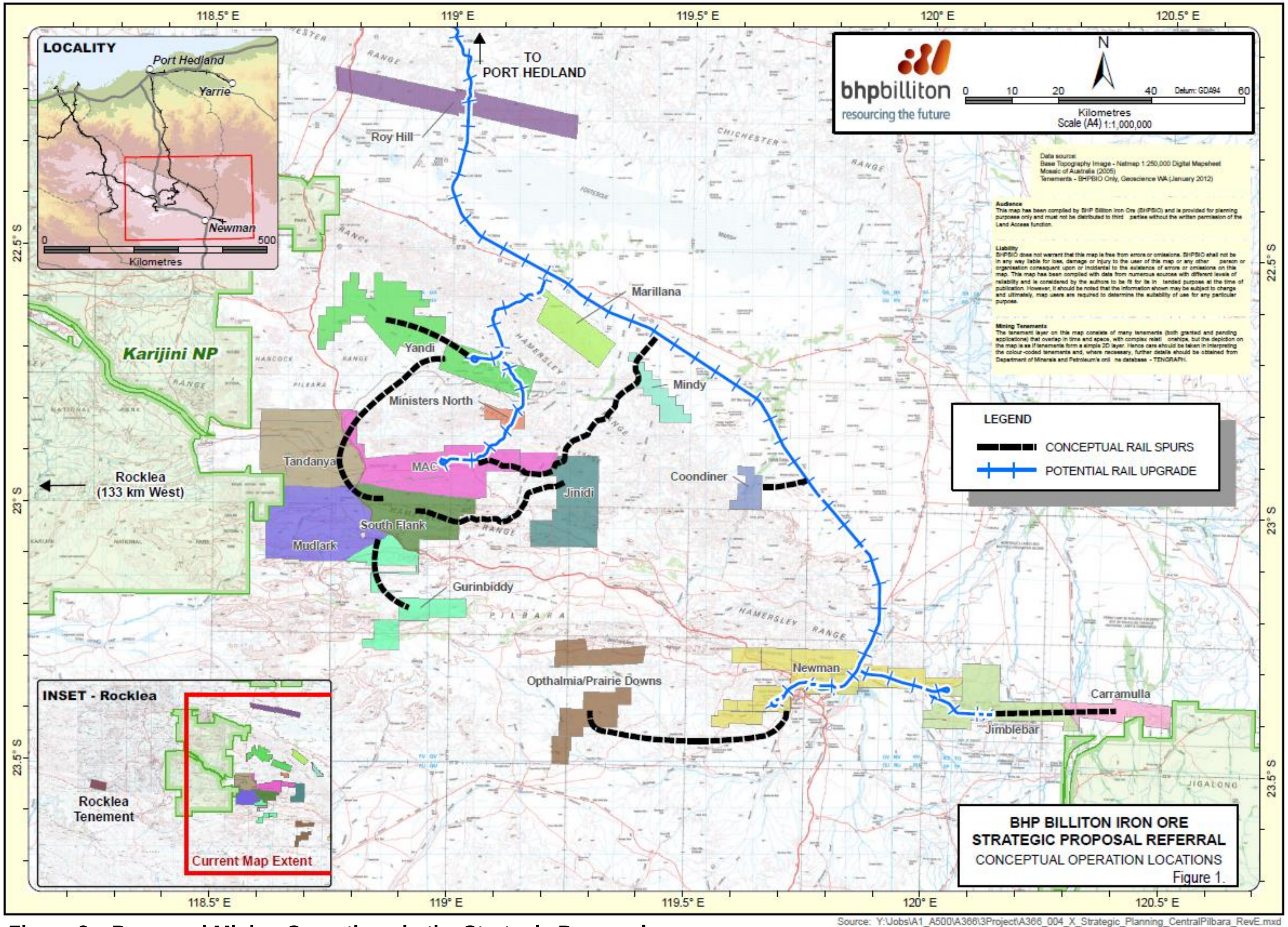



**Figure 3. Proposed Mining Operations in the Strategic Proposal.**

# 2.0 REHABILITATION IN THE PILBARA CONTEXT

This section is a review of the science and current thinking as it relates to rehabilitation in the Pilbara. This is important for providing an informed and balanced approach to determining the appropriate type, scale, indices and timelines considered appropriate for measuring rehabilitation success in the Pilbara iron ore context. Given the key purpose of this report is to provide evidence of the success of rehabilitation (not merely evidence of rehabilitation), a brief discussion of the key concepts is included for clarity.

## 2.1 KEY CONCEPTS

There are three related, however distinct aspects/concepts discussed in this report, which we consider fundamental to distinguish.

1. First is the concept of rehabilitation as a process, and which in simple terms improves a degraded environment toward some agreed goal. It (should) flow on from an agreed final land use and embeds a set of objectives as well as a range of implicit or explicit risks and uncertainties. There may be a set of instructive procedures to guide the process of rehabilitation, and there should be a set of rehabilitation criteria to assess compliance. Rehabilitation monitoring is undertaken to assess if the design and construction compliance criteria have been undertaken.

2. Second, is the concept of final land use, which is the outcome environment one seeks to establish after disturbance. The final land use is characterised by a range of attributes which presuppose a range of services, based on the intended uses of this end point state.

3. Third is the concept of completion criteria, which are applied to a subset of attributes understood to best define the desired final land use and which are then used as a surrogate for measuring success. Criteria are either pass or fail. The choice for failed sites is either to revisit the rehabilitation process, or to set a new end point (shift the goalpost).

The key concepts and the major influencing stakeholders are shown in Figure 4.

There are complexities associated with each concept, proportionate to the level of risk and uncertainty. In terms of rehabilitation processes, risks are technical (how to achieve?). In terms of final land use and completion criteria, risks are regulatory and economic (what to decide, and how to measure?). In terms of both rehabilitation and final land use, uncertainties add complexity, and are wider ranging, time sensitive and cover regulatory, climatic, social, and political aspects. To some extent, uncertainty can be set aside if part of the criteria for final land use enables a shift to an alternate state, that is, if a particular agreed final land use (e.g. pastoral grazing) at one point in time, can be converted to a higher final land use (e.g. form of nature protection) in time. In other words, the ‘raw materials’ needed for a site to pivot between multiple states over time, become key to providing greater certainty that the rehabilitation will be resilient, adaptable and ultimately acceptable.

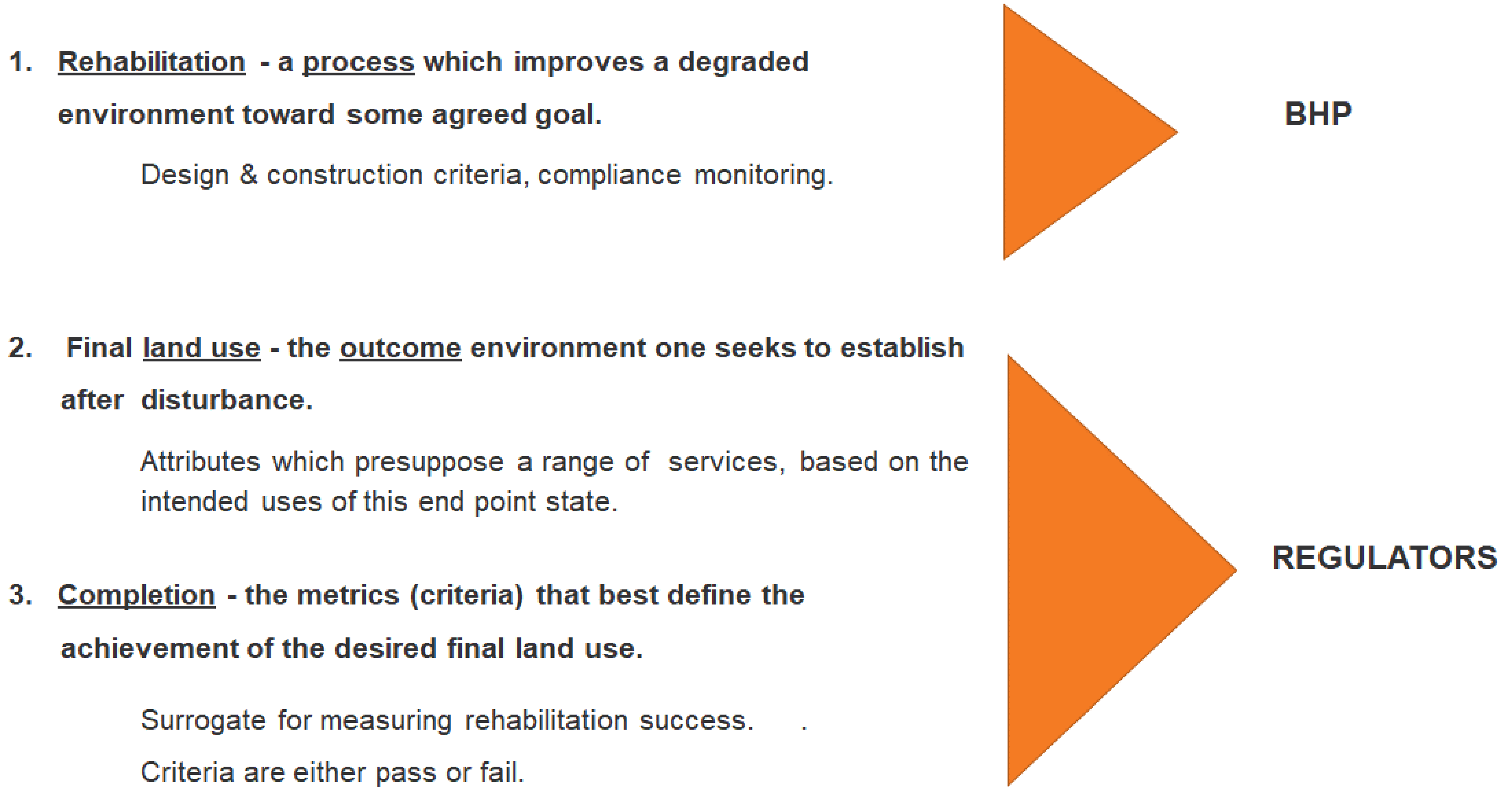



**Figure 4. Key concepts.**

The three concepts discussed above are similarly distinguished within the Western Australian Biodiversity Science Institute (WABSI) Completion Criteria Framework as stages, however, the current draft framework proposes the use of time-bound criteria that mesh together compliance targets (e.g. landform construction) with progress measurements (e.g. a certain density of plants after 1 year), with actual criteria at completion (e.g. target final vegetation cover). Compliance with best practice rehabilitation is already covered in existing mining approval reporting documents. What is not covered are the final land uses and their varying measurements of success.

## 2.2 REHABILITATION STANDARDS AND EXPECTATIONS

There is currently no adopted international, national or State standard for mine rehabilitation and management. However, it has been recognised that there are several principles that are common to all mines including minimisation of mine impacts throughout the mine's lifecycle and re-establishing mine closure at every stage of operation to foster sustainable resource development and risk management.

***Overall, the expectations for best practice mine rehabilitation include progressive, pragmatic and measured success against fairly standard objectives (safe, stable, non-polluting, supportive of final land use).***

WABSI have recently completed a thorough review of the current international, national and State best practice guidelines and benchmarks used to inform mining rehabilitation and the setting of completion criteria (WABSI 2019). They conclude that the most relevant and detailed sources of publicly available guidance for establishing criteria in WA were those from EPA, DWER, DMIRS, and the Australian LPSDP. The 2006 EPA guidance on rehabilitation of terrestrial ecosystems remains relevant for its ecological perspective on the issues related to re-establishing WA native ecosystems.

### 2.2.1 International Standards

Currently the standard for mine closure and reclamation management is being developed by the International Organisation for Standardisation (ISO) (ISO, 2019). It is intended that this document will provide overarching standards for mine rehabilitation for different stages of mine operation including planning, implementation and closure processes.

The International Council on Mining and Metals (ICMM) Integrated Mine Closure Toolkit is currently the most adopted benchmark for integrated mine closure planning internationally and promotes a more disciplined approach and increasing uniformity of good practices across the mining sector. The toolkit covers the entire mine life cycle including: exploration, pre-feasibility, feasibility (which includes planning and design), construction, operation, decommissioning and closure and post closure and provides links to specific resources or tools on each topic. While the toolkit outlines a methodology for development of rehabilitation goals and criteria, it does not provide standards for assessment of the criteria nor the 'acceptable limits' that would render rehabilitation successful.

Given that mine rehabilitation often involves environmental repair or restorative activities, some mines include standards for ecological restoration as part of their rehabilitation criteria such as those outlined in the International Standards for the Practice of Ecological Restoration (McDonald *et.al.,* 2016). These guidelines are currently under review with expected updates in early 2019. This is unlikely to apply to most of the WAIO rehabilitation sites.

***In general, international standards require a commitment to progressive rehabilitation and progressive measurement of success.***

### 2.2.2 National and State Standards

Under the Australian Constitution mining control is the responsibility of states and territories.

Under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) conditions for rehabilitation and monitoring related to matters of national significance (MNES) can be set by the Minister (upon mine referral) to "*protect and manage nationally and internationally important flora, fauna, ecological communities and heritage places*".

The Australian government (Department of Industry Innovation and Science or DIIS) has developed a program of guidelines for the mining industry under the heading of Leading Practice Sustainable Development Program (LPSDP); this has a number of handbooks that outline best practice standards for mine operation, including mine rehabilitation.

The Guidelines for Preparing Mine Closure Plans (DMP & EPA 2015) cover the preparation of Mine Closure Plans to meet Western Australian regulatory requirements. The guidelines acknowledge that the standards for rehabilitation are continuously evolving and outlines the expectations of the DMIRS (former Department of Mines and Petroleum) and EPA for rehabilitation. For those operations approved prior to 2011, it is DMIRS's expectation that permanent landforms at existing mines/operations meet DMIRS's (DMP & EPA 2015) closure objectives:

- Rehabilitated mines to be (physically) safe to humans and animals;
- (Geo-technically) stable;
- (Geo-chemically) non-polluting/ non-contaminating; and
- Capable of sustaining an agreed post-mining land use.

The Environmental Protection Authority's (EPA) objective for Rehabilitation and Decommissioning in Ministerial Statement 1105 for the Strategic Proposal (and future Derived Proposals) is *"to ensure that the proposal is decommissioned and the site of the proposal rehabilitated to be safe, stable and non-polluting and in an ecologically appropriate and sustainable manner".*

***DMIRS and the EPA encourage proponents to progressively rehabilitate, where possible, recognising that some forms of mining, may make progressive rehabilitation more or less feasible. For existing mine sites, attention needs to be given to the best pragmatic options for mine closure. Rehabilitation success is implied as the ability to sustain an agreed post-mining land use.***

### 2.2.3 BHP WAIO Current Standards

BHP Iron Ore's commitments to the closure of disturbed lands exist within the BHP Billiton Charter, the Sustainable Development Policy, the BHPBIO Group Level Documents (GLDs) the BHPBIO Biodiversity Strategy (2010), and the BHPBIO Rehabilitation Strategy (2011). As part of the Biodiversity Strategy stakeholder process, a vision for successful rehabilitation in the Pilbara was agreed, which has informed the current rehabilitation goal and research activities undertaken for WAIO.

Multiple Rehabilitation Standards also govern the planning and delivery of rehabilitation works. WAIO has a progressive rehabilitation approach that is tailored to each site, each landform, and each type of disturbance and aligned with an internal 5 Year Mine Plan. Within this management framework, research programs support continual improvement of rehabilitation activities. As such, BHP aligns with the current best practice standards.

## 2.3 FACTORS IMPACTING REHABILITATION SUCCESS IN THE PILBARA REGION

Irrespective of governance and capacity, the Pilbara is a large, arid, remote region which has many complexities that impact on rehabilitation success. These factors range from climate (aridity, variability) to land use impacts to knowledge gaps regarding biodiversity, reproductive biology, ecological processes and patterns, among others. These factors influence the timescales needed to achieve rehabilitation success, and impact on what can be realistically achieved.

Whilst there are knowledge gaps, understanding of the Pilbara region has increased in recent years, partly arising from the Department of Parks and Wildlife (DPaW) Pilbara Biological Survey, practical rehabilitation trials, dedicated research programmes (predominantly the BHP funded Pilbara Seed Bank and Restoration Initiative) and international progress in the understanding of arid ecosystems. As such, there is a far more consolidated set of information available to guide the process and trajectory of rehabilitation available now than when BHP first commenced its early rehabilitation efforts in the 1990s.

This section summarises a review of published and unpublished scientific information that cover the fundamental characteristics and processes that underpin natural ecosystems in the Pilbara. Whilst this is by no means exhaustive, it extracts the major principles that are likely to underpin successful rehabilitation in the Pilbara, irrespective of the type and nature of disturbance.

### 2.3.1 Macroscale Influences - Rainfall

The most profound and overwhelming factor influencing biological productivity, seedling recruitment, vegetation growth, successional rates, and vegetation pattern in arid regions globally is rainfall.

The Pilbara region is characterised by some of the most variable annual and inter-annual rainfall patterns on the planet (van Etten, 2009, Rouillard *et al* 2015). The large variability in rainfall means that there is equal variation in the production of seed and availability of seed resources for rehabilitation from year-to-year. Similarly, the variable rainfall translates to significant variation in the germination of seed broadcast to site and survival of seedlings.

Generally, ‘good’ rainfall years (defined as >80mm summer cyclone rains with follow-on autumn rains) which are sufficient to support flowering, fruiting and germination of most species, occurs on average every 2 years for some species, and up to 5 years for others (such as *Triodia* spp).

*These conditions mean that the average time taken to successfully complete the rehabilitation cycle will inevitably be longer in the Pilbara region than most other mining areas across Australia.*

### 2.3.2 Microscale Interactions – Vegetation Cover and Soil Moisture

Over the last decade in particular, evidence of microscale processes on the determination of vegetation patterns, and the links between hydrology and vegetation (ecohydrology), have yielded new insights around the subtleties of process and functions within ecosystems that cover often grand geographic scales within semi-arid and arid landscapes.

In arid regions, there are a range of factors that dictate the ability of ecosystems to capture each rainfall event and exploit increased soil moisture. Vegetation cover, topography, tree canopy, and leaf litter all act to trap rainfall and prevent run-off, thereby increasing the available window of water supply for germination and growth. They are the key ‘ingredients’ that dictate how successful or otherwise rehabilitation may be, and over what timescale.

There is a significant body of research undertaken in semi-arid environments (e.g. Chesson *et al* 2004, Ravi and Oderico *et al* 2007, McGrath, and Paik *et al* 2012) and the Pilbara in particular (e.g. Caylor *et al* 2004, Van Vreeswyk *et al* 2004, McIntyre *et al* 2009, Merritt and Dixon 2011, Syrinx Environmental 2011, Broadhurst *et al* 2015, Munoz-Rojas *et al* 2016, Espeland *et al* 2017, Erickson *et al* 2017, Miller *et al* 2017, Ritchie e*t al* 2017). Summary findings from these and other works (refer to full reference list) are as follows:

1. Tree canopy cover and *Triodia* hummocks influence the daily distribution of soil moisture availability at the local scale, by increasing local infiltration and reducing radiation. This enables grasses (and other understorey species) to co-occur with trees in resource constrained environments.

   Soil stability is also strongly influenced by vegetation cover. Perennial plants are the most efficient means of providing year-round groundcover, and hence perennial vegetation cover is seen as a strong indicator of resilience in the Pilbara.

2. Soil moisture availability largely controls the processes of transpiration, runoff generation, carbon assimilation, nutrient cycling and seed productivity. For example, nitrogen mineralized under *Triodia* hummocks with greater soil moisture, was shown to be twice that of open spaces between hummocks.

   Seed productivity varies considerably with local seasonal conditions with many species having specific requirements in terms of rainfall amount and timing in order to complete a successful reproductive cycle.

3. Substrate quality is not a strong influence on recruitment or nutrient cycling processes, however soil carbon is. Soil carbon increases with vegetation cover. Data from monitored rehabilitation

at BHP sites, along with experimental data from trials undertaken on Pilbara species and others, indicate that soil types per se are not a significant influence on seedling recruitment or survival where soil moisture is adequate.

The use of growth media such as waste materials has proved to be a competent alternative to the original soil (i.e. topsoil), and mine waste materials can reach levels of microbial activity and organic carbon similar to those of topsoil once vegetation has become established. In general, topsoil has a higher available water content, hence not unexpectedly seedling emergence is generally more consistent across species where this is available. However, for some species, most critically *Triodia* species, seedling emergence was found to be lower in waste materials than in topsoil or blended materials, predominantly in water stressed conditions. Research is progressing (under the Restoration Seedbank Initiative) to identify options for large scale improvements to organic carbon and water retention properties in growth media to improve seedling emergence and accelerate rehabilitation.

4. Resource pulses (nutrient and moisture) in combination with species seasonal growth differences and seed properties, determine species variability and vegetation patterns.

   In terms of rehabilitation, species that can respond early to soil moisture levels, or can respond to lower soil moisture levels (e.g. many annuals), can take advantage of drier seasons. Species with a higher moisture threshold (such as *Triodia*), will only germinate during a 'good' rainfall year. Fluctuations from year to year in the timing of rain favour different species in different years.

   Studies undertaken as part of the Seed Atlas and later Restoration Initiative Projects show species also vary in the temperature conditions needed to break seed dormancy, and in dormancy types. Since soil temperature conditions vary temporally and spatially, conditions suit one species over another in different years and in different areas.

### 2.3.3 Implications for Rehabilitation Success

Plant-soil-climate interactions are complex in arid environments. From a rehabilitation perspective, climate and soils influence vegetation cover and species distributions, however plants are significant in influencing soil moisture and microclimates, in increasing soil mineralisation, and in determining vegetation pattern.

Key points from the summarised literature review are:

*Vegetation cover (and litter) is pivotal to maintenance of soil moisture, and soil stability, and maintaining nutrient and carbon processes - it is the single most important variable for rehabilitation.*

*A diversity of species, (with different lifeforms, growth traits and seed properties) that respond differently to soil moisture, soil carbon and soil temperatures, is needed to improve rehabilitation success across all years, and accelerate vegetation cover.*

*The shortage of topsoil is not an a priori risk for successful rehabilitation post-mining in the Pilbara, provided alternative materials with adequate soil moisture properties are available*.

# 3.0 FINAL LAND USES, REHABILITATION GOAL & CLOSURE OBJECTIVES

The measurement of rehabilitation success is fundamentally linked to an agreement around the final land use of the land, as well as agreement on what is possible technically and economically to achieve in the rehabilitation process. Mining operations in the Pilbara sit within a larger land use (pastoral) and abut significant biodiversity conservation areas. Hence, this context needs to be considered.

## 3.1 PROPOSED FINAL LAND-USES

The WABSI Completion Criteria Framework sets out possible final land uses after mining that are consistent with the Australian Land Use and Management (ALUM) classification (ABARE 2016). This segregates the primary use from secondary and tertiary uses. For consistency, BHP will also align with this framework. The ALUM classification and the relevance of its primary and secondary classes to BHP WAIO operations are presented in Table 2.

In terms of possible land uses, the dominant current land uses within the Pilbara (Figure 5 and Figure 6) are considered the most suitable base for post-mining, given the limitations of alternative land uses in this arid and predominantly remote zone. The Pilbara bioregion is dominated by pastoral use (~52%) with the balance a mix of conservation reserves (~10%), Aboriginal Reserves (~4%), unallocated Crown land (~23%) and mining (2%) (DPIRD, 2018). The distribution of current tenure types within each hub and site, are relevant in informing the final land use decisions (Table 3).

Noting the above it will be appropriate to aim for Primary Classes 1 *Conservation and Natural Environments* (for the purposes of managed resource protection) and 2 *Production from Relatively Natural Environments* (for the purposes of pastoral grazing) for most post-mined areas in the Pilbara. Figure 7 presents the suitability of land for pastoral grazing, based on pre-mining natural vegetation types and landforms.

Note, a final land use goal of Natural Environments (Primary Class 1) for the purposes of Nature Conservation (Secondary Class) could apply to any sites likely to impact high conservation assets where there are no Environment Offsets in place. At the time of writing, there are no BHP sites where this is probable, hence this final land use is not included in the proposed completion criteria. Should it become applicable in the case of a derived proposal, then a specific set of criteria would need to be developed in consultation with stakeholders.

For the purpose of this report and reflecting the current and future known proposals, the adopted final land uses are proposed to be:

1. *Natural Environments for managed resource protection (Primary Class 1), and*
2. *Relatively Natural Environments for pastoral grazing purposes (Primary Class 2).*

Within the Pilbara, there are precedents for conservation uses transferring to mining or pastoral uses, and precedents for reversing pastoral uses to conservation (e.g. recent relinquishments of pastoral land to protection within the conservation estate). Hence, a priori, if a post mining final land use becomes pastoral in the Pilbara, and where this is within natural environments, then a pastoral final land use could transition into a managed resource protection or even conservation final land use in time.

**Table 2. Summary of Australian Land Use and Management (ALUM) classification (ABARES 2016) and relevance of classes to BHP WAIO closure*.**

| PRIMARY CLASS | DEFINITION | SECONDARY CLASSES | RELEVANT TO BHP WAIO OPERATIONS |
|---|---|---|---|
| **1 - Conservation and Natural Environments** | Conservation purposes based on maintaining the essentially natural ecosystems present. | Nature conservation; **Managed resource protection**; **Other minimal use** | **Yes** |
| **2 - Production from Relatively Natural Environments** | Primary production with limited change to the native vegetation. | **Grazing native vegetation;** Production native forests | **Yes** |
| 3 - Production from Dryland Agriculture and Plantations | Primary production based on dryland farming systems. | Plantation forests; Grazing modified pastures; Cropping; **Perennial horticulture**; Seasonal horticulture; Land in transition | Possible, linked to open water pits |
| 4 - Production from Irrigated Agriculture and Plantations | Primary production based on irrigated farming. | Irrigated plantation forests; **Grazing irrigated modified pastures**; Irrigated cropping; Irrigated perennial horticulture; Irrigated seasonal horticulture; Irrigated land in transition | Possible, linked to open water pits |
| 5 - Intensive Uses | Land subject to extensive modification, generally in association with closer residential settlement, commercial or industrial uses. | **Intensive horticulture**; Intensive animal production; Manufacturing and industrial; Residential and farm infrastructure; Services; Utilities; Transport and communication; Mining; **Waste treatment and disposal** | Possible for localised sites near Newman. |
| 6 - Water | Water features. | Lake; Reservoir; River; Channel/aqueduct; Marsh/wetland; Estuary/coastal waters | Possible for artificial (e.g. pits) or modified water bodies or wetlands |

***Note, land use classes most relevant to BHP WAIO operations are *highlighted in bold***

### 3.1.1 Natural Environments for Managed Resource Protection (Primary Class 1)

***Definition***

ABARE define *Natural Environments for managed resource protection* as areas managed primarily for the sustainable use of natural resources. This includes areas with largely unmodified natural systems that are managed primarily to ensure the long-term protection and maintenance of biological diversity, water supply, aquifers or landscapes, while providing a sustainable flow of natural products and services.

These objectives of this land use category are already embedded in the WAIO closure principles, the rehabilitation goals and the standards and Ministerial commitments already made for existing sites.

***Applicability***

This final land use is likely to be preferred in sites adjacent to lands managed for conservation, and / or in sites not suited to pastoral grazing or isolated from larger pastoral tenured lands. This is likely to include Tandanya and Mudlark (Mining Area C Hub) as well as Marillana (Yandi Hub) given a significant portion of the land in these areas is proposed to be resumed into the conservation estate and/or they immediately abut existing conservation areas (Figure 5).

### 3.1.2 Relatively Natural Environments for Pastoral Grazing Purposes (Primary Class 2)

***Definition***

ABARE define this class as land that is subject to relatively low levels of intervention. The structure of the native vegetation generally remains intact despite deliberate use. Land uses based on grazing by domestic stock on native vegetation where there has been limited or no deliberate attempt at pasture modification. Some change in species composition may have occurred, however there must be greater than 50 per cent dominant native species.

Pastoral activities in the Pilbara are supported in the main by tussock grasslands in the valleys and plains. Some hummock grassland communities have very low pastoral potential, hence not all post-mine areas will be suited to pastoral grazing as a final land use. BHP is currently undertaking assessment of potential final land uses across its sites for discussion with stakeholders.

***Applicability***

Sites which already are within a pastoral grazing tenure, are assumed to return to this final land use after mining (e.g. Yandi, Figure 7). Where sites are largely within unallocated crown land but surrounded by pastoral grazing tenure, these have been assumed to adopt a pastoral final land use.

Where pastoral grazing is adopted as the final land use, BHP could enhance the pastoral value of some sites after mining, e.g. by targeting rehabilitation of tussock grasses or other palatable species.

### 3.1.3 Other Uses

Certain sites might in future potentially support other uses such as Production from Dryland Agriculture (Primary Class 3) or Irrigated Agriculture (Primary Class 4) (Table 2).There may also be more diverse options surrounding Newman, depending on how growth plans for this centre outside of mining are imagined, and for localised transitional uses, such as landfill.

**Table 3. Current proportion of land tenures within individual hubs and sites.**

| HUB | IBRA SUBREGION/S | GEOGRAPHIC REGION | TENURE (estimated cover) | % |
|---|---|---|---|---|
| **Jimblebar** | Hamersley, Fortescue, Augustus | Eastern Pilbara, Northern Gascoyne | Pastoral<br>UCL<br>DBCA interest ex pastoral<br>Other | 46<br>48<br>0<br>6 |
| **Newman** | Hamersley | Eastern Pilbara | Pastoral<br>UCL<br>DBCA interest ex pastoral<br>Other | 11<br>72<br>0<br>17 |
| **Yandi*** | Hamersley, Fortescue | Central Pilbara | Pastoral<br>UCL<br>DBCA interest ex pastoral<br>Other | 70<br>9<br>20<br>1 |
| **Mining Area C** | Hamersley | Central Pilbara | Pastoral<br>UCL<br>DBCA interest ex pastoral<br>Other | 23<br>65<br>7<br>5 |
| **Yarrie** | Chichester | Northern Pilbara | Pastoral<br>UCL<br>DBCA interest ex pastoral<br>Other | 86<br>0<br>0<br>14 |
| **Goldsworthy** | Chichester | Northern Pilbara | Pastoral<br>UCL<br>DBCA interest ex pastoral<br>Other | 76<br>2<br>0<br>22 |

*Data Reference: Department of Primary Industries and Regional Development [DPIRD] (2018) Rangeland land system mapping Western Australia - Land system mapping for the pastoral area of Western Australia (Version April 2018 – Shapefile: SoilLandscapeMapping_RangelandsDPIRD_063. Last updated 8th Jun 2018.*

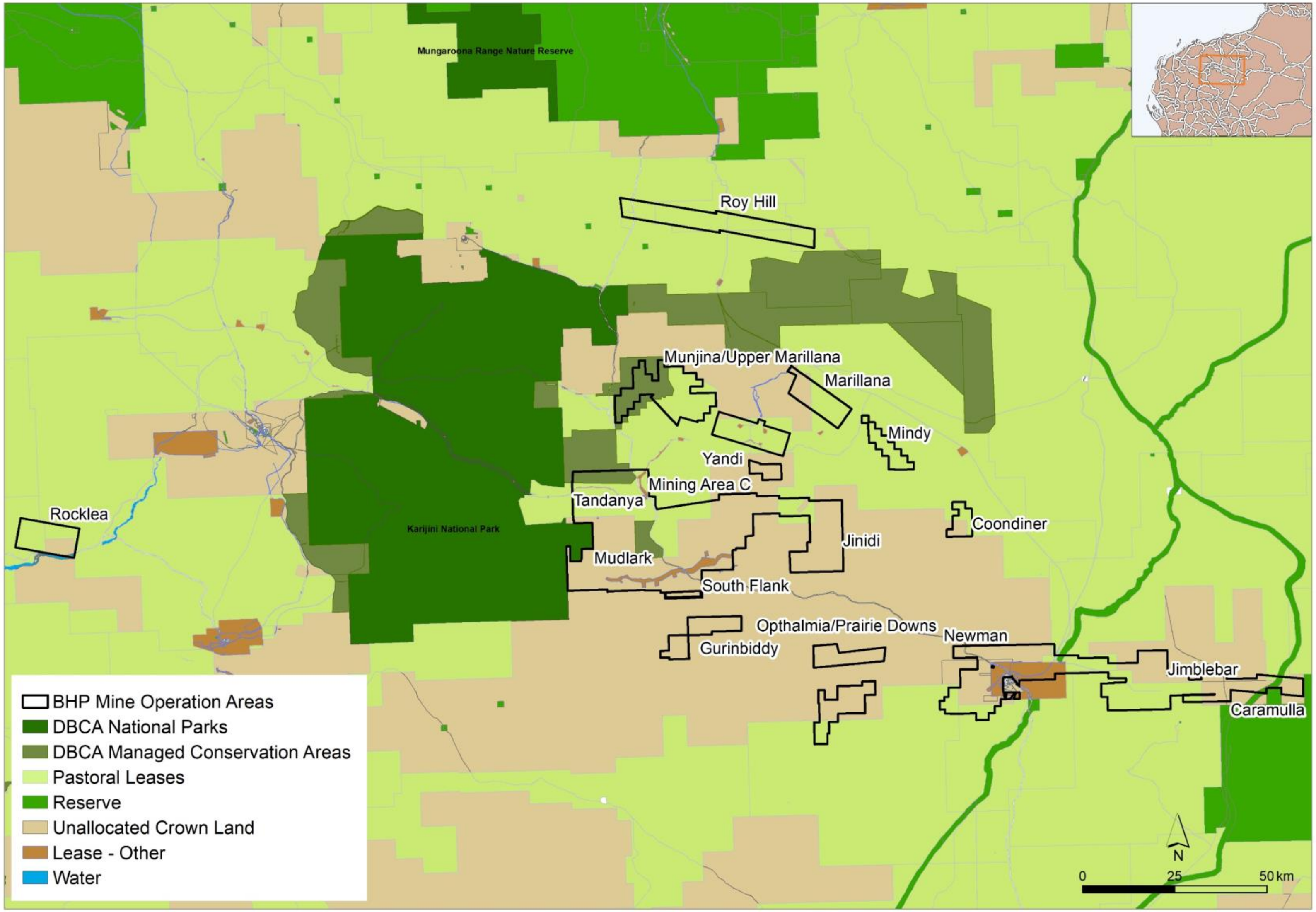



**Figure 5. Current land tenure distribution in the Pilbara (Hamersley and Fortescue subregions) (DPIRD 2018).**

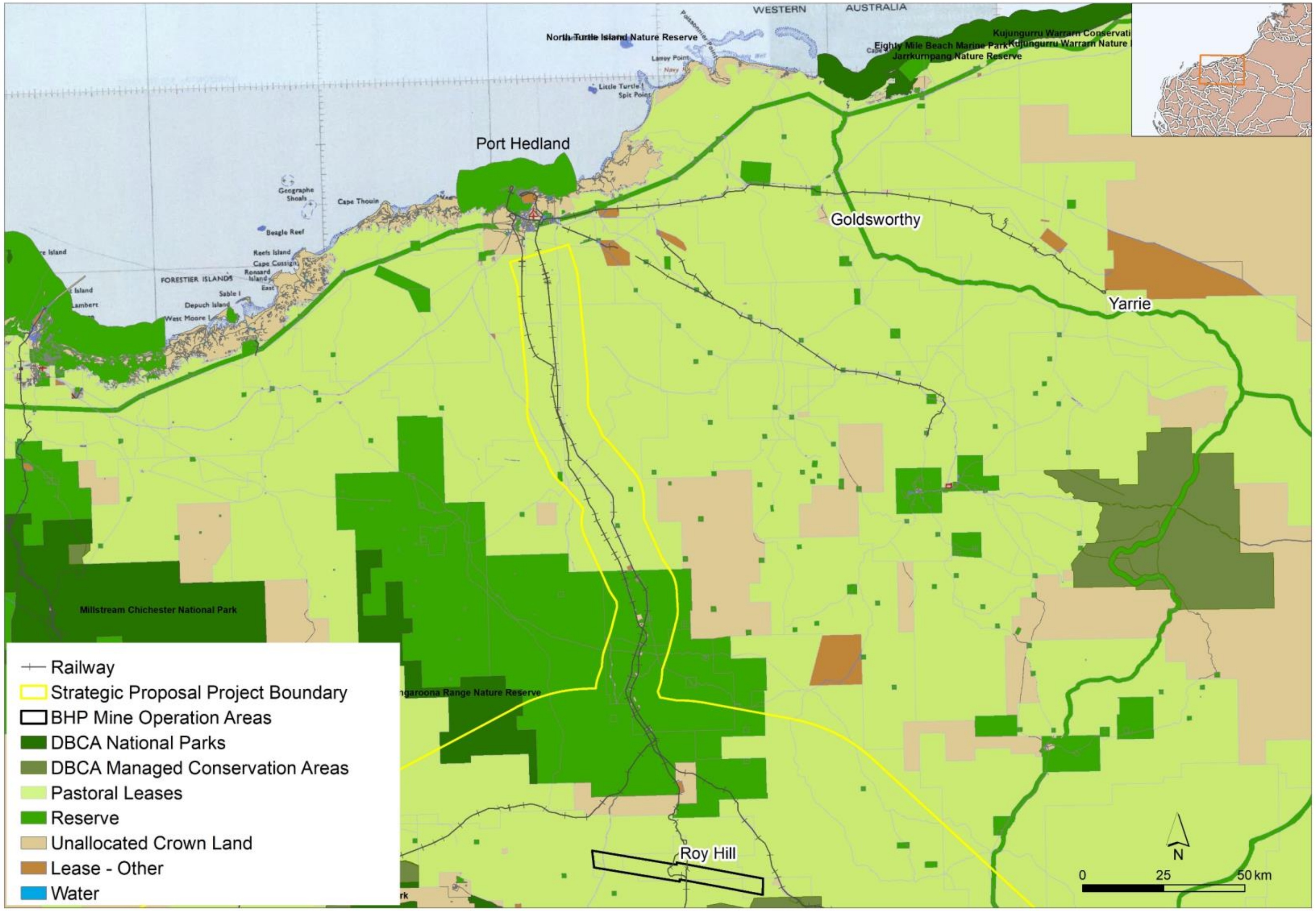



**Figure 6. Current land tenure distribution in the Pilbara (Chichester subregion) (DPIRD 2018).**

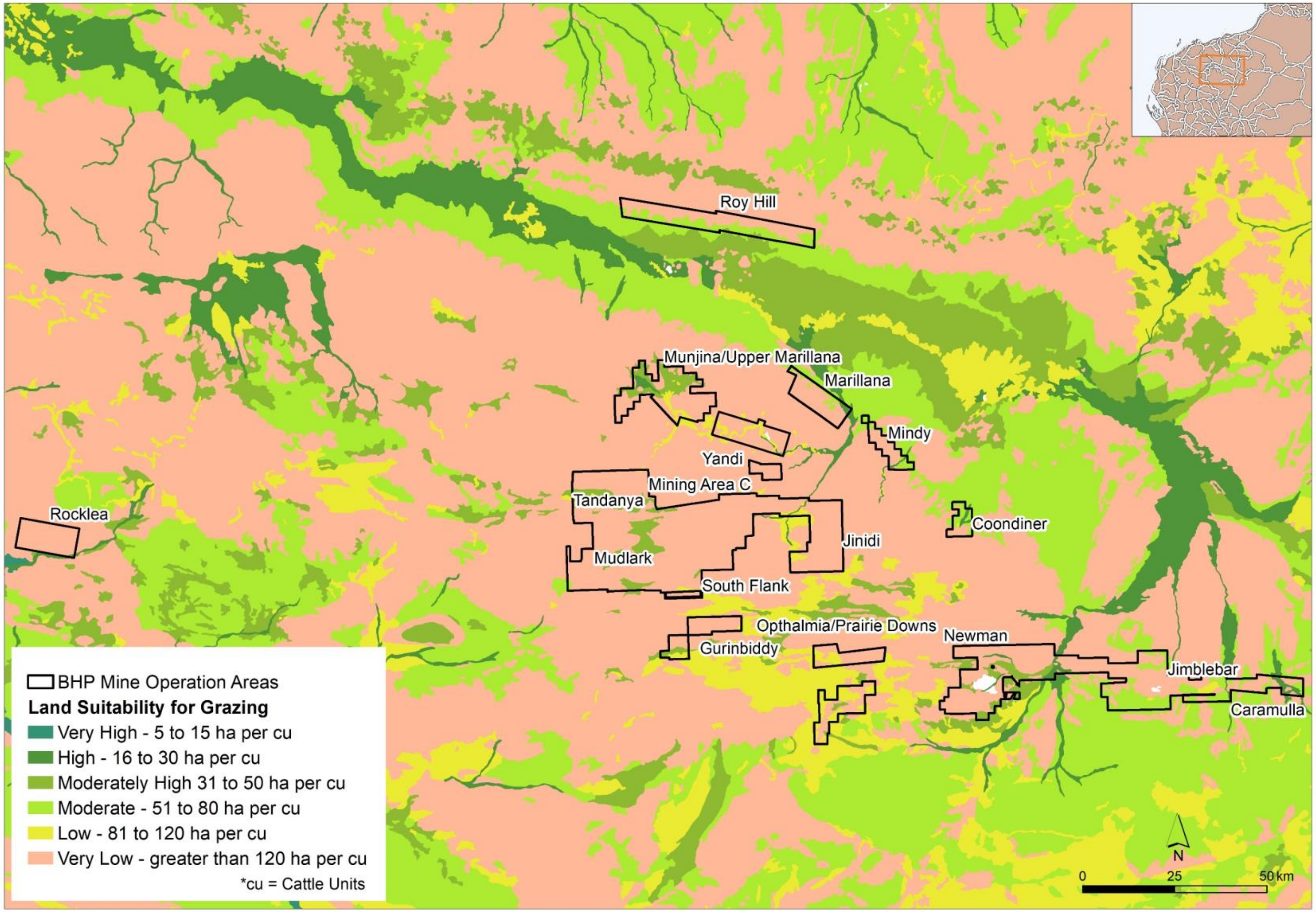



**Figure 7. BHP current tenure overlaid on lands considered suitable for pastoral grazing (DPIRD 2018).**

### 3.2 REHABILITATION GOAL

BHP has set the following rehabilitation goal for its WAIO operations, which applies to both pastoral grazing and managed resource protection final land uses:

*"To leave safe, stable, non-polluting and sustainable systems that conform with the regional landforms and vegetation types, and support the agreed final land use".*

### 3.3 CLOSURE OBJECTIVES

Given both major final land uses (managed resource protection or pastoral grazing) require the rehabilitation of natural environments (excluding voids), the key objectives need to reflect this. As such, the following objectives are proposed:

1. ***Naturalness*** – rehabilitated landscapes must have sufficient characteristics of the regional landforms and vegetation to be visually harmonious.

2. ***Resilience*** – rehabilitated landscapes must be able to recover from impacts typical of the region and final land use (i.e. fire, drought climatic changes, grazing) and continue to support the ecosystem services relevant to the final land use.

3. ***Habitat Connectivity*** - rehabilitated landscapes must provide suitable habitat (breeding, feeding, shelter, or migration) for regional and local fauna and must not sever ecological connections.

# PART 2 DERIVING CRITERIA

## 4.0 APPROACH TO MEASURING SUCCESS

Following on from the final land use selection, the following investigative steps were taken to develop completion criteria for measuring rehabilitation success in the context of BHP's WAIO operations in the Pilbara:

1. Determination of assessment scale.

   Baseline and reference site data were analysed in order to assess what spatial scale is right for assessment of rehabilitation success (e.g. regions, sites, vegetation types).

2. Determination of assessment metrics.

   Findings from both, the literature review and analysis of baseline and reference site data were used to assess the type of metrics appropriate for the Pilbara context (cover, density, richness etc).

3. Determination of assessment time frame.

   Data from rehabilitation plots and reference sites were analysed to determine the time scale that is appropriate for measuring success (completion) in the Pilbara.

4. Determination of assessment targets.

   Quantitative reference site and baseline data was used to derive targets for critical attributes. This was then compared and verified with published data specific to the Pilbara.

These steps and their outcomes are discussed in detail in individual sections below.

### 4.1 SELECTION OF APPROPRIATE ATTRIBUTES (FLORISTIC)

In order to select the most appropriate attributes for measuring completion success, those relevant to each of the closure objectives were first identified, based on the literature and review above (Section 2.3).

Key naturalness attributes include:

- Landform variability – hills, drainage lines etc.;
- Vegetation structure and associations – woodland, shrubland, grassland;
- Vegetation cover and pattern; and
- Presence of distinctive indicator species (e.g. snappy gum, hummock grasses etc).

The most significant variable in terms of naturalness (and habitat) is structure and pattern.

Key <u>resilience</u> attributes include:

- Soil properties - moisture, stability, carbon;
- Reproductive capacity of vegetation (ability to recover from fire or other impacts via a seed bank or via vegetative re-sprouting);
- Diversity - species, lifeforms and growth traits; and
- Weed type and cover.

Key <u>habitat</u> connectivity attributes include:

- Connectivity of vegetation patches;
- Vegetation patterns (and presence of bare ground);
- Diversity of structure; and
- Vegetation cover.

Note, analysis of BHP floristic reference plots indicates no clear correlations between the density of any plant lifeform or structural class, and cover, with the exception of weeds. As such, and given vegetation cover is the key attribute, density has not been included as a completion attribute. Note, plant density may be useful in early rehabilitation stages for gaining an understanding of the trajectory of success.

A few key attributes capture the objectives of naturalness, resilience and habitat connectivity. Hence, the proposed attributes are as follows:

- Bare Ground;
- Vegetation Types;
- Indicator Species;
- Plant Cover;
- Species Richness;
- Reproductive Capacity (Resilience);
- Weed Invasiveness; and
- Feral Animals.

## 4.2 TARGET ECOSYSTEMS AND VEGETATION TYPES

On the basis that both pastoral grazing and managed resource use final land uses are associated with relatively natural or natural environments, rehabilitated areas should aim to tie in with the natural features and ecosystems present within the Pilbara.

In terms of the closure objectives (naturalness, resilience, habitat), and the level of disturbance (which fundamentally alters landforms, stratigraphy, soils), rehabilitated areas should reflect the broad landforms and vegetation character. Targeting specific vegetation associations and communities is not considered practical or appropriate for post-mining rehabilitation in the Pilbara.

### 4.2.1 Ecosystem Types

The Pilbara is characterised by a range of ecosystems that reflect and interact with the geology, landform and climatic setting of region. Those that characterise areas within the Strategic Proposal Boundary cover terrestrial and wetland ecosystems, and include terrestrial and riparian woodlands and forests, shrublands, and grasslands; wetland ecosystems, including those associated with channel wetlands (major rivers, and minor watercourses), flats and plains, (floodplains, palusplains, claypans) and springs and other groundwater dependent ecosystems. The term ecosystem is applied at various scales, and in WA has been used at the scale of a specific community (e.g. wetland communities associated with Weeli Wolli Spring) as well as at the broader vegetation scale (e.g. spinifex grasslands) or geomorphic scale (e.g. claypan).

In terms of rehabilitation, the specific pre-mining environment is in general significantly altered and does not necessarily form the appropriate target ecosystem for future rehabilitation. As such, we propose to use the Major Vegetation Types defined in Beard et al (2013) and which are present within the Pilbara as the target ecosystems for rehabilitation.

### 4.2.2 Subregions

Most of the BHP WAIO tenure within the Strategic Proposal Boundary is located within the Hamersley, Fortescue and Chichester subregions within the Pilbara bioregion.

The Hamersley subregion is 5,634,727 ha in area (DSEWPaC 2012a) and is a mountainous area of Proterozoic sedimentary ranges and plateaux, dissected by gorges of basalt, shale and dolerite (Kendrick 2001). Mulga low woodland over bunch grasses on fine-textured soils dominates in valley floors, while on the skeletal soils of the ranges snappy gum (*Eucalyptus leucophloia*) over *Triodia brizoides* predominates (Kendrick 2001).

The Fortescue subregion is characterised by alluvial plains and river frontages. Extensive salt marsh, mulga-bunch grass, and short grass communities occur on alluvial plains in the east, and river gum woodlands fringe the drainage lines (Kendrick 2001b). An extensive calcrete aquifer (originating within a palaeodrainage valley) feeds numerous permanent springs in the central Fortescue subregion, supporting large permanent wetlands with extensive stands of river gum and cadjeput woodlands.

The Chichester subregion forms the northern part of the Pilbara Craton and is characterised by Basalt plains divided by Archaean granite and substantial areas of basaltic ranges. *Acacia inaequilatera* over

*Triodia wiseana* hummock grasslands characterise the shrub-steppe of the plains with tree-steppes of *Eucalyptus leucophloia* found on the ranges (Kendrick & McKenzie 2001).

### 4.2.3 Vegetation

Vegetation complexes and communities at all scales reflect the underlying geology, climatic zones (extent of aridity) and hydrology (extent of water availability).

The most recent broad-scale vegetation mapping undertaken in the Pilbara is the revised Beard mapping, which aggregates the original mapping done at a scale of 1:250,000 (Beard *et al* 2013) in a systematic way based on structural, floristic and geographic characteristics to generate at a 1:3,000,000 map scale. This scale describes broad ecosystems, defined by the dominant structure (grassland, woodland, forest etc), and identifies the typical (dominant, common) species present and typical landform and soil features. This scale is suggested as appropriate for capturing the objectives, deriving target vegetation types, and for assessing completion success.

The distribution of the major vegetation types is shown in Figure 8 and Figure 9, with a brief description of the main types present within the BHP Strategic Proposal Boundary provided below. Text is extracted from Beard *et al* 2013.

**1. Spinifex Grasslands**

***Low tree-steppe***

This vegetation type covers extensive areas of the Pilbara (over 3.4 million ha), predominantly on the ranges of the Hamersley subregion.

The hummock grassland has an overstorey of scattered low trees (<10 m tall with <10% projective foliage cover (pfc)), with the spinifex layer dominated by *Triodia wiseana*. The dominant eucalypt is *E. leucophloia* (Pilbara snappy gum), with *E. gamophylla* and *E. kingsmillii* also present. There are few large shrubs (*Senna* spp. *Grevillea wickhamii*, *Hakea lorea*) but a rich flora of small shrubs and forbs (*Acacia* spp, *Atriplex* sp. *Gompholobium* sp, *Gastrolobium grandiflorum, Keraudrenia integrifolia*, *Mirbelia viminalis*, *Petalostylis labicheoides, Ptilotus rotundifolius, Sida echinocarpa*, s.sp. aff. *petrophila* and *Triumfetta chaetocarpa*.

***Shrub-steppe***

This hummock grassland vegetation type covers 8 million ha in the Pilbara Bioregion.

It has *Triodia* spp.with a 10–30% pfc, with an open overstorey (<10% pfc) of shrubs such acacia, grevillea and mallee eucalypts. It is the characteristic vegetation of the interdunal swales and desert sandplains that receive less than 250 mm rainfall per annum, and on stony ground under higher rainfall conditions.

In the Pilbara Bioregion, there are several different units of sparse shrub-steppe. Common is *Acacia bivenosa* over a variety of *Triodia* species, including the hard spinifexes *T. basedowii* and *T. wiseana* and *T. brizoides* in the north-east. *Acacia bivenosa* and *A. trachycarpa* over *Triodia wiseana* sparse shrub-steppe occurs on very poor rocky country on gneiss in the central east of the Pilbara.

Shrub-steppe of *Acacia pyrifolia* over soft spinifex (*Triodia pungens*) occurs on the deeper soils on granite in the Abydos Plain, Oakover Valley and extends south into the Chichester Plateau. Other shrub species include *Grevillea pyramidalis*, *G. wickhamii*, *Hakea lorea* and *Acacia pachycarpa*. Further south on the basaltic soils flanking the Fortescue River, the association is joined by *Acacia xiphophylla* (snakewood).

The shrub-steppe unit of *Acacia aneura* s.l. (mulga) and *A. pyrifolia* over *T pungens* and *T. basedowii* occurs on the basaltic hills on the Hamersley Plateau.

***Grass-steppe***

This vegetation type consists of a hummock grassland without emergent trees or shrubs and is classified according to the dominant spinifex species (*Triodia* spp.). A variety of herbs may be present between the hummocks, and the species composition of this component is dependent upon the amount and season of rainfall.

Grass-steppe is not common and in general occurs as patches on rocky outcrops rather than in wide expanses. In the Pilbara Bioregion it is found in the central north - west coast around Roebourne and in small diffuse pockets within the Hamersley subregion. The grass-steppe is generally mapped as *Triodia pungens* (soft spinifex) north of latitude 22°S and *Triodia basedowii* (hard spinifex) south of this latitude. The hummock grasslands to the south and south-east of Point Samson around Roebourne are a mixture of *Triodia pungens* (soft spinifex) and *Triodia wiseana* (limestone spinifex). Here they occur on hilly ground adjacent to the alluvial plains that support a mosaic of mixed short bunchgrasses and spinifex.

### 2. Low Woodlands

***Low woodland, open low woodland and sparse woodland: mulga***

The *Acacia aneura* s.l. (mulga) low woodland (10–30% pfc), open low woodland (<10% pfc) and sparse woodland (negligible pfc) type is typical of the valley plains in the Pilbara Bioregion. It has an understorey of shrubs of *Eremophila* spp. and *Senna* spp. and annuals such as *Ptilotus nobilis*.

### 3. Bunch Grasslands

***Riverine sedgeland/grassland with trees***

This vegetation type is associated with drainage lines. In the Pilbara the trees are mainly *Eucalyptus victrix* (coolibah) and *E. camaldulensis* (river gum) over mixed sedges from the families Cyperaceae and Restionaceae, and grasses (*Aristida* spp. and *Eragrostis* spp.).

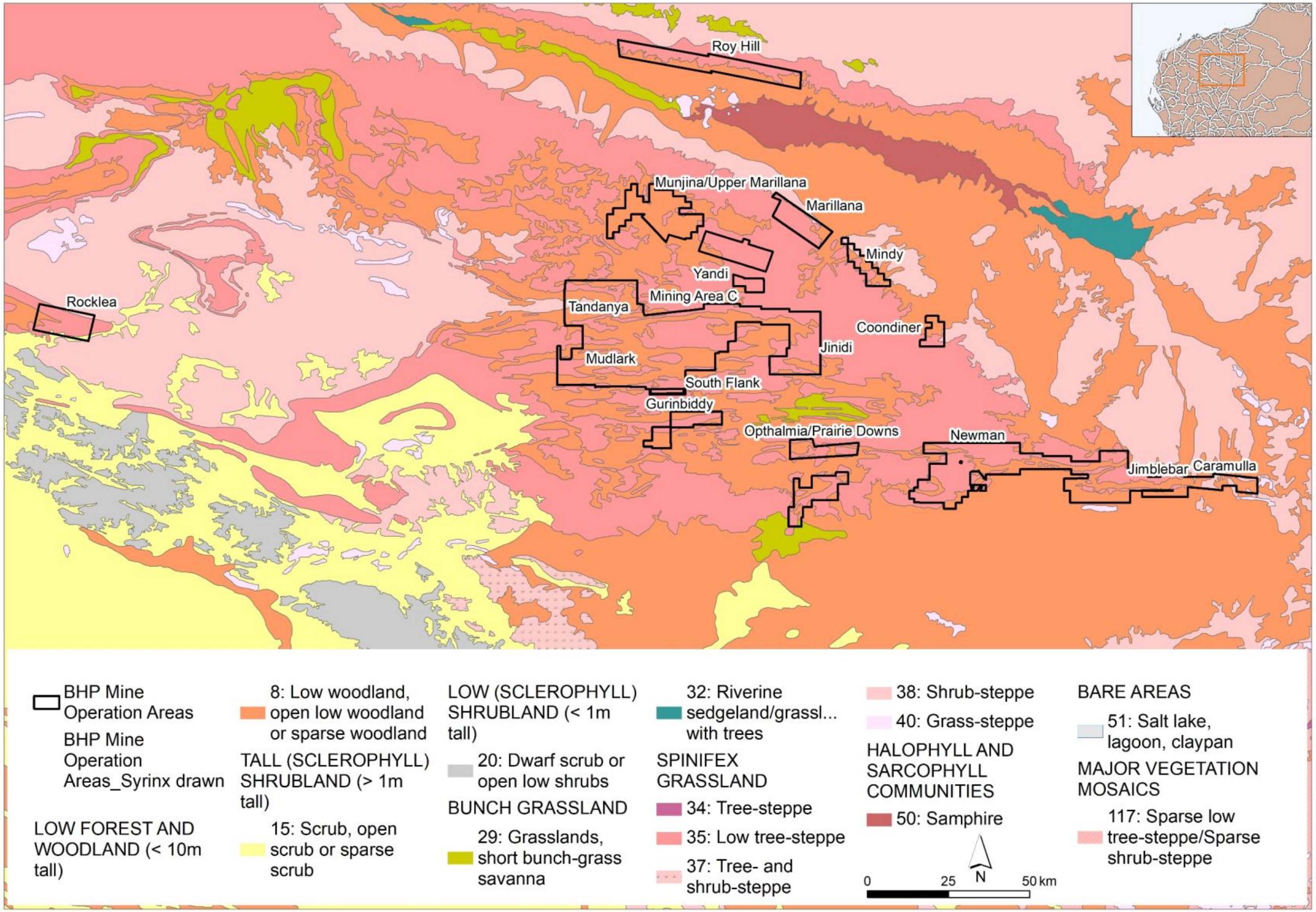



**Figure 8. Major vegetation types in the Pilbara (Hamersley and Fortescue subregions) (Beard *et al*, 2013).**

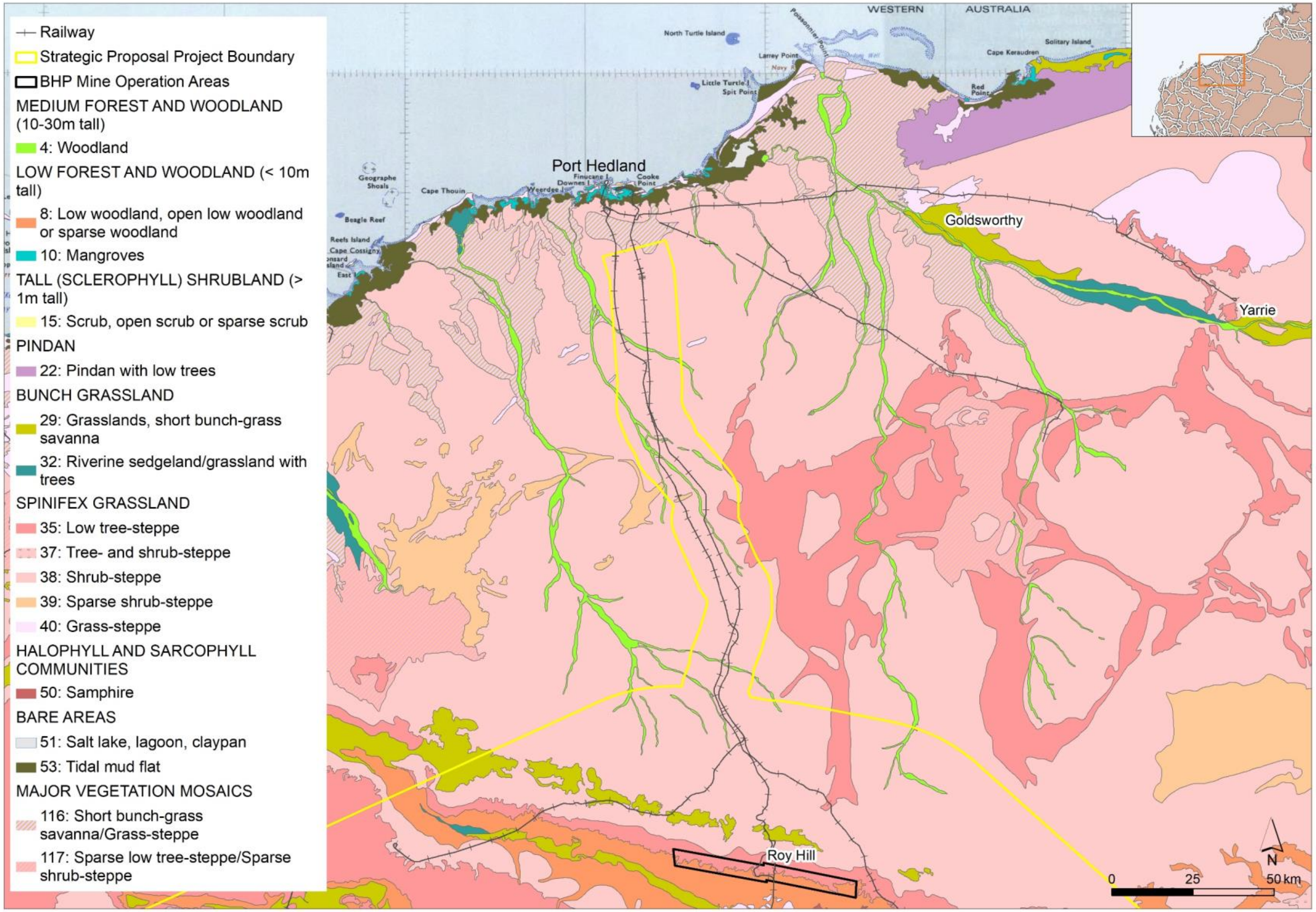



**Figure 9. Major vegetation types in the Pilbara (Chichester subregion) (Beard *et al*, 2013).**

# 5.0 INFLUENCE OF SCALE

All the above attributes are scale-sensitive however the appropriate scales at which these apply meaningfully in measuring rehabilitation success in the Pilbara region have not been defined. This section uses BHP reference data to determine the key influencing factors.

## 5.1 SITE SCALE

Current BHP rehabilitation monitoring is done at the local scale (sites within hubs) and has been compared against nearby vegetation reference sites and compared for landform features (crest, slope, flats).

There are three issues with this:

1. Each site typically has only a few plots (since monitoring is costly and time-consuming) which do not capture the spatial variability well. Measurements of success are therefore strongly influenced by the sampling method and may not represent reality.

2. The reference vegetation plots are at the scale of a vegetation community and may not be appropriate to the final land use or restored vegetation types. Whilst the plots are used to represent broader vegetation associations, again the plots do not represent the variability within the broad vegetation associations. This also generates a false evaluation of failure (see Miller *et al* 2018, which portrays the BHP rehabilitation efforts as falling short of requirements, and highlights dissimilarity issues in terms of species composition between rehabilitation sites and reference sites).

3. Comparisons made separately for crests, slopes and flats, while potentially relevant for species composition, do not necessarily have relevance to the major attributes.

To illustrate the first issue, a comparison of two sampling methods BHP has used at WAIO sites is given in Table 4.

Prior to and including 2016, reference sites and rehabilitation sites were monitored using the belt transects method, with plots each 1m x 50m. In 2017, this method changed to align with new EPA floristic survey standards (EPA 2016), and plots are now done as 50m x 50m quadrats.

As to be expected, the comparison showed a significant influence of sampling method on median ranges for cover, density and species richness. In particular, reference sites monitored in 2017/18 were found to have significantly <u>lower</u> cover and density (median ranges) for *Triodia* and herbs, while shrub cover and density showed an <u>increase</u>. This is a substantial change and indicates how much the assessment of rehabilitation success is influenced by the spatial scale of assessment.

In terms of crests, slopes and flats, analysis of all reference sites combined (2018 data) indicates there is no difference between these landform features in terms of rehabilitation attributes (Figure 10).

**Table 4. Influence of the sampling method on some key assessment metrics.**

**COMPARISON OF REFERENCE SITES BETWEEN 2011/16 AND 2018 DATA SETS**

| Triodia Cover | 2011 - 16 (no fire) | 2018 | % diff |
|---|---|---|---|
| CENTRAL | 31.8 | 20.2 | 37% |
| EASTERN | 35.9 | 15.8 | 56% |
| NORTHERN | 34.6 | 30.5 | 12% |
| **ALL REGIONS** | 33.6 | 21.1 | 37% |

| Shrub Cover | 2011 - 16 (no fire) | 2018 | % diff |
|---|---|---|---|
| CENTRAL | 3.9 | 8.2 | -110% |
| EASTERN | 3.6 | 7.6 | -114% |
| NORTHERN | 4.6 | 4.7 | -1% |
| **ALL REGIONS** | 4.0 | 7.0 | -73% |

| Herb Cover | 2011 - 16 (no fire) | 2018 | % diff |
|---|---|---|---|
| CENTRAL | 0.5 | 0.2 | 59% |
| EASTERN | 7.7 | 0.5 | 93% |
| NORTHERN | 1.9 | 0.3 | 86% |
| **ALL REGIONS** | 7.7 | 0.4 | 95% |

| Triodia Density | 2011 - 16 (no fire) | 2018 | % diff |
|---|---|---|---|
| CENTRAL | 34,222 | 27,108 | 21% |
| EASTERN | 80,484 | 14,133 | 82% |
| NORTHERN | 16,143 | 23,215 | -44% |
| **ALL REGIONS** | 40,706 | 20,234 | 50% |

| Shrub Density | 2011 - 16 (no fire) | 2018 | % diff |
|---|---|---|---|
| CENTRAL | 2,384 | 4,231 | -77% |
| EASTERN | 2,600 | 3,505 | -35% |
| NORTHERN | 1,829 | 4,385 | -140% |
| **ALL REGIONS** | 2,286 | 3,949 | -73% |

| Herb Density | 2011 - 16 (no fire) | 2018 | % diff |
|---|---|---|---|
| CENTRAL | 2,130 | 7,785 | -266% |
| EASTERN | 12,884 | 7,400 | 43% |
| NORTHERN | 3,867 | 9,862 | -155% |
| **ALL REGIONS** | 5257.1 | 8187.2 | -56% |

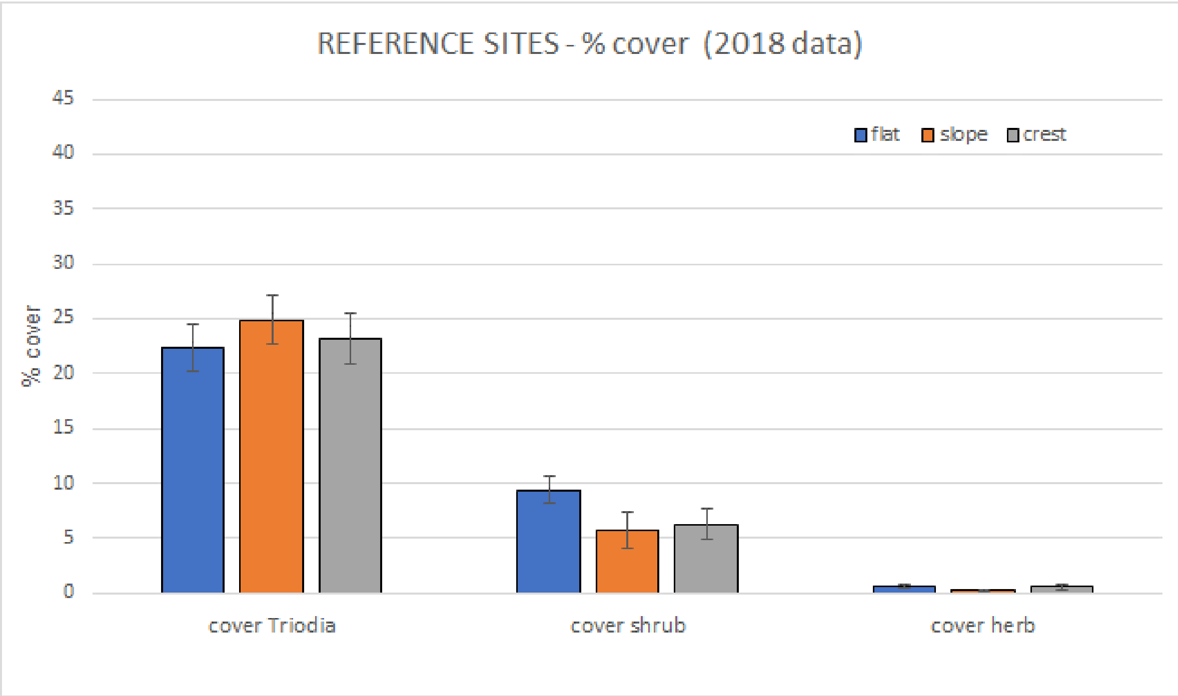



**Figure 10. Comparison of cover of *Triodia*, shrubs and herbs separated by crests, slopes and flats** (no of reference sites: flats=28; slope = 14; crest = 13).

## 5.2 HUB SCALE

To determine differences at the hub scale, the percentage cover of *Triodia* and shrub cover from the 2018 reference sites (all available plot data combined) was graphed (Figure 11). Given the hubs cluster regionally, these are grouped within the broad geographical regions.

There are some obvious differences between hubs, however the variation (standard error bars) is high and hence these observed differences are not considered to be significant (based on the limited data available). Therefore, at the hub scale, it is difficult to see merit in setting specific targets for *Triodia* cover for example, although shrub cover may be valid.

When perennial and annual richness is analysed per hub, a more pronounced hub-specific variation can be observed, especially for native perennial species (Figure 12).

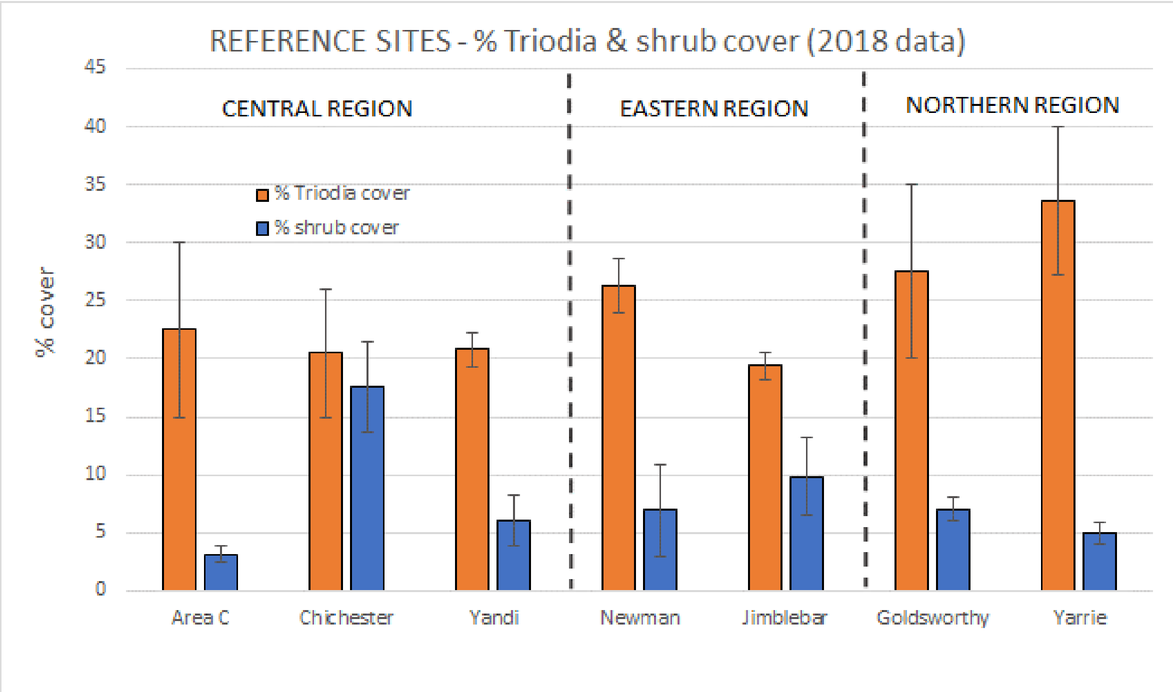



**Figure 11. Comparison of hubs for *Triodia* and shrub cover** (no of reference sites: Area C=2; Chichester Rail = 2; Yandi=8; Newman = 16; Jimblebar=5; Goldsworthy=2; Yarrie=6).

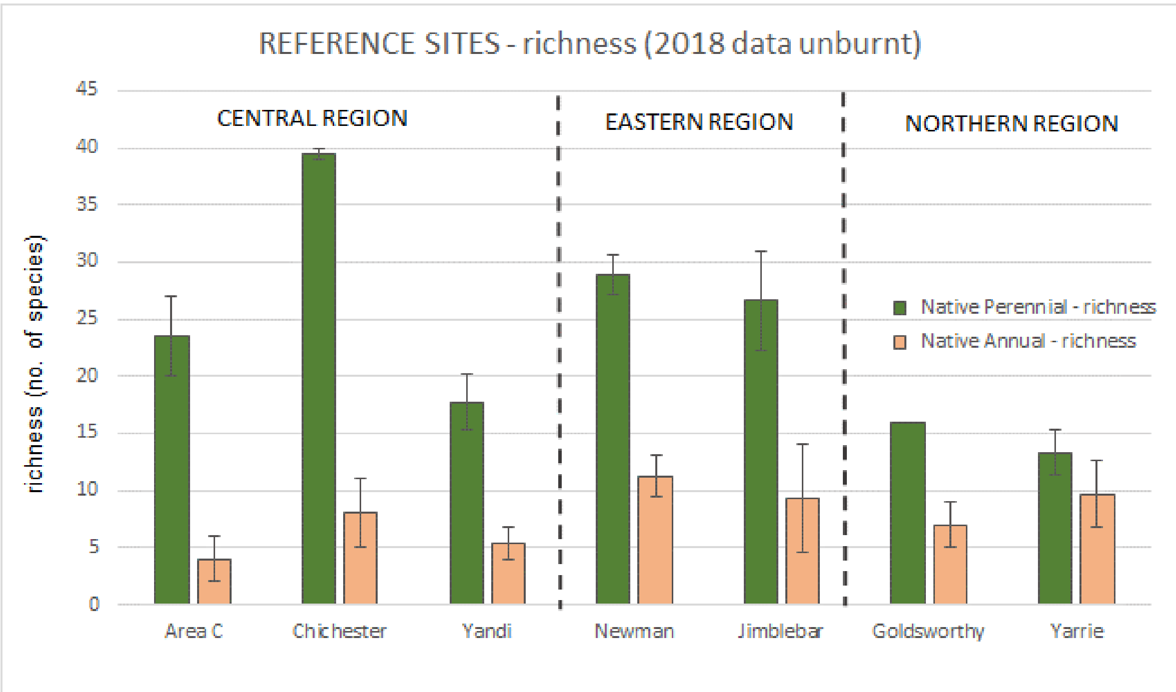



**Figure 12. Comparison of hubs for native perennial and annual richness** (no of reference sites: Area C = 2; Chichester Rail = 2; Yandi = 8; Newman = 16; Jimblebar = 5; Goldsworthy =2; Yarrie = 6).

## 5.3 REGIONAL SCALE

If the comparison is made at the geographic regional scale, there are more clear differences in terms of both *Triodia* cover and shrub cover, especially between the northern region (Goldsworthy, Yarrie) and central and eastern regions (Figure 13).

In terms of native annual and in particular perennial species richness, geographic regions show more substantial variations than cover (similar to patterns observed at the hub scale) (Figure 14) with the eastern region the highest.

This data clearly indicates that species richness exhibits regional and sub-regional 'signatures', but at the regional and hub scales, the number of species is low and the range typically 15 – 30 species. Focusing on species richness during rehabilitation is likely to be sufficient to meet targets, and this has been shown to be the case for BHP's historical rehabilitation to date (Miller *et al* 2018).

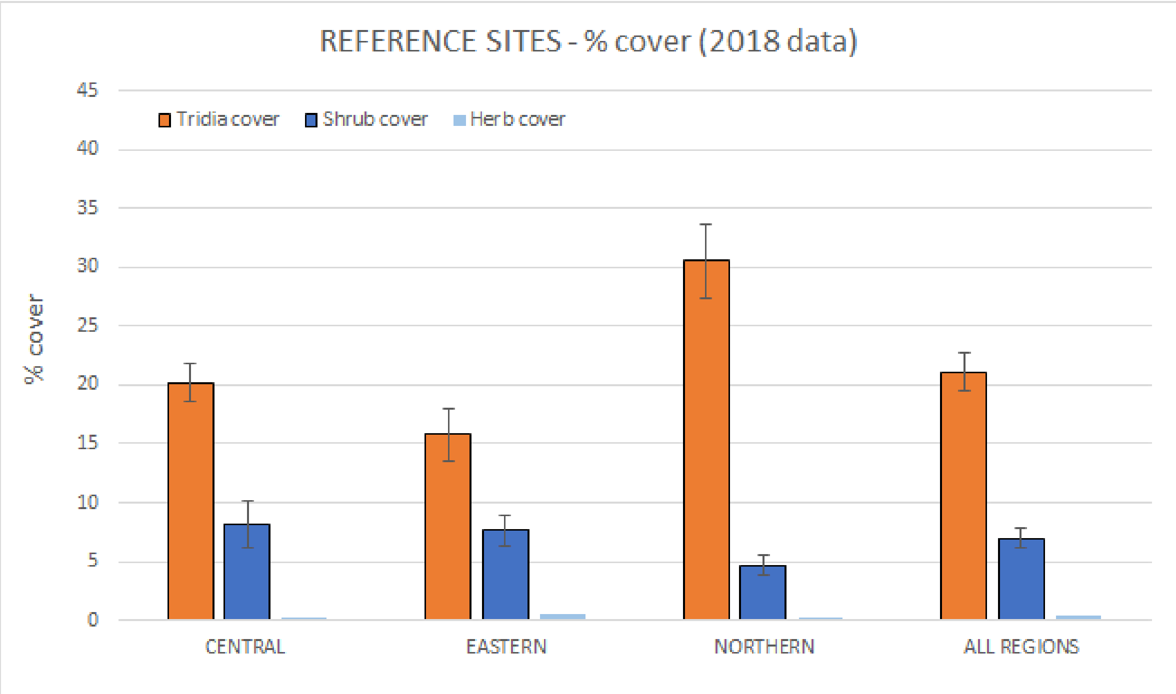



**Figure 13. Comparison of geographic regions for *Triodia*, shrub, and herb cover** (include sites with recent fire; Number of reference sites: Central region = 13; Eastern region = 21; Northern region = 13; All regions = 47).

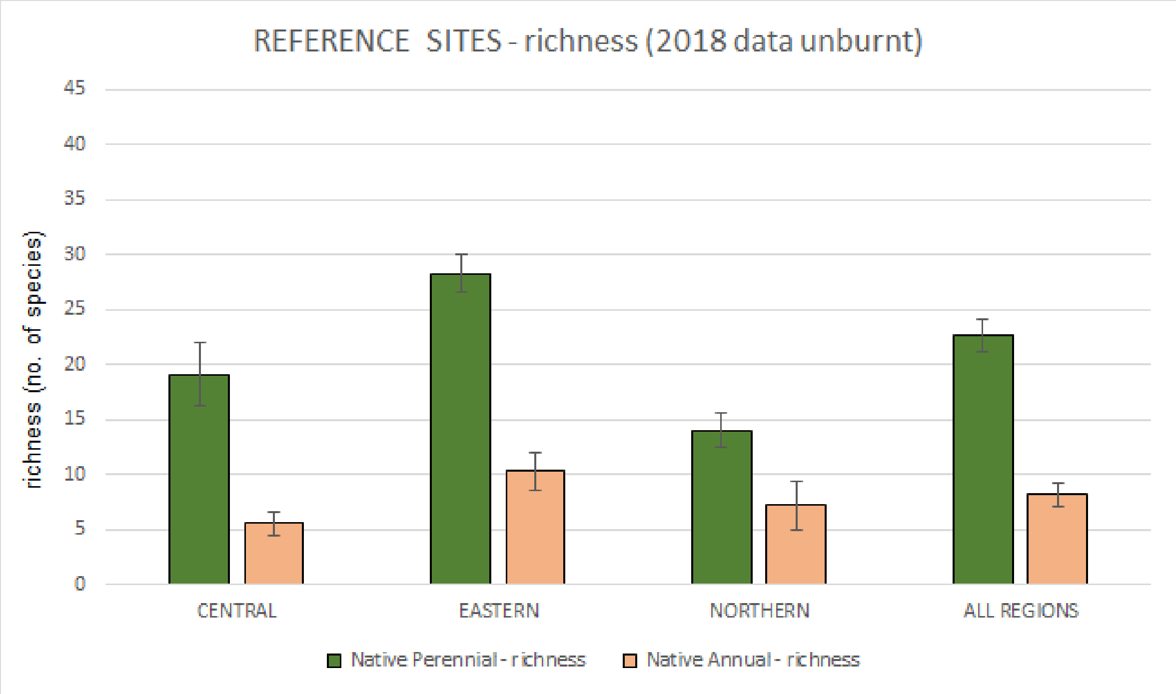



**Figure 14. Comparison of geographic regions for native perennial and annual species richness** (no. of reference sites: Central region = 12; Eastern region = 19; Northern region= 8; All regions = 39).

## 5.4 VEGETATION TYPE (ECOSYSTEM) SCALE

The relationship between vegetation cover as a key attribute, and vegetation type (grass steppe, shrub steppe, low tree steppe, low woodland) was also assessed (Figure 15). As per other comparisons, the 2018 reference data sets were used with individual plots assigned to their respective regional vegetation type, based on the spatial information and BHP vegetation descriptors included in the associated data tables.

Noting the data limitations due to relatively small plot numbers, there is variation in *Triodia* cover between vegetation types (highest for low woodland), as well as tree cover (highest for grass steppe), shrub and herb cover (highest in low tree steppe) and other grass cover (highest in shrub steppe). This indicates that <u>vegetation type is an important determinant of vegetation cover.</u> As more reference site data becomes available, this pattern is expected to be consolidated.

There is little variability in total species richness or richness within each stratum however perennial species richness is highest in low tree steppe and lowest in shrub steppe vegetation (Figure 16).

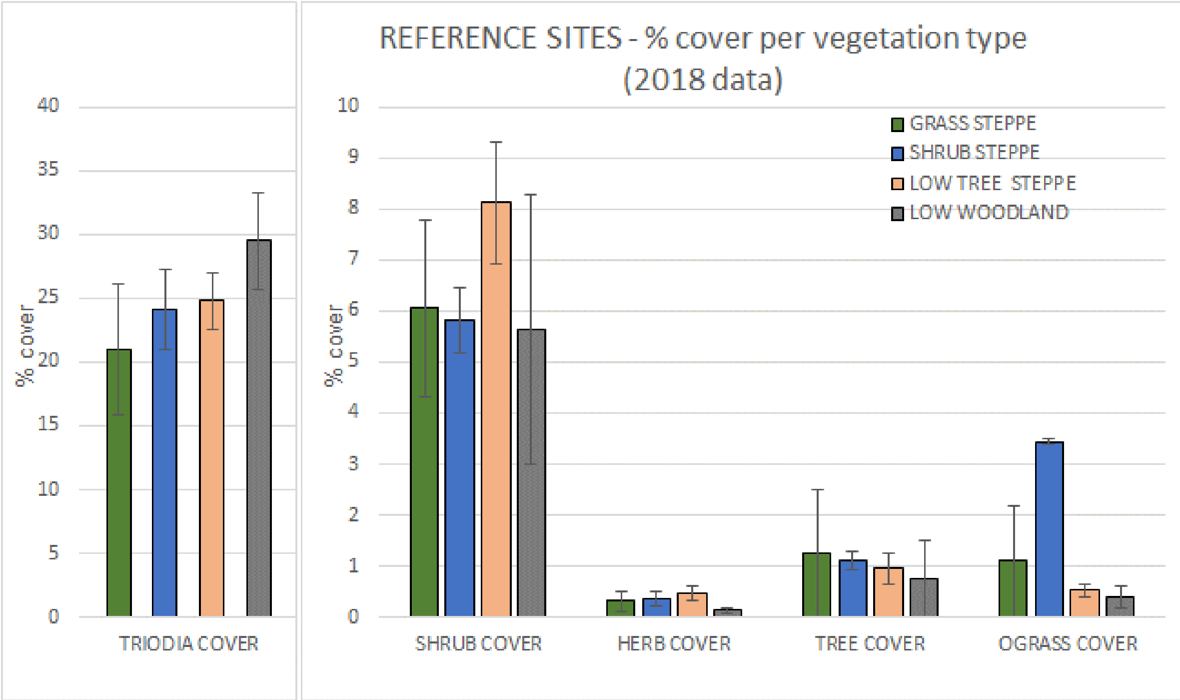



**Figure 15. Comparison of *Triodia*, shrub, herb and other grasses cover by major vegetation type** (no of reference sites: grass steppe = 4; shrub steppe = 7, low tree steppe = 24, low woodland = 4).

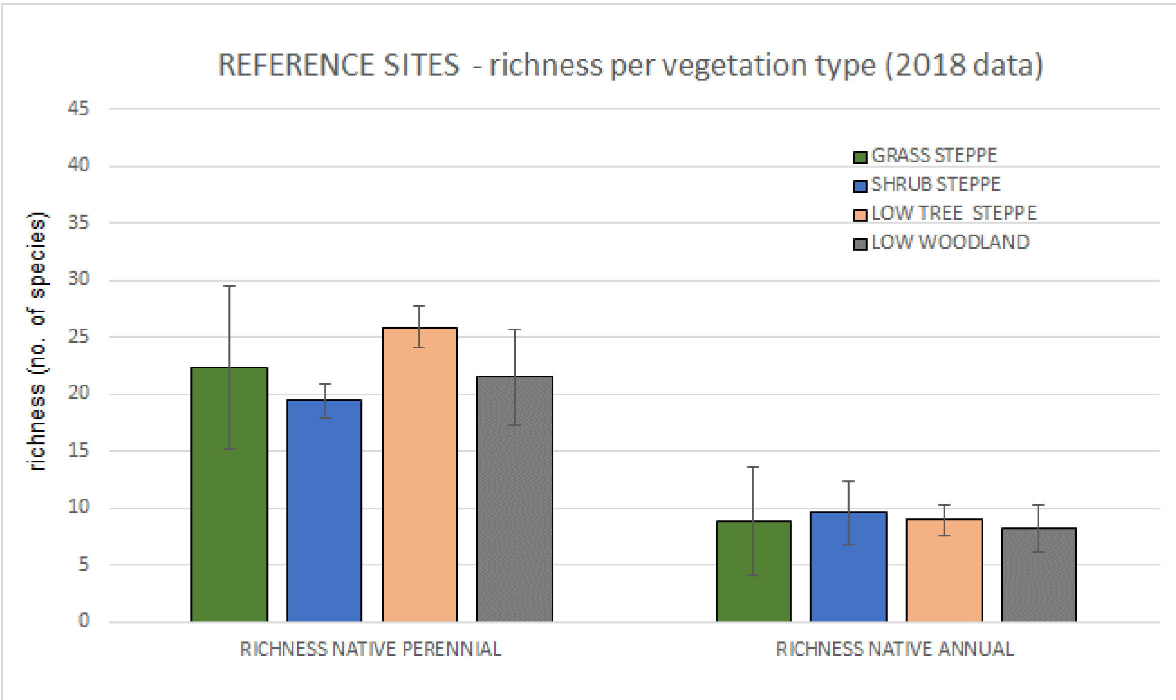



**Figure 16. Comparison of native perennial and annual species richness by major vegetation type.** (no of reference sites: grass steppe = 4; shrub steppe = 7, low tree steppe = 24, low woodland = 4). Note, recently burnt sites excluded.

Previous analysis of BHP data undertaken by BGPA (and published in Shackelford *et al* 2017) showed a high level of dissimilarity between the species composition of reference sites compared with rehabilitation sites. Without interrogating the differences in detail, it is probable that this may hamper the ability of rehabilitated sites to follow normal niche separation and successional processes typical of Pilbara vegetation types (at least until natural colonisation and competition effects sort out the imbalances) and may also mean some sites do not conform to the 'naturalness' objective. The inclusion of Indicator Species as an attribute, which requires the dominant and common species present within each stratum to be present in the rehabilitated landscape, will adequately capture this as a measurement of success criterion, however again rehabilitation protocols will be key to ensuring this criterion can be met.

### 5.5 SUMMARY

In summary, the site, hub and regional scales do not provide a meaningful basis of assessment for most of the selected attributes, because they are geographic and not climatic or ecological boundaries. It is clear that some variation should apply given the rough patterns observed between northern and other sites, between flats and slopes and crests, and within the hubs themselves.

Both land systems and vegetation types are key influencing variables in the Pilbara region. Comparisons using land systems is complex, is geological not ecological, and does not tease out the key ecological differences useful to determining the appropriate reference scale for measuring rehabilitation success. Vegetation at the broad scale (shrub-steppe, low woodland etc) is the logical reference unit, based on the above analysis of data.

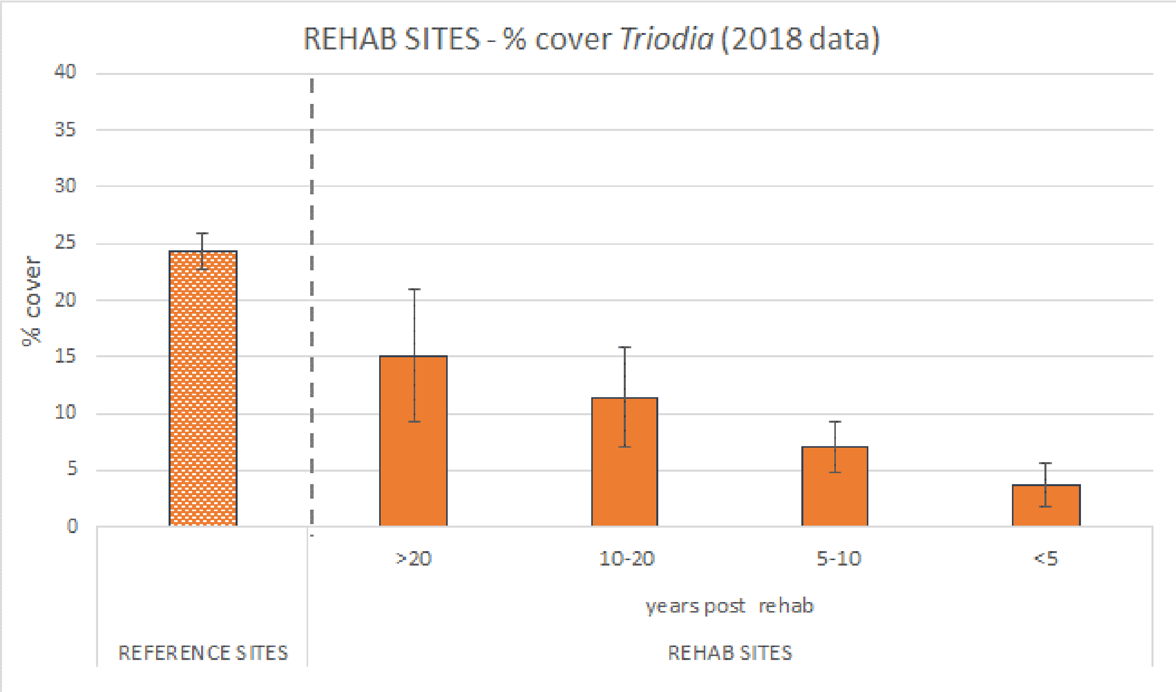
## 6.0 INFLUENCE OF TIME

In addition to spatial scale, a key consideration in setting realistic expectations around what constitutes a completed site, is time. To assess this, data from all rehabilitation plots (surveyed in 2018 ( Figure 17A) and in the 2011-2016 period (Figure 17B)) were aggregated into classes based on the age of rehabilitation, and assessed for *Triodia* cover, given this species is the major component of most of the target vegetation groups, and has typically been considered as the most important plant genera in terms of naturalness. Whilst this is a coarse approach, since the same plots are not actually followed in sequence, it provides some index of typical attributes at different time points.

The data indicates there is a strong impact of time on *Triodia* cover. Measuring success within the first 10 to 15 years after rehabilitation is not likely to reflect the potential of a site to complete its successional trajectory. Note, the reference sites are those currently used by BHP to assess sites and is not based on the broader vegetation types proposed here.

The data supports the measurement of a site against completion criteria after 15 years, and 20 years would not be an unreasonable time point for final assessment. Even with a sequence of good rainfall years and improvements in rehabilitation methods, it is unlikely that any site will be ready for assessment against completion criteria before 10 years, since even if some areas do attain the required metrics at this time, the site would need to sustain this during a poor climatic period and fire event to demonstrate resilience of the rehabilitation.

A)




B)

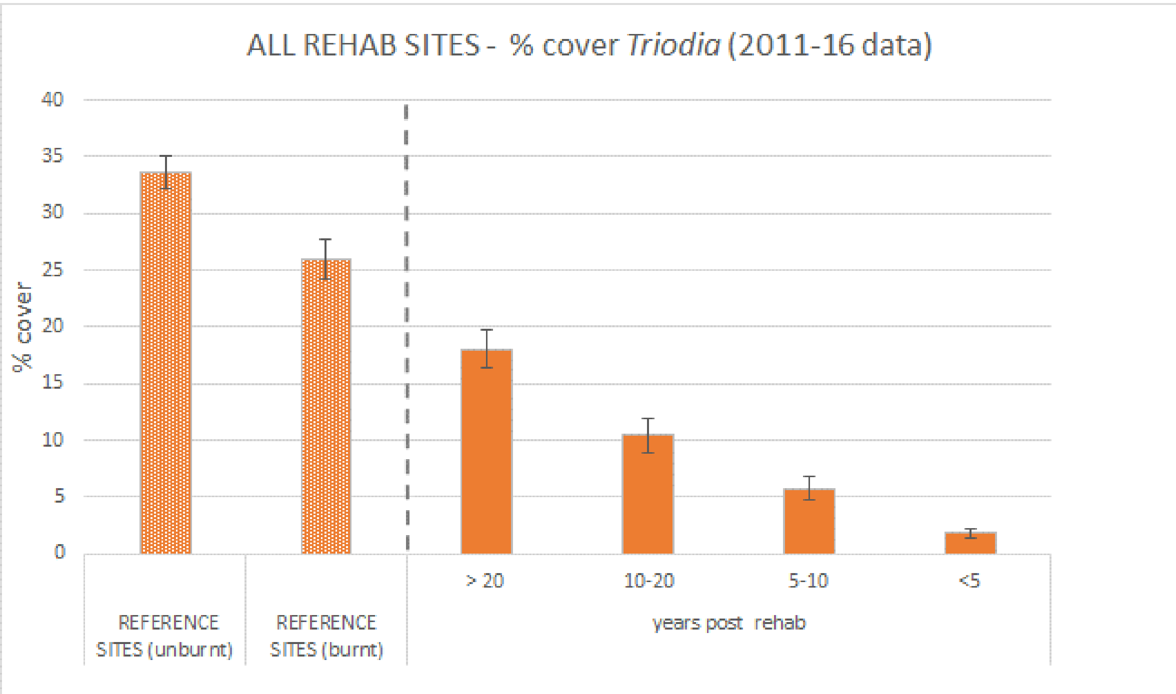



**Figure 17. Influence of time post rehabilitation on *Triodia* cover in rehabilitation sites using aggregated 2018 data (A) and 2011-2016 data (B)** (no. of rehabilitation site: 2018 data= 32 sites ; 2011-16 data = 229 sites).

## 7.0 FACTORS INFLUENCING WEED TYPE AND DISTRIBUTION

Buffel grass (**Cenchrus ciliaris*) cover, and the presence/absence of species listed as declared species in the Pilbara, have been included in BHPs rehabilitation annual reporting, using site-based reference data in a similar way to species richness and vegetation cover. The same criteria are proposed here, however the targets need to be agreed for both pastoral and natural final land uses.

Buffel grass is the most significant weed in terms of cover and extent. This species is not confined to mining operations and is seen by many pastoralists as an important component of pastoral lands.

Regionally, buffel grass has increased in coverage significantly over the past 20 years or so, and the actual extent of this species has been poorly understood and largely based on herbarium records.

In 2016, the CSIRO (Webber, Batchelor & Scott, 2016) aggregated data from 630 flora and vegetation reports in 2016 (for DPaW), which shows that this weed is widespread and known from nearly 12,000 locations (Figure 18). This includes occurrences within DPaW lands managed for conservation.

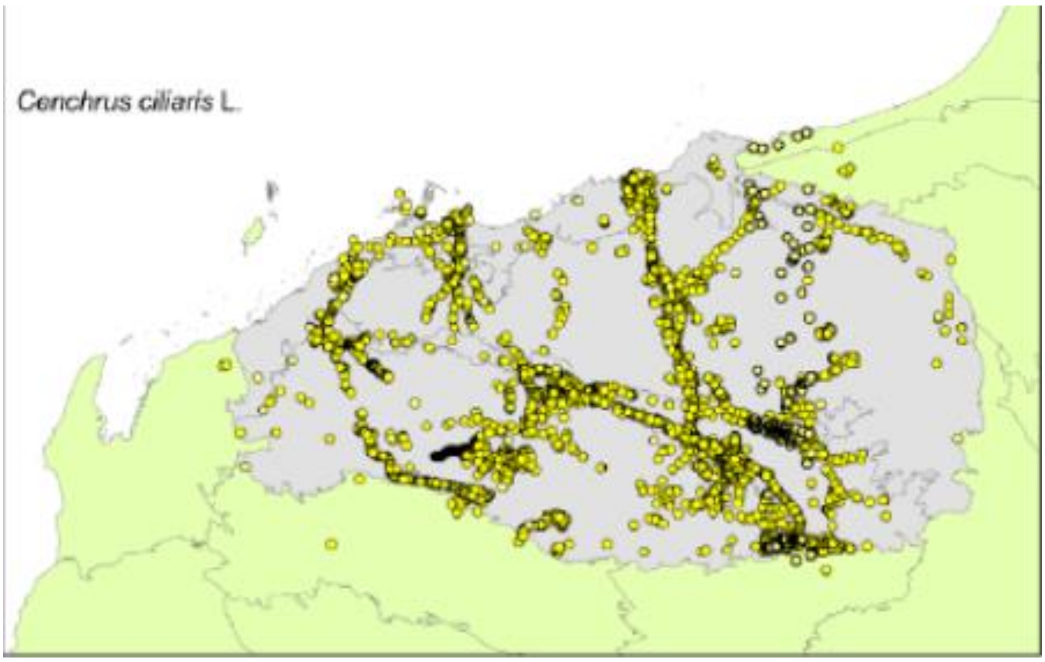



**Figure 18. Presence of buffel grass in Pilbara** (from aggregated Pilbara database, Webber *et al* 2016).

In addition to the CSIRO analysis, the presence of buffel grass within BHP reference plots grouped into broad landform types (Table 5) was assessed, and an extrapolated distribution of buffel grass within selected BHP tenement areas (Figure 19) generated.

It is clear that buffel grass is now widely distributed in BHP tenements, especially in areas with high moisture sites (floodplains, drainage channels) and high grazing activity.

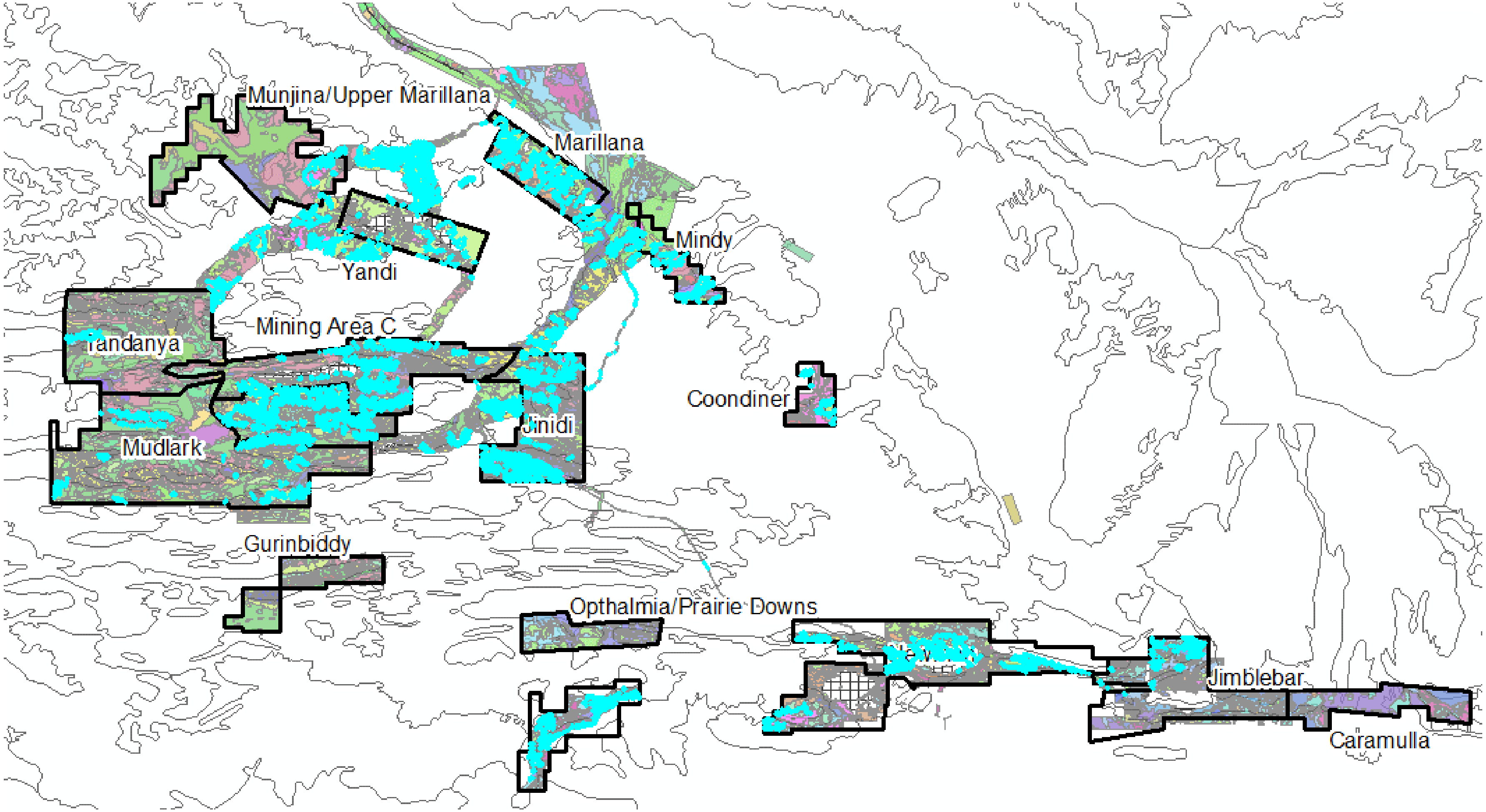



**Figure 19. Extent of buffel grass (blue) and probable frequency (average 16% of area) within minor drainage lines in selected central tenements.**

**Table 5. Frequency of buffel grass within plots in different landforms (BHP data).**

| LANDFORM | % Area Containing Buffel Grass |
|---|---|
| DISTURBED | 2% |
| FLOOD PLAINS | 13% |
| GRANITE OUTCROPS AND ROCK PILES | 3% |
| MAJOR DRAINAGE LINES | **21%** |
| MINOR DRAINAGE LINES | **16%** |
| SALINE FLATS AND MARSH | 0.5% |
| SAND PLAINS | 0.2% |
| STONY PLAINS | 3% |

Further to this, an analysis of historic rehabilitation weed cover data shows widespread presence of weeds across all of the hubs and regions (Figure 20) with buffel grass being the dominant weed species.  The average weed cover across all hubs is ~5.3%. Historic data analysis also shows that weed cover (%) is very comparable between different regions and hubs.

Analysis of total weed cover in reference sites, the influence of spatial scale and location are relatively unimportant. The key factors determining weed distribution are disturbance type and soil moisture.  On average total weed cover is higher in infrastructure and waste dump sites, and less common along road/rail, camp, borrow pits.

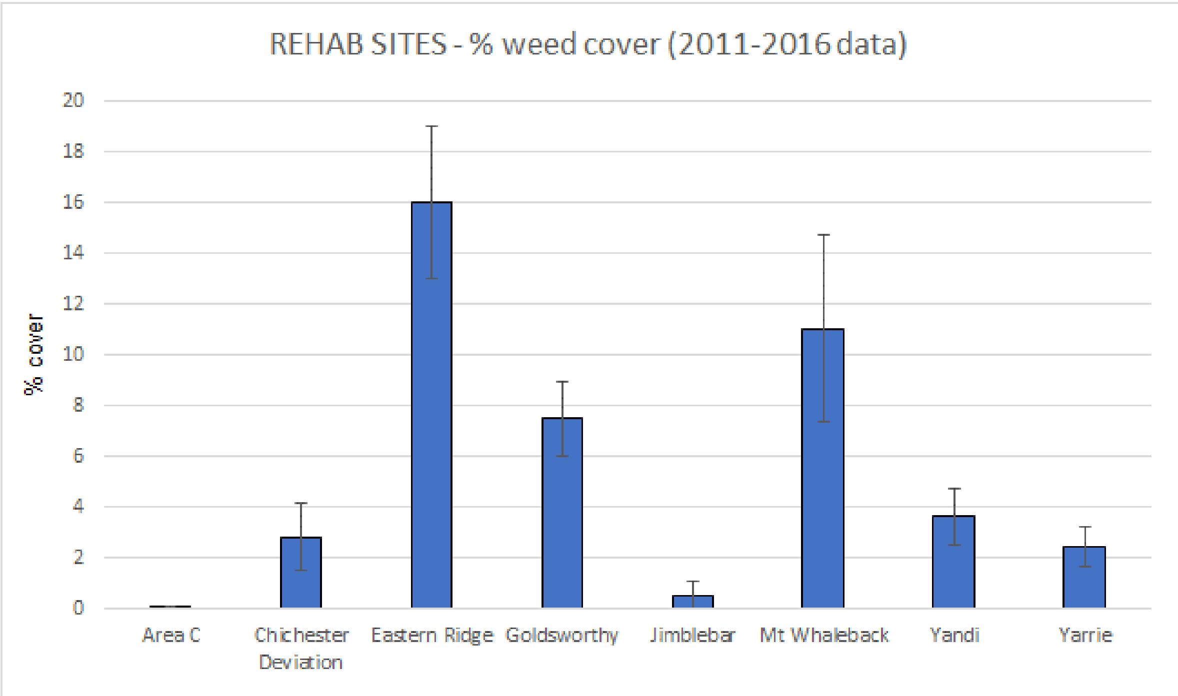



**Figure 20. Weed cover in BHP rehabilitation sites (historic data 2011-2016)** (no. of rehabilitation site = 229).

Based on the CSIRO information and combined with the BHP data, it appears that setting a blanket criterion of ‘no buffel grass’ within rehabilitation areas with a *Natural Environments for Managed Resource Protection* final land use is not practical.

As such, the baseline weed cover values combined with the historic rehabilitation data have been used to set practical and appropriate completion targets. If the cover of buffel grass declines regionally with tighter eradication controls, these targets would shift accordingly.

At this point in time, the determination of weed cover per landform could not be achieved using data currently provided by BHP, since regional reference plots do not contain information on weed cover. A separate analysis which would involve analysis of individual weed species data for each monitoring plot aggregated per site (rather than the summary data), is needed to provide a stronger foundation for the targets proposed.

# 8.0 DEVELOPING COMPLETION CRITERIA

## 8.1 SELECTION OF CRITERIA AND TARGETS

The proposed completion criteria (attributes, criteria, rationale) are provided in Table 6.

The criteria (what is to be achieved) require clear metrics as to how they should be measured (targets).

At this point in the process, attributes and criteria have been selected based on their appropriateness in representing the closure objectives and the science around sustainable ecosystems in the Pilbara. The target vegetation types have been set at the large-scale (Low Woodland, Grass Steppe etc), and the timescales for measuring a site against completion, is set at >15 years, based on the evidence of time taken to achieve adequate vegetation cover.

The final step in the measuring success process is the setting of targets.

The approach to the setting of specific targets is based on the following principles:

1. The closure objectives, which are not seeking replication of nature, but conformity with naturalness, resilience of rehabilitated landscapes, and habitat connectivity.

2. The attributes shown to best capture the objectives, based on analysis of reference data and the literature.

3. The variability within the Pilbara, which does not favour the use of averages for ecological targets, but ranges that capture the typical variability based on vegetation types and landform (weeds attributes).

4. Disturbance impacts, such as from existing pastoral activities, road and rail corridors, townships etc, as well as wider climate influences, that have resulted in modifications to the pre-European condition.

For simplicity, the completion criteria table contains the attribute, criteria, rationale and measurement method, however, where there are quantitative targets set for vegetation type, these are provided in a separate table (Table 7 and Table 8). This is also schematically presented in Figure 22.

The reference ranges for some attributes (e.g. buffel grass) may be adjusted periodically, in response to regional shifts caused by climate change, new legislative control requirements, or other regional scale influences.

In general, the targets applied to the attributes include:

- Minimum or maximum values, derived from reference sites (weeds, bare ground);
- Presence/absence data (indicator species); and
- Ranges (species richness, vegetation cover).

Whilst the first two are clear and standard, deriving appropriate ranges is not so clear. To date, BHP has been assessing targets using average data from rehabilitation plots, compared with average data from nearby reference plots. More recently datasets have been compared using 95$^{th}$ percentile targets, or even the lowest point on a range, however, again, the scale of comparison was site-based (Shackelford *et al* 2017).

The approach for deriving the quantitative targets set for plant cover and species richness is provided below.

1. To best capture natural variability of vegetation covers within individual vegetation types, the 'typical' <u>cover ranges</u> for each stratum was determined for each of the major vegetation types. These ranges were defined using the following approach:
    - Vegetation cover and species richness data for reference sites surveyed in 2017/18 was used. Note, reference sites with evidence of recent fire were excluded from the analysis.
    - Each reference site was defined in terms of the major vegetation type they are located within, using spatial mapping data and georeferenced plot positions.
2. For each vegetation type and each stratum (tree, shrub, *Triodia*, other grasses, herb) ranges were determined using the interquartile range (IQR) statistical approach.

IQR is a measure of variability, based on dividing a data set into quartiles. This approach divides the sorted data set into four equal groups (by count of numbers), each representing a fourth of the distributed sampled population. There are three quartiles: the first quartile (Q1), the second quartile (Q2), and the third quartile (Q3).

- The first quartile (lower quartile, QL), is equal to the 25$^{th}$ percentile of the data. (splits off the lowest 25% of data from the highest 75%).
- The second (middle) quartile or median of a data set is equal to the 50$^{th}$ percentile of the data (cuts data in half).
- The third quartile, the upper quartile (QU), is equal to the 75$^{th}$ percentile of the data. (splits off the lowest 75% of data from highest 25%).

- Q1 (lower quartile) is the "middle" value in the first half of the rank-ordered data set and is equal to the 25th percentile of the data.
- Q2 (middle quartile) is the median value in the set and is equal to the 50th percentile of the data
- Q3 (upper quartile) is the "middle" value in the second half of the rank-ordered data set, and is equal to the 75th percentile of the data.

The interquartile Q1-Q3 range is defined as the difference between the largest and smallest values in the middle 50% of a set of data (Figure 21).

Because of the natural variability of the Pilbara, and because the objectives are based around naturalness and resilience, and are not attempting to replicate natural vegetation communities, this approach that effectively targets the 'middle-range' is considered appropriate and has been applied to all quantitative targets.

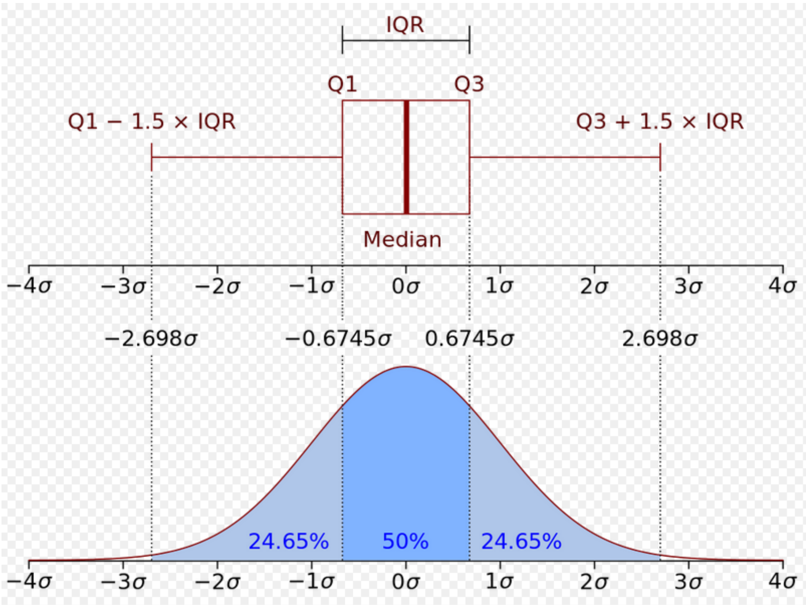



**Figure 21. The interquartile range (IQR) statistical approach adopted for setting cover targets.**

## 8.2 VARIATION IN TARGETS BASED ON FINAL LAND USE

The key differences in the targets set for *Relatively Natural Environments (pastoral grazing) areas* (Table 7) vs *Natural Environments for managed resource protection* (Table 8) relates to:

1. Permissible cover of buffel grass;
2. Area to which naturalness targets apply; and
3. Application of quartile target ranges.

The proposed buffel grass targets are shown diagrammatically for a hypothetical pastoral final land use scenario, and a natural area scenario (Figure 22). As discussed in Section 7.0, the occurrence of buffel grass correlates with landform more than vegetation type and is particularly dominant in drainage lines and floodplains at most sites. As such, and for both final land use scenarios, separate targets have been applied to hills, plains and drainage lines/floodplains to reflect this.

In terms of vegetation cover, species richness, and indicator species, these targets are set to apply to a minimum of 50% of rehabilitated areas, and to all rehabilitation areas classed as not suitable for supporting native perennial pasture grasses (i.e. OSAs and other areas where soil depth and soil moisture can only support hummock grassland.

For cover criteria, the targets are >Q1, given the composition of species in pastoral areas will not be typical of natural areas.

## 8.3 REFINING AND VALIDATING COMPLETION CRITERIA

To validate and refine the initial completion criteria, some additional reference plots monitored in 2017 but not in 2018, were added to the reference site database in order to expand the datasets. Specifically, the 2017 and 2018 BHP rehabilitation datasets, along with new information sets provided on vegetation associations within hubs, enabled refinement of the Target Vegetation Types applicable to each hub (previously this was estimated using small scale Beard et al 2013 mapping), recalculation of target metrics for completion criteria (i.e. Q1-Q3 ranges). No further changes to the reference targets should be needed, except for new mines which may have target vegetation types for which there is currently insufficient baseline data.

**Table 6. Completion criteria (attributes, criteria and metrics).**

| **CLOSURE OBJECTIVES:** | NATURALNESS (major vegetation types, characteristic (icon) species, structure, pattern), HABITAT and RESILIENCE (vegetation cover, richness, recruitment, stability) | | | |
|---|---|---|---|---|
| **ATTRIBUTE** | **CRITERIA** | **METRIC** | **RATIONALE** | **METHOD OF ASSESSMENT** |
| **Bare Ground (Non-vegetated)** | Bare ground to have stony/rocky cover and be typical of the regional landforms and generally evenly dispersed between vegetation | % bare ground with rock or stony cover for individual landforms (e.g. hills, slopes, etc) | Critical for achieving key attributes such as patterns, diversity, soil stability. | Survey by plot or equivalent method. |
| **Target Vegetation Types** | Vegetation types to respond to biogeographic region and finished landforms. All major Vegetation Types (Beard et al 2013) present at each site to be represented in post-mined landscapes | Presence of appropriate vegetation types | Provides variability of habitat types and is critical for achieving naturalness objective. | Survey by plot or equivalent method and comparison with Beard et al 2013 Pilbara vegetation types. |
| **Indicator Species** | Presence of dominant and common species from each Target Vegetation Type represented in post-mined landscapes | Presence of dominant species to reflect end use.<br>Presence of iconic species | Critical for achieving naturalness objective and ensuring required species and structure diversity. | Survey by plot or equivalent method |
| **Plant Cover** | Vegetation cover for each strata to reflect major vegetation type present within the rehab | % cover for each strata (e.g. trees, shrubs, grasses, etc.) to be within the median range (Q1 - Q3) for each major vegetation type | Key attribute of closure objectives (naturalness, resilience and habitat connectivity) | Survey by plot or equivalent method (median of aggregated plots per site compared to Q1-Q3 range for natural end use, >Q1 for pastoral)<br>By plot not less than 15 years post rehab |
| **Species Richness** | Perennial and annual native species richness to reflect each major vegetation type present within the rehab | Number of perennial and annual species to be within the median range (Q1 - Q3) for each major vegetation type | Strong indicator of resilience in Pilbara; important for achieving diversity and vegetation cover. | Survey by plot and releve (median of aggregated plots per site compared to Q1-Q3 range for natural end use, >Q1 for pastoral)<br>Not less than 15 years post rehab |
| **Reproductive Capacity (resilience)** | Demonstrated capacity of the site to recover from fire, drought and other disturbances. | Demonstrated capacity of flora to reproduce as evidenced by seedling recruitment and vegetative production. | Critical for achieving resilience objective. | Survey data to include type, age and extent of seedling recruitment and vegetative production |
| **Weed Invasiveness** | DBCA priority list weed species to be managed so as not to cause unacceptable risk to surrounding environments. | Absence of priority weed species or if present, cover not greater than in the regional surrounds. No new priority species to be introduced. | Critical for achieving naturalness and resilience objectives. | Surveys and comparison with regional baseline data. |
| | Total weed cover to be typical for each site and landform, and reflect final end use. | % total weed cover and % buffel grass cover per end use and landform | | Survey by plot and releve or equivalent method |
| **Feral Pests** | Feral animals and pests to be managed to protect native fauna and surrounding native habitats. | No new declared feral pests to be introduced as a consequence of BHPs operations | Critical for achieving naturalness and resilience objectives. | Surveys and comparison with regional baseline data. |

**Table 7. Targets for individual attributes – Land Use: Natural Environments for Managed Resource Protection.**

| **TARGETS** | | | | | | | |
|---|---|---|---|---|---|---|---|
| LAND USE: | NATURAL ENVIRONMENTS FOR MANAGED RESOURCE PROTECTION | | | | | | |
| **ATTRIBUTE** | **METRIC** | **TARGETS** | | | | | |
| **Bare Ground (non-vegetated)** | % bare ground with rock or stony cover | Hills, slopes, dryplains | ≤ 50 % | | | | |
| | | Drainage lines (excluding channel bed) | ≤ 20 % | | | | |
| | | Floodplains | ≤ 10 % | | | | |
| **Species Richness** | Perennial and annual native species richness (number of species per 50 x 50 m plot) | Perennial native | 14% - 30% | | | | |
| | | Annual native species | 4% - 11% | | | | |
| **Weed Invasiveness** | Priority alert weed species presence and cover | Presence and cover | Not present or if present, cover ≤ the surrounding areas (regional baseline) | | | | |
| | | Priority species | No new priority species introduced | | | | |
| | % all weed cover and % buffel grass cover | Total weed cover | | | | | |
| | | drainage lines, floodplains | < 15% | | | | |
| | | upland hills, slopes and flats | < 5% | | | | |
| | | Buffel grass cover | | | | | |
| | | drainage lines, floodplains | < 10% | | | | |
| | | upland hills, slopes and flats | < 5% | | | | |
| **Feral Animals** | Presence of declared feral animals and pests | Presence | No new priority species introduced | | | | |
| **Target Vegetation Types** | Presence of appropriate vegetation types | | **Grass Steppe** | **Shrub Steppe** | **Low Tree Steppe** | **Low Woodland** | **Riverine sedgeland/grassland** |
| **Indicator Species** | Presence of dominant and common species from each Target Vegetation Type<br><br>*Note, if more than one type is applicable, choose the most representative for each rehabilitated area* | At least one dominant species from each strata present<br><br>>70% of common species present | | | Dominant Trees<br><br>*Eucalyptus leucophloia, E. gamophylla* | Dominant Trees<br><br>*Acacia aneura group* | Dominant Trees<br><br>*Eucalyptus camaldulensis, E. victrix* |
| | | | | Dominant Shrubs<br><br>*Acacia bivenosa, A. aneura group, A. pyrifolia, Grevillea pyramidalis* | Dominant Shrubs<br><br>*Senna artemisioides, S. pleurocarpa var. pleurocarpa, Senna spp., Grevillea wickhamii, Hakea lorea* | Dominant Shrubs<br><br>*Eremophila spp. Senna spp.* | Dominant Shrubs |
| | | | Dominant Grasses:<br><br>*Triodia wiseana, T. basedowii* | Dominant Grasses:<br><br>*Triodia wiseana, T. basedowii, T. pungens.* | Dominant Grasses:<br><br>*Triodia wiseana* | Dominant Grasses:<br><br>*Triodia spp, Tussock grasses* | Dominant Grasses/Sedges:<br><br>Tussock grasses, sedges |
| **Plant Cover** | % cover for each strata and each Vegetation Type | Trees | 0 - 1 | 1 - 10 | 1 -10 | 2 - 10 | 10 - 70 |
| | | Shrubs | 0.2 - 7 | 3 - 7 | 2 - 10 | 2.6 - 6.8 | 2 -10 |
| | | Hummock Grasses | 15 - 34 | 19 - 33 | 20 - 30 | 17 - 33 | |
| | | Other Grasses | 0.01 - 0.4 | 0.02 - 0.16 | 0.04 - 0.62 | 0.2 - 1 | 2 -10 |
| | | Herbs | 0.1 -0.2 | 0.1 - 1 | 0.05 - 0.4 | 0.06 - 0.27 | |

**Table 8. Targets for individual attributes – Land Use: Relatively Natural Environments for Pastoral Grazing Purposes.**

| TARGETS | | | | | | | |
|---|---|---|---|---|---|---|---|
| LAND USE: | RELATIVELY NATURAL ENVIRONMENTS FOR PASTORAL GRAZING PURPOSES | | | | | | |
| **ATTRIBUTE** | **METRIC** | **TARGETS** | | | | | |
| **Bare Ground (non-vegetated)** | % bare ground with rock or stony cover | Hills, slopes, dryplains | ≤ 50 % | | | | |
| | | Drainage lines (excluding channel bed) | ≤ 20 % | | | | |
| | | Floodplains | ≤ 10 % | | | | |
| **Species Richness** | Perennial and annual native species richness within >50% of rehabilitated sites (number of species per 50x50 m plot) | Perennial native | 14 - 30 | | | | |
| | | Annual native species | 4 - 11 | | | | |
| **Weed Invasiveness** | Priority alert weed species presence and cover | Presence and cover | Not present or if present, cover ≤ the surrounding areas (regional baseline) | | | | |
| | | Priority species | No new priority species introduced | | | | |
| | % all weed cover & % buffel grass cover | Total weed cover | | | | | |
| | | drainage lines, floodplains | < 20% | | | | |
| | | upland hills, slopes and flats | < 10% | | | | |
| | | Buffel grass cover | | | | | |
| | | drainage lines, floodplains | < 10% | | | | |
| | | upland hills, slopes and flats | < 10% | | | | |
| **Feral Animals** | Presence of declared feral animals and pests | Presence | No new priority species introduced | | | | |
| **Target Vegetation Types** | Presence of appropriate vegetation types | | **Grass Steppe** | **Shrub Steppe** | **Low Tree Steppe** | **Low Woodland** | **Riverine sedgeland/grassland** |
| **Indicator Species** | Presence of dominant and common species from each Target Vegetation Type | All dominant species present | | | Dominant Trees<br>*Eucalyptus leucophloia, E. gamophylla* | Dominant Trees<br>*Acacia aneura group* | Dominant Trees<br>*Eucalyptus camaldulensis, E. victrix* |
| | *Note, if more than one type is applicable, choose the most representative for each rehabilitated area* | >50% of common species present | | Dominant Shrubs<br>*Acacia bivenosa, A. aneura group, A. pyrifolia, Grevillea pyramidalis* | Dominant Shrubs<br>*Senna artemisioides subsp. sturtii, S. pleurocarpa var. pleurocarp, Grevillea wickhamii, Hakea lorea* | Dominant Shrubs<br>*Eremophila spp. Senna spp.* | Dominant Shrubs |
| | | | Dominant Grasses:<br>*Triodia wiseana, T. basedowii* | Dominant Grasses:<br>*Triodia wiseana, T. basedowii, T. pungens.* | Dominant Grasses:<br>*Triodia wiseana* | Dominant Grasses:<br>*Triodia spp, Tussock grasses* | Dominant Grasses/Sedges:<br>Tussock grasses, sedges |
| **Plant Cover** | % cover for each strata and each Vegetation Type to be > Q1 for relevant reference sites | Trees | >0 | >1 | >1 | >2 | >10 |
| | | Shrubs | >0.2 | >3 | >2 | >2.6 | >2 |
| | | Hummock Grasses | >15 | >19 | >20 | >17 | |
| | | Other Grasses | >0.01 | >0.02 | >0.04 | >0.2 | >2 |
| | | Herbs | >0.1 | >0.1 | >0.05 | >0.06 | |

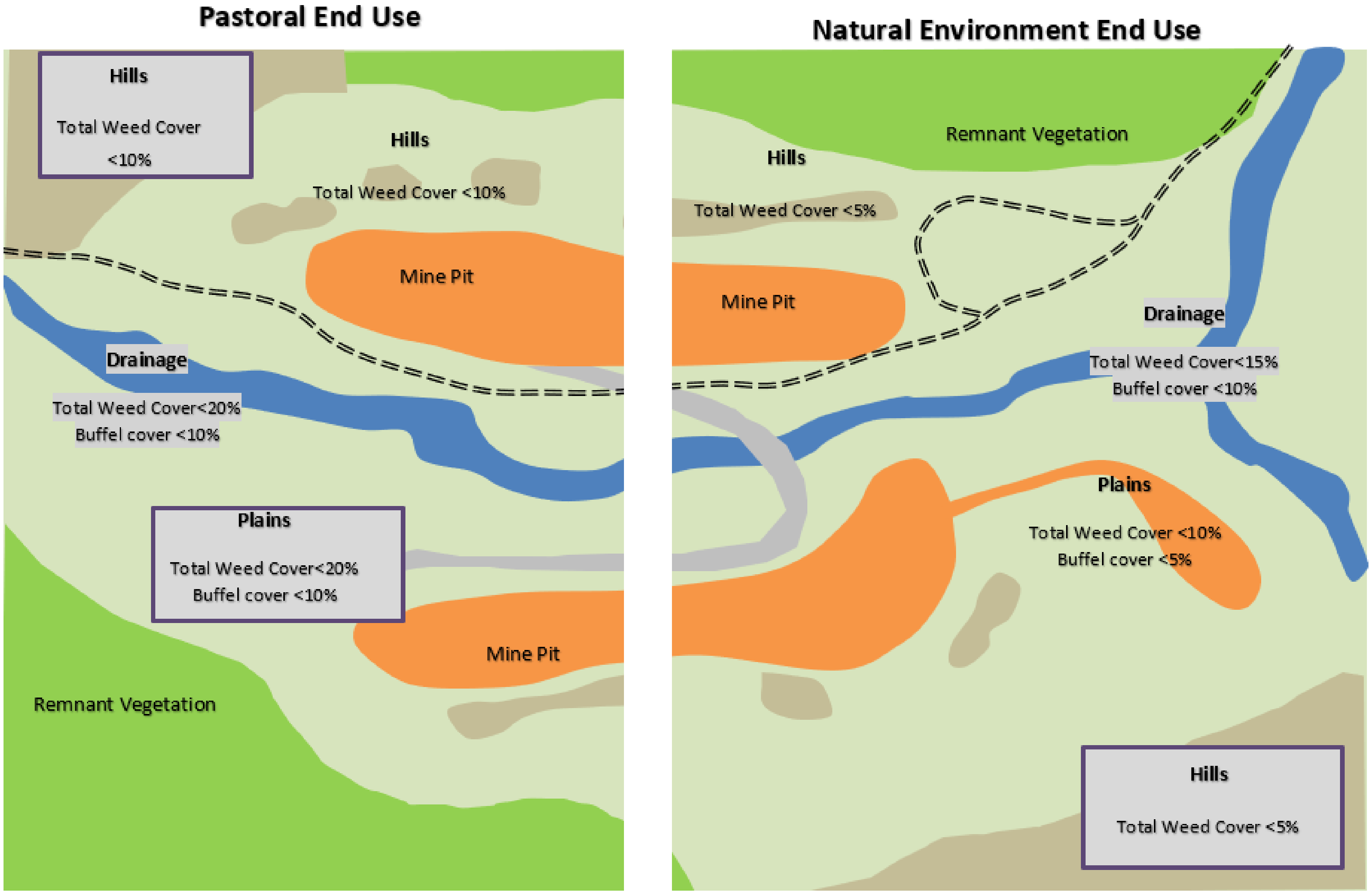



**Figure 22. Weed cover targets for different final land uses and landforms.**

# 9.0 DEVELOPING PROGRESSIVE CRITERIA

## 9.1 AGE CATEGORIES

While rehabilitation areas are unlikely to be ready for comparison against completion criteria for at least 15 years, sites should be tracked against interim targets or trajectory targets at certain intervals.

Previous analysis of the historical data showed that the age of rehabilitation has a positive effect on the probability of success, particularly *Triodia* cover (correlation was moderate positive ($r = 0.4$) using the 2011-2016 datasets combined across all sites). Sites generally do not meet completion (at least for cover targets) until they are at least 15 years old. Rehabilitated areas tend to group into three broad age categories: <5 years, 5-15 years, and >15 years.

Progressive rehabilitation areas are those that are in the process of reaching closure objectives but have not developed sufficiently to be assessed against completion criteria. Whilst the age of rehabilitation is a key factor in determining the probability of rehabilitation success, it is less clear what factors are pivotal to ensuring a site can attain success in time. Review of the historical BHP data (Section 11.0) and research previously undertaken by Kings Park, e.g. Miller et al 2018) indicated that there is little apparent correlation between some 'standard' ecological indices (species richness, plant density) early in rehabilitation with probability of success, nor is there clear differences between sites that have been seeded or not seeded, or those that have topsoil vs those that have growth media, with time (noting there are data deficiencies that may underlie the lack of trends). A cursory view of BHP data shows plant cover may show some relationships; however, this has not been well interrogated for different aged rehabilitation as yet.

Progressive rehabilitation areas need specific measurable targets that can provide assurance that a site is heading in the right direction, or if not, prompt remedial actions to bring it back along the right trajectory.

Based on patterns observed in the historical rehabilitation datasets to date, the following progressive categories have been defined:

1. Young rehabilitation (<5 years) – areas in which all rehabilitation activities have been completed however revegetation is incomplete (seedlings still emerging or too young to monitor accurately). The focus for monitoring should be on assessing whether or not the foundation to support successional development is adequate.

2. Progressive Rehabilitation

    a. Early rehabilitation (5-10 years) – ecological succession processes are establishing with progress made against most criteria, but sites not yet sufficient to support all species or adequate cover targets. The focus at this stage should be on showing growth and the potential for reaching completion targets in the future.

    b. Late rehabilitation (10-15 years) – sites show continual improvement against all criteria and resilience (the ability to recover from disturbances or climatic extremes). Some sites may be ready to assess against completion criteria if climate conditions have been favourable and/or accelerated rehabilitation processes have been undertaken.

3. Completed rehabilitation (>15 years) – assessed against completion criteria.

Whilst age is a helpful way to group rehabilitation sites, sites should be assessed at key points against 'threshold criteria' to ensure they are at a level ready to transition into the next group. For young rehab, this assessment should be made in year 4 or 5 after rehabilitation. For progressing sites, assessments should be made at year 10 and year 15. If young sites meet the threshold criteria, then they progress into the progressive rehabilitation category, and if they do not, remedial work will be required. Similarly, if 10-year-old sites are not meeting threshold criteria, remedial works are likely needed to ensure they will be ready for assessment against completion criteria after year 15. Note, the broad age categories are a guide only; successful sites can be assessed against progressive and completion criteria earlier if desired, provided they have had sufficient longevity to demonstrate resilience. It is unlikely that sites younger than 10 years old will be able to reach completion against all targets.

## 9.2 KEY PRINCIPLES

Whilst specific criteria should apply to the measurement of progressive rehabilitation, these must conform with the completion criteria and be consistent with the final land use objectives of naturalness, resilience and habitat connectivity. Progress (or trajectory) criteria also need to reflect the two most likely final land use scenarios (Natural Environments and Modified Pastoral Environments).

For young rehabilitated areas, criteria will essentially need to provide evidence that the site has been designed and implemented in accordance with appropriate rehabilitation standards. For progressing sites, at least some of the criteria will be the same as those used at completion (e.g. plant cover), however the metrics (e.g. actual % cover) are likely to be different. New criteria, however, are needed to provide assurance that a given site will either eventually meet completion with no further intervention or is unlikely to meet completion without remedial action.

*Young rehabilitation* metrics in terms of **naturalness** indices should ensure that the reconstructed landforms conform more or less with the surrounds. *Young rehabilitation* should evidence an appropriate species composition and evidence of distinctive indicator species appropriate to the target vegetation group. *Progressive rehabilitation* should also be able to evidence appropriate vegetation structure, cover and pattern.

Monitoring of natural landscape features and impacts in the Pilbara indicate that key landform (stability) and soil parameters (soil stability, soil moisture, soil carbon) determine the **resilience** of natural ecosystems used for either conservation or pastoral purposes, and the reproductive capacity of vegetation determines its recovery potential after disturbance events (fire, extreme rainfall events, extended drought etc).

Landform stability and safety should be achieved in the *early rehabilitation* phase, (and is already embedded in the design criteria for rehabilitated landforms).

## 9.3 DERIVING PROGRESSIVE CRITERIA

In order to derive meaningful criteria to enable confidence that a site is progressing along the appropriate trajectory, a review of critical ecological thresholds was undertaken, using both literature review and deeper analysis of the historical data. The following tasks were undertaken:

1. A high-level review and synthesis of the existing literature to extract any patterns and key influencing factors on early successional processes in the Pilbara.

2. A statistical analysis of BHP datasets to establish if there are any relationships between early stage metrics with later success rehabilitation performance. This involved the following tasks:

   a. Conversion of the raw 2017 database and integration with the 2018 BHP reference and rehabilitation datasets.

   b. Interrogation of recently burnt reference sites (<5 years) to determine total cover and cover ratios. Whilst burnt sites are not equivalent to young rehabilitation, since they already have well developed soil carbon and moisture profiles, as well as the presence of species that resprout after fire, they may be useful to assess the composition of a site in terms of lifeforms after disturbance.

   c. Interrogation of the combined rehabilitation database to identify correlations between different metrics with age.

In addition, some additional reference plots monitored in 2017 but not in 2018, were added to the reference site database in order to expand the datasets for the purpose of deriving trajectory criteria (and validating completion criteria as previously stated).

### 9.3.1 Research Base for Setting Threshold Criteria

Given the volume of research undertaken in arid and semi-arid ecosystems and in the Pilbara in particular, there is a general paucity of research that addresses succession or post disturbance cycles of plant species. Most research has followed the impacts of fire on soil properties (e.g. van Etten 2009), however vegetation responses seem rare. As such, there are no ready accessible generalisations that can be made about natural systems that can assist the question at hand regarding what early and progressive stage rehabilitation sites should 'look' like in terms of ecological features. That is, are early systems post-disturbance dominated by annuals or perennials, by shrubs or grasses etc.

Some of the research useful for assisting with the setting of some principles for rehabilitation and understanding if a site is on the right trajectory towards completion or not is briefly summarised below:

1. *Triodia, and other grasses have seeds that are relatively short-lived (>3 years) (Erickson et al 2017).*

   If *Triodia* and other short-lived species have not emerged within the first 3 years after seeding, they are highly unlikely to emerge without the addition of further seed in following years since they lose viability. Therefore, a 'reasonable' cohort of *Triodia* germinants should be expected in young rehabilitation to ensure continued *Triodia* coverage with time.

2. *Transitions from grass to woody plant dominance is widely reported in arid systems (Pierce et al 2019).* Globally, grasses are known to ameliorate the abiotic environment to facilitate the introduction of other species.

   If Pilbara systems are typical of global arid grasslands, they should be dominants in the young and progressive rehabilitation stages. Shrubs should increase later in the rehabilitation cycle.

3. *Competition from grasses appears to attenuate the rate at which shrubs achieve the size necessary to modify the physical environment in self-reinforcing ways, but only during the early stages of shrub encroachment (Pierce et al 2019).*

   This indicates that shrubs and grasses appear to achieve a niche separation balance over time, however compete in early establishment phases.

4. *Shrubs show a stronger effect on improving habitat conditions (e.g. Maestre et al. 2009) than grasses.*

   This indicates that shrubs are pivotal to delivering resilience and habitat value.

5. *Plant-soil-climate interactions are complex in semi-arid environments.*

   From a rehabilitation perspective, climate and soils influence vegetation cover and species distributions, however, plants are significant in influencing soil moisture and microclimates, in increasing soil mineralisation, and in determining vegetation pattern.

### 9.3.2 Statistical Analysis of BHP Rehabilitation Data

In order to identify any patterns useful for setting trajectory criteria, the rehabilitation data and the reference data was analysed to determine if there were any correlations between key parameters. Unfortunately, insufficient data was available from recently burnt plots to establish any successional patterns in relative abundance, hence reference data is only useful to compare with completion sites. Further, some future mines are located in Bunch Grassland vegetation communities. As yet there is no reference data or rehabilitation data for these areas, hence trajectory criteria will need to be derived at a later date for these.

The correlation coefficient r measures the strength and direction of a linear relationship between two variables. Given the significance of hummock grasses (*Triodia*) cover to the completion of a rehabilitation site, an understanding of antagonistic or synergistic variables affecting this group is important. As such, the following correlations were run for the 2011 – 2016 datasets and 2017- 2018 separately:

1. Lifeform groups with *Triodia* cover;
2. Lifeform groups with total cover;
3. Weed cover with *Triodia* cover; and
4. *Triodia* density vs cover.

Analyses were run separately for each age category.

***Correlations***

The summary of the correlation analysis undertaken for *Triodia* cover vs other parameters in rehabilitation sites is shown in Table 9.

The summary of the correlation analysis undertaken for cover in reference sites is shown in Table 10. This is useful for comparison of completion sites only.

No or very minor differences were found between the 2011-2016 data and the 2017-2018 datasets in terms of correlations, hence only the latter dataset is shown. Note, density data was not collected in the 2017 surveys, hence *Triodia* density data represents the 2018 monitoring plots only.

**Table 9. Correlations (r values) between *Triodia* cover and selected parameters vs age of rehabilitation.**

| 2017-2018 REHABILITATION SITES | Parameter | age | Total cover | Native cover | Shrub cover | Weed cover | Weed + Shrub cover | Triodia density |
|---|---|---|---|---|---|---|---|---|
| ALL AGES COMBINED | *Triodia* cover | 0.38 | 0.44 | 0.62 | -0.12 | -0.24 | -0.29 | |
| YOUNG (0-5 years) | *Triodia* cover | 0.27 | 0.23 | 0.41 | -0.35 | -0.17 | -0.29 | 0.28 |
| PROGRESSIVE (5 -15 years) | *Triodia* cover | 0.12 | 0.30 | 0.49 | -0.14 | -0.23 | -0.31 | 0.67 |
| COMPLETION (>15 years) | *Triodia* cover | -0.10 | 0.54 | 0.79 | -0.04 | -0.32 | -0.32 | |

**Table 10. Relative abundance correlations (r values) for reference sites.**

| 2017 - 2018 REFERENCE SITES | TRIODIA COVER | SHRUB COVER | HERB COVER | TREE COVER | OTHER GRASS COVER |
|---|---|---|---|---|---|
| TRIODIA COVER | | | | | |
| SHRUB COVER | 0.65 | | | | |
| HERB COVER | -0.33 | -0.14 | | | |
| TREE COVER | 0.15 | 0.17 | 0.57 | | |
| OGRASS COVER | -0.16 | 0.14 | 0.70 | 0.83 | |
| TOTAL COVER | 0.88 | 0.84 | -0.05 | 0.39 | 0.13 |

*Total Cover*

For combined ages as well as completion sites, there was a moderate positive correlation between total cover and *Triodia* cover. This relationship was weak for the 5-15 year age category, and very weak for the young rehabilitation group. This relationship is strong in reference sites.

All age categories however had a moderate to strong (completion sites) positive correlation between total native cover and *Triodia* cover. Because these are not independent variables, it is obvious that increased *Triodia* cover will increase total cover, hence a stronger relationship with time is not surprising. It is less obvious if a minimum total cover is needed to support *Triodia* establishment and growth (since there is a known relationship between vegetation cover and soil moisture and organic carbon). This pattern seems to be supported since the correlation is moderate positive in young rehabilitation (<5 years). Data for the young sites suggests that total native cover may positively influence *Triodia* cover, as well as more obviously native cover being influenced by *Triodia* cover.

*Triodia density vs Triodia cover*

Whilst there is no relationship between *Triodia* density and *Triodia* cover for all ages combined, or for young sites or completion sites, there was a strong correlation between *Triodia* density and *Triodia* cover in the 5-15 year age group. Therefore, ensuring a sufficient minimum number of *Triodia* seedlings have established within this age category seems essential to a site progressing towards completion targets. If total density and cover is too low in the initial years, then *Triodia* is not likely to be present or be present at sufficient cover to enable steady growth over time.

*Shrub Cover*

Shrubs may have a negative effect on *Triodia* cover if they compete within the same soil horizon for moisture. It is probable (and typical) in semi-arid environments that trees/shrubs show vertical partitioning of roots to enable co-existence, however in rehabilitated areas, soils are often very shallow hence shrubs and grasses may have a higher competition effect.

Correlation data shows that there was a moderate negative effect of shrub cover on *Triodia* cover only for young sites (<5 years), indicating that if shrubs are too dominant in the initial rehabilitation, then *Triodia* establishment and cover may be suppressed. The relationship between *Triodia* cover and shrub cover in reference sites is moderate positive, indicating at late successional stages, these two lifeforms do not compete and potentially have a synergistic effect. The absence of this pattern in rehabilitated sites may indicate that some sites may not reach this balance, presumably because soil depth or soil conditions (moisture, carbon etc) are not ideal.

*Weed Cover*

For all sites and ages, there was a very weak negative correlation between total weed cover and *Triodia* cover, with the effect strongest for young rehabilitation and older sites. This is likely because weed cover is generally only a small proportion of plots cover in the reference data. Review of individual plots shows that if weed cover is very high (>20%), then *Triodia* cover is low, and if the combined shrub and weed cover is high, then *Triodia* cover is very low.

The relationship between weed cover and *Triodia* cover is important enough to indicate that control measures are important. There is also a cumulative weak negative effect of weeds and shrub cover on *Triodia* cover for all age categories. Both weed cover and shrub cover need to be below a certain threshold to support *Triodia* growth and establishment, particularly in early years.

*Other Lifeforms*

There was no correlation between *Triodia* cover and trees or other grasses at any age, which is similar in reference sites. However, rehabilitation data showed no pattern between herb cover and *Triodia* cover, which did have a weakly negative effect in reference sites. Tree cover had a strong positive relationship with herb cover and other grasses cover, likely due to these groups benefiting from higher moisture sites.

### 9.3.3 Summary and Implications for Threshold Criteria

Overall, the analysis indicates that *Triodia* cover, *Triodia* density, Shrub cover, and Weed cover are key trajectory criteria. Relative abundance is key, and differs at different time points. This can be represented as ratios since this better represents the dynamics of developing sites and is instantly informative in terms of flagging remedial actions.

Interestingly, within the 5 -15 years rehabilitation category, *Triodia* density is strongly negatively correlated with age (***r = -0.7***). This is an important relationship since it reinforces that whilst the seed bank of these hummock grasses is short-lived, and a fair proportion of the seed would lose viability in the first few years, those plants that successfully establish from the early cohort of germinants in the first 5 years are critical to the success of the rehabilitation. Unfortunately, given at this stage that no plots have been followed through a rehabilitation cycle (even with the 2011-2016 datasets), identifying what happens in these first few years is important to assess in future monitoring.

The following criteria are thus proposed for young and progressive sites:

1. Young Rehabilitation

    a. *Triodia cover*: shrub cover ratio – major criterion.

    b. Minimum total native cover – supporting criterion.

    c. Weed cover: *Triodia* cover ratio - supporting criterion.

2. Progressive Rehabilitation

    *a.* *Triodia* cover*:* Total native cover – major criterion.

    b. *Triodia* density - major criterion.

    c. Weed cover: *Triodia* cover ratio - supporting criterion.

## 9.4 DETERMINING THE TARGETS

Given obvious patterns and differences in the rehabilitation data vs age, an approach is needed to determine the actual metrics that can be used to assess young and progressive rehabilitation sites, against the key trajectory criteria shown to be relevant. The proposed approach is to use the reference site data combined with review of the best performing rehabilitation sites, to set trajectory criteria.

***Young Rehabilitation (<5 years)***

*Triodia : Shrub Ratios*

For all vegetation types, reference sites maintain a minimum *Triodia*:shrub ratio of around 1-2, and a median of 3-7, which may be inferred as the ‘balance’ for successionally mature Pilbara ecosystems. The minimum ratio varies from 1 for Low Shrub Steppe, 1.8 for Low Woodland, 1.9 for Shrub Steppe and 4.1 for Grass Steppe (most of these sites have been recently burnt). Since we have established that it is more important in young rehabilitation to have significantly more *Triodia* than shrubs to manage the early stage competitive effects, this ratio should be higher for young rehabilitation. In assessing plots to determine better performers, it would appear that a **ratio of 2 is** the minimum target.

The dataset for reviewing potential targets in this category is limited (using the 2017-2018 data), hence the proposed targets should be reviewed as more data becomes available.

*Minimum Total Native Cover*

The minimum native cover is not as important as the composition, however, given vegetation cover is a surrogate for soil carbon and moisture, a minimum native total cover is suggested at >12%. Note, this metric may be adjusted to reflect a more robust database, or may be superseded in time if actual soil parameters (soil moisture, soil carbon) data is monitored.

*Weed : Triodia Cover*

Within reference sites, weeds are either not present (majority of sites) or have extremely low cover values. Since the completion criteria are linked to the current percentage covers for surrounding similar landforms, targeting zero weeds is clearly not pragmatic. In order to assess what may work as threshold criteria, the rehabilitation data for each age category was reviewed, and ratios set based on the performance of the other key attributes in top performing plots.

The Weed:*Triodia* cover is proposed to be <1 in order to support total native cover and *Triodia* establishment.

### ***Progressive Rehabilitation (5-15 years)***

The key criteria of importance to this group are the ratio between *Triodia* cover and total native cover, and *Triodia* density.

*Triodia Cover : Total Native Cover*

The proposed *Triodia* cover:Total Native cover target is >0.32. Based on the data at hand, this minimum value correlates with a *Triodia* cover of 8%.

*Triodia density*

In progressive sites, the relative abundance of *Triodia* to shrubs becomes less important and it is the density of *Triodia* that matters. Plots that meet a 14% average *Triodia* cover 6-8 years post rehabilitation, have an average *Triodia* density of around 6500 plants per plot, and older plots (10-15 years) average almost 40,000 per plot. A minimum suggested density measured at year 10 for progressive plots is therefore proposed to be 10,000 per plot. If *Triodia* cover has already attained or nearly attained completion targets, then density data criteria do not apply.

*Weed:Triodia Ratios*

Similar to young rehabilitation, the Weed:*Triodia* cover is proposed to be <1 in order to support total native cover and *Triodia* establishment.

## 9.5 PROPOSED TRAJECTORY TARGETS

The proposed trajectory targets for young rehabilitation (<5 years) and progressive rehabilitation (5 - 15-year sites) are shown in Table 11.

**Table 11. Proposed Ecological Trajectory Criteria for Assessing Young and Progressive Rehabilitation.**

| YOUNG REHABILITATION (< 5 YEARS) | | |
|---|---|---|
| | **CRITERIA** | **TARGETS** |
| *Major Criterion* | Triodia cover /Shrub cover ratio | > 2 |
| *Supporting Criteria* | Minimum total native cover (%) | > 12% |
| | Weed cover / Triodia cover ratio | < 1 |
| **PROGRESSIVE REHABILITATION (5-15 YEARS)** | | |
| | **CRITERIA** | **TARGETS** |
| *Major Criterion* | Triodia Cover / Total Native Cover | ≥ 0.32 |
| | Triodia density | ≥ 10,000 per plot |
| | Weed cover / Triodia cover ratio | < 1 |

At each site, all areas that are no longer part of the required operational footprint should be rehabilitated as soon as they become available in order for the 5 years to be sufficiently progressed to assess. As a minimum, this means landforming and stabilisation works should be completed. Topsoil and/or growth media spreading and revegetation works are to be completed within 5 years. Timing of these works should be targeted to the optimal time of year and the optimal climatic years as far as practicable. In extended drought periods, accelerated and/or advanced revegetation methods are recommended to avoid extensive bare areas and to facilitate plant cover.

# PART 3 REHABILITATION SUCCESS

## 10.0 BRIEF HISTORY OF BHP WAIO REHABILITATION PRACTICES

BHP undertook the first WAIO rehabilitation in the Pilbara in the early 1990s.

Whilst BHP now has appropriate systems in place to undertake a good standard of rehabilitation, the historical record shows that the proportion of areas rehabilitated to date compared to active or legacy areas in BHP WAIO sites, is low. As such the evidence indicates that progressive rehabilitation has been difficult to achieve. As discussed elsewhere, older rehabilitation sites and some other particular sites are generally not viewed as adequate.

This reflects a range of factors, including:

- Historical lack of prioritisation of rehabilitation (pre-2000).
- The relatively long life-of iron ore mines in the Pilbara, which means that the proportion of tenement areas available for rehabilitation is relatively low compared with other mines.
- Knowledge constraints.
- Unresolved final land use agreements.
- Changing expectations of what constitutes ‘good’ rehabilitation and quantitative assessment of rehabilitation against pre-mined vegetation communities.

Since the early rehabilitation efforts, many changes have occurred in BHP practices, the general knowledge base regarding the biodiversity and ecology of the Pilbara has significantly improved, and regulatory expectations associated with rehabilitation have also evolved. This has driven continuous improvement and some key step change shifts in the planning and process of rehabilitation.

The major change points are shown chronologically in Table 12. In very brief summary, the trajectory of improvements are as follows:

1. Landform improvements – integrating OSAs into the landscape, altering slopes to minimise erosion, use of covers to prevent acid and gas hazards.
2. Soil Improvements – understanding of substrate properties and how to best maximise topsoil and waste materials to support revegetation.
3. Revegetation improvements – understanding of seed biology and improvements in collection, dormancy breaking, seeding methods.

In all, the most fundamental knowledge gaps have only been filled in relatively recent times (2010 onwards). Whilst there are still further improvements to be made, BHP is now at a point where the combined knowledge can be applied routinely to new sites. Large scale application of revegetation improvements has occurred in the last two years at some sites, and early qualitative assessment of these sites by BHP personnel indicates positive results.

**Table 12. Changes in Practices and Evidence of Improved Outcomes.**

| YEAR | REGION/IBRA SUBREGION | SITE/S | LANDFORMING METHODS | REVEGETATION METHODS | QUALITY MANAGEMENT | KEY PUBLICATIONS |
|---|---|---|---|---|---|---|
| 1981-1987 | Central Pilbara, Hamersley IBRA | Mt Whaleback | **First rehabilitation undertaken.** Slopes steep, use of incompetent materials (base pit materials used as surface materials) | Topsoil applied<br>Seed from local Contractor supply (no provenance control)<br>Revegetation lists generic to Pilbara and mainly limited to *Acacia*, tussock grasses and when available, *Triodia*.<br>Poor *Triodia* recruitment, high erosion. | ▪ No specific guidelines or standards. ▪ Reliance on trials and general mining industry practices. Reliance on Contractors.<br>▪ No seed quality checks<br>▪ Rehabilitation ‘ad hoc’ and not timed to suit recruitment Poor or no records of rehabilitation works | |
| 1990 | Central Pilbara, Hamersley IBRA | Mt Whaleback | **First ‘moonscaping’** (scalloping) of rehabilitation landforms to increase water harvesting potential. No change to slope grades or material types. | As above.<br>Good *Acacia* recruitment, poor diversity. | ▪ As above, however various trials initiated to determine success/failure factors. | |
| 1992 - 2002 | Central, Northern, and Eastern Pilbara.<br>Hamersley IBRA, Chichester IBRA | Mt Whaleback, Jimblebar, Eastern Ridge, Nimingarra, Shay Gap, Mt Goldsworthy | First trials with linear landforms, gentler slopes (20°), & contour ripping. | As above. Less erosion and improved recruitment noted. Review of seed collection methods and quality. Rapid audit of *Triodia* seed collected by Contractors by BGPA indicates >90% of seed collected and used in rehabilitation was chaff. | ▪ Improved trials, audit process undertaken and improved monitoring of success across different landforms. | Various internal records. |
| 2003 - 2004 | All | All sites | **Moonscaping abandoned, and linear landform with ripping adopted as new approach. New OSA cover systems implemented.** | | ▪ BHP closure standards developed and implemented. | BHP Billiton Closure Standard (BHPB 2004)<br>O’Kane and Waters (2003) (OSA covers). |
| 2007-2008 | All | All sites | **Material classification and management of rehabilitation substrates initiated across sites.** Concept of ‘growth media’ introduced to enable use of subsoil in place of topsoil. First use of rock armouring on OSAs to reduce erosion and mimic natural mesa formations. | **Seed collection methods, and revegetation species lists changed** - seed quality assessment, provenance records, revegetation lists targeted to each mine region. | ▪ Business appoints new Senior Rehabilitation Coordinator and external specialist consultant to audit existing practices, build knowledge across sites, and develop formal standards.<br>▪ First Rehabilitation Framework and Rehabilitation Standards developed to guide future rehabilitation across sites. Pilbara Seed Atlas initiated with partnership established between BHP and Botanic Gardens and Parks Authority. | Draft control documents; research agreements. |

| YEAR | REGION/IBRA SUBREGION | SITE/S | LANDFORMING METHODS | REVEGETATION METHODS | QUALITY MANAGEMENT | KEY PUBLICATIONS |
|---|---|---|---|---|---|---|
| 2010 - 2013 | All | All new OSAs | **Slope profiles changed to 15-18 degrees.**<br>Final landforms designed using geofluvial models to ensure integration with surrounding terrain.<br>Lower erosion impacts. | | ▪ Rehabilitation Strategy developed.<br>▪ Rehabilitation Standards completed covering landforms, seed collection & storage, revegetation.<br>▪ BHP Billiton Iron Ore Rehabilitation Standard and procedures adopted.<br>▪ Draft completion criteria developed and used to assess sites.<br>▪ Research Strategy developed to guide investments in research to support improvement in rehabilitation outcomes.<br>▪ Restoration Seed Bank Initiative funded (2013 - 2018) | BHP Billiton Iron Ore (2011) Rehabilitation Strategy.<br>BHP Rehabilitation Standard (2011)<br>Syrinx Environmental PL (2011). Pilbara Seed availability and storage requirements. Report to BHP BIO.<br>BHP Draft Completion Criteria (2011) |
| 2015 - 2016 | All | All new rehabilitation sites | | **Seed technologies (pre-treatment, seeding) show improvements in recruitment in rehabilitation sites.** Rehabilitation of all sites undertaken using primed seeds (*Acacia* spp). Trials show that burial of seeds below surface improves recruitment. Airseeders used in some sites to improve depth of seed burial.<br>**Growth media** studies show that soil moisture and secondly carbon content, not substrate type, are the overriding factor influencing emergence of a range of Pilbara species. | ▪ Seed sourcing strategy established to address quality control, provenance and seasonal variation.<br>▪ Standardised approach to monitoring of sites introduced. | Rehabilitation Monitoring Procedure (BHP 2016).<br>Muñoz-Rojas, M. et al (2015). Applying soil science for restoration of post mining degraded landscapes in semi-arid Australia: challenges and opportunities. *Geophysical Research Abstracts* Vol. 17, EGU2015-3967-1, 2015. |
| 2017-2018 | | | | Long range data analysis used to assess rehabilitation and define gaps and future directions. | ▪ New survey methods (plot size etc) rolled out to analogue sites (2017) and rehabilitation sites (2018).<br>▪ Final reports and papers from the Restoration Seed Bank Initiative Phase 1 projects published. Further funding (federal) for co-engineering solutions to improve mine-site rehabilitation outcomes focussed on the invention and modification of direct seeding equipment needed to deliver native seeds at scale. | Erickson et al (2017). Benefits of adopting seed-based technologies for rehabilitation in the mining sector: a Pilbara perspective. *Australian Journal of Botany* 65, 646-660.<br>Shackelford, N. et al (2018). Restoration of Open-Cut Mining in Semi-Arid Systems: A Synthesis of Long-Term Monitoring Data and Implications for Management. *Land Degradation and Development,* Volume 29 (4).<br>Numerous other papers. |

# 11.0 METHODOLOGY FOR ASSESSING REHABILITATION SUCCESS

## 11.1 SEQUENCE OF ANALYSIS

Currently, the rehabilitation performance is reported in Annual Environmental Reports on a per plot basis, with plots compared to one or more reference plots within the same hub and for the same landform (crest, slope, flat).

In this report, the historic rehabilitation success within BHP WAIO has been assessed in several ways, in all cases using cover as the indicator of success for the purposes of comparison (and because this is the key completion criterion as discussed in previous sections) and comparing data against the Q1 -Q3 range of each reference site (aggregated plot data, removing burnt plots).

1. Firstly, all rehabilitation data at the hub scale was compared against reference plots aggregated for the corresponding region, using the 2011-2016 datasets (belt transects). Given that the rehabilitation to date has not targeted the proposed vegetation types and scale proposed in this current report, rehabilitation data is compared against regional reference sites (which aggregate the various relevant vegetation types).

   The above datasets were then analysed by the age of rehabilitation, given rehabilitation success has been shown in earlier sections to be strongly influenced by time.

2. Secondly, the rehabilitation plot data from 2011-2016 were compared against the proposed completion criteria targets and method of assessment proposed in this report (Section 8.0). This was done for all major hubs.

3. Finally, the 2017 - 2018 datasets were compared, given this adopted a different sampling method (50 x 50 m plots). Note there are limitations of the dataset (limited data due to the single sampling event). This dataset effectively resets the rehabilitation performance clock back at zero, that is, the plots are not the same as used previously, hence comparing this data to the older datasets is statistically not valid.

   The 2018 datasets were analysed by the age of rehabilitation against the proposed completion criteria, given rehabilitation success has been shown in earlier sections to be strongly influenced by time.

   Because this dataset is still evolving, the results are provided in Appendix 1, and are only provided as a starting point for future analyses, once more data becomes available. As such, this dataset is not discussed further.

## 11.2 ASSIGNING TARGET VEGETATION TYPES

Because completion criteria are derived differently for each target vegetation type, ensuring the appropriate target vegetation types are applied to each mine or hub is important. Further, multiple assessments within a site to account for variability in vegetation types would require the establishment of potentially many new rehabilitation plots to capture sufficient data to enable assessment, hence assessing a site against the dominant one or two vegetation types is desirable. The small scale of the Beard mapping is likely to be inaccurate if used at the hub scale, particularly along the boundaries between different vegetation types, hence this first task involved a process of data checking and correction using larger scale vegetation data as follows:

1. Comparison of the Vegetation Types (Beard) within hubs with the vegetation association mapping undertaken by BHP to check and calibrate accuracy.

2. Assigning of corrected vegetation types to each rehabilitation and reference plot within the excel datasets.

3. Assigning of Target Vegetation Types to each mine and hub as follows:

    a. Where one vegetation type dominated the mine and/or hub (i.e. >70% of the area), this was used as the Target Vegetation Types for assessment of all rehabilitation plots.

    b. Where several vegetation types were more or less equally represented, sites ready for assessment against completion criteria can be assessed against either of these.

The key spatial datasets used to generate outputs for this study included the Physiognomic Vegetation Groups layer (based on Beard's broad vegetation mapping for the state), and the BHP supplied vegetation association mapping, BHP granted tenements, hub outlines, the cleared areas (operation), rehabilitated areas, exploration areas (both cleared and rehabilitated) and the shapefile of 2017 and 2018 monitoring plot data.

To derive vegetation type targets which would form part of the completion criteria set, the point data of 2017-2018 monitoring plots was overlaid on top of Physiognomic Vegetation Group layer. Where monitoring data points intersect the vegetation layer, the attributes of the Beard's vegetation layer (e.g. vegetation number, type and description) were taken and joined to monitoring plot data set. The combined data set was then overlapped with BHP vegetation association map layer and the hub outline to join additional attributes from this layer.

Once the joins in data were completed, the attribute table from the monitoring plot shapefile was exported to excel spreadsheet and the comparisons made between the vegetation descriptions (and associated species) for BHP vegetation association and Broad (Beard's) vegetation descriptions for each reference plot. Where data did not match further examination of tabulated monitoring data sets including species, % cover, form and abundance for each plot were used to assign a 'corrected' broad vegetation type. This 'corrected broad vegetation type was added to the monitoring plot data shapefile as an additional attribute (denoted target vegetation type).

Given the time factors, it is proposed that rehabilitation is assessed on a 3-yearly to 5-yearly basis.

# 12.0 ANALYSIS OF 2011 – 2016 REHABILITATION DATA

## 12.1 ANALYSIS OF COVER BY HUB & REGION

In this initial analysis of rehabilitation performance, rehabilitation data at the hub scale was compared against reference plots aggregated for the corresponding region, using the 2011-2016 datasets (belt transects). Given that the rehabilitation to date has not targeted the proposed vegetation types and scale proposed in this current report, rehabilitation data is compared against regional reference sites (which aggregate the various relevant vegetation types).

The above datasets were then analysed by the age of rehabilitation, given rehabilitation success has been shown in earlier sections to be strongly influenced by time. Select data is shown in sections below, with more detailed analyses provided in Appendix 1.

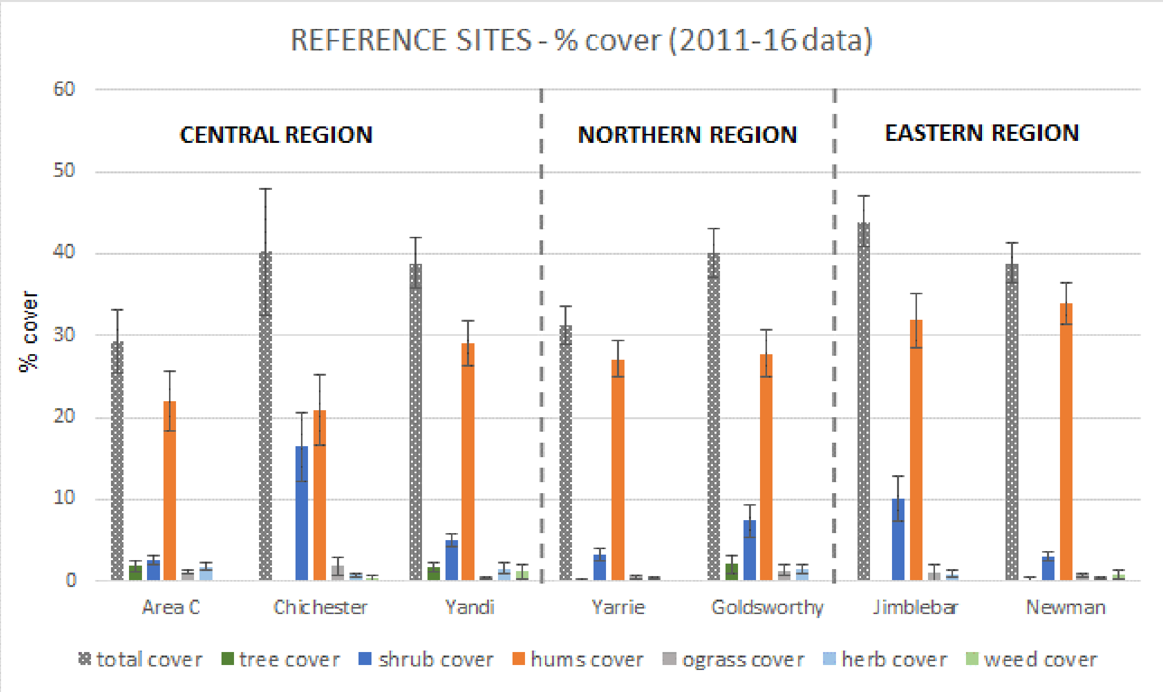
Reference sites within all of the hubs (and regions) showed very similar patterns in terms of total cover and cover breakdown; they were all dominated by *Triodia* (50-90% of total cover) and shrubs (10-40%), while other grasses and herbs made up ~5-10% of total cover (Figure 23). Tree cover showed a marked difference between hubs with Area C showing the highest tree cover of 6.2 % whilst trees were not recorded at all within Jimblebar reference sites. Weeds were found to be a particular issue at Mt Whaleback and Yandi hubs, comprising more than 1.5% of total cover.

Figure 24, Figure 25 and Figure 26 show the overall rehabilitation performance of individual hubs compared to their respective reference sites.

All of the rehabilitation sites showed a general lack of tree cover (these were not included in seed mixes until recently), hence are not included in the graphs. Most hubs also have high standard errors indicating the variability between plots.

For central region hubs, the composition within plots is weighted by shrubs, not *Triodia*. This probably partly reflects early rehabilitation approaches (limited diversity in seed mixes). For the northern hubs, there is a closer match in terms of composition, with *Triodia* cover more dominant. In the Eastern region, all hubs are poor in terms of *Triodia* cover, compared with the reference data.

In summary, comparing rehabilitation sites against their respective reference sites, (i.e. as per reporting of rehabilitation success in annual reports up to this point in time), shows that no sites match the reference sites very well. This reinforces the point that comparing rehabilitation against reference sites is not an inappropriate method of assessment, as discussed in Sections 4 and 5 above.




*No. of sites: > 20 years = 61; 10-20 years = 61; 5-10 years = 75; <5 years = 32; reference unburnt sites = 77; reference with burnt sites= 112.*

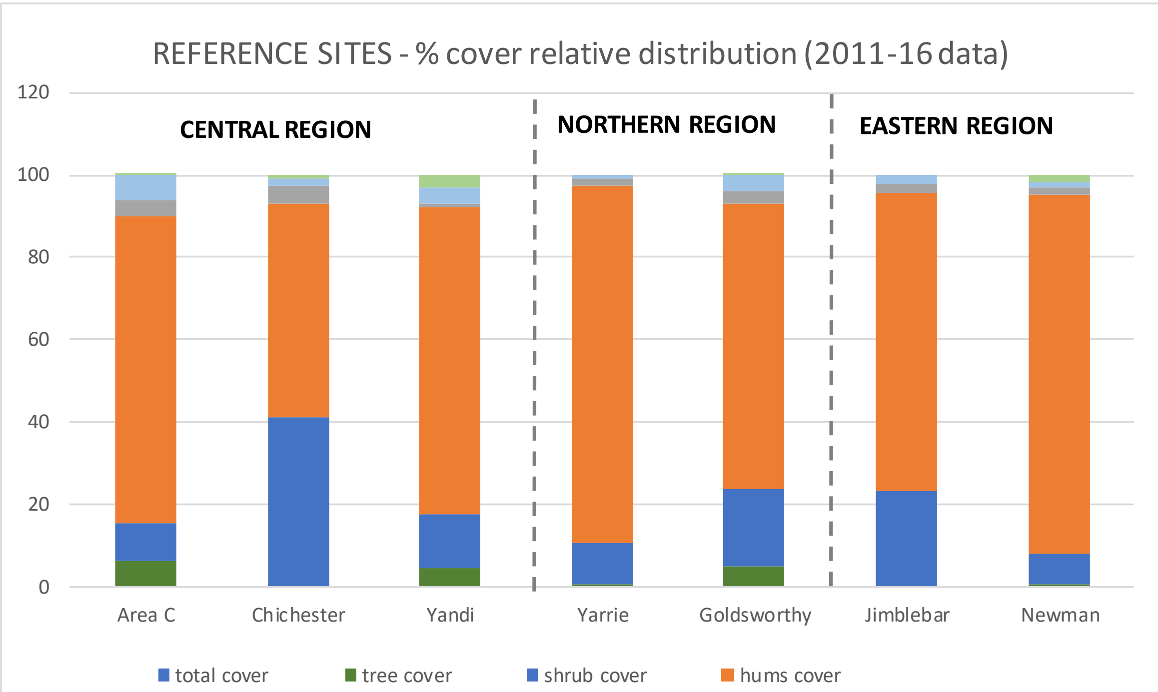



**Figure 23. Comparison of individual hubs for % cover in reference sites (2011-2016 data).**

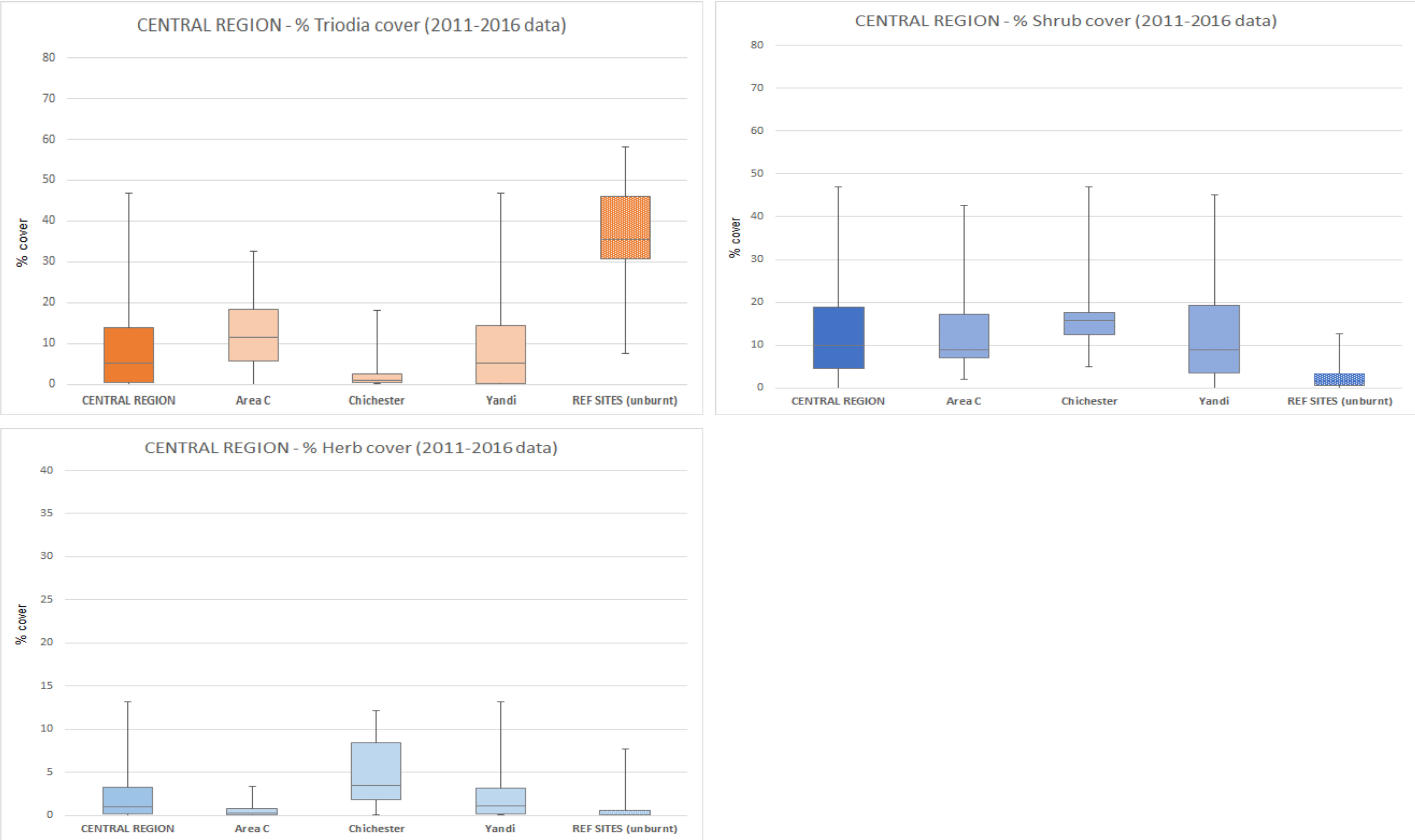



**Figure 24. Comparison of individual hubs for % cover in rehabilitated sites (2011-2016 data) for Central Region.**

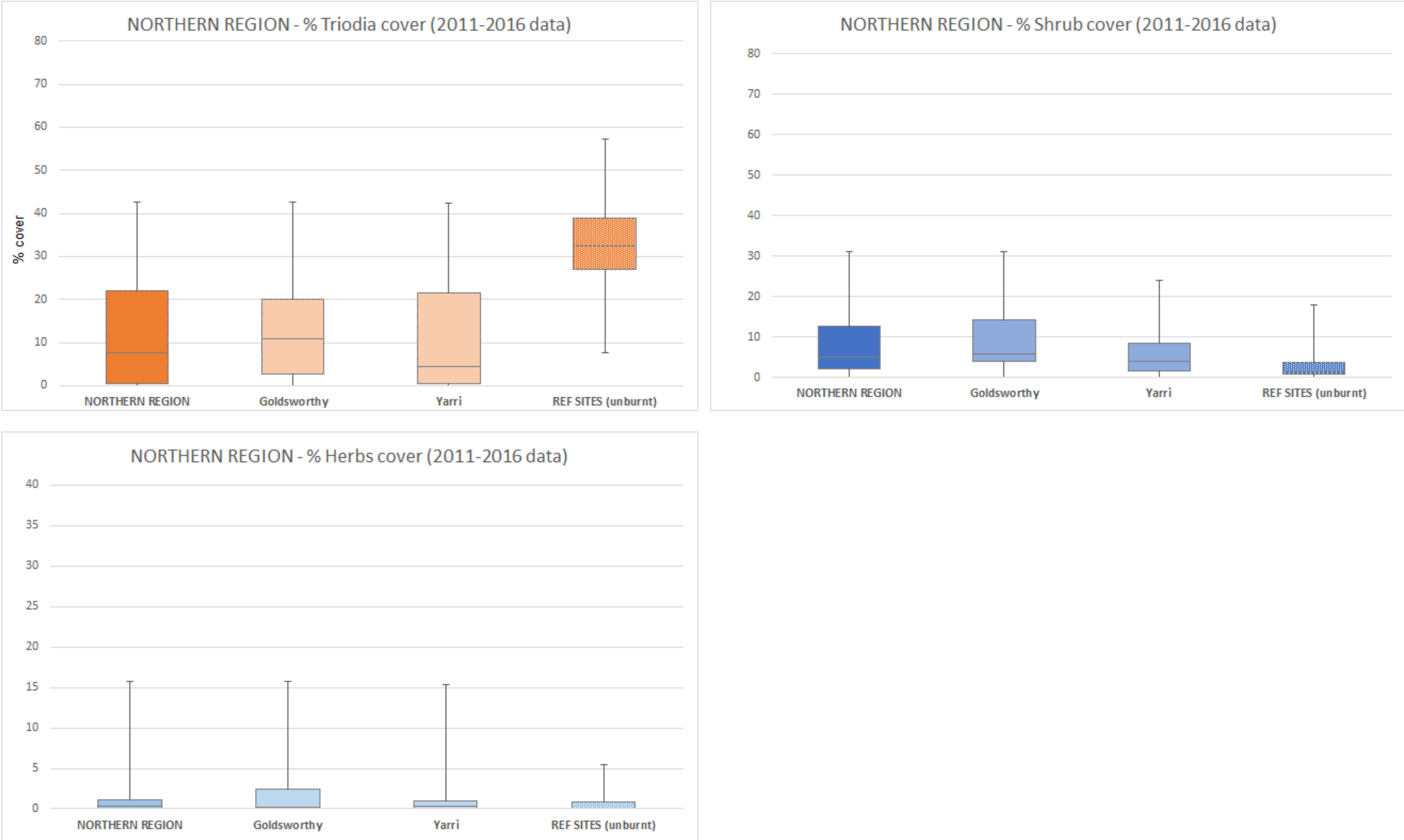



**Figure 25. Comparison of individual hubs for % cover in rehabilitated sites (2011-2016 data) for Northern Region.**

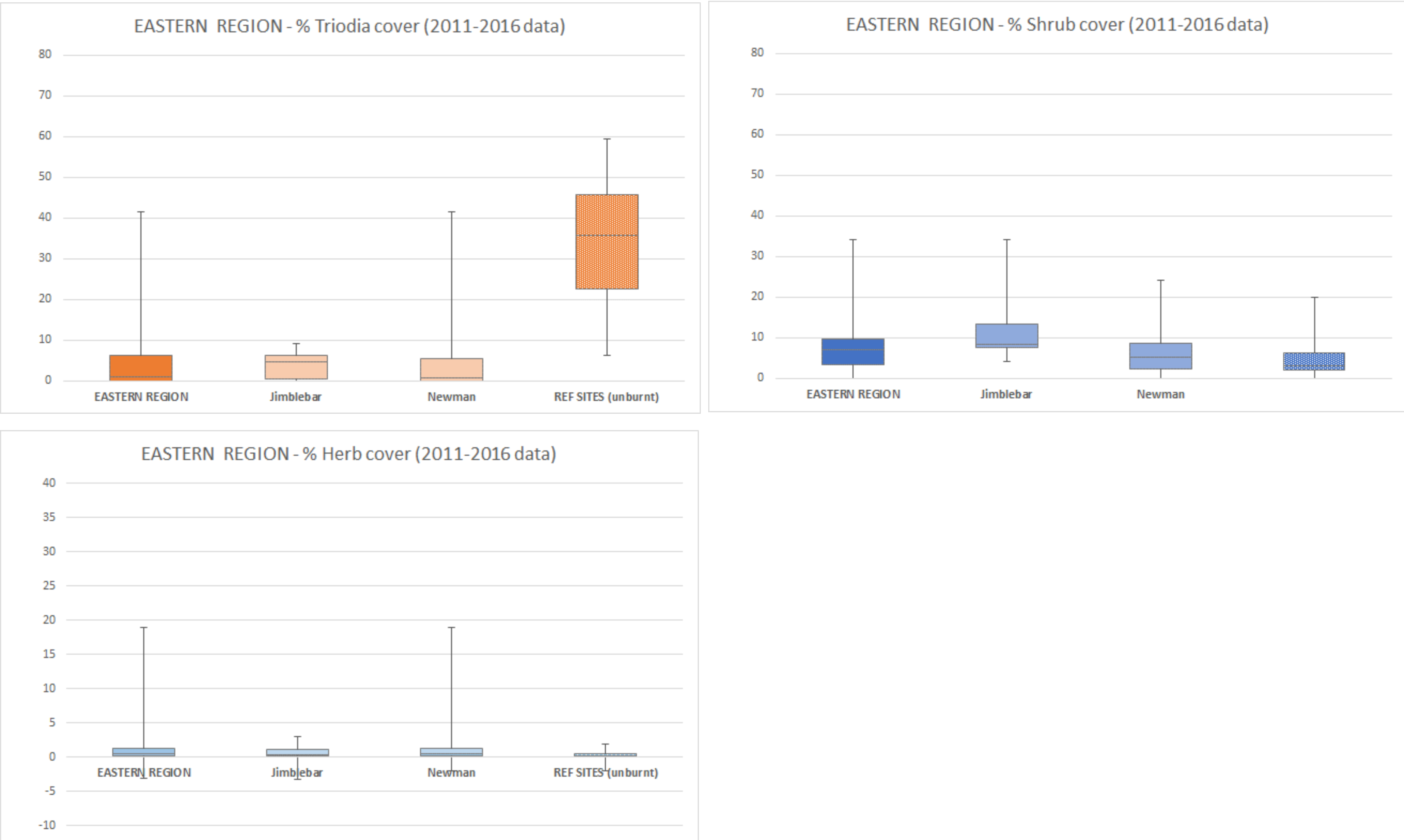



**Figure 26. Comparison of individual hubs for % cover in rehabilitated sites (2011-2016 data) for Eastern Region.**

## 12.2 ASSESSMENT OF HUBS AGAINST COMPLETION CRITERIA

To assess what impact the proposed new criteria may have on interpreting the success or otherwise of sites, the historical rehabilitation data (2011 - 2016) from all hubs (Yandi and Area C hubs from the Central region, Yarrie and Goldsworthy from the Northern region and Jimblebar and Newman from the Eastern region) was re-assessed against the revised targets. Only Area C is expected to have a Natural Environment land use; all other analysed hubs have Pastoral Grazing as a final land use. These analysed hubs provide an example of the three major vegetation types within the Strategic Proposal Boundary: Shrub steppe, Low tree steppe and Grass steppe.

Goldsworthy and Yarrie hubs have the most mature rehabilitation areas. That is, these hubs have the greatest number of plots which are 15+ years post rehabilitation, the age which is considered to be a cut off for assessment of rehabilitation success against completion criteria (see Section 6.0).

Note, only data that was available in digital form was used for the assessment against all attributes and targets (however this information may be present in hard copy documents or separate data sheets). It is important to note that this assessment was done for all hubs regardless of data sufficiency from a statistical point of view. Moving forward, when sites are assessed against the completion criteria, there will need to be sufficient sampling data to reduce the standard error to acceptable levels.

### *YANDI HUB*

The Yandi Hub assessment against the proposed completion criteria is shown in Table 13, with the performance of individual plots (useful for pinpointing areas for remedial works possibly) shown in Table 14 and Figure 27. It should be noted that not all the criteria could be assessed using the available information given the existing data sets do not specifically address % bare ground, perennial and annual species richness, and presence of weeds in various landforms.

Rehabilitation plots at Yandi lie mainly within the Low tree steppe Target Vegetation Type. The final land use of this site is assumed as pastoral and hence cover criteria targets are set to be >Q1 (Section 8.2). The overall assessment of Yandi rehabilitation sites that are >15 years old (Table 13) shows that the Target Vegetation Type (Low tree steppe) and indicator species criteria as well as weed criteria were met (Passed). Table 15 shows that Yandi rehabilitation sites contained an adequate representation of dominant indicator species within each stratum compared with reference sites. To conform with the Target Vegetation Type, a wider selection of shrub species would improve outcomes.

The sites also passed cover criteria for trees, shrubs, herbs and other grasses. In terms of hummock grasses (*Triodia*) cover, whilst most of the transects located within borrow pits had *Triodia* cover above the set target (> 20% ), in total only 46% of all individual sites (plots) met this target meaning that, overall, Yandi did not pass this criterion (Table 14).

Overall, Yandi performs relatively well against the proposed criteria and method of assessment, and as such, this site has a very good prognosis moving forward. There are obvious plots (crests in the main) that may warrant follow up works to ensure the variability within sites (as indicated in Table 14) is acceptable. However, the spread of data by age of rehabilitation (Figure 28) also provides confidence that time alone (plots >20 years), with occasional exceptions, do meet target cover criteria.

**Table 13. Yandi hub historical rehabilitation (2011-2016) - assessment of rehabilitation success.**

| SITE: YANDI<br>YEARS POST REHAB: > 15<br>END USE: PASTORAL GRAZING | | | | | |
|---|---|---|---|---|---|
| **ATTRIBUTE** | **METRIC** | **TARGETS** | | **PERFORMANCE** | |
| **Bare Ground** | % bare ground | Hills, slopes, dryplains | ≤ 50 % | Data not available - performance could not be assessed | |
| | | Drainage lines (excluding channel bed) | ≤ 20 % | | |
| | | Floodpalins | ≤ 10 % | | |
| **Species Richness** | Perennial and annual native species richness (number of species) | Perennial native | 14 - 30 | Data not available - performance could not be assessed | |
| | | Annual native species | 4 - 11 | | |
| **Weed Invasiveness** | Priority Alert weed species | Presence | None | | √ |
| | % all weed cover & % buffel grass cover | Total weed cover (%) | | 2.6 | √ |
| | | drainage lines, floodplains | < 20% | | |
| | | upland hills, slopes and flats | < 10% | | |
| | | Buffel grass cover | | Data not available - performance could not be assessed | |
| | | drainage lines, floodplains | < 10% | | |
| | | upland hills, slopes and flats | < 5% | | |
| **Target Vegetation Types** | Presence of appropriate vegetation types | | | **Low Tree Steppe** | √ |
| **Indicator Species** | Presence of dominant and common species from each Target Vegetation Type | All dominant species present | | YES | √ |
| | | >50% of common species present | | YES | √ |
| **Plant Cover** | % cover for each strata **LOW TREE STEPPE** | | **> Q1** | median | |
| | | Trees | >1 | 0 | - |
| | | Shrubs | >2 | 2.5 | √ |
| | | Hummock Grasses | >20 | 12 | - |
| | | Other Grasses | >0.04 | 2 | √ |
| | | Herbs | >0.05 | 1 | √ |

**Table 14 . Yandi hub historical rehabilitation (2011-2016) – performance of individual plots for vegetation cover criteria.**

| transect | years post | type | impact | terrain | shrub_cov | hum_cov | ograss_cov | herb_cov |
|---|---|---|---|---|---|---|---|---|
| | | | | target | >2 | >20 | >0.04 | >0.05 |
| YN-19 | 24 | Borrow Pit | Low | Flat | 5.1 | 28.9 | 0.1 | 0.9 |
| YN-20 | 24 | Borrow Pit | Low | Flat | 1.2 | 40.7 | 0.8 | 1.5 |
| YN-21 | 24 | Borrow Pit | Low | Flat | 0.5 | 5.8 | 2.0 | 0.2 |
| YN-23 | 24 | Borrow Pit | Low | Flat | 4.3 | 27.0 | 0.0 | 0.1 |
| YN-25 | 24 | Borrow Pit | Low | Flat | 3.0 | 46.8 | 0.0 | 0.0 |
| YN-26 | 24 | Borrow Pit | Low | Flat | 1.1 | 31.0 | 0.4 | 0.8 |
| YN-27 | 24 | Borrow Pit | Low | Flat | 2.5 | 24.3 | 0.0 | 0.0 |
| BMC-13 | 18 | OSA | High | Crest | 3.0 | 9.2 | 5.4 | 0.1 |
| BMC-14 | 18 | OSA | High | Crest | 31.5 | 12.0 | 8.2 | 3.3 |
| BMC-15 | 18 | OSA | High | Crest | 22.4 | 2.8 | 6.2 | 4.1 |
| BMC-13 | 15 | OSA | High | Crest | 0.3 | 5.1 | 2.1 | 0.6 |
| BMC-14 | 15 | OSA | High | Crest | 1.4 | 4.0 | 9.4 | 2.5 |
| BMC-15 | 15 | OSA | High | Crest | 2.1 | 0.0 | 4.4 | 0.1 |
| | | | | **% sites > Q1** | 62% | 46% | 77% | 85% |

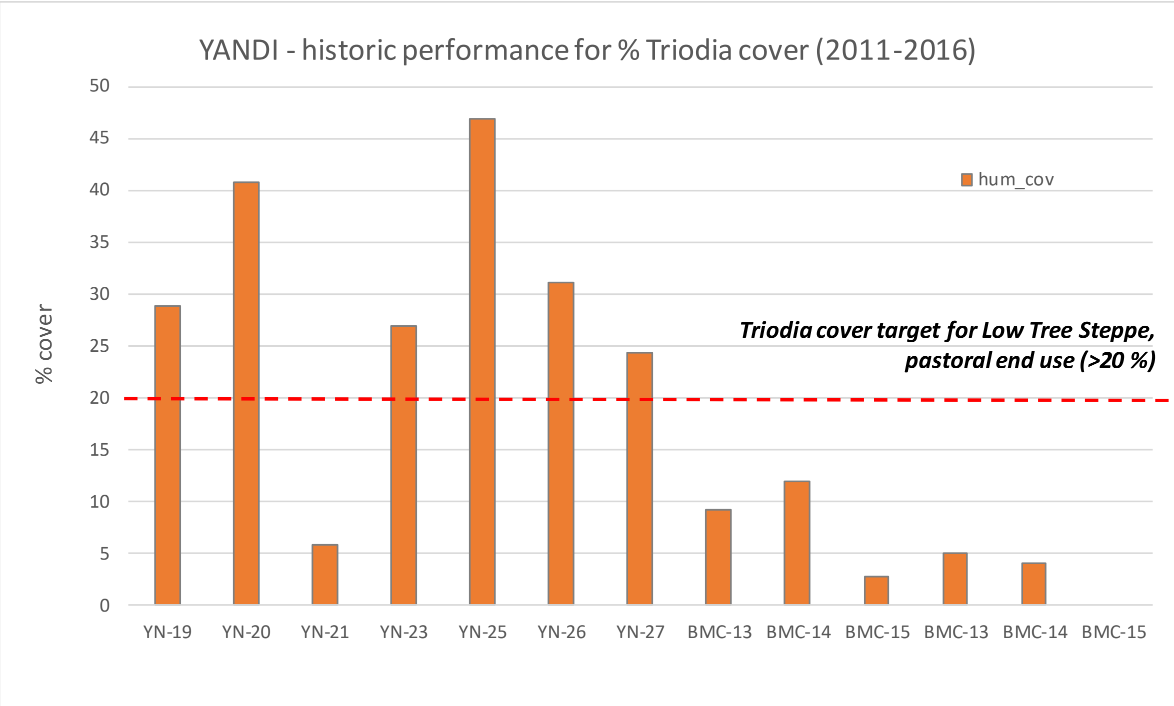



**Figure 27. Yandi hub– performance of individual plots for *Triodia* cover criteria** (note, numbers on the individual bars denote years post rehabilitation for each plot).

**Table 15. Yandi sites compared against presence/absence of indicator species from each stratum.**

| Stratum | Low Tree Steppe Number of Dominant & Common Species per Stratum | Number of dominant Low Tree Steppe Species occurring in Rehabilitated sites | % of Low Tree Steppe Species occurring in Rehabilitated sites | Number of dominant Low Tree Steppe Species occurring in Reference sites | % of Low Tree Steppe Species occurring in Reference Sites |
|---|---|---|---|---|---|
| **Tree** | **3** | 2 | 67% | 2 | 67% |
| **Shrub** | **19** | 3 | 16% | 4 | 21% |
| **Hummock** | 1 | 1 | 100% | 1 | 100% |

*Note, frequency is shown for both reference and rehabilitation plots. The number of dominant and common species per stratum in Column 1 are derived from the descriptions of vegetation in Beard et al 2013, and would apply to future assessments where sufficient survey plots and releves have been undertaken to adequately capture the site.*

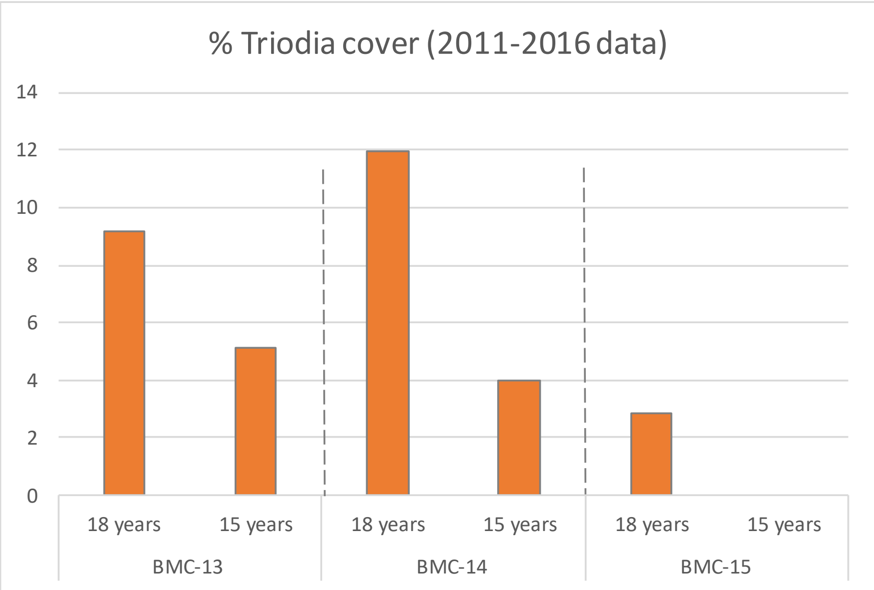



**Figure 28. Impact of age post rehabilitation on % *Triodia* cover at three Yandi plots.**

***AREA C HUB***

The Area C Hub assessment against the proposed completion criteria is shown in Table 16 with the performance of individual plots shown in Table 17 and Figure 29**.**

As with Yandi hub, not all the criteria could be assessed using the available information given the existing data sets do not specifically address % bare ground, perennial and annual species richness, and presence of weeds in various landforms.

Area C contains both Low tree steppe and Low woodland Target Vegetation Types. Most of the current rehabilitation areas sit within the Low tree steppe type, hence this has been used as the basis for the assessment.

The final land use of this site is assumed as Natural Environment given the proximity of this hub to the Department of Biodiversity, Conservation and Attractions (DBCA) conservation areas and current dominant tenure being Unallocated Crown Land (see Table 3). As such, the cover targets are set to be in the Q1-Q3 range as per Section 8.0.

All of the analysed rehabilitation sites within Area C (2011-2016 data) are 7 to 12 years old, meaning they are relatively young and do not meet the post rehabilitation age cut off (15+ years) established as a minimum needed for the full assessment of rehabilitation success.

As it stands currently, the overall assessment of Area C rehabilitation sites shows that the Target Vegetation Type (Low tree steppe) and the weed cover criteria were met (Passed).

Area C also met cover criteria for shrubs and herbs (median value for sites is within the set Q1-Q3 target range), but currently did not meet cover criteria for hummock grasses (below Q1-Q3 range). Area C also failed cover criteria for other grasses; these were well above the target cover range (Table 16). Similar to other analysed hubs, trees were absent from Area C and the hub did not pass tree cover criteria.

Table 17 and Figure 29 further highlight the shortcomings of Area C hub in terms of hummock and other grasses cover as it shows that none of the individual sites met the hummock grass cover target, while only one of the 12 analysed sites (8%) fully met the set range criteria for other grasses cover. In contrast, 67% of the sites met shrub cover criteria.

In summary, the available historic data suggests that, although the hub shows some indications of rehabilitation success (in terms of weeds and shrubs for instance), in general Area C is too young to be compared against completion criteria.

**Table 16. Area C hub historical rehabilitation (2011-2016) - assessment of rehabilitation success.**

| SITE: | AREA C | | | | |
|---|---|---|---|---|---|
| YEARS POST REHAB: | 7 - 12 | | | | |
| END USE: | NATURAL ENVIRONMENTS FOR MANAGED RESOURCE PROTECTION | | | | |
| **ATTRIBUTE** | **METRIC** | **TARGETS** | | **PERFORMANCE** | |
| **Bare Ground** | % bare ground | Hills, slopes, dryplains | ≤ 50 % | Data not available - performance could not be assessed | |
| | | Drainage lines (excluding channel bed) | ≤ 20 % | | |
| | | Floodpalins | ≤ 10 % | | |
| **Species Richness** | Perennial and annual native species richness (number of species) | Perennial native | 14 - 30 | Data not available - performance could not be assessed | |
| | | Annual native species | 4 - 11 | | |
| **Weed Invasiveness** | Priority Alert weed species | Presence | None | Not assessed | |
| | % total weed cover and % buffel grass cover | total average weed cover | < 20% | 0.0 | √ |
| | | total Buffel Grass cover | < 10% | | |
| | | total Buffel Grass cover per landform | | Data not available - performance could not be assessed | |
| | | drainage lines | < 10% | | |
| | | floodplains | | | |
| | | upland hills, slopes and flats | < 10% | | |
| **Target Vegetation Types** | Presence of appropriate vegetation types | | | **Low Tree Steppe** | √ |
| **Indicator Species** | Presence of dominant and common species from each Target Vegetation Type | All dominant species present | | Not assessed | |
| | | >50% of common species present | | Not assessed | |
| **Plant Cover** | % cover for each strata **LOW TREE STEPPE** | | **Q1-Q3** | median | |
| | | Trees | 1 -10 | 0.00 | - |
| | | Shrubs | 2 - 10 | 8.87 | √ |
| | | Hummock Grasses | 20 - 30 | 11.39 | - |
| | | Other Grasses | 0.04 - 0.62 | 4.58 | - |
| | | Herbs | 0.05 - 0.4 | 0.23 | √ |

**Table 17. Area C hub historical rehabilitation (2011-2016) – performance of individual plots for vegetation cover criteria.**

| transect | years post rehab | type | impact | terrain | shrub_cov | hum_cov | ograss_cov | herb_cov |
|---|---|---|---|---|---|---|---|---|
| | | | | target | 2 - 10 | 20 - 30 | 0.04-0.62 | 0.05-0.4 |
| BAC-04 | 12 | Borrow | Low | Flat | 17.4 | 32.4 | 1.4 | 0.0 |
| BAC-01 | 11 | Borrow | Low | Flat | 42.6 | 3.5 | 6.9 | 0.3 |
| BAC-08 | 11 | Camp | Low | Flat | 7.6 | 0.0 | 4.4 | 0.0 |
| BAC-09 | 11 | Camp | Low | Slope | 17.2 | 6.6 | 4.7 | 0.3 |
| BAC-04 | 9 | Borrow | Low | Flat | 2.4 | 19.9 | 0.1 | 0.0 |
| BAC-08 | 8 | Camp | Low | Flat | 2.1 | 0.0 | 3.0 | 0.0 |
| BAC-14 | 7 | OSA | High | Slope | 24.4 | 11.9 | 6.0 | 2.0 |
| AC-02 | 7 | Borrow Pit | Low | Flat | 7.1 | 18.0 | 7.2 | 1.5 |
| AC-03 | 7 | Borrow Pit | Low | Flat | 9.9 | 10.2 | 1.4 | 0.0 |
| AC-04 | 7 | Borrow Pit | Low | Flat | 9.2 | 32.6 | 6.1 | 0.5 |
| AC-05 | 7 | Borrow Pit | Low | Flat | 8.5 | 12.2 | 3.9 | 0.2 |
| AC-07 | 7 | Borrow Pit | Low | Flat | 6.9 | 10.8 | 14.6 | 3.4 |
| | | | | % sites within Q1-Q3 | 67% | 0% | 8% | 25% |

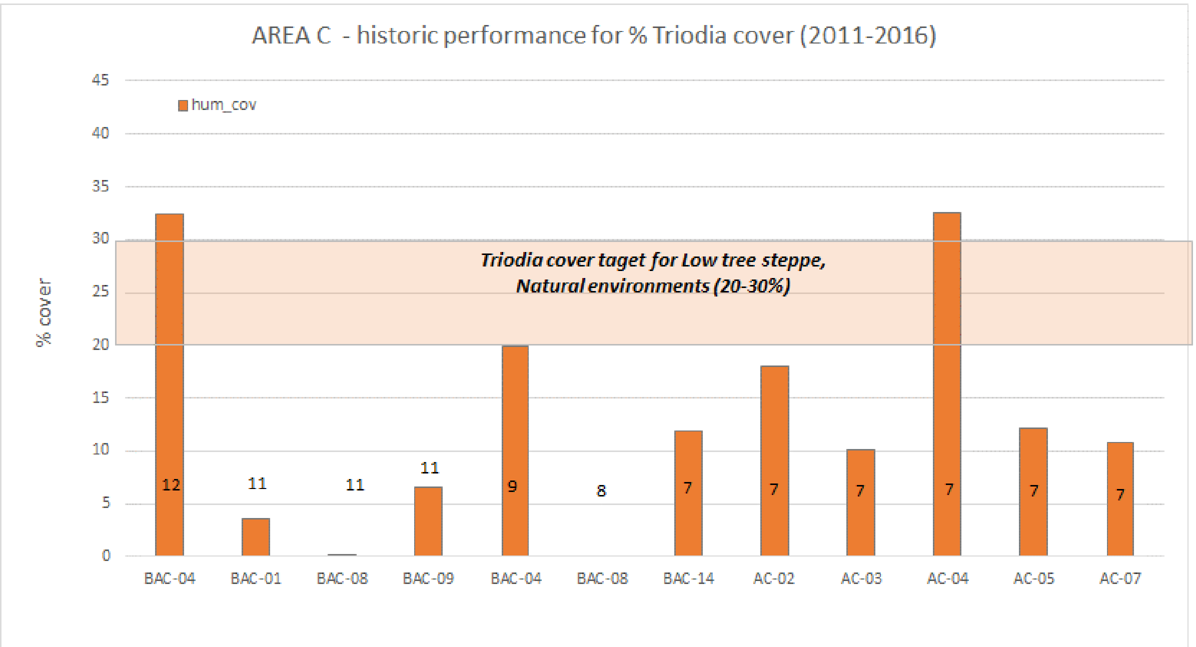



**Figure 29. Area C hub – performance of individual plots for *Triodia* cover criteria** (note, numbers on the individual bars denote years post rehabilitation for each plot).

## *YARRIE HUB*

The Yarrie Hub assessment against the proposed completion criteria is shown in Table 18 with the performance of individual plots (useful for pinpointing areas for remedial works possibly) shown in Table 19 and Figure 30. It should be noted that not all the criteria could be assessed using the available information given the existing data sets do not specifically address % bare ground, perennial and annual species richness, and presence of weeds in various landforms.

Rehabilitation plots at Yarrie lie mainly within the Shrub steppe Target Vegetation Type. As with Yandi, the final land use of this site is assumed as pastoral and for cover criteria, the targets are set to be >Q1.

The overall assessment of Yarrie rehabilitation sites that are >15 years old (Table 18, 27 sites in total) shows that the Target Vegetation Type (Shrub steppe) and indicator species criteria as well as weed criteria were met (Passed). Table 20 shows that Yarrie rehabilitation sites contained an adequate representation of dominant indicator species within each stratum.

The Yarrie Hub also passed cover criteria for hummock grasses, shrubs and herbs (Table 18), however trees were absent, and other grasses were marginally below targets (44%) (Table 19).

Overall, Yarrie performs well against the proposed criteria and method of assessment, and as such, this site has a very good prognosis moving forward.  Similar to Yandi, there are obvious plots that may warrant follow up works to ensure the variability within sites (as indicated in Table 19) is acceptable.

**Table 18. Yarrie hub historical rehabilitation (2011-2016) - assessment of rehabilitation success.**

| SITE: | YARRIE | | | | |
|---|---|---|---|---|---|
| YEARS POST REHAB: | > 15 | | | | |
| END USE: | PASTORAL GRAZING | | | | |
| **ATTRIBUTE** | **METRIC** | **TARGETS** | | **PERFORMANCE** | |
| **Bare Ground** | % bare ground | Hills, slopes, dryplains | ≤ 50 % | Data not available - performance could not be assessed | |
| | | Drainage lines (excluding channel bed) | ≤ 20 % | | |
| | | Floodpalins | ≤ 10 % | | |
| **Species Richness** | Perennial and annual native species richness (number of species) | Perennial native | 14 - 30 | Data not available - performance could not be assessed | |
| | | Annual native species | 4 - 11 | | |
| **Weed Invasiveness** | Priority Alert weed species | Presence | None | | √ |
| | % total weed cover and % buffel grass cover | total average weed cover | < 20% | 0.0 | √ |
| | | total Buffel Grass cover | < 10% | | |
| | | total Buffel Grass cover per landform | | Data not available - performance could not be assessed | |
| | | drainage lines | < 10% | | |
| | | floodplains | | | |
| | | upland hills, slopes and flats | < 10% | | |
| **Target Vegetation Types** | Presence of appropriate vegetation types | | | **Shrub Steppe** | √ |
| **Indicator Species** | Presence of dominant and common species from each Target Vegetation Type | All dominant species present | | YES | √ |
| | | >50% of common species present | | YES | √ |
| **Plant Cover** | % cover for each strata **SHRUB STEPPE** | | **> Q1** | median | |
| | | Trees | >1 | 0.00 | - |
| | | Shrubs | >3 | 3.12 | √ |
| | | Hummock Grasses | >19 | 25.15 | √ |
| | | Other Grasses | >0.02 | 0.01 | - |
| | | Herbs | >0.1 | 0.1 | √ |

**Table 19. Yarrie hub historical rehabilitation (2011-2016) – performance of individual plots for vegetation cover criteria.**

| transect | years post rehab | type | impact | terrain | shrub_cov | hum_cov | ograss_cov | herb_cov |
|---|---|---|---|---|---|---|---|---|
| | | | | target | >3 | >19 | >0.02 | >0.1 |
| BYA12_15 | 22 | Borrow | Low | Flat | 15.0 | 39.3 | 0.0 | 1.1 |
| BYA13_15 | 22 | Borrow | Low | Flat | 4.9 | 11.4 | 0.1 | 0.5 |
| Site YR01_15 | 22 | Borrow Pit | Low | Flat | 4.9 | 35.0 | 0.02 | 1.4 |
| Site YR02_15 | 22 | Borrow Pit | Low | Flat | 7.0 | 33.8 | 0.002 | 1.4 |
| Site YR04_15 | 22 | Borrow Pit | Low | Flat | 5.6 | 14.9 | 0.00 | 0.1 |
| Site YR05_15 | 22 | Borrow Pit | Low | Flat | 0.0 | 20.4 | 0.00 | 0.0 |
| Site YR08_15 | 22 | Borrow Pit | Low | Flat | 13.9 | 36.2 | 0.00 | 0.0 |
| Site YR09_15 | 22 | Borrow Pit | Low | Flat | 0.002 | 36.8 | 0.016 | 0.1 |
| Site YR10_15 | 22 | Borrow Pit | Low | Flat | 3.4 | 15.1 | 0.00 | 1.0 |
| Site YR11_15 | 22 | Borrow Pit | Low | Flat | 1.0 | 15.9 | 0.00 | 0.018 |
| BYA11_16 | 21 | OSA | High | Slope | 1.7 | 4.7 | 0.6 | 0.4 |
| BYA11_15 | 20 | OSA | High | Slope | 1.9 | 2.7 | 1.2 | 3.0 |
| Site YR07_15 | 20 | Borrow Pit | Low | Flat | 8.8 | 25.2 | 0.00 | 0.008 |
| Site YR0a_15 | 20 | Borrow Pit | Low | Flat | 1.3 | 14.3 | 0.00 | 0.000 |
| Site YR0b_15 | 20 | Borrow Pit | Low | Flat | 0.2 | 37.7 | 0.31 | 0.000 |
| Site YR14a_15 | 20 | Borrow Pit | Low | Flat | 5.2 | 42.3 | 0.01 | 0.000 |
| Site YR14b_15 | 20 | Borrow Pit | Low | Flat | 0.3 | 25.2 | 0.06 | 0.008 |
| Site YR14c_15 | 20 | Borrow Pit | Low | Flat | 5.3 | 34.9 | 0.35 | 0.062 |
| Site YR14d_15 | 20 | Borrow Pit | Low | Flat | 2.5 | 28.7 | 0.00 | 0.000 |
| Site YR15_15 | 20 | Borrow Pit | Low | Flat | 3.7 | 28.8 | 0.00 | 0.020 |
| Site YR20_15 | 20 | Borrow Pit | Low | Flat | 3.8 | 7.3 | 0.00 | 0.004 |
| BYA11_14 | 19 | OSA | High | Slope | 1.6 | 1.4 | 1.3 | 5.5 |
| BYA07_13 | 18 | OSA | High | Crest | 1.4 | 13.1 | 11.4 | 0.1 |
| BYA08_13 | 18 | OSA | High | Crest | 5.3 | 2.6 | 1.5 | 0.1 |
| BYA11_13 | 18 | OSA | High | Slope | 1.7 | 36.6 | 1.0 | 0.8 |
| BYA02_16 | 18 | OSA | High | Slope | 0.6 | 41.2 | 0.00 | 0.004 |
| BYA02_13 | 15 | OSA | High | Slope | 3.1 | 16.8 | 0.1 | 3.0 |
| | | | | **% sites > Q1** | **52%** | **56%** | **44%** | **48%** |

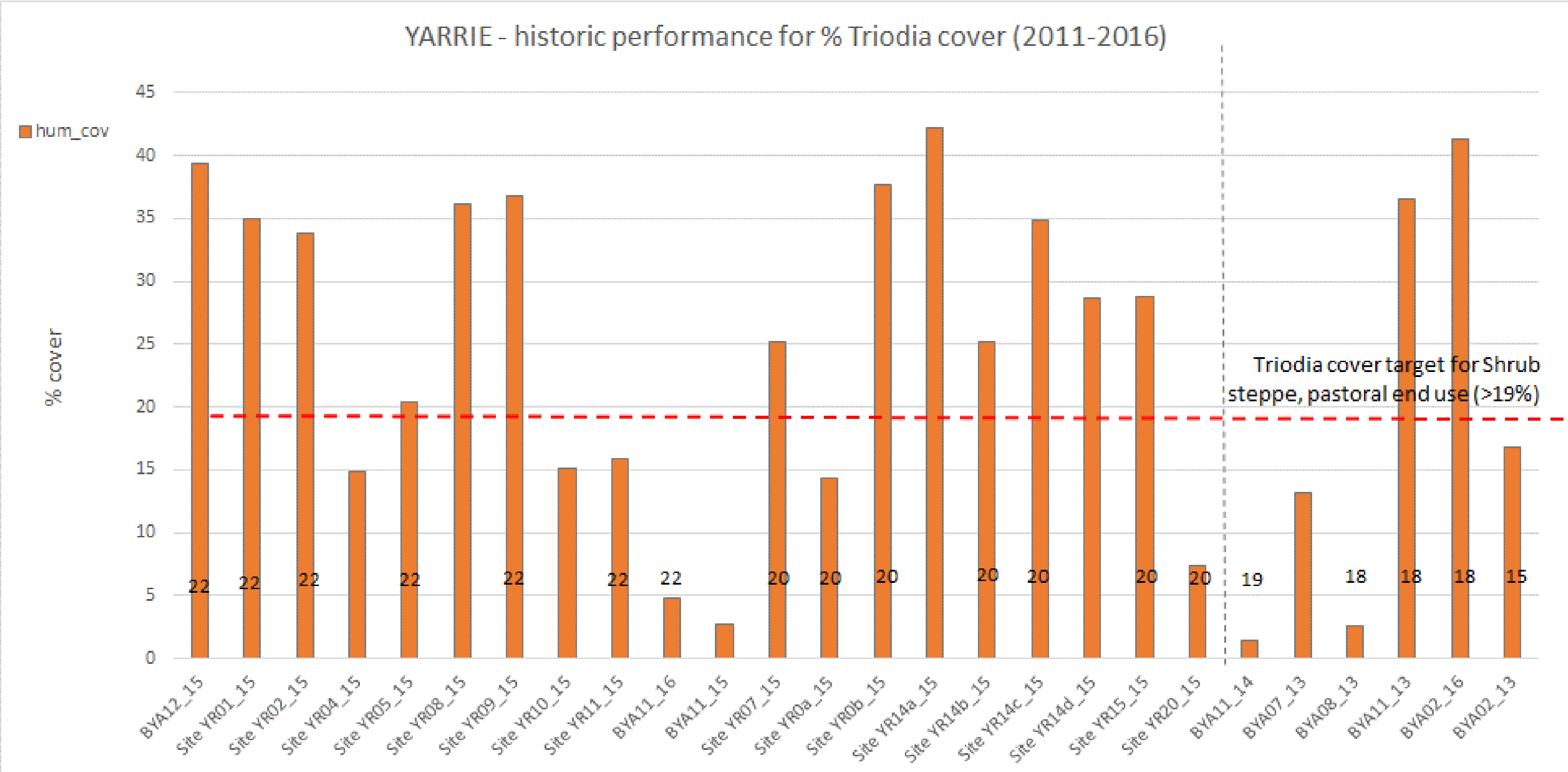



**Figure 30. Yarrie hub – performance of individual plots for *Triodia* cover criteria.** (note, numbers on the individual bars denote years post rehabilitation for each plot).

**Table 20. Yarrie sites compared against presence/absence of indicator species from each stratum.**

| Stratum | Low Tree Steppe Number of Dominant & Common Species per Stratum | Number of dominant Low Tree Steppe Species occurring in Rehabilitated sites | % of Low Tree Steppe Species occurring in Rehabilitated sites | Number of dominant Low Tree Steppe Species occurring in Reference sites | % of Low Tree Steppe Species occurring in Reference Sites |
|---|---|---|---|---|---|
| **Tree** | **3** | 1 | 33% | 0 | 0% |
| **Shrub** | **19** | 5 | 26% | 3 | 16% |
| **Hummock** | **1** | 1 | 100% | 1 | 100% |

*Note, frequency is shown for both reference and rehabilitation plots. The number of dominant and common species per stratum in Column 1 are derived from the descriptions of vegetation in Beard et al 2013, and would apply to future assessments where sufficient survey plots and releves have been undertaken to adequately capture the site.*

### ***GOLDSWORTHY HUB***

The Goldsworthy Hub assessment against the proposed completion criteria is shown in Table 21 with the performance of individual plots shown in Table 22 and Figure 31. As previously stated, not all the criteria could be assessed using the available information given the existing data sets do not specifically address % bare ground, perennial and annual species richness, and presence of weeds in various landforms.

Rehabilitation plots at Goldsworthy lie mainly within the Grass steppe Target_Vegetation Type, and this is the only analysed hub with this target vegetation type. The final land use is assumed as pastoral given most of the existing land tenure within this hub (76%) is already pastoral (Table 3). All of the rehabilitation sites within Goldsworthy (43 in total) fall into the age that warrants assessment against completion criteria (> 15 years post rehabilitation) (Table 22).

As can be seen in Table 21,  Goldsworthy Hub as a whole passed the cover criteria for shrubs, herbs, other grasses and weeds. Most of the individual sites (95%) passed shrub cover criterion, while 56% to 60% also met cover targets for herbs and other grasses (Table 22).

In contrast, and as is the case with all other analysed hubs, trees were absent, and Goldsworthy failed for the tree cover criterion.

Median % cover of hummock grasses, although relatively high (11%), was below the set target of 15%, and as such the hub did not pass this *Triodia*-specific criterion either. Only 35% of individual sites met this target (Table 22).

In summary, while Goldsworthy performs relatively well against most of the proposed criteria, the failure to meet % *Triodia* cover despite the maturity of rehabilitation sites (>18 years post rehabilitation) raises doubts as to whether this hub can fully meet completion criteria in the future, without further intervention.

**Table 21. Goldsworthy hub historical rehabilitation (2011-2016) - assessment of rehabilitation success.**

| SITE: | GOLDSWORTHY | | | | |
|---|---|---|---|---|---|
| YEARS POST REHAB: | 18+ YEARS | | | | |
| END USE: | PASTORAL GRAZING | | | | |
| **ATTRIBUTE** | **METRIC** | **TARGETS** | | **PERFORMANCE** | |
| **Bare Ground** | % bare ground | Hills, slopes, dryplains | ≤ 50 % | Data not available - performance could not be assessed | |
| | | Drainage lines (excluding channel bed) | ≤ 20 % | | |
| | | Floodpalins | ≤ 10 % | | |
| **Species Richness** | Perennial and annual native species richness (number of species) | Perennial native | 14 - 30 | Data not available - performance could not be assessed | |
| | | Annual native species | 4 - 11 | | |
| **Weed Invasiveness** | Priority Alert weed species | Presence | None | Not assesed | |
| | % total weed cover and % buffel grass cover | total average weed cover | < 20% | 7.5 | √ |
| | | total Buffel Grass cover | < 10% | | |
| | | total Buffel Grass cover per landform | | Data not available - performance could not be assessed | |
| | | drainage lines | < 10% | | |
| | | floodplains | | | |
| | | upland hills, slopes and flats | < 10% | | |
| **Target Vegetation Types** | Presence of appropriate vegetation types | | | **Grass Steppe** | √ |
| **Indicator Species** | Presence of dominant and common species from each Target Vegetation Type | All dominant species present | | Not assessed | |
| | | >50% of common species present | | Not assessed | |
| **Plant Cover** | % cover for each strata **GRASS STEPPE** | | **> Q1** | median | |
| | | Trees | > 0 | 0.00 | - |
| | | Shrubs | > 0.2 | 5.9 | √ |
| | | Hummock Grasses | > 15 | 11.0 | - |
| | | Other Grasses | > 0.01 | 0.1 | √ |
| | | Herbs | > 0.1 | 0.3 | √ |

**Table 22. Goldsworthy hub historical rehabilitation (2011-2016) – performance of individual plots for vegetation cover criteria.**

| transect | years post rehab | type | impact | terrain | shrub_cov | hum_cov | ograss_cov | herb_cov |
|---|---|---|---|---|---|---|---|---|
| | | | | target | > 0.2 | > 15 | > 0.01 | >0.1 |
| BGW-01 | 22 | Infrastructure | Low | Flat | 9.5 | 7.8 | 0.0 | 1.3 |
| BGW-02 | 22 | Infrastructure | Low | Flat | 8.2 | 3.9 | 0.2 | 0.1 |
| BGW-03 | 22 | Infrastructure | Low | Flat | 5.7 | 16.4 | 1.1 | 0.6 |
| BGW-04 | 22 | Infrastructure | Low | Flat | 2.0 | 10.8 | 0.0 | 0.2 |
| BGW-05 | 22 | Infrastructure | Low | Flat | 25.7 | 15.0 | 0.0 | 0.0 |
| BGW-06 | 22 | Infrastructure | Low | Flat | 6.1 | 25.6 | 0.0 | 0.0 |
| BGW-07 | 22 | Infrastructure | Low | Flat | 0.1 | 27.5 | 0.0 | 0.0 |
| BGW-10 | 22 | Infrastructure | Low | Flat | 14.0 | 12.5 | 0.0 | 0.9 |
| BGW-11 | 22 | Infrastructure | Low | Flat | 4.8 | 31.8 | 0.3 | 0.0 |
| BGW-13 | 22 | Waste Dump | High | Flat | 2.4 | 0.6 | 0.3 | 2.3 |
| BGW-15 | 22 | Infrastructure | Low | Flat | 31.2 | 4.9 | 0.4 | 0.3 |
| BGW-17 | 22 | Waste Dump | High | Flat | 0.0 | 0.0 | 0.0 | 0.0 |
| BGW-21 | 22 | Waste Dump | High | Flat | 0.4 | 0.0 | 0.1 | 0.3 |
| BGW-22 | 22 | Waste Dump | High | Flat | 14.2 | 14.1 | 1.4 | 0.1 |
| BGW-23 | 22 | Waste Dump | High | Flat | 2.8 | 26.5 | 0.2 | 0.0 |
| BGW-30 | 22 | Waste Dump | High | Flat | 15.1 | 8.7 | 2.2 | 0.2 |
| BGW-33 | 22 | Borrow Pit | Low | Flat | 3.9 | 17.3 | 0.0 | 0.0 |
| BGW-34 | 22 | Infrastructure | Low | Flat | 24.2 | 26.4 | 0.1 | 0.1 |
| BGW-35 | 22 | Borrow Pit | Low | Flat | 29.5 | 11.8 | 0.0 | 0.7 |
| BGW-36 | 22 | Road | Low | Flat | 2.8 | 14.9 | 0.1 | 0.1 |
| BGW-40 | 22 | Infrastructure | Low | Flat | 3.9 | 0.0 | 0.0 | 1.1 |
| BGW-45 | 22 | Borrow Pit | Low | Flat | 9.1 | 6.0 | 0.1 | 3.0 |
| BGW-54 | 22 | infrastructure | Low | Flat | 14.3 | 25.1 | 1.0 | 0.8 |
| BGW-02 | 18 | Infrastructure | Low | Flat | 7.3 | 2.9 | 0.0 | 0.0 |
| BGW-04 | 18 | Infrastructure | Low | Flat | 12.2 | 11.2 | 0.0 | 0.0 |
| BGW-06 | 18 | Infrastructure | Low | Flat | 5.9 | 23.1 | 0.0 | 0.0 |
| BGW-07 | 18 | Infrastructure | Low | Flat | 2.1 | 42.6 | 0.0 | 0.0 |
| BGW-08 | 18 | Infrastructure | Low | Flat | 17.6 | 11.7 | 1.2 | 0.0 |
| BGW-09 | 18 | Infrastructure | Low | Flat | 15.5 | 11.0 | 0.6 | 0.2 |
| BGW-11 | 18 | Infrastructure | Low | Flat | 4.0 | 39.8 | 2.3 | 2.6 |
| BGW-13 | 18 | Waste Dump | High | Flat | 3.9 | 0.4 | 0.5 | 3.4 |
| BGW-15 | 18 | Infrastructure | Low | Flat | 18.2 | 3.8 | 0.0 | 4.4 |
| BGW-16 | 18 | Waste Dump | High | Flat | 2.1 | 0.0 | 0.6 | 15.7 |
| BGW-17 | 18 | Waste Dump | High | Flat | 4.5 | 0.0 | 0.0 | 0.5 |
| BGW-19 | 18 | Waste Dump | High | Flat | 4.0 | 0.0 | 0.0 | 10.8 |
| BGW-21 | 18 | Waste Dump | High | Flat | 5.8 | 0.0 | 4.1 | 10.3 |
| BGW-22 | 18 | Waste Dump | High | Flat | 15.0 | 5.6 | 3.2 | 5.4 |
| BGW-23 | 18 | Waste Dump | High | Flat | 4.2 | 23.5 | 0.1 | 2.9 |
| BGW-30 | 18 | Waste Dump | High | Flat | 10.6 | 2.3 | 0.0 | 11.8 |
| BGW-33 | 18 | Borrow Pit | Low | Flat | 15.6 | 17.2 | 0.0 | 0.0 |
| BGW-36 | 18 | Road | Low | Flat | 5.4 | 31.4 | 0.4 | 0.0 |
| BGW-37 | 18 | Waste Dump | High | Flat | 5.6 | 0.0 | 0.6 | 8.0 |
| BGW-38 | 18 | Waste Dump | High | Flat | 11.8 | 4.4 | 1.2 | 2.1 |
| | | | % sites > Q1 | | 95% | 35% | 56% | 60% |

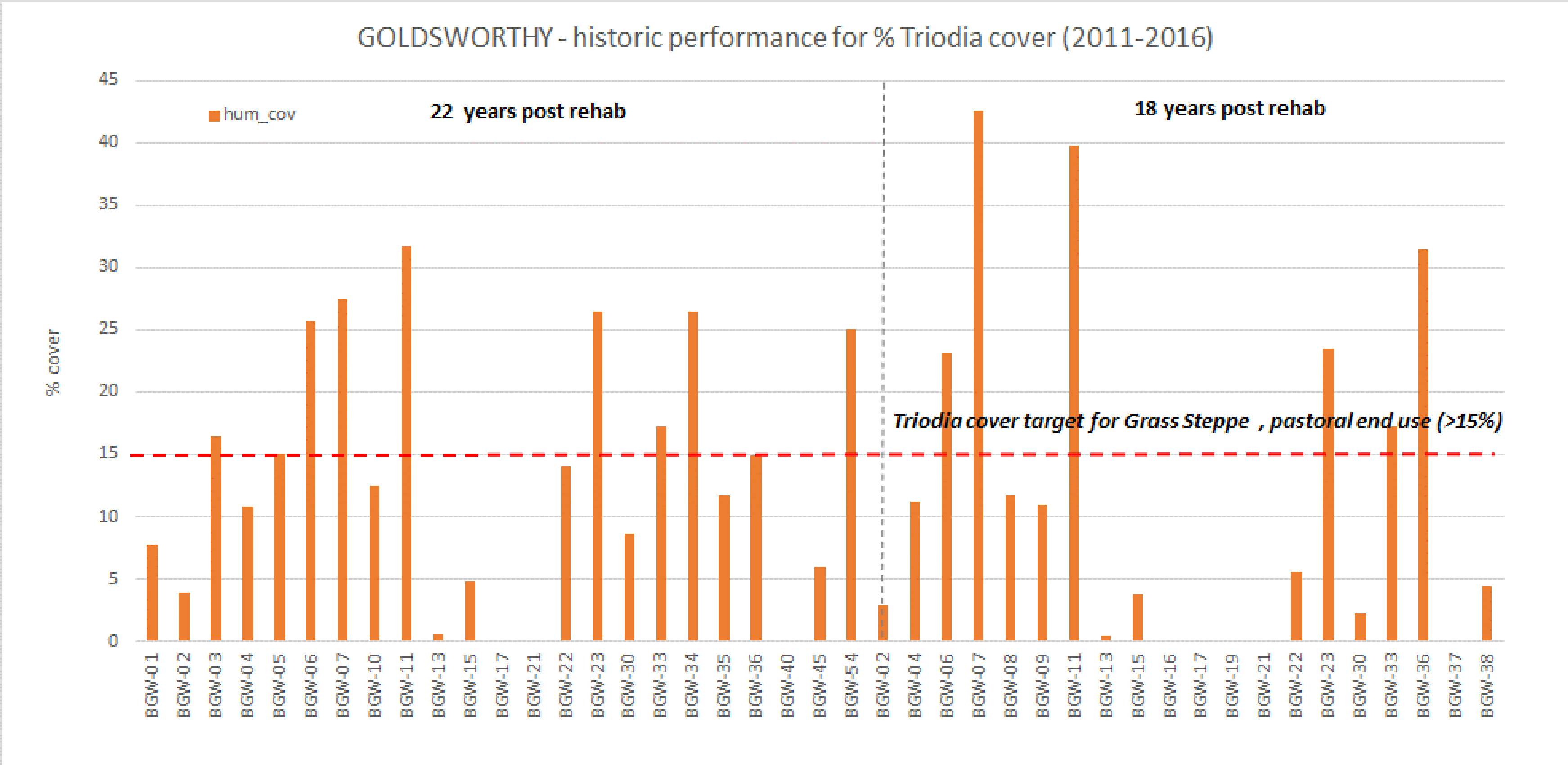



**Figure 31. Goldsworthy Hub– performance of individual plots for Triodia cover criteria** (note, numbers on the individual bars denote years post rehabilitation for each plot).

### *JIMBLEBAR HUB*

The Jimblebar Hub assessment against the proposed completion criteria is shown in Table 23 with the performance of individual plots shown in Table 24 and Figure 32. As with other hubs, not all the criteria could be assessed given the limitation of available information.

Jimblebar contains both Low tree steppe and Low woodland Target Vegetation Types. Most of the current rehabilitation areas sit within the Low tree steppe type, hence this has been used as the basis of the assessment. The final land use of this site is assumed as pastoral given half of the site already has this tenure (see Table 3); hence targets are set to be >Q1 for cover criteria.

Not all of the analysed rehabilitation sites within Jimblebar are mature enough to warrant assessment against completion criteria. Of the13 analysed rehabilitation sites (2011-2016 data) nine (9) are older than 15 years, while four (4) are relatively young (5 to 7 years post rehabilitation).

The overall assessment of Jimblebar rehabilitation sites shows that the Target Vegetation Type (Low tree steppe) and the weed cover criteria (Table 23) were met (Passed).

These sites also passed the cover criteria for shrubs, other grasses and herbs (median values were above the Q1 target) with all of the analysed individual sites passing the shrub and other grasses criterion and the majority of individual plots (77%) also meeting cover targets for herbs (Figure 32 and Table 23).

However, none of the Jimblebar sites passed cover targets for hummock grasses (Table 24 and Figure 32) and the hub as a whole failed this particular criterion (Table 23).

Also, and similar to other analysed hubs, trees were absent within Jimblebar rehabilitated areas and therefore the hub did not pass the tree cover criteria (Table 23).

In summary, the available historic data suggests that Jimblebar is trending well against most of the completion criteria but performs very poorly for *Triodia* regardless of rehabilitation age. At present and using the available information, it is not clear why this is the case however many sites are immediately adjacent to active mining operations and possibly are impacted by some level of associated disturbances.

**Table 23. Jimblebar hub historical rehabilitation (2011-2016) - assessment of rehabilitation success.**

| SITE: JIMBLEBAR<br>YEARS POST REHAB: 5 - 18<br>END USE: PASTORAL GRAZING | | | | | |
|---|---|---|---|---|---|
| **ATTRIBUTE** | **METRIC** | **TARGETS** | | **PERFORMANCE** | |
| **Bare Ground** | % bare ground | Hills, slopes, dryplains | ≤ 50 % | Data not available - performance could not be assessed | |
| | | Drainage lines (excluding channel bed) | ≤ 20 % | | |
| | | Floodpalins | ≤ 10 % | | |
| **Species Richness** | Perennial and annual native species richness (number of species) | Perennial native | 14 - 30 | Data not available - performance could not be assessed | |
| | | Annual native species | 4 - 11 | | |
| **Weed Invasiveness** | Priority Alert weed species | Presence | None | Not assesed | |
| | % total weed cover and % buffel grass cover | total average weed cover | < 20% | 0.5 | √ |
| | | total Buffel Grass cover | < 10% | | |
| | | total Buffel Grass cover per landform | | Data not available - performance could not be assessed | |
| | | drainage lines | < 10% | | |
| | | floodplains | | | |
| | | upland hills, slopes and flats | < 10% | | |
| **Target Vegetation Types** | Presence of appropriate vegetation types | | | **Low Tree Steppe** | √ |
| **Indicator Species** | Presence of dominant and common species from each Target Vegetation Type | All dominant species present | | Not assessed | |
| | | >50% of common species present | | Not assessed | |
| **Plant Cover** | % cover for each strata **LOW TREE STEPPE** | | **> Q1** | median | |
| | | Trees | >1 | 0.00 | - |
| | | Shrubs | >2 | 8.4 | √ |
| | | Hummock Grasses | >20 | 4.5 | - |
| | | Other Grasses | >0.04 | 3.3 | √ |
| | | Herbs | >0.05 | 0.3 | √ |

**Table 24. Jimblebar hub historical rehabilitation (2011-2016) – performance of individual plots for vegetation cover criteria.**

| transect | years post rehab | type | impact | terrain | shrub_cov | hum_cov | ograss_cov | herb_cov |
|---|---|---|---|---|---|---|---|---|
| | | | | target | > 2 | > 20 | > 0.04 | >0.05 |
| BJB11_13 | 18 | Borrow | Low | Flat | 34.2 | 9.1 | 0.1 | 0.1 |
| BJB03_13 | 18 | OSA | High | Slope | 7.6 | 0.4 | 2.1 | 0.1 |
| BJB04_13 | 18 | OSA | High | Slope | 8.4 | 0.0 | 1.3 | 0.0 |
| BJB06_13 | 18 | OSA | High | Crest | 15.6 | 4.5 | 4.8 | 0.2 |
| Site J08_15 | 17 | Borrow Pit | Low | Flat | 7.5 | 0.4 | 3.8 | 0.3 |
| Site J09_15 | 17 | Borrow Pit | Low | Flat | 9.7 | 6.3 | 0.8 | 0.0 |
| Site J10_15 | 17 | Borrow Pit | Low | Flat | 6.2 | 0.0 | 3.3 | 2.2 |
| Site J13_15 | 17 | Borrow Pit | Low | Flat | 4.2 | 6.2 | 4.8 | 3.0 |
| Site J14_15 | 17 | Borrow Pit | Low | Flat | 5.6 | 7.4 | 4.5 | 0.5 |
| BJB14_16 | 7 | Rail | Low | Flat | 7.5 | 0.9 | 0.4 | 0.0 |
| BJB19_12 | 5 | OSA | High | Slope | 9.6 | 0.4 | 1.6 | 1.8 |
| BJB14_14 | 5 | Rail | Low | Flat | 13.2 | 5.0 | 5.3 | 0.6 |
| BJB15_14 | 5 | Rail | Low | Flat | 20.4 | 8.2 | 5.8 | 1.1 |
| | | | | % sites > Q1 | 100% | 0% | 100% | 77% |

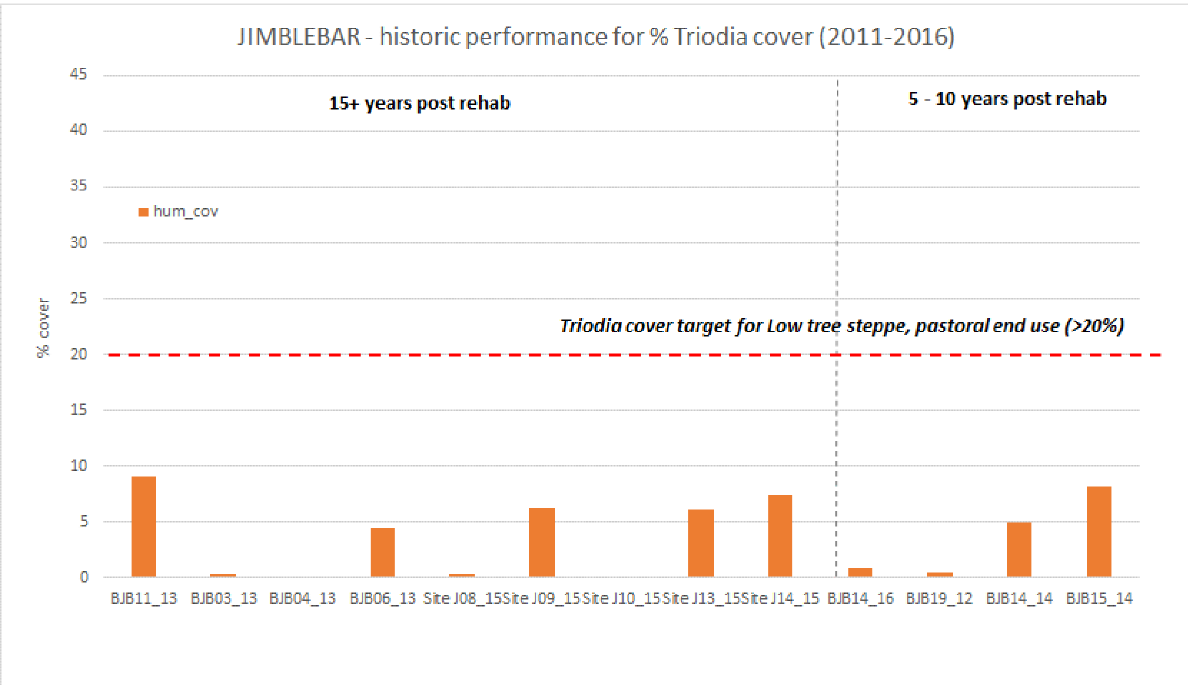



**Figure 32. Jimblebar Hub– performance of individual plots for *Triodia* cover criteria** (note, numbers on the individual bars denote years post rehabilitation for each plot).

***NEWMAN HUB***

The assessment of the Newman Hub against the revised completion criteria is shown in Table 25 with the performance of individual plots shown in Table 26 and Figure 33. As with other hubs, not all the criteria could be assessed given the limitation of available information.

Similar to Jimblebar hub, which is also located in the Eastern region, assessment of the Newman hub was undertaken adopting the Low tree steppe as the Target Vegetation Type for the rehabilitated areas and assuming the final land use of this site will be pastoral (i.e. targets are set to be >Q1) given that pastoral use is the dominant surrounding land tenure (Figure 5).

In total 12 rehabilitation sites within Newman hub were mature enough to warrant assessment against completion criteria (> 15 years post rehabilitation). These sites plus a further site 14 years post rehabilitation were used for the overall assessment. Seven (7) sites were located within Mt Whaleback operation area, while the remaining six (6) were in Eastern Ridge.

The assessment (Table 25) shows that the Newman hub met the Target Vegetation Type (Low tree steppe) criterion and also passed cover criteria for shrubs, herbs and other grasses (median values were above Q1 target). Ninety percent (90%) of the analysed individual sites passed the criteria for other grasses and herb cover and 80% also met cover targets for shrubs (Table 26).

However, trees were absent, and hummock grass cover was well below the set target (only 0.7 % compared to target of >20%). Analysis of the individual sites (Table 26, Figure 33) shows that only 10% of analysed sites met the cover target for hummock grasses (hummock grasses were absent from more than 40% of sites). Interestingly, almost all sites with no or very low hummock grass cover are located in Eastern Ridge. Mt Whaleback sites performed much better for *Triodia* cover (median % cover was 11.2 %, which although still below the target of 20% is significantly greater than the median value calculated for the entire Newman hub).

The analysis also revealed a relatively high weed presence at Newman; median weed cover was 13.2% across the hub. While this value is below the set target, meaning Newman passed the weed criterion, the weed cover recorded at this hub is the highest compared to all other analysed hubs.

Overall, Newman performs well against most of the proposed criteria and method of assessment, apart from tree and *Triodia* cover.

**Table 25. Newman hub historical rehabilitation (2011-2016) - assessment of rehabilitation success.**

**SITE:** NEWMAN
**YEARS POST REHAB:** >15 YEARS
**END USE:** PASTORAL GRAZING

| ATTRIBUTE | METRIC | TARGETS | | PERFORMANCE | |
|---|---|---|---|---|---|
| **Bare Ground** | % bare ground | Hills, slopes, dryplains | ≤ 50 % | Data not available - performance could not be assessed | |
| | | Drainage lines (excluding channel bed) | ≤ 20 % | | |
| | | Floodplains | ≤ 10 % | | |
| **Species Richness** | Perennial and annual native species richness (number of species) | Perennial native | 14 - 30 | Data not available - performance could not be assessed | |
| | | Annual native species | 4 - 11 | | |
| **Weed Invasiveness** | Priority Alert weed species | Presence | None | Not assesed | |
| | % total weed cover and % buffel grass cover | total average weed cover | < 20% | 13.2 | √ |
| | | total Buffel Grass cover | < 10% | | |
| | | total Buffel Grass cover per landform | | Data not available - performance could not be assessed | |
| | | drainage lines | < 10% | | |
| | | floodplains | | | |
| | | upland hills, slopes and flats | < 10% | | |
| **Target Vegetation Types** | Presence of appropriate vegetation types | | | **Low Tree Steppe** | √ |
| **Indicator Species** | Presence of dominant and common species from each Target Vegetation Type | All dominant species present | | Not assessed | |
| | | >50% of common species present | | Not assessed | |
| **Plant Cover** | % cover for each strata **LOW TREE STEPPE** | | **> Q1** | median | |
| | | Trees | >1 | 0.00 | - |
| | | Shrubs | >2 | 5.6 | √ |
| | | Hummock Grasses | >20 | 0.7 | - |
| | | Other Grasses | >0.04 | 1.1 | √ |
| | | Herbs | >0.05 | 0.4 | √ |

**Table 26. Newman hub historical rehabilitation (2011-2016) – performance of individual plots for vegetation cover criteria.**

| transect | years post rehab | type | impact | terrain | shrub_ cov | hum_ cov | ograss_ cov | herb_ cov |
|---|---|---|---|---|---|---|---|---|
| | | | | target | > 2 | > 20 | > 0.04 | >0.05 |
| BWB-04 | 31 | OSA | High | Slope | 10.9 | 12.6 | 0.0 | 0.3 |
| BWB-34 | 29 | Borrow Pit | Low | Flat | 8.0 | 20.2 | 0.0 | 0.3 |
| BWB-04 | 28 | OSA | High | Slope | 2.1 | 1.4 | 0.9 | 3.1 |
| W-0 | 28 | Infrastructure | Low | Flat | 11.3 | 0.0 | 1.8 | 0.3 |
| BWB-01 | 26 | Borrow | Low | Flat | 4.1 | 12.3 | 1.3 | 0.5 |
| BWB-02 | 26 | Borrow | Low | Flat | 7.0 | 27.1 | 0.8 | 0.2 |
| BWB-03 | 26 | OSA | High | Crest | 3.5 | 5.2 | 4.0 | 1.1 |
| ER-28 | 28 | Borrow Pit | Low | Flat | 0.2 | 0.0 | 0.0 | 0.0 |
| ER-29 | 28 | Borrow Pit | Low | Flat | 4.0 | 0.1 | 4.0 | 0.7 |
| ER-31 | 28 | Borrow Pit | Low | Flat | 1.3 | 0.0 | 0.4 | 0.4 |
| BO2-11 | 17 | OSA | High | Slope | 20.2 | 0.0 | 20.0 | 0.3 |
| BO2-11 | 14 | OSA | High | Slope | 12.4 | 0.0 | 21.0 | 0.5 |
| | | | | % sites > Q1 | 80% | 10% | 90% | 90% |

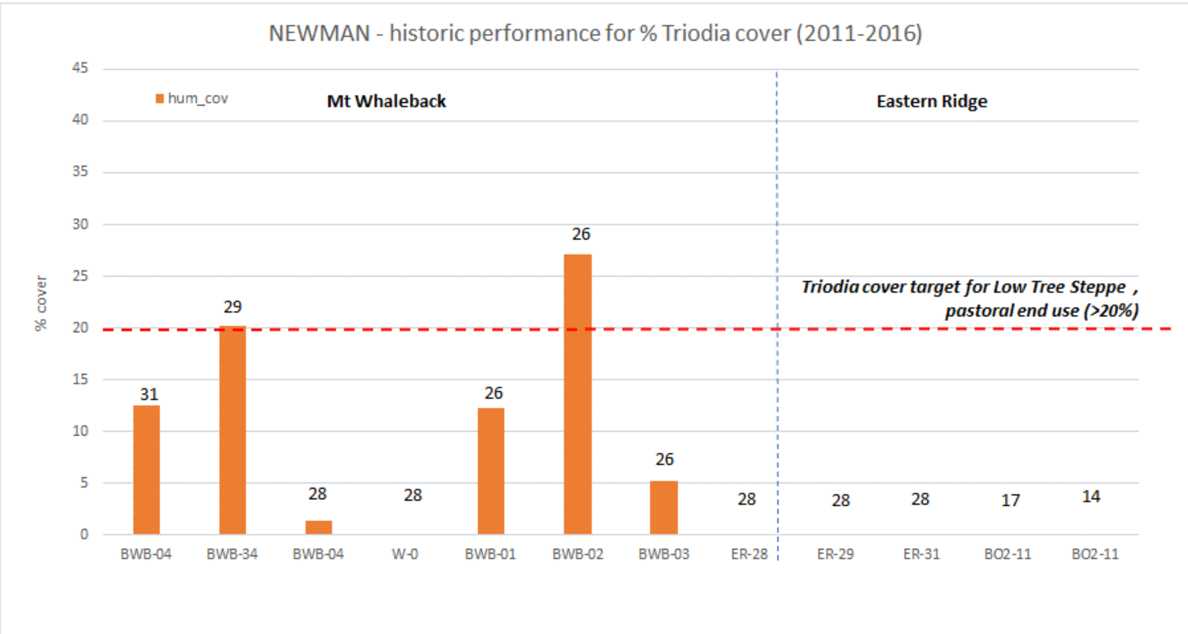



**Figure 33. Newman Hub– performance of individual plots for *Triodia* cover criteria** (note, numbers on the individual bars denote years post rehabilitation for each plot).

## 12.3 INFLUENCE OF AGE OF REHABILITATION ON REHABILITATION PERFORMANCE

Table 27, Table 28 and Table 29 show how the age of rehabilitation impacts on performance for each hub grouped by region. A distinctive trend of increased cover of *Triodia* with age (as noted in previous sections) is obvious in all of the hubs with sufficient data to enable analysis. This is particularly evident for Yandi and Yarrie hubs.

By contrast, shrub cover does not show any clear pattern, and in all cases for hubs assessed against pastoral targets (i.e. excluding Area C), meets relevant criteria regardless of the age.

**Table 27. Comparison of individual hubs based on age post rehabilitation - Central Region**

| CENTRAL REGION | | | | |
|---|---|---|---|---|
| **HUB** | **age post rehabilitation** | **% Triodia cover** | | ***Target*** |
| | | *average* | *no. of plots* | |
| **Area C (5-12)** | 7-12 | 13.2 | 12 | *20 - 30* |
| **Yandi** | >20 | 29.2 | 7 | *>20* |
| | 10-20 | 9.5 | 10 | |
| | 5-10 | 6.5 | 29 | |
| | <5 | 2.5 | 7 | |
| | | | | |
| **HUB** | **age post rehabilitation** | **% shrub cover** | | ***Target*** |
| | | *average* | *no. of plots* | |
| **Area C (5-12)** | 7-12 | 12.9 | 12 | *2 - 10* |
| **Yandi** | >20 | 2.5 | 7 | *>2* |
| | 10-20 | 10.6 | 10 | |
| | 5-10 | 15.0 | 29 | |
| | <5 | 12.3 | 7 | |

**Note, failure to meet relevant criteria is highlighted in red*

**Table 28. Comparison of individual hubs based on age post rehabilitation - Northern Region.**

| NORTHERN REGION | | | | |
|---|---|---|---|---|
| HUB | age post rehabilitation | % Triodia cover average | % Triodia cover no. of plots | Target |
| Goldsworthy | >20 | 13.4 | 23 | > 15 |
| | 10-20 | 11.5 | 20 | |
| Yarrie | >20 | 24.3 | 21 | > 19 |
| | 10-20 | 17.1 | 9 | |
| | 5-10 | 1.2 | 16 | |
| | <5 | 1.4 | 13 | |
| HUB | age post rehabilitation | % shrub cover average | % shrub cover no. of plots | Target |
| Goldsworthy | >20 | 10.0 | 23 | > 0.2 |
| | 10-20 | 8.6 | 20 | |
| Yarrie | >20 | 4.3 | 21 | > 3 |
| | 10-20 | 5.6 | 9 | |
| | 5-10 | 9.7 | 16 | |
| | <5 | 4.5 | 13 | |

**Note, failure to meet relevant criteria is highlighted in red*

**Table 29. Comparison of individual hubs based on age post rehabilitation - Eastern Region.**

| EASTERN REGION | | | | |
|---|---|---|---|---|
| HUB | age post rehabilitation | % Triodia cover average | % Triodia cover no. of plots | Target |
| Newman | >15 | 6.6 | 12 | > 20 |
| | 5-10 | 6.3 | 21 | |
| | <5 | 1.4 | 5 | |
| Jimblebar | 10-20 | 3.8 | 9 | > 20 |
| | 5-10 | 3.6 | 4 | |
| HUB | age post rehabilitation | % shrub cover average | % shrub cover no. of plots | Target |
| Newman | >15 | 7.1 | 12 | > 2 |
| | 5-10 | 5.7 | 21 | |
| | <5 | 6.2 | 5 | |
| Jimblebar | 10-20 | 11.0 | 9 | >2 |
| | 5-10 | 12.7 | 4 | |

**Note, failure to meet relevant criteria is highlighted in red*

# 13.0 ANALYSIS OF 2017-2018 REHABILITATION DATA

## 13.1 OBJECTIVES

Section 12.2 compared the historical datasets (2011 – 2016 datasets) for hubs against the proposed completion criteria and assessed only mature rehabilitation plots.

The objective of this section of the report is to assess sites at the current point in time and using the 2017-2018 datasets (which have adopted the revised sampling methods and so represent the new 'baseline' for analysis), and facilitate spatial reporting of sites by linking the Excel tabulated assessments of hubs against criteria with GIS data. This section provides worked examples using the 2017-2018 financial year data. Information provided in the rehabilitation report submitted with a derived proposal will be based on data up to the previous financial year.

As such, the broad objectives are to:

1. Compare hubs against the completion and progressive criteria, using the 2017 and 2018 datasets; and

2. Generate maps that can be used to incorporate into BHP rehabilitation reports as a way of spatially communicating and tracking rehabilitation progress.

These tasks required extraction of additional data from spatial and tabulated datasets and deeper analysis of the data provided in order to generate a more resolved assessment of the existing hubs against the criteria.

## 13.2 LAND STATUS CATEGORIES AND SCALE OF ASSESSMENT

The categories within each hub are as shown for the hypothetical site (Figure 34) and as follows:

- Active operations (No rehabilitation): Not assessable.
- Disturbed area available for rehabilitation (No rehabilitation): Not assessable.
- Young rehabilitation (less than 5 years old).
- Progressing towards criteria (rehabilitation greater than 5 years old).
- Completion criteria met (assessed for sites generally >15 years old).
- Completion criteria not met (assessed for sites generally >15 years old).

The traffic light approach is used to spatially represent areas as follows:

1. HATCHED - under rehabilitation (not assessable - not yet fully revegetated),

2. ORANGE - progressing (tracked separately against rehabilitation criteria).

3. GREEN - completed and passed (assessed against completion criteria).

4. RED - completed and failed for one or more criteria.

A visual report for a hypothetical site is provided in Figure 34.

Rehabilitation areas that fail completion criteria will either require remedial works, or may require targets to be revisited, particularly for older rehabilitation that commenced prior to current rehabilitation practices and/or regulator expectations.

At this point in time it is intended that completion criteria reporting will be done by aggregating individual mine data within each hub (i.e. all rehabilitation polygons 15 years and above will be assessed together to generate a red (does not meet) or green (does meet) report against completion criteria. However, in order to generate the required spatial outputs, the analysis of the datasets need to be undertaken at the scale of the individual mine, and against the target vegetation types that apply at the mine scale. This scale is also the most useful for communicating which rehabilitation area require remedial actions which is of interest to BHP.

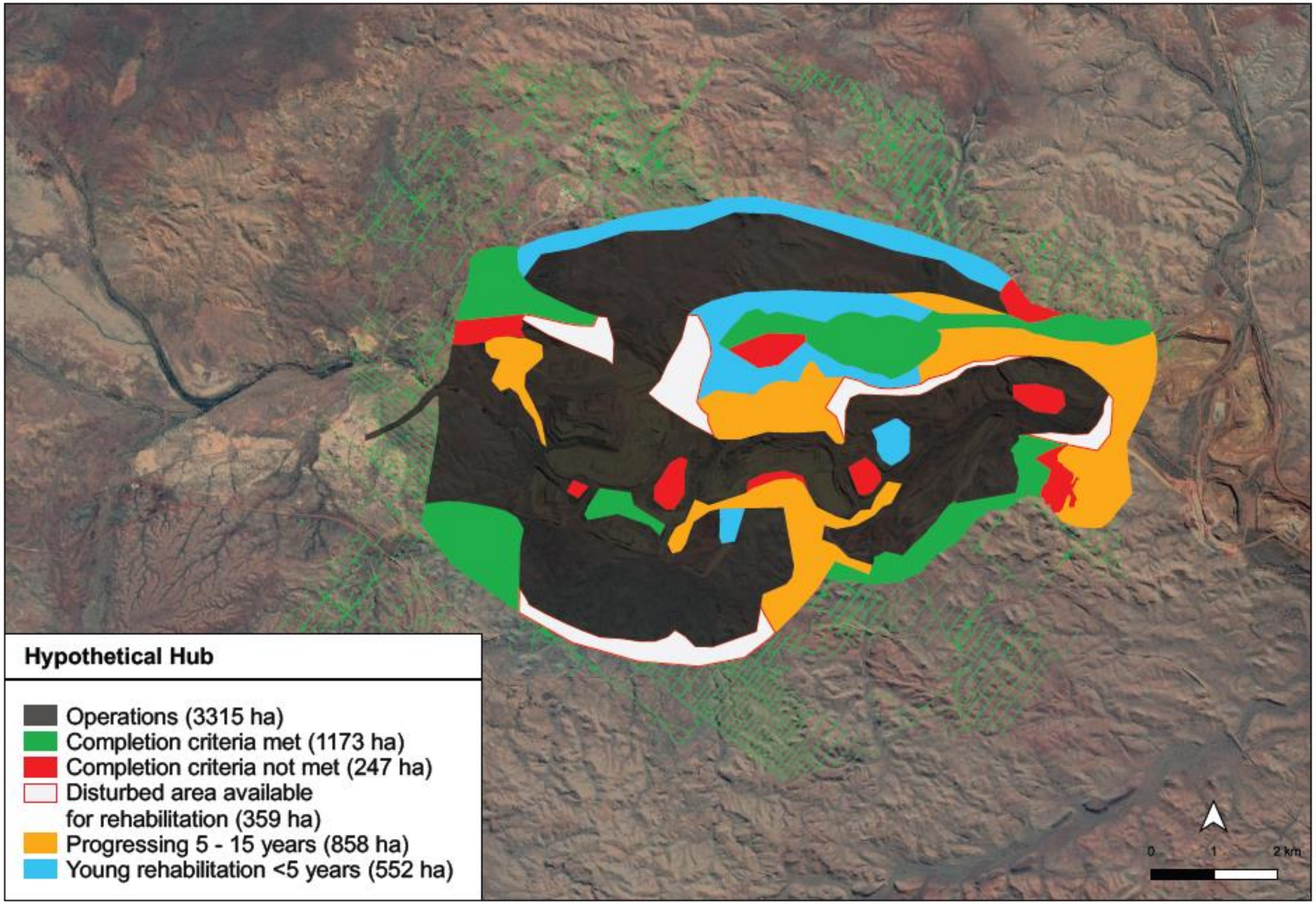



**Figure 34. Hypothetical mine / hub rehabilitation completion assessment.**

## 13.3 ASSESSMENT OF HUBS AGAINST COMPLETION CRITERIA

All sites were assessed against the relevant criteria based on their current age post-rehabilitation. Results are shown in the Table 30 to Table 38 below.

Note, neither Jimblebar nor Area C have sites old enough to assess against completion criteria. Area C also does not have sites that are <5 years post rehabilitation (young rehabilitation). Goldsworthy has no new sites, hence all sites are assessed against completion criteria only.

***Completion Assessment Summary***

- Newman hub (>15 year sites) - meet all criteria <u>except for tree cover.</u>
- Goldsworthy (mine) (all sites since all are >15 year sites) - does not meet *Triodia* (hummock grasses) cover target, and contains a weed species on the current DBCA alert list.
- Yandi hub (>15 year sites) - meets all criteria except for <u>tree cover</u> and <u>*Triodia* cover</u>.
- Yarrie hub (>15 year sites) - does not meet *Triodia* (hummock grasses) cover target.

***Progressive Assessment Summary***

Young and progressive rehabilitation sites provide BHP with an internal view of how sites are tracking towards completion, and which sites need remedial actions.

The following is the current summary for hubs:

*Young Rehabilitation (<5 years)*

- Jimblebar hub – there are only a few sites, however these are tracking poorly against two of the three threshold criteria (mainly due to weed effects).
- Newman hub – sites are tracking poorly against two of the three threshold criteria (mainly due to weed effects).
- Yandi hub – only 1 site, tracking well.
- Yarrie hub – only 1 site, tracking well, especially for *Triodia* cover /Shrub cover ratio target.

*Progressive Rehabilitation (5-15 years)*

- Jimblebar hub – tracking poorly against two of the three threshold criteria (low *Triodia* density and cover).
- Area C hub – only a few sites all meeting threshold criteria.
- Newman hub - failing against all criteria.
- Yandi hub – mostly meeting criteria (a few poor performing sites).
- Yarrie hub - failing against all criteria.

**Table 30. Assessment of Progressive rehabilitation sites at Area C Hub.**

| AREA C - ASSESSMENT OF PROGRESSIVE REHABILITATION SITES | | | | | | |
|---|---|---|---|---|---|---|
| | | | | PROGRESSIVE REHABILITATION (5-15 YEARS) CRITERIA | | |
| | | | | *MAJOR* | | *SUPPORTING* |
| **transect** | **years post rehab** | **type** | **terrain** | **Triodia cover /Total native cover ratio** | **Triodia density (plants per plot)** | **Weed cover / Triodia cover ratio** |
| | | | *target* | ≥ **0.32** | ≥ **10,000** | < **1** |
| BAC 29 | 14 | Coondewanna Airport - Borrow Pit | Flat | 0.37 | | 0 |
| BAC 24 | 6 | Packsaddle Range Detritals - Rail Borrow Pit | Flat | 0.58 | | 0 |
| BAC30 | 6 | Rail Borrow Pit | Flat | 0.60 | 50,000 | 0 |
| | | | **% sites meeting criteria** | **100%** | **100%** | **100%** |

## Table 31. Assessment against Completion Criteria at Yandi Hub.

**YANDI HUB - ASSESSMENT AGAINST COMPLETION CRITERIA**

| | | | | | |
|---|---|---|---|---|---|
| **SITE:** | **YANDI** | | | | |
| **YEARS POST REHAB:** | **> 15** | | | | |
| **VEG TYPE** | **LOW TREE STEPPE** | | | | |
| **END USE:** | **PASTORAL GRAZING** | | | | |
| **ATTRIBUTE** | **METRIC** | **TARGETS** | | **PERFORMANCE** | |
| **Bare Ground** | % bare ground | Hills, slopes, dryplains | ≤ 50 % | Data not available - performance could not be assessed | |
| | | Drainage lines (excluding channel bed) | ≤ 20 % | | |
| | | Floodpalins | ≤ 10 % | | |
| **Species Richness** | Perennial and annual native species richness (number of species) | | **> Q1** | median | |
| | | Perennial native | > 16 | 28 | √ |
| | | Annual native species | > 5 | 15 | √ |
| **Weed Invasiveness** | Priority Alert weed species | Priority alert weed species presence and cover | Not present or cover ≤ regional baseline | none | √ |
| | | Inttroduction of new priority species | No new priority species introduced | none | √ |
| | % all weed cover & % buffel grass cover | Total weed cover (%) | | 2.3 | √ |
| | | drainage lines, floodplains | < 20% | | |
| | | upland hills, slopes and flats | < 10% | | |
| | | Buffel grass cover | | | √ |
| | | drainage lines, floodplains | < 10% | 2.3 | |
| | | upland hills, slopes and flats | < 5% | | |
| **Target Vegetation Types** | Presence of appropriate vegetation types | | | **Low Tree Steppe** | √ |
| **Indicator Species** | Presence of dominant and common species from each Target Vegetation Type | All dominant species present | | YES | √ |
| | | >50% of common species present | | YES | √ |
| **Plant Cover** | % cover for each strata **Low Tree Steppe** | | **> Q1** | median | |
| | | Trees | > 1 | 0 | not assessed |
| | | Shrubs | > 2 | 13.4 | √ |
| | | Hummock Grasses | > 20 | 13.6 | - |
| | | Other Grasses | > 0.04 | 4.8 | √ |
| | | Herbs | > 0.05 | 0.8 | √ |

| | |
|---|---|
| √ | Pass |
| - | Fail |
| | not assessed |

## YANDI HUB - ASSESSMENT AGAINST COMPLETION CRITERIA

| | | | | % cover | | | | | | species richness | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| transect | years post rehab | type | terrain | tree | shrub | triodia | other grasses | herb | weed | perennial | annual |
| | | | target | > 1 | > 2 | > 20 | > 0.04 | > 0.05 | < 10 | > 16 | > 5 |
| BMC13 | 19 | OSA - E20SA | Crest | 0.0 | 10.1 | 12.0 | 4.5 | 0.8 | 4.3 | 23 | 14 |
| BMC14 | 19 | OSA - E20SA | Crest | 0.0 | 13.8 | 35.0 | 5.2 | 0.8 | 0.4 | 32 | 19 |
| BMC15 | 19 | OSA - E20SA | Crest | 0.0 | 34.7 | 1.0 | 10.7 | 0.4 | 0.0 | 21 | 8 |
| BMC10 | 16 | Borrow Pit for Ba | Flat | 0.0 | 13.1 | 15.1 | 0.06 | 0.02 | 0.00 | 17 | 5 |
| BMC03 | 16 | OSA - E20SA | Slope | 0.0 | 9.2 | 5.2 | 5.9 | 1.5 | 20.0 | 40 | 16 |
| BMC04 | 16 | OSA - E20SA | Slope | 0.0 | 16.1 | 15.5 | 2.3 | 5.6 | 12.0 | 38 | 15 |
| | | | **% sites > Q1** | **0%** | **100%** | **17%** | **100%** | **83%** | **67%** | **100%** | **100%** |

**Table 32. Assessment of Young & Progressive rehabilitation sites at Yandi hub.**

**YANDI HUB - ASSESSMENT OF YOUNG REHABILITATION SITES**

| transect | years post rehab | type | terrain | YOUNG REHABILITATION (< 5 YEARS) CRITERIA – MAJOR: Triodia cover /Shrub cover ratio | SUPPORTING: Minimum total native cover (%) | SUPPORTING: Weed cover / Triodia cover ratio |
|---|---|---|---|---|---|---|
| | | | target | > 2 | > 12 | < 1 |
| BMC63 | 3 | W1 Pit - Drainage | Flat | 0.02 | 16.1 | 0 |

**YANDI HUB - ASSESSMENT OF PROGRESSIVE REHABILITATION SITES**

| transect | years post rehab | type | terrain | PROGRESSIVE REHABILITATION (5-15 YEARS) CRITERIA – MAJOR: Triodia cover /Total native cover ratio | MAJOR: Triodia density (plants per plot) | SUPPORTING: Weed cover / Triodia cover ratio |
|---|---|---|---|---|---|---|
| | | | target | ≥ 0.32 | ≥ 10,000 | < 1 |
| BMC08 | 15 | Borrow Pit for Barimunya Airport | Flat | 0.342 | 73,400 | 0.0 |
| BMC09 | 15 | Borrow Pit for Barimunya Airport | Flat | 0.658 | 44,600 | 0.0 |
| BMC12 | 14 | OSA - E20SA | Crest | 0.008 | 0 | 0.0 |
| BMC05 | 14 | OSA - E20SA | Slope | 0.009 | 0 | 0.0 |
| BMC06 | 14 | OSA - E20SA | Slope | 0.136 | 200 | 0.0 |
| BMC20 | 13 | OSA - Central OSA East | Crest | 0.433 | 1,600 | 0.0 |
| BMC18 | 8 | Borrow Pit - Marrillana | Flat | 0.123 | | 15.0 |
| BMC21 | 8 | OSA - Central OSA | Flat | 0.660 | | 0.1 |
| BMC25 | 6 | OSA - Central OSA | Slope | 0.084 | | 0.0 |
| BMC26 | 6 | OSA - Central OSA | Crest | 0.184 | | 0.1 |
| BMC27 | 6 | No Evidence of Fire | Flat | 0.329 | | 0.0 |
| BMC62 | 6 | Yandi 2 Rail Loop Borrow Pit | Flat | 0.378 | | 0.1 |
| | | % sites meeting criteria | | 50% | 33% | 92% |

**Table 33. Assessment of Young & Progressive rehabilitation sites at Jimblebar Hub.**

| JIMBLEBAR - ASSESSMENT OF YOUNG REHABILITATION SITES | | | | | | |
|---|---|---|---|---|---|---|
| | | | | YOUNG REHABILITATION (< 5 YEARS) CRITERIA | | |
| | | | | *MAJOR* | *SUPPORTING* | |
| transect | years post rehab | type | terrain | Triodia cover /Shrub cover ratio | Minimum total native cover (%) | Weed cover / Triodia cover ratio |
| | | | *target* | > 2 | > 12 | < 1 |
| BJB 41 | 4 | Previous Geotech - Jimblebar Geotech Village | Flat | 0.003 | 10.8 | 750 |
| BJB 40 | 3 | Previous Geotech - Jimblebar Geotech Village | Flat | 0.002 | 13.3 | 20 |
| BJB 44 | 3 | West Jimblebar | Flat | 0.001 | 12.6 | 20 |
| | | | **% sites meeting criteria** | **0%** | **100%** | **0%** |

| JIMBLEBAR - ASSESSMENT OF PROGRESSIVE REHABILITATION SITES | | | | | | |
|---|---|---|---|---|---|---|
| | | | | PROGRESSIVE REHABILITATION (5-15 YEARS) CRITERIA | | |
| | | | | *MAJOR* | | *SUPPORTING* |
| transect | years post rehab | type | terrain | Triodia cover /Total native cover ratio | Triodia density (plants per plot) | Weed cover / Triodia cover ratio |
| | | | *target* | ≥ 0.32 | ≥ 10,000 | < 1 |
| BJB33 | 6 | Borrow Pit - Rail | Flat | 0.000 | | 0.0 |
| BJB34 | 6 | Borrow Pit - Rail | Flat | 0.236 | | 0.0 |
| BJB35 | 6 | Borrow Pit - Rail | Flat | 0.036 | | 0.0 |
| BJB42 | 6 | Wheelara 1/2 | Flat | 0.052 | 2,400 | 0.1 |
| BJB46 | 6 | Unnamed Area | Flat | 0.278 | 3,400 | 0.0 |
| BJB 43 | 6 | Wheelara 1/2 | Slope | 0.129 | 1,000 | 0.0 |
| | | | **% sites meeting criteria** | **0%** | **0%** | **100%** |

## Table 34. Assessment against Completion Criteria at Newman Hub.

| NEWMAN HUB - ASSESSMENT AGAINST COMPLETION CRITERIA | | | | | |
|---|---|---|---|---|---|
| SITE: | NEWMAN HUB | | | | |
| YEARS POST REHAB: | > 15 | | | | |
| VEG TYPE | LOW TREE STEPPE | | | | |
| END USE: | PASTORAL GRAZING | | | | |
| **ATTRIBUTE** | **METRIC** | **TARGETS** | | **PERFORMANCE** | |
| **Bare Ground** | % bare ground | Hills, slopes, dryplains | ≤ 50 % | Data not available - performance could not be assessed | |
| | | Drainage lines (excluding channel bed) | ≤ 20 % | | |
| | | Floodpalins | ≤ 10 % | | |
| **Species Richness** | Perennial and annual native species richness (number of species) | | **> Q1** | median | |
| | | Perennial native | > 16 | 30 | √ |
| | | Annual native species | > 5 | 7 | √ |
| **Weed Invasiveness** | Priority Alert weed species | Priority alert weed species presence and cover | Not present or cover ≤ regional baseline | none | √ |
| | | Inttroduction of new priority species | No new priority species introduced | none | √ |
| | % all weed cover & % buffel grass cover | Total weed cover (%) | | 2 | √ |
| | | drainage lines, floodplains | < 20% | | |
| | | upland hills, slopes and flats | < 10% | | |
| | | Buffel grass cover | | 2 | √ |
| | | drainage lines, floodplains | < 10% | | |
| | | upland hills, slopes and flats | < 5% | | |
| **Target Vegetation Types** | Presence of appropriate vegetation types | | | **Low Tree Steppe** | √ |
| **Indicator Species** | Presence of dominant and common species from each Target Vegetation Type | All dominant species present | | YES | √ |
| | | >50% of common species present | | YES | √ |
| **Plant Cover** | % cover for each strata **Low Tree Steppe** | | **> Q1** | median | |
| | | Trees | > 1 | 0 | not assessed |
| | | Shrubs | > 2 | 16.1 | √ |
| | | Hummock Grasses | > 20 | 26.0 | √ |
| | | Other Grasses | > 0.04 | 1.4 | √ |
| | | Herbs | > 0.05 | 0.12 | √ |

| | |
|---|---|
| √ | Pass |
| - | Fail |
| | not assessed |

## NEWMAN HUB - ASSESSMENT AGAINST COMPLETION CRITERIA

| | | | | | % cover | | | | | | species richness | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| transect | Mine | years post | type | terrain | tree | shrub | triodia | other grasses | herb | weed | perennial | annual |
| | | | | | > | > | > | > | > | < | > | > |
| | | | | target | 1 | 2 | 20 | 0.04 | 0.05 | 10 | 16 | 5 |
| BWB01 | Whaleback | 30 | Borrow Pit - Security Gate | Flat | 0.0 | 16.1 | 26.0 | 1.4 | 0.2 | 2.0 | 30 | 7 |
| BO2-11 | Eastern Ridge | 20 | Pit 1 Face South Face, 1995 | Slope | 0.1 | 19.0 | 1.5 | 2.4 | 0.1 | 10.0 | 37 | 8 |
| BFO03 | Eastern Ridge | 19 | OSA - OB25 Fire Trial (crest) | Crest | 0.0 | 9.0 | 35.0 | 0.01 | 0.1 | 0.1 | 22 | 1 |

| % sites > Q1 | tree | shrub | triodia | other grasses | herb | weed | perennial | annual |
|---|---|---|---|---|---|---|---|---|
| % sites > Q1 | **0%** | **100%** | **67%** | **67%** | **100%** | **100%** | **100%** | **67%** |

## Table 35. Assessment of Young & Progressive rehabilitation sites at Newman Hub.

NEWMAN HUB - ASSESSMENT OF YOUNG REHABILITATION SITES

| transect | mine | years post rehab | type | terrain | YOUNG REHABILITATION (< 5 YEARS) CRITERIA<br>*MAJOR*<br>Triodia cover /Shrub cover ratio | *SUPPORTING*<br>Minimum total native cover (%) | Weed cover / Triodia cover ratio |
|---|---|---|---|---|---|---|---|
| | | | | *target* | > 2 | > 12 | < 1 |
| BWB45 | Mount Whaleback | 4 | W28 Old Topsoil storage | Crest | 1.50 | 20.8 | 0 |
| BWB46 | Mount Whaleback | 4 | OB35 PAF contingency dump | Flat | 0.48 | 9.7 | 19 |
| BWB44 | Mount Whaleback | 4 | W28 Old Topsoil storage | Slope | 5.95 | 32.1 | 0 |
| BWB36 | Whaleback | 3 | WD 41_EXTN1 | Flat | 0.01 | 12.9 | 455 |
| BWB37 | Whaleback | 3 | WD 41_EXTN2 | Flat | 0.05 | 25.6 | 10 |
| BWB39 | Whaleback | 3 | OB29 Old Town Landfill | Flat | 3.14 | 20.3 | 0.4 |
| BWB41 | Whaleback | 3 | OB29 Old Town Landfill | Flat | 0.00 | 31.4 | 200 |
| BO2-26 | Eastern Ridge | 3 | OB32 Exploration - Laydown yard | Flat | 0.27 | 19.4 | 3 |
| BWB52 | Mount Whaleback | 2 | SPA | Crest | 0.07 | 5.0 | 77 |
| BWB35 | Whaleback | 2 | OSA - W19 Graveyard | Flat | 0.26 | 19.0 | 2 |
| BO2-28 | Eastern Ridge | 2 | OB23 WS Dump | Crest | 0.12 | 12.0 | 0 |
| | | | | **% sites meeting criteria** | **18%** | **73%** | **36%** |

NEWMAN HUB- ASSESSMENT OF PROGRESSIVE REHABILITATION SITES

| transect | mine | years post rehab | type | terrain | PROGRESSIVE REHABILITATION (5-15 YEARS) CRITERIA<br>*MAJOR*<br>Triodia cover /Total native cover ratio | Triodia density (plants per plot) | *SUPPORTING*<br>Weed cover / Triodia cover ratio |
|---|---|---|---|---|---|---|---|
| | | | | *target* | ≥ 0.32 | ≥ 10,000 | < 1 |
| BO2-12 | Eastern Ridge | 12 | OSA - Southern Landform | Slope | 0.016 | 0 | 136 |
| BO2-13 | Eastern Ridge | 12 | OSA - OB23 OSA | Slope | 0.317 | 1,400 | 4 |
| BWB26 | Mount Whaleback | 8 | W41 Soak Cells (cells 1-3) | Crest | 0.000 | 0 | |
| BWB27 | Mount Whaleback | 8 | W41 Soak Cells (cells 4-17) | Flat | 0.195 | 2,800 | 4.9 |
| BO2-18 | Eastern Ridge | 8 | OSA - OB23 OSA | Slope | 0.205 | | 2 |
| BWB49 | Mount Whaleback | 6 | Old Landfill | Flat | 0.321 | 7,800 | 1 |
| BWB50 | Mount Whaleback | 6 | Old Landfill | Flat | 0.094 | 0 | 7 |
| BO2-27 | Eastern Ridge | 6 | Rail Borrow Pit | Crest | 0.717 | 3,200 | 2 |
| BO2-47 | Eastern Ridge | 6 | Borrow Pit | Flat | 0.000 | 0 | 401 |
| BO2-48 | Eastern Ridge | 6 | Borrow Pit | Flat | 0.017 | 200 | 60 |
| BO2-51 | Eastern Ridge | 6 | Borrow Pit | Flat | 0.005 | 0 | 150 |
| | | | | **% sites meeting criteria** | **18%** | **0%** | **10%** |

## Table 36. Assessment against Completion Criteria at Goldsworthy.

**GOLDSWORTHY - ASSESSMENT AGAINST COMPLETION CRITERIA**

**SITE:** GOLDSWORTHY
**YEARS POST REHAB:** > 15
**VEG TYPE** GRASS STEPPE
**END USE:** PASTORAL GRAZING

| ATTRIBUTE | METRIC | TARGETS | | PERFORMANCE | |
|---|---|---|---|---|---|
| **Bare Ground** | % bare ground | Hills, slopes, dryplains | ≤ 50 % | Data not available - performance could not be assessed | |
| | | Drainage lines (excluding channel bed) | ≤ 20 % | | |
| | | Floodpalins | ≤ 10 % | | |
| **Species Richness** | Perennial and annual native species richness (number of species) | | **> Q1** | median | |
| | | Perennial native | > 8 | 20 | √ |
| | | Annual native species | > 6 | 7 | √ |
| **Weed Invasiveness** | Priority Alert weed species | Priority alert weed species presence and cover | Not present or cover ≤ regional baseline | *Calotropis procera* present but not above regional baseline | √ |
| | | Inttroduction of new priority species | No new priority species introduced | none | √ |
| | % all weed cover & % buffel grass cover | Total weed cover (%) | | 0.6 | √ |
| | | drainage lines, floodplains | < 20% | | |
| | | upland hills, slopes and flats | < 10% | | |
| | | Buffel grass cover | | 0.6 | √ |
| | | drainage lines, floodplains | < 10% | | |
| | | upland hills, slopes and flats | < 5% | | |
| **Target Vegetation Types** | Presence of appropriate vegetation types | | | **Grass Steppe** | √ |
| **Indicator Species** | Presence of dominant and common species from each Target Vegetation Type | All dominant species present | | YES | √ |
| | | >50% of common species present | | YES | √ |
| **Plant Cover** | % cover for each strata **GRASS STEPPE** | | **> Q1** | median | |
| | | Trees | > 0 | 0.010 | √ |
| | | Shrubs | > 0.2 | 5.6 | √ |
| | | Hummock Grasses | > 15 | 8.5 | - |
| | | Other Grasses | > 0.01 | 0.2 | √ |
| | | Herbs | > 0.1 | 0.12 | √ |

| Legend | |
|---|---|
| √ | Pass |
| - | Fail |
| | not assessed |

**GOLDSWORTHY - ASSESSMENT AGAINST COMPLETION CRITERIA**

| transect | years post rehab | type | terrain | % cover: tree | shrub | triodia | other grasses | herb | weed | species richness: perennial | annual |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | target | > 0 | > 0.2 | > 15 | > 0.01 | > 0.1 | < 10 | > 8 | > 6 |
| BGW13 | 25 | Rosemary Waste Dump 7 - upper bench | Crest | 0.00 | 8.2 | 0.1 | 0.1 | 0.2 | 1.0 | 14 | 8 |
| BGW17 | 25 | Railway Waste Dump 8 - upper bench | Crest | 0.01 | 3.1 | 0.0 | 1.0 | 0.00 | 0.3 | 15 | 6 |
| BGW21 | 25 | Water Tank Waste Dump 2 - upper bench | Crest | 0.00 | 12.4 | 5.0 | 4.1 | 1.2 | 23.1 | 24 | 9 |
| BGW22 | 25 | Magazine Waste Dump 8 - upper bench | Crest | 3.0 | 7.5 | 15.0 | 6.0 | 0.1 | 0.1 | 24 | 8 |
| BGW26 | 25 | Billygoat Dump | Crest | 0.00 | 4.7 | 2.0 | 0.2 | 0.7 | 0.1 | 18 | 9 |
| BGW28 | 25 | Goldsworthy and Erection Site Waste Dumps | Crest | 0.03 | 6.9 | 0.5 | 2.0 | 0.1 | 0.0 | 24 | 10 |
| BGW30 | 25 | Goldsworthy and Erection Site Waste Dump 3 - upper bench | Crest | 0.01 | 5.1 | 5.0 | 4.1 | 0.1 | 5.3 | 20 | 11 |
| BGW31 | 25 | Goldsworthy and Erection Site Waste Dumps | Crest | 2.5 | 4.8 | 30.0 | 0.3 | 0.3 | 0.2 | 30 | 6 |
| BGW32 | 25 | Railway OSA | Crest | 0.1 | 1.1 | 1.0 | 0.03 | 1.0 | 21.6 | 19 | 9 |
| BGW04 | 25 | Town site - Mixed Road and Housing Area | Flat | 0.5 | 3.6 | 9.0 | 0.04 | 0.06 | 15.0 | 23 | 4 |
| BGW05 | 25 | Town site - Mixed Road and Housing Area | Flat | 0.3 | 9.9 | 8.0 | 0.04 | 0.05 | 20.2 | 19 | 6 |
| BGW07 | 25 | Industrial area C - Light Industrial, Dump Surrounds | Flat | 0.00 | 1.5 | 25.0 | 0.00 | 0.03 | 0.0 | 12 | 2 |
| BGW09 | 25 | Airstrip - sandy soils | Flat | 0.00 | 14.5 | 20.0 | 0.1 | 0.03 | 0.0 | 21 | 2 |
| BGW10 | 25 | Old town site | Flat | 0.00 | 13.1 | 40.0 | 0.1 | 0.09 | 11.0 | 20 | 8 |
| BGW11 | 25 | Industrial Area B - Mine Office | Flat | 0.00 | 4.3 | 30.0 | 0.1 | 0.2 | 0.9 | 24 | 6 |
| BGW35 | 25 | Gravel/Borrow Pit (near ICI Depot) | Flat | 0.00 | 26.7 | 5.0 | 0.2 | 0.07 | 0.0 | 17 | 6 |
| BGW40 | 25 | Sewerage Ponds | Flat | 0.00 | 4.3 | 1.5 | 1.1 | 0.4 | 60.0 | 18 | 14 |
| BGW42 | 25 | Golf Course (sandy soils) | Flat | 1.5 | 11.9 | 19.3 | 0.1 | 0.08 | 3.3 | 29 | 6 |
| BGW43 | 25 | | Flat | 1.5 | 4.3 | 20.0 | 3.1 | 0.6 | 0.2 | 29 | 10 |
| BGW45 | 25 | | Flat | 1.5 | 6.0 | 40.0 | 0.0 | 0.07 | 0.1 | 20 | 3 |
| | | | **% sites > Q1** | **55%** | **100%** | **45%** | **95%** | **55%** | **30%** | **100%** | **80%** |

**Table 37. Assessment against Completion Criteria at Yarrie.**

**YARRIE HUB - ASSESSMENT AGAINST COMPLETION CRITERIA**

| | |
|---|---|
| SITE: | YARRIE - SHAY GAP & YARRIE |
| YEARS POST REHAB: | > 15 |
| VEG TYPE | SHRUB STEPPE |
| END USE: | PASTORAL GRAZING |

| ATTRIBUTE | METRIC | TARGETS | | PERFORMANCE | |
|---|---|---|---|---|---|
| **Bare Ground** | % bare ground | Hills, slopes, dryplains | ≤ 50 % | Data not available - performance could not be assessed | |
| | | Drainage lines (excluding channel bed) | ≤ 20 % | | |
| **Species Richness** | Perennial and annual native species richness (number of species) | | **> Q1** | median | |
| | | Perennial native | > 16 | 23 | √ |
| | | Annual native species | > 5 | 13 | √ |
| **Weed Invasiveness** | Priority Alert weed species | Priority alert weed species presence and cover | Not present or cover ≤ regional baseline | none | √ |
| | | Inttroduction of new priority species | No new priority species introduced | none | √ |
| | % all weed cover & % buffel grass cover | Total weed cover (%) | | 0.0 | √ |
| | | drainage lines, floodplains | < 20% | | |
| | | upland hills, slopes and flats | < 10% | | |
| | | Buffel grass cover | | - | √ |
| | | drainage lines, floodplains | < 10% | | |
| | | upland hills, slopes and flats | < 5% | | |
| **Target Vegetation Types** | Presence of appropriate vegetation types | | | **Shrub Steppe** | √ |
| **Indicator Species** | Presence of dominant and common species from each Target Vegetation Type | All dominant species present | | YES | √ |
| | | >50% of common species present | | YES | √ |
| **Plant Cover** | % cover for each strata **SHRUB STEPPE** | | **> Q1** | median | |
| | | Trees | >0 | 0.56 | √ |
| | | Shrubs | >3 | 10.7 | √ |
| | | Hummock Grasses | >19 | 13.5 | - |
| | | Other Grasses | >0.02 | 0.2 | √ |
| | | Herbs | >0.1 | 0.16 | √ |

| | |
|---|---|
| √ | Pass |
| - | Fail |
| | not assessed |

| YARRIE HUB - ASSESSMENT AGAINST COMPLETION CRITERIA | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | % cover | | | | | | species richness | |
| transect | Location | years post rehab | type | terrain | tree | shrub | triodia | other grass | herb | weed | perennial | annual |
| | | | | *target* | >0 | > 3 | > 19 | > 0.02 | > 0.1 | <10 | >16 | >5 |
| BYA07 | Shay Gap | 23 | OSA - Flying Circus | Crest | 1.0 | 21.9 | 15.0 | 0.2 | 0.2 | 0 | 28 | 15 |
| BYA08 | Shay Gap | 23 | Shay Ridge Flat | Flat | 10.1 | 17.6 | 5.0 | 4.1 | 0.2 | 0.0 | 35 | 17 |
| BYA03 | Yarrie | 25 | Borrow Pit 1 | Flat | 0.1 | 1.3 | 20.0 | 0.1 | 0.1 | 0.0 | 10 | 7 |
| BYA11 | Yarrie | 22 | OSA - Nim A | Slope | 0.0 | 3.9 | 12.0 | 0.2 | 15.0 | 0.2 | 18 | 10 |

| | tree | shrub | triodia | other grass | herb | weed | perennial | annual |
|---|---|---|---|---|---|---|---|---|
| **% sites > Q1** | **50%** | **75%** | **25%** | **100%** | **75%** | **100%** | **75%** | **100%** |

**Table 38. Assessment of Young & Progressive rehabilitation sites at Yarrie Hub.**

| YARRIE SHUB - ASSESSMENT OF YOUNG REHABILITATION SITES | | | | | | |
|---|---|---|---|---|---|---|
| | | | | YOUNG REHABILITATION (< 5 YEARS) CRITERIA | | |
| | | | | *MAJOR* | *SUPPORTING* | |
| **transect** | **years post rehab** | **type** | **terrain** | **Triodia cover /Shrub cover ratio** | **Minimum total native cover (%)** | **Weed cover / Triodia cover ratio** |
| | | | **target** | **> 2** | **> 12** | **< 1** |
| BYA44 | 3 | Y10 Sisters | Crest | 1.56 | no data available | 0.1 |

| YARRIE HUB - ASSESSMENT OF PROGRESSIVE REHABILITATION SITES | | | | | | |
|---|---|---|---|---|---|---|
| | | | | PROGRESSIVE REHABILITATION (5-15 YEARS) CRITERIA | | |
| | | | | *MAJOR* | | *SUPPORTING* |
| **transect** | **years post rehab** | **type** | **terrain** | **Triodia cover /Total native cover ratio** | **Triodia density (plants per plot)** | **Weed cover / Triodia cover ratio** |
| | | | **target** | **≥ 0.32** | **≥ 10,000** | **< 1** |
| BYA01 | 14 | OSA - Y10 Contour Ripped | Slope | no data available | no data available | no data available |
| BYA31 | 13 | Y7D Growth Trials - Topsoil | Slope | no data available | no data available | no data available |
| BYA41 | 10 | Y6/7 | Crest | no data available | no data available | no data available |
| BYA43 | 10 | Y6/7 | Slope | no data available | no data available | no data available |
| BYA28 | 10 | OSA - W1 Lower batter | Slope | 0.218 | 800 | 16.7 |
| BYA29 | 10 | OSA - W1 Lower batter | Crest | 0.332 | 1,400 | 3.1 |
| BYA36 | 10 | OSA - W1 238 RL Batter | Slope | 0.131 | no data available | 4.2 |
| BYA35 | 8 | OSA - W1 238 RL Batter | Slope | no data available | no data available | 15.1 |
| BYA45 | 7 | Yarrie 4 Crustal | Crest | no data available | no data available | no data available |
| BYA51 | 6 | Nimingarra A | Crest | 0.022 | no data available | 5.0 |
| BYA52 | 6 | Nimingarra A | Crest | 0.107 | no data available | 2.0 |
| | | | **% sites meeting criteria** | **9%** | **0%** | **0%** |

# 14.0 PREDICTING FUTURE REHABILITATION SUCCESS

The rehabilitation journey for BHP in the Pilbara has been difficult because of a lack of clear direction (agreed final land use and targets), a default assessment of rehabilitation performance against pre-mining systems which is not generally pragmatic, and the relatively late emergence of relevant research targeted to the improvement of knowledge vital to accelerating rehabilitation success in the Pilbara.

Nevertheless, in assessing the historical rehabilitation record against the new targets indicates that the record of success is variable, but overall is generally good, with most older sites likely to reach completion but potentially over a longer timeframe than more recent sites. Natural colonisation and succession within post-mined landscapes in the Pilbara and BHP minesites appears to have occurred without intervention after the original rehabilitation was completed, but only in areas where some form of growth media has been applied. The key issue has been the rate of rehabilitation, which has reflected less than ideal timing of rehabilitation, but also climatic influences.

The comparison of historic data against the proposed new completion criteria and methods of assessment show an encouraging prognosis for rehabilitated areas within BHP WAIO sites, albeit the current data sets (i.e. using the revised plot dimensions to accord with the new EPA Guidelines (EPA, 2016)) are still limited. Yarrie and Yandi for example appear to be on the right trajectory and are likely to achieve criteria in time, with minimal targeted interventions (see previous section). Other hubs, such as Area C, are generally too young to be compared against completion criteria and data is not in ready format to enable assessment at this stage. Some sites (e.g. Jimblebar hub) are likely to require further investigation to understand why the older plots that are expected to be trending towards targets, are currently underperforming (at least in term of cover).

Predicting future success based on the current datasets is not a simple exercise. Plots have not been progressively monitored over time to draw clear conclusions on trends, survey methods have changed and major shifts in the understanding of how-to best approach rehabilitation in the Pilbara have only occurred relatively recently (within the last 10 years). BHP will assess performance against progressive criteria to help gauge whether rehabilitation currently underway (i.e. rehabilitation less than 15-20 years old) is likely to be successful in the future, and to indicate where intervention may be necessary, to improve the likelihood of future rehabilitation success.

However, while data is limited, some analysis of recent rehabilitated areas compared with older sites (e.g. Table 39 for Yarrie) shows significant gains in *Triodia* cover (as a key indicator) in very young plots, which indicates that accelerated succession and improved overall rehabilitation outcomes look feasible.

Table 39 shows that the sites rehabilitated in 2016 have a significantly higher *Triodia* cover compared with similar aged sites which were rehabilitated in 2008 and 2011 (when rehabilitation methods had not yet been modified to reflect the findings of the research undertaken over this period – see Table 12). Whilst the 2016 rehabilitated sites are (as expected) below completion targets, they are more or less equivalent to a 10 year outcome recorded for Yarrie historically (see Table 28).

**Table 39. Comparison of % *Triodia* cover for young sites (<4 years post rehab) at Yarrie Hub.**

**YARRIE**

| SITE | REHAB DATE | SURVEY YEAR | AGE OF REHAB (years) | TYPE | IMPACT | TERRAIN | % *Triodia* COVER |
|---|---|---|---|---|---|---|---|
| BYA-26 | 2008 | 2011 | 3 | OSA | High | Crest | 0.0 |
| BYA-27 | 2008 | 2011 | 3 | OSA | High | Crest | 0.0 |
| BYA-28 | 2008 | 2011 | 3 | OSA | High | Slope | 0.0 |
| BYA-29 | 2008 | 2011 | 3 | OSA | High | Slope | 0.3 |
| BYA-38 | 2011 | 2014 | 3 | OSA | High | Crest | 0.3 |
| BYA-39 | 2011 | 2014 | 3 | OSA | High | Slope | 1.9 |
| BYA-40 | 2011 | 2014 | 3 | OSA | High | Crest | 5.9 |
| BYA-37 | 2011 | 2013 | 2 | OSA | High | Slope | 0.5 |
| BYA-38 | 2011 | 2013 | 2 | OSA | High | Crest | 0.0 |
| BYA-39 | 2011 | 2013 | 2 | OSA | High | Slope | 1.7 |
| BYA-40 | 2011 | 2013 | 2 | OSA | High | Crest | 2.4 |
| BYA67 | 2016 | 2018 | 2 | waste dump | | Crest | 8 |
| BYA66 | 2016 | 2018 | 2 | waste dump | | Slope | 9 |

Taking into consideration: i) the improved methods of survey (which best capture the spatial variability), ii) the recent application of years of research investment in seed biology which appear to be translating to on-ground outcomes, iii) BHPs continued commitment to research, and assuming that the completion criteria, methods and targets proposed in this report are adopted, the future success of rehabilitation at BHP WAIO sites is on the right trajectory.

The majority of rehabilitation is yet to be done, hence the application of new learnings and new methods can yield substantial gains, provided progressive rehabilitation keeps pace with the mining operations. It is critical that there is a commitment to the final land use of each site, to the completion criteria set, and to how quickly the available knowledge is rolled out across sites. Whilst there are and always will be knowledge gaps, the current knowledge base seems more than sufficient for progressing with contextually appropriate, best practice rehabilitation.

Table 40 summarises the main research projects BHP has completed to date, which will feed into continued improvements to rehabilitation performance. New research programs are underway, including the Global Innovation Linkage Programme, which is focussed on innovative ecologically guided engineering solutions to direct seeding. The new 5-year research plan is currently under review and will include other initiatives to address some of the methodology and ecological process issues identified within this report.

**Table 40. BHP current and completed research projects.**

| ENVIRONMENTAL INITIATIVE | OUTCOME |
|---|---|
| Pilbara Seed Atlas | Climate Controlled seed store on site. |
| Pilbara Seed Bank | Significant improvement to seed management practices, resulting in a step change in revegetation of rehabilitated areas. |
| Pilbara Restoration Initiative | |
| Pilbara Rehabilitation Group | Facilitated Pilbara Industry engagement in rehabilitation issues & research |
| Coondewanna Flats ecohydrology study | Determination of groundwater-dependent ecosystem requirements. |
| Wetlands values of eastern Pilbara | Identification and evaluation of ecohydrological assets and their ecological linkages. |
| Window into Underworld | Improved understanding of subterranean fauna population of the Pilbara |
| Regional vegetation & habitat mapping | Standardisation of environmental studies approach. |
| Ecological community-level modelling | Production of a consolidated vegetation and habitat map for all BHP Billiton Iron Ore tenements. |
| Rapid biodiversity assessment | Modelled approach to identifying biodiversity values of the Pilbara. |
| Pilbara leaf-nosed bat genetic research | Genetic mapping of threatened species for population linkages. |
| Dynamics of woody vegetation and water in the central Pilbara | Improved understanding of biogeochemistry of floodplain and riparian landscapes, dynamics of water and tree populations in riparian woodlands, encroachment by woody shrub , and effects of fire and climate. |
| Ecological responses of native fish to extreme flow variability in arid Australia | Understanding of the impacts of altered water flows in arid Australia on native fish. |
| WAMinals | Making invertebrate taxonomic information more robust and available to the public through the Western Australian Museum. |
| Western Australian Herbarium | Improved taxonomic key flora of the Pilbara, including increased collection of voucher specimens. |
| Global Innovation Linkage Program | Development of innovative ecologically guided engineering solutions to direct seeding. |

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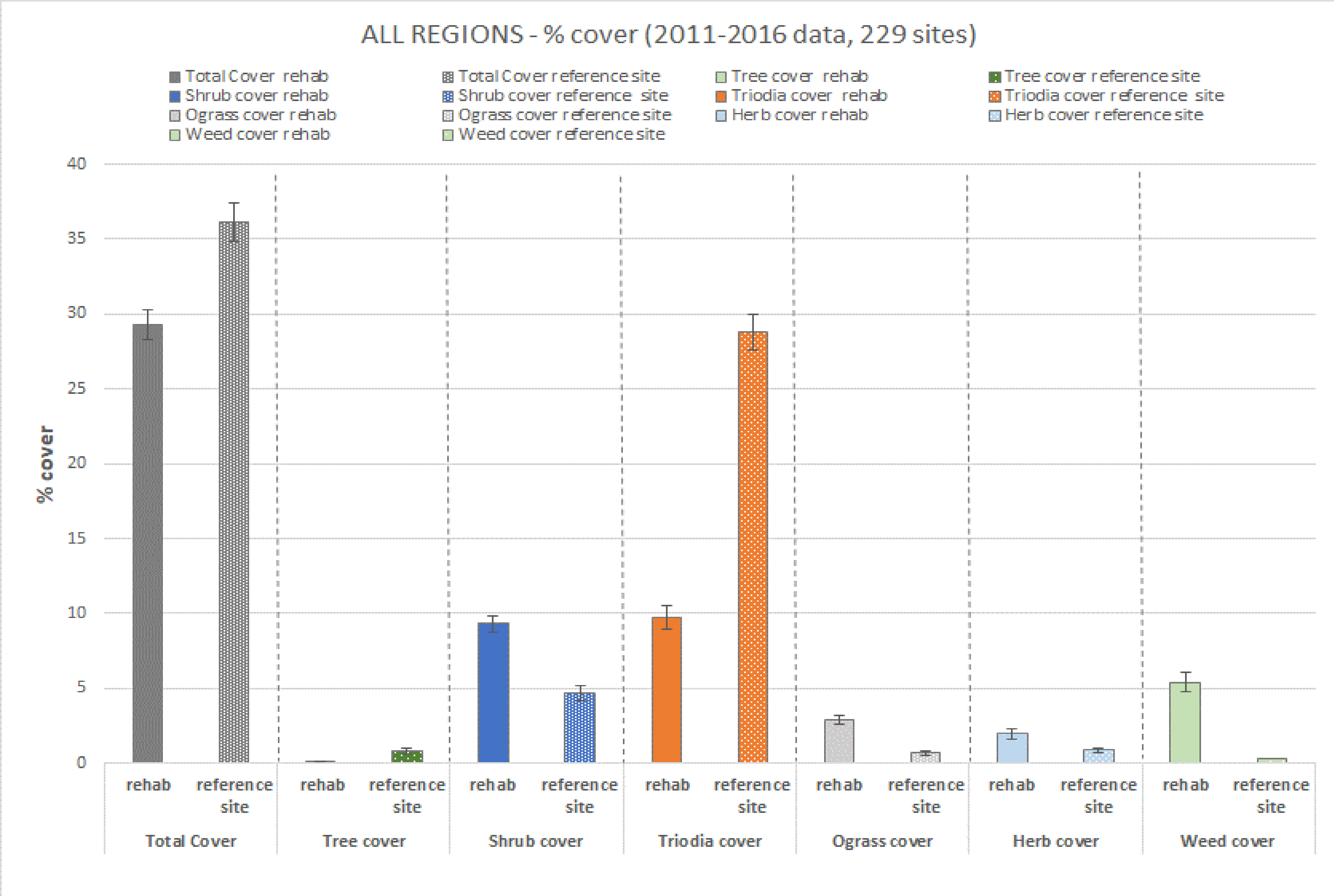
# APPENDICES

## APPENDIX 1 ANALYSIS OF SUCCESS OF HISTORICAL REHABILITATION

# 2011- 2016 HISTORIC DATA

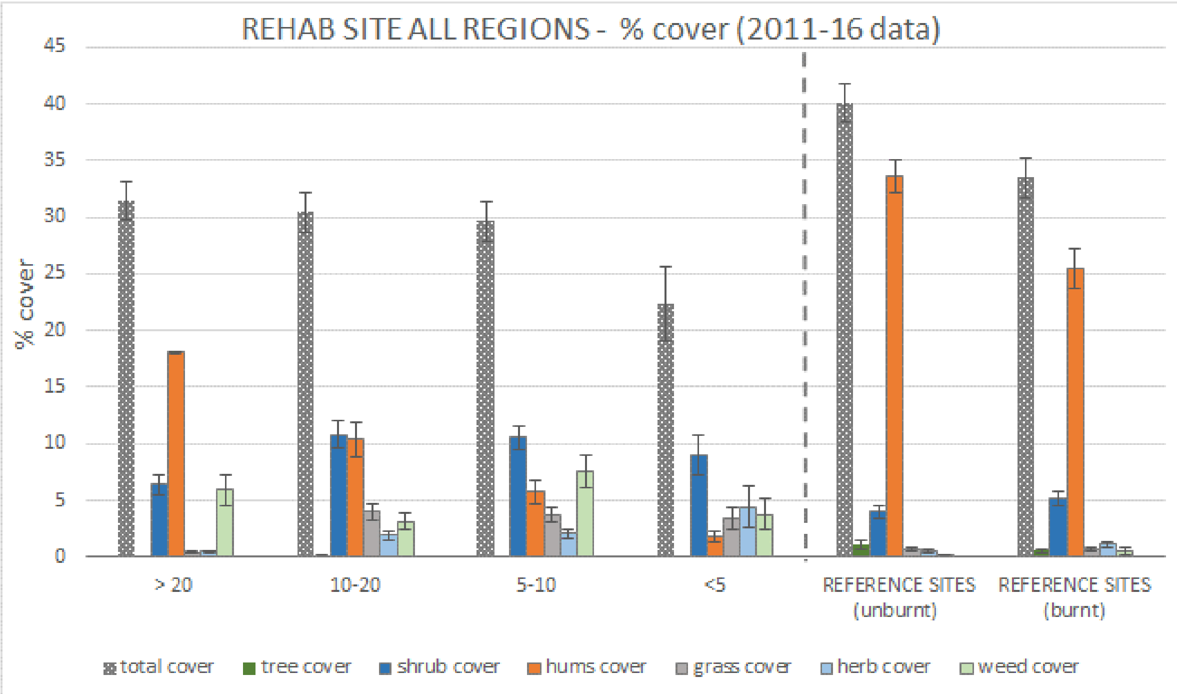
## SCALE OF ASSESSMENT: ALL REGIONS

### Comparison of Rehabilitation and Reference Sites for Cover

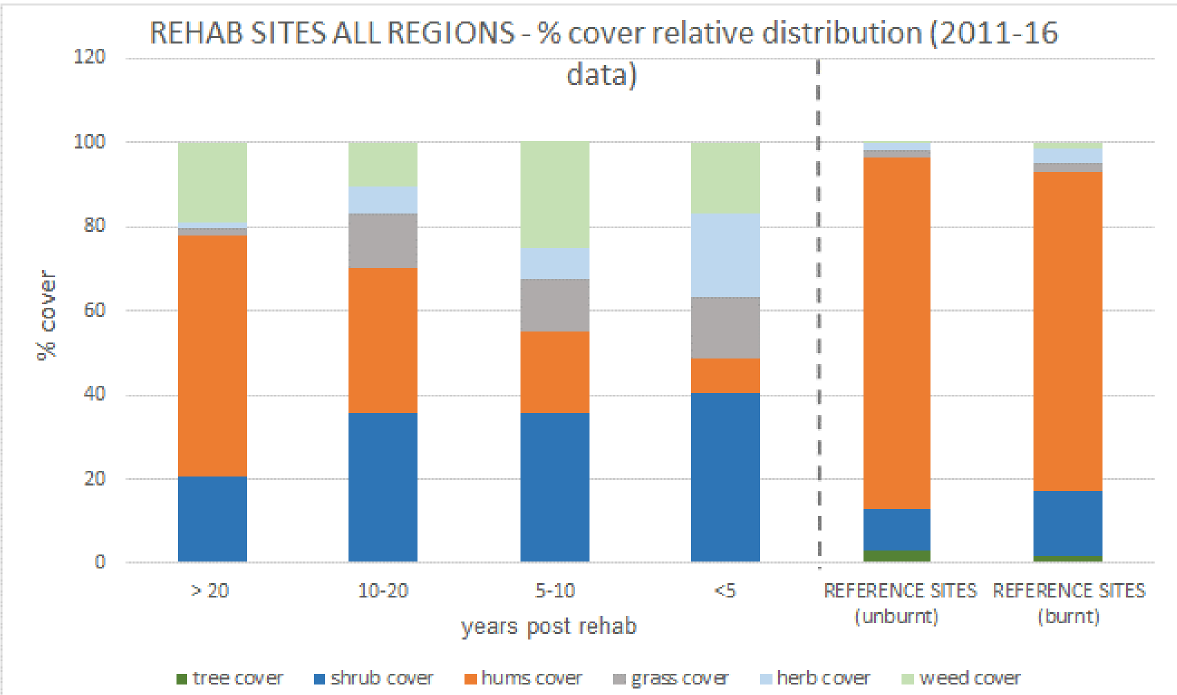


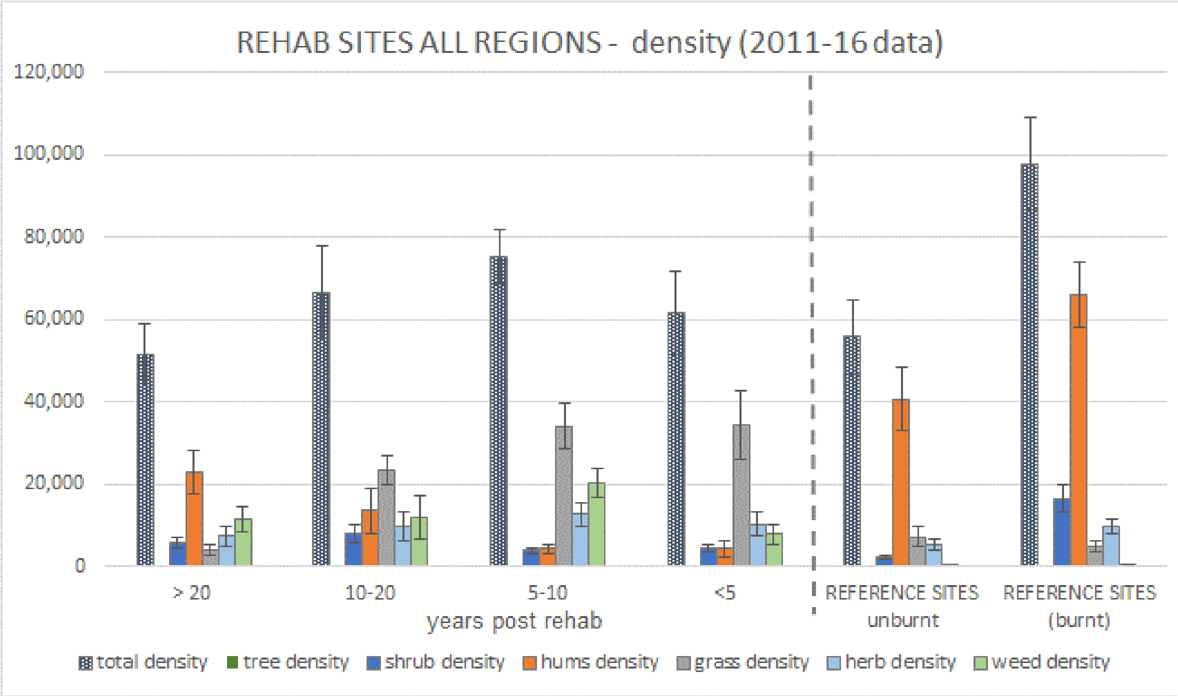
## SCALE OF ASSESSMENT: ALL REGIONS

## Comparison of rehabilitation and reference sites for cover, density & richness

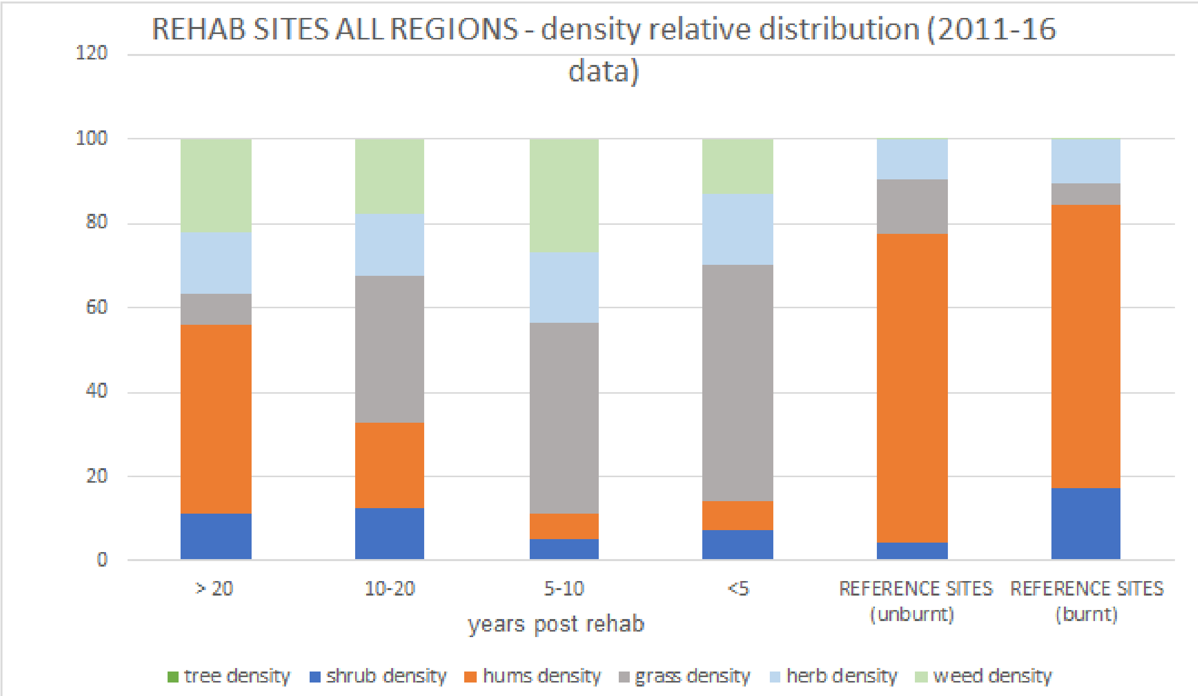


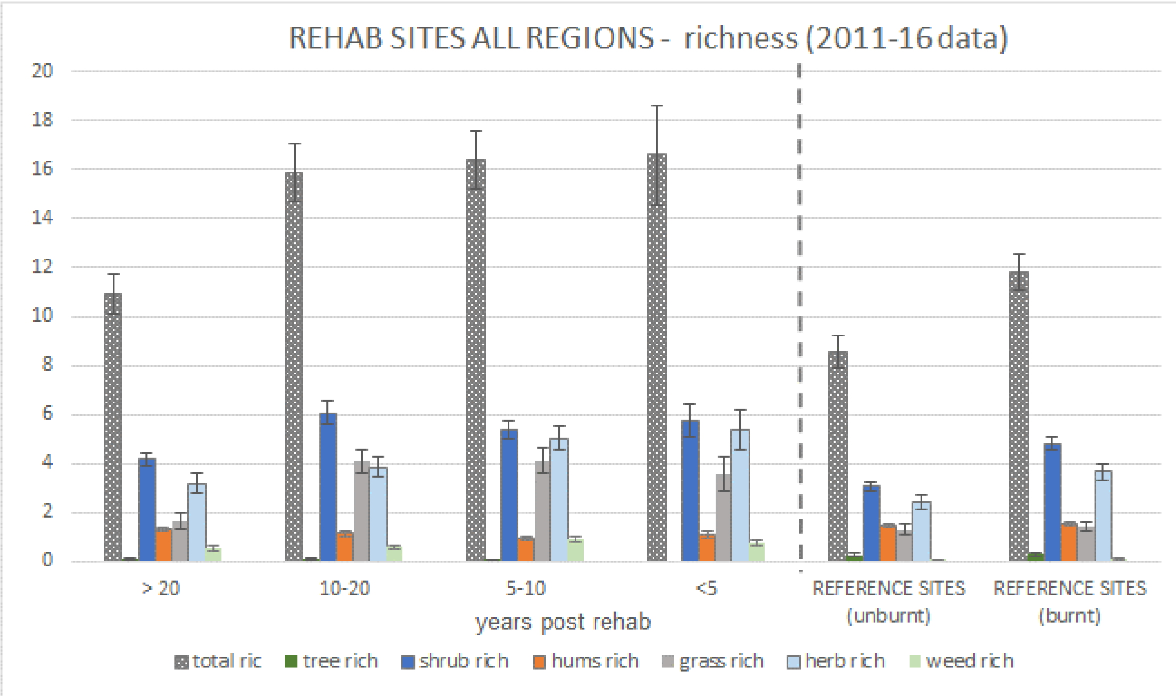

*No. of sites: > 20 years = 61; 10-20 years = 61; 5-10 years = 75; <5 years = 32; reference unburnt sites = 77; reference with burnt sites= 112.*



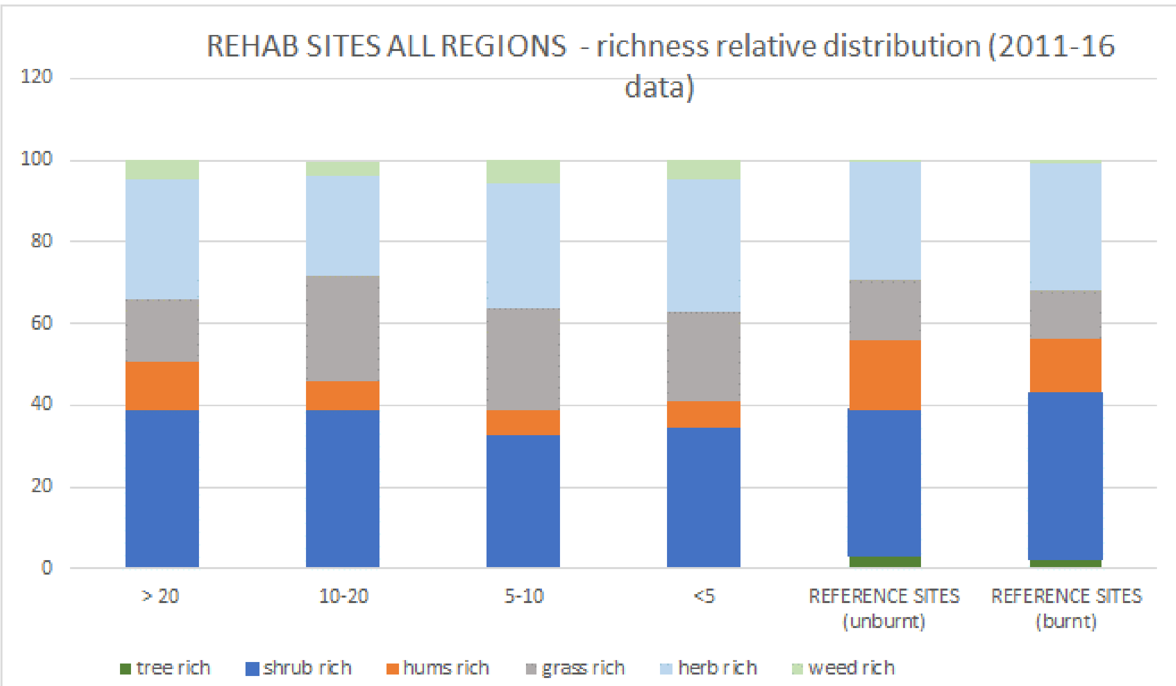



*No. of sites: > 20 years = 61; 10-20 years = 61; 5-10 years = 75; <5 years = 32; reference unburnt sites = 77; reference with burnt sites= 112.*



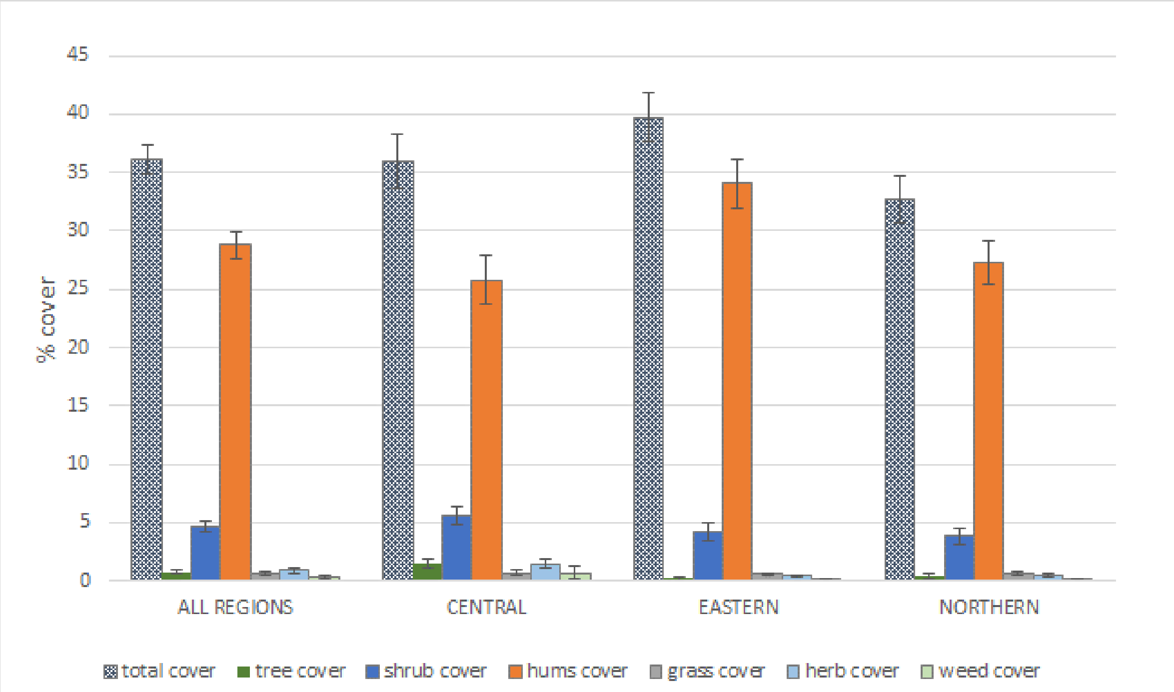



*No. of sites: > 20 years = 61; 10-20 years = 61; 5-10 years = 75; <5 years = 32; reference unburnt sites = 77; reference with burnt sites= 112.*



## SCALE OF ASSESSMENT: INDIVIDUAL REGIONS

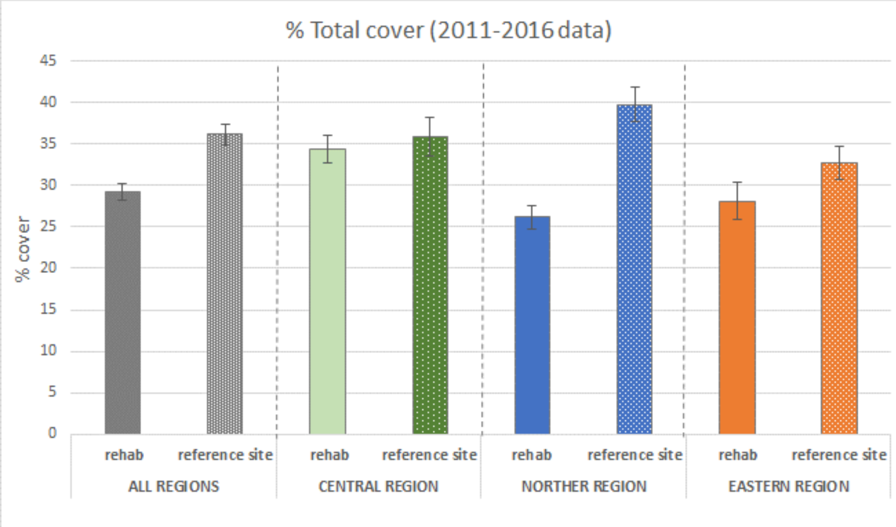
### Comparison of reference sites within different regions for cover

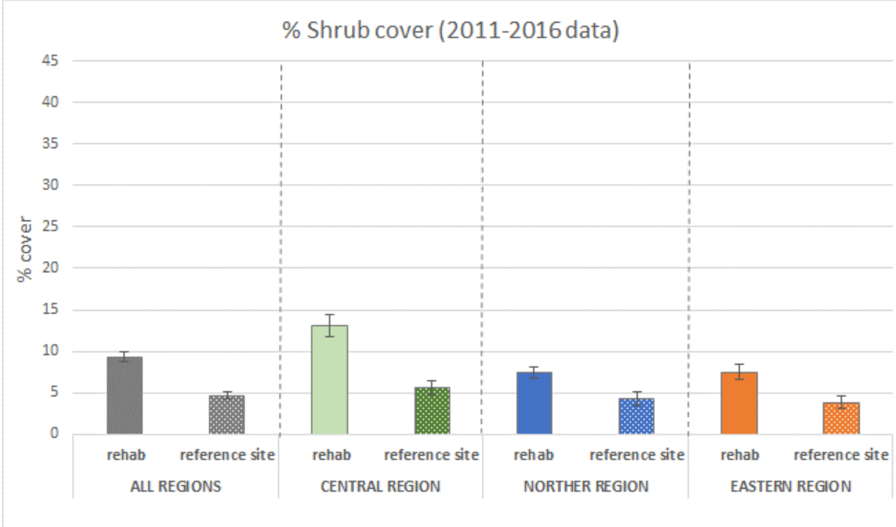


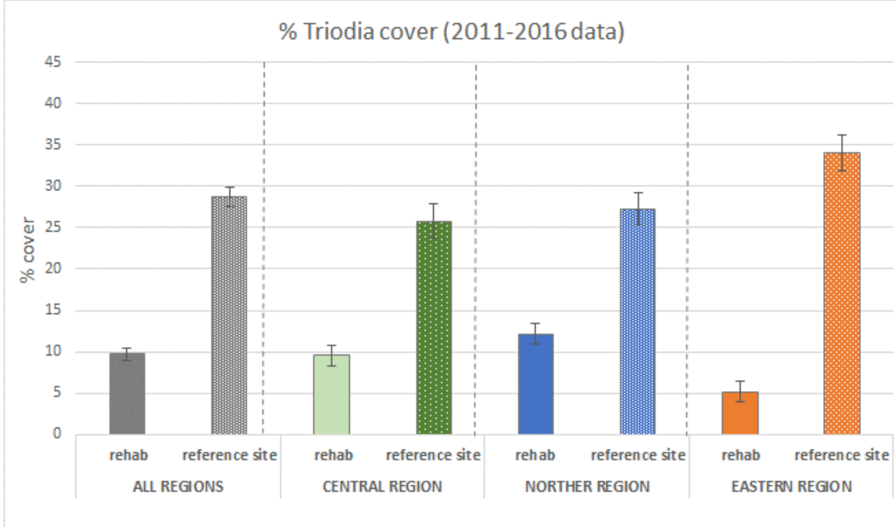

*No. of sites: All regions = 189; Central region = 75; Eastern region=58; Northern region = 56.*

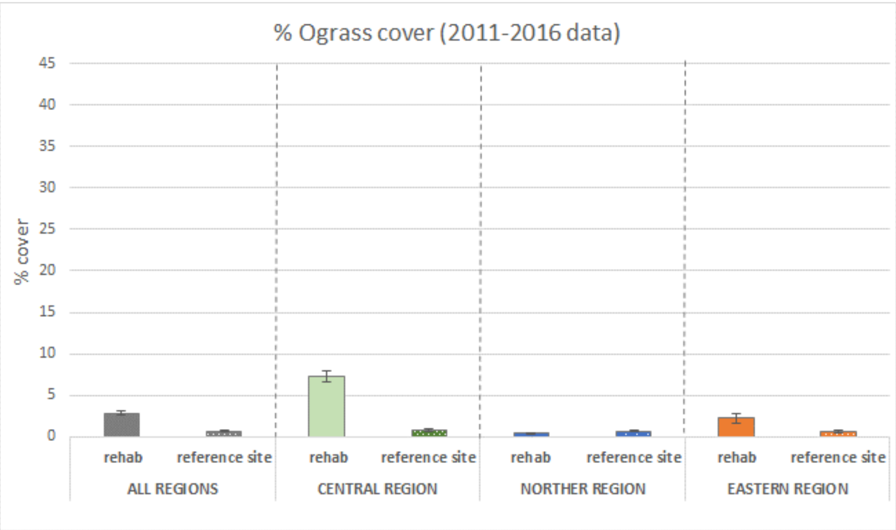
## SCALE OF ASSESSMENT: INDIVIDUAL REGIONS

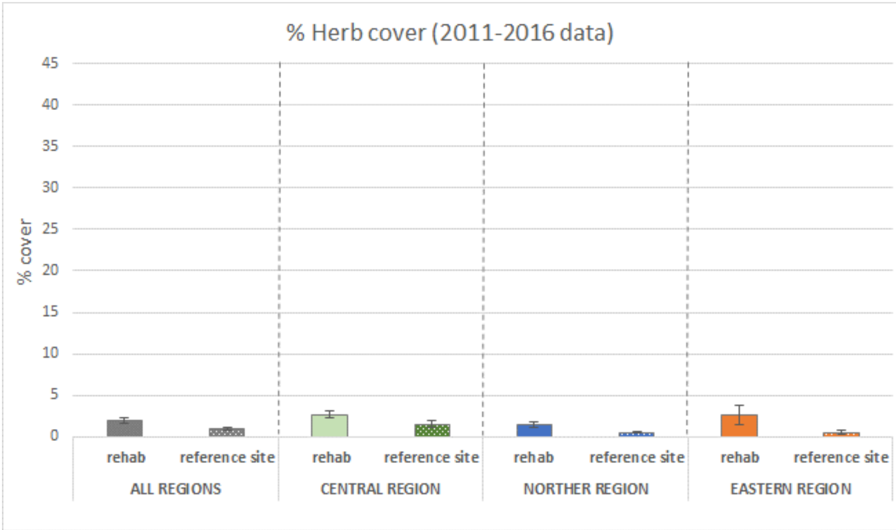
### Comparison of rehabilitation sites within different regions for cover

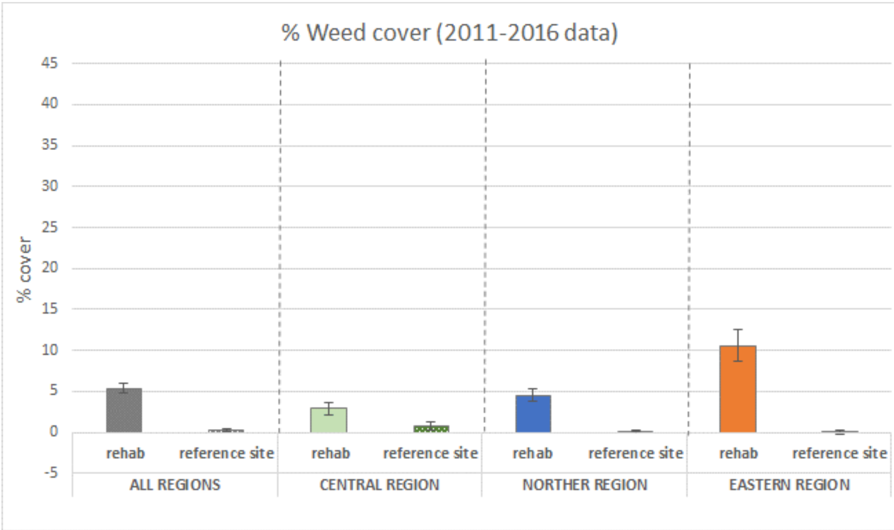


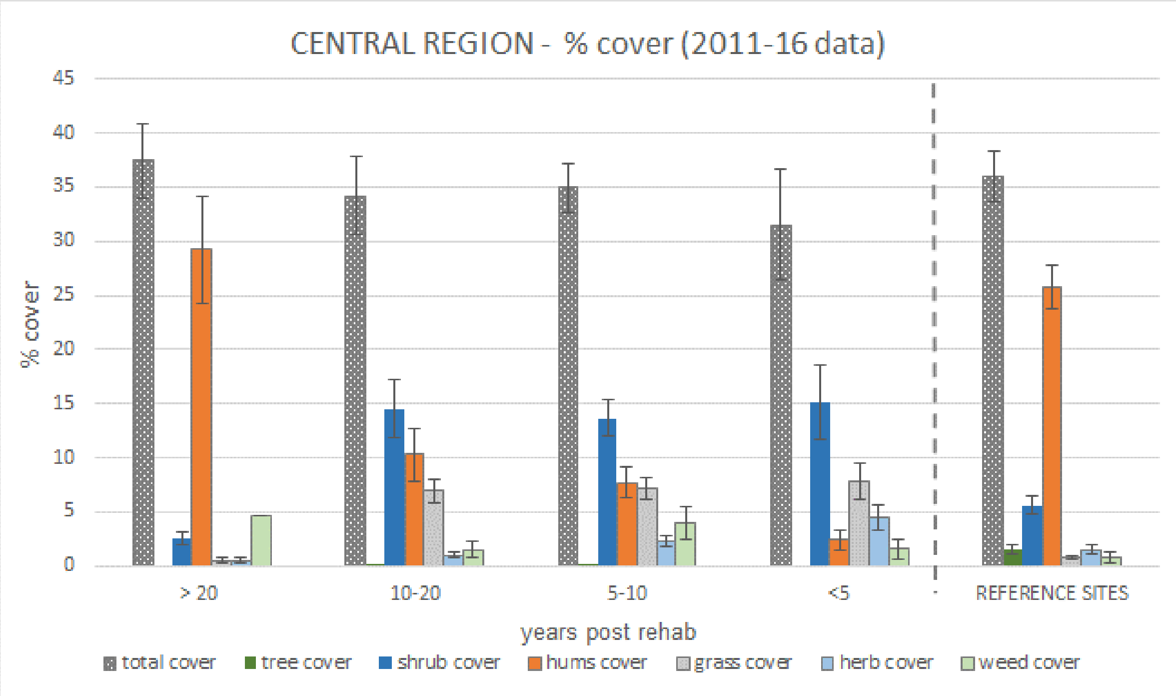



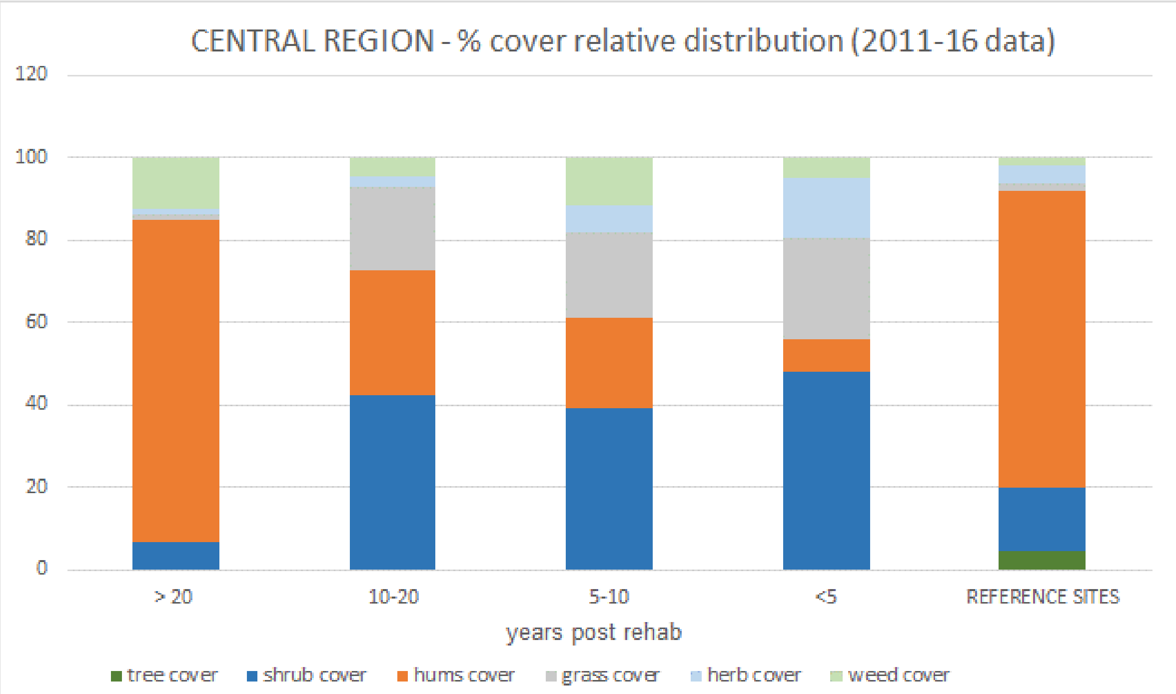

*No. of sites: All regions = 229; Central region = 75; Eastern region=52; Northern region = 102.*

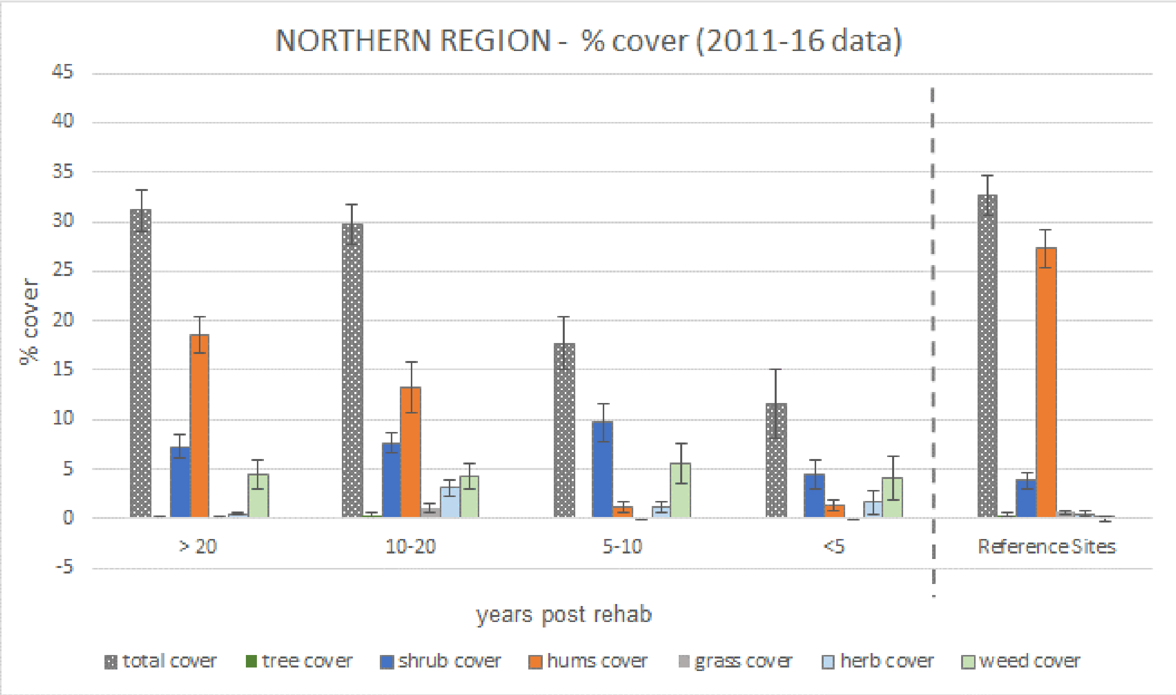
## SCALE OF ASSESSMENT: INDIVIDUAL REGIONS

### Impact of time post rehabilitation on cover

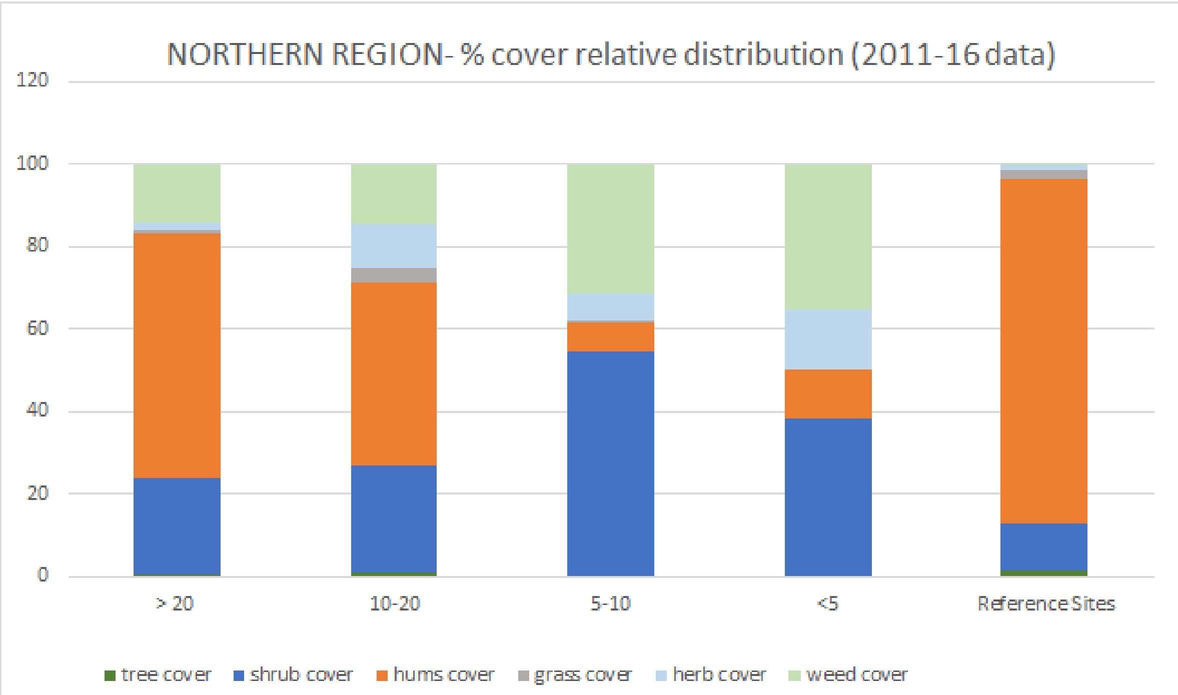


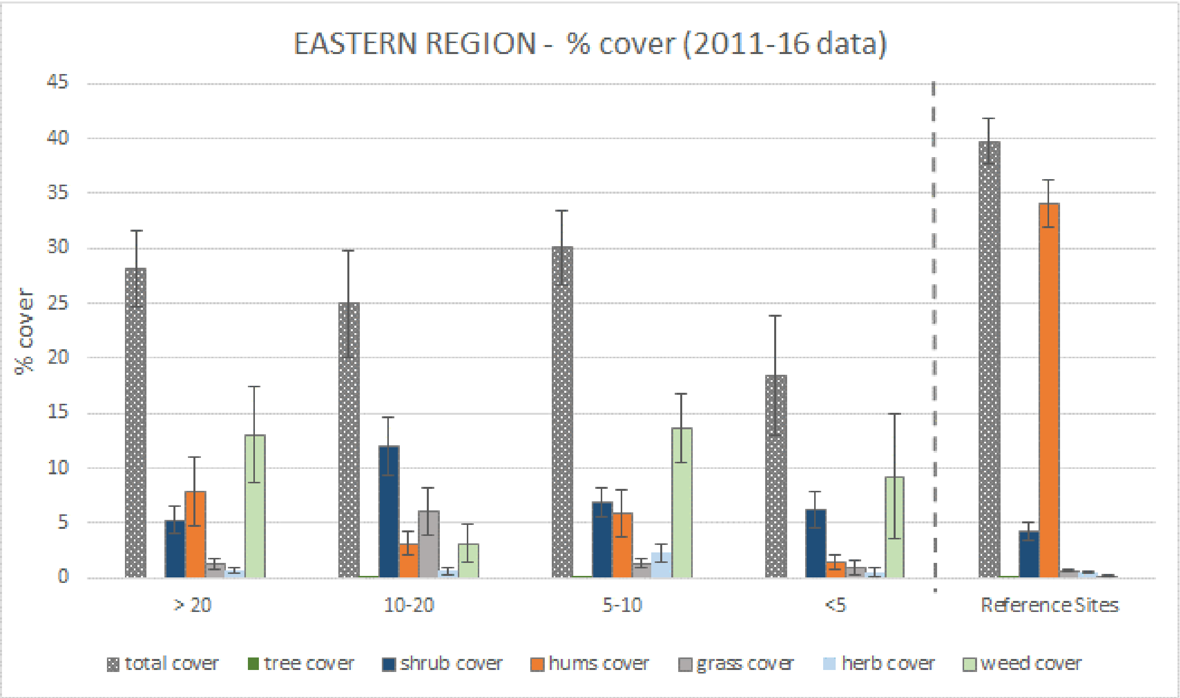

*No. of sites: > 20 years = 9; 10-20 years = 17; 5-10 years = 13; <5 years = 18; reference sites= 75.*



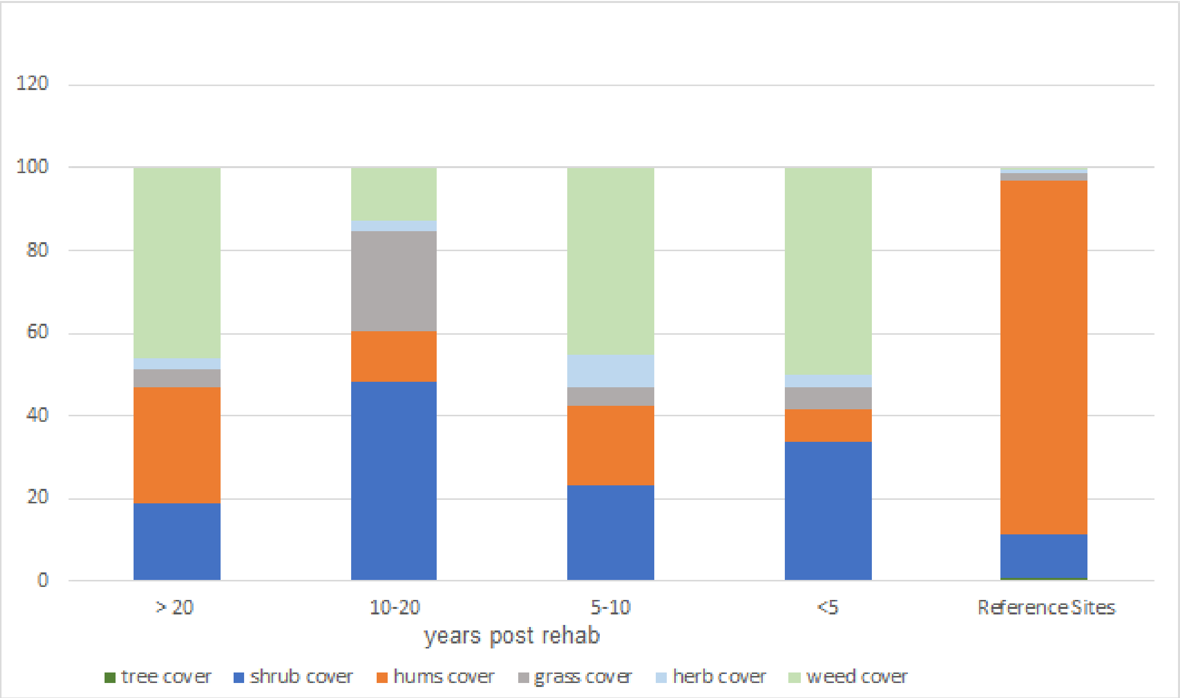



*No. of sites: > 20 years = 44; 10-20 years = 29; 5-10 years = 16; <5 years = 13; reference sites= 56.*



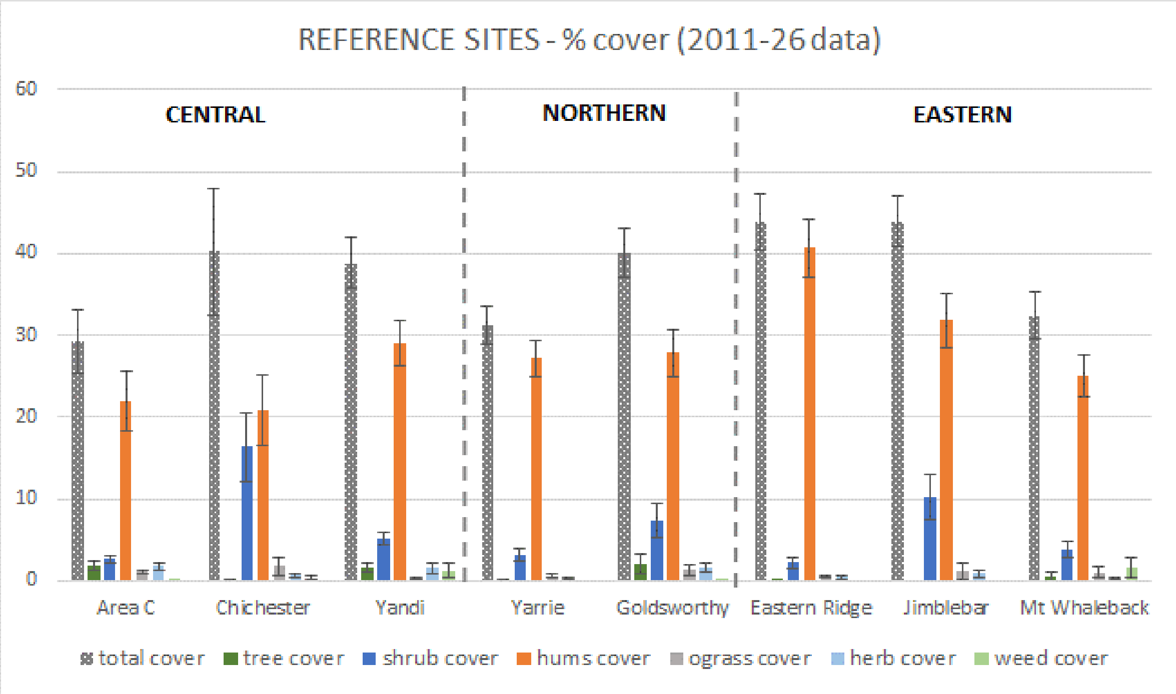



*No. of sites: > 20 years = 10; 10-20 years = 11; 5-10 years = 25; <5 years = 5; reference sites= 58.*

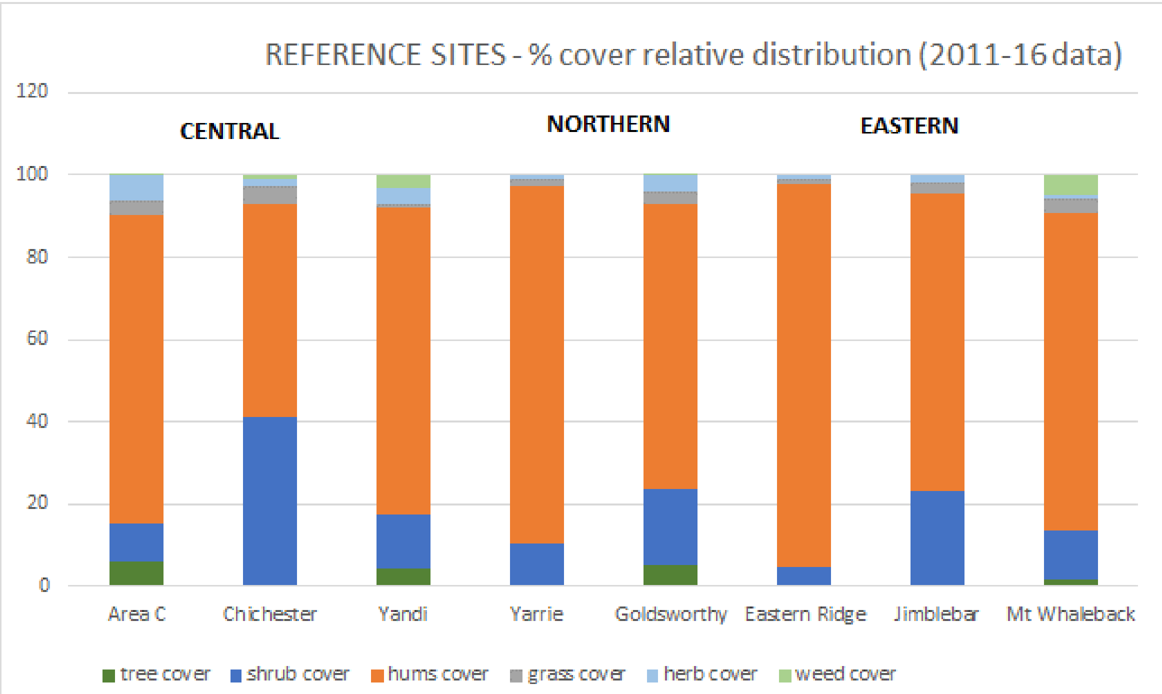


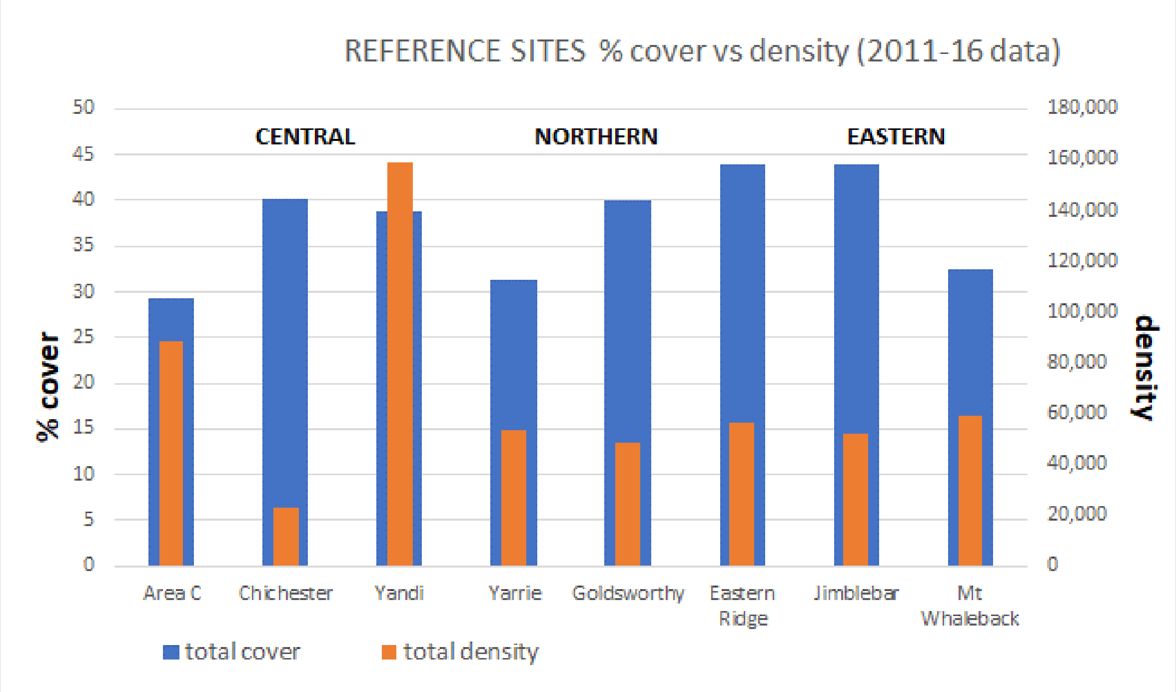
## SCALE OF ASSESSMENT: INDIVIDUAL HUBS

### Comparison of reference sites in individual hubs




*No. of sites: Area C = 24; Chichester Rail = 9; Yandi = 42; Yarrie = 47; Goldsworthy =9; Eastern Ridge = 27; Jimblebar = 11; Mt Whaleback = 21.*

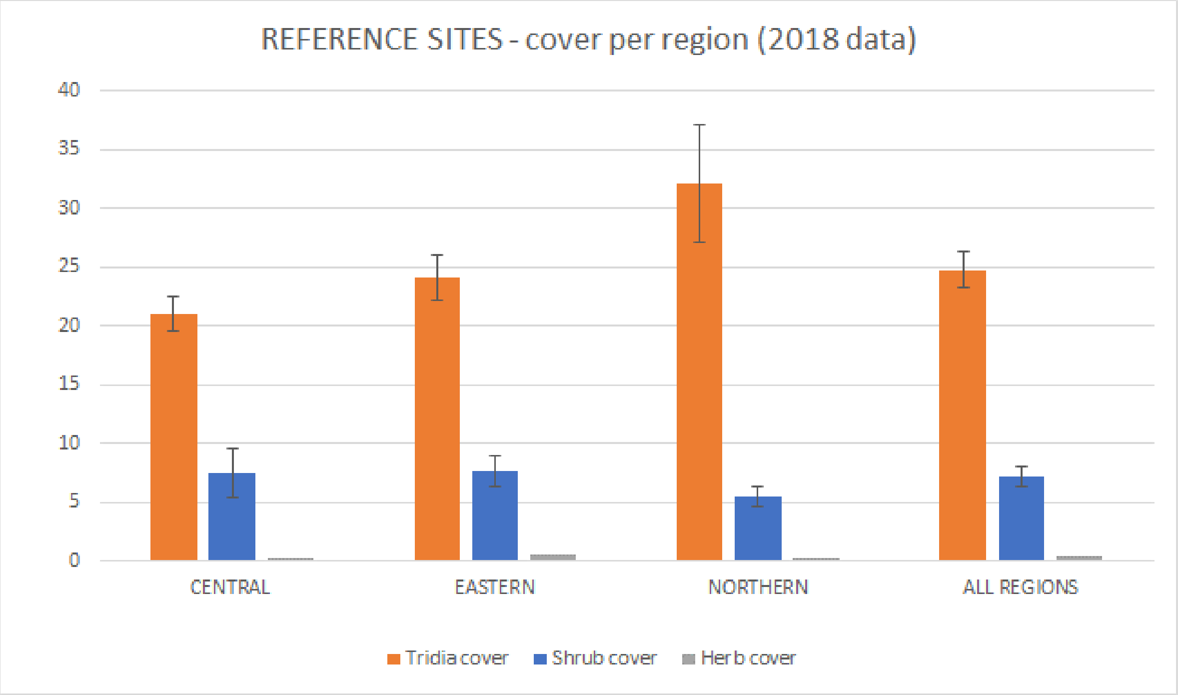



REFERENCE SITES % cover vs density (2011-16 data)
% cover
density
50
45
40
35
30
25
20
15
10
5
0
180,000
160,000
140,000
120,000
100,000
80,000
60,000
40,000
20,000
0
CENTRAL
NORTHERN
EASTERN
Area C
Chichester
Yandi
Yarrie
Goldsworthy
Eastern Ridge
Jimblebar
Mt Whaleback
total cover
total density

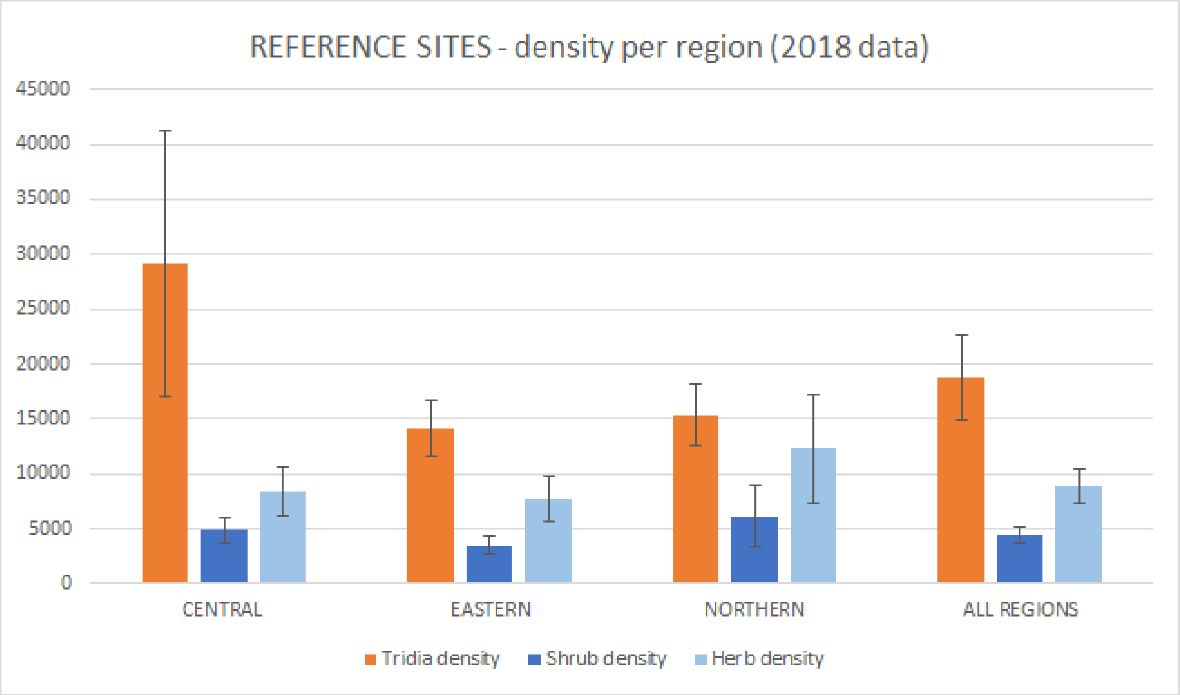
# 2018 DATA

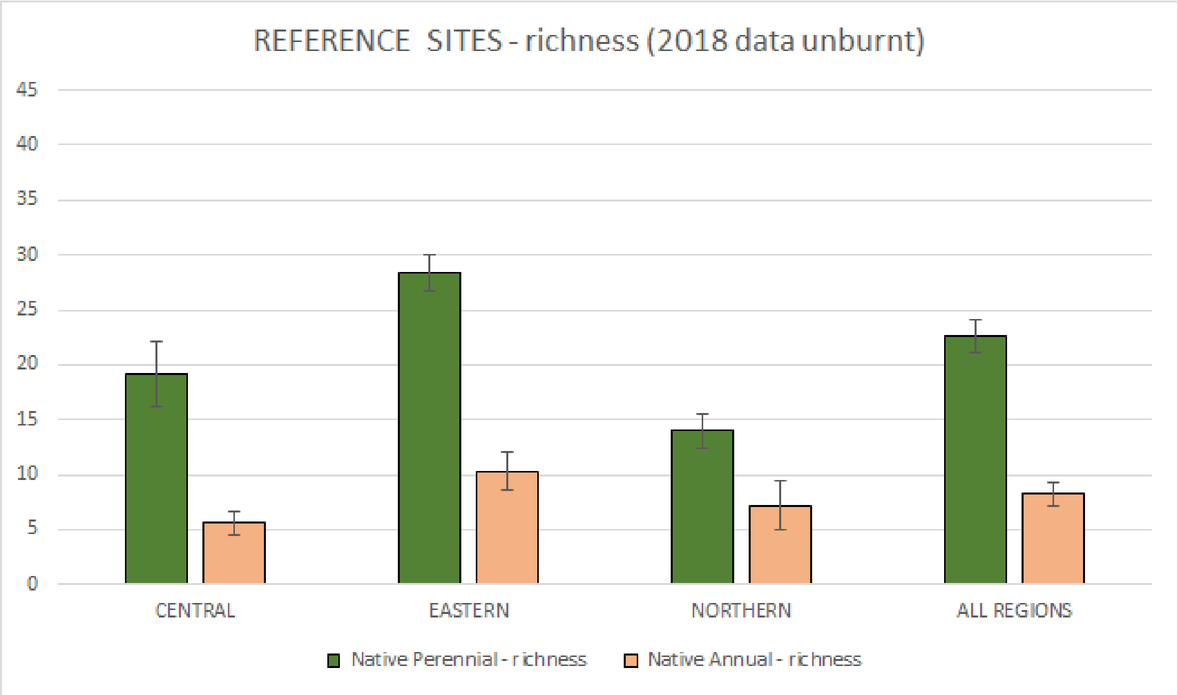
## SCALE OF ASSESSMENT: REGIONS

### Comparison of reference sites within individual regions



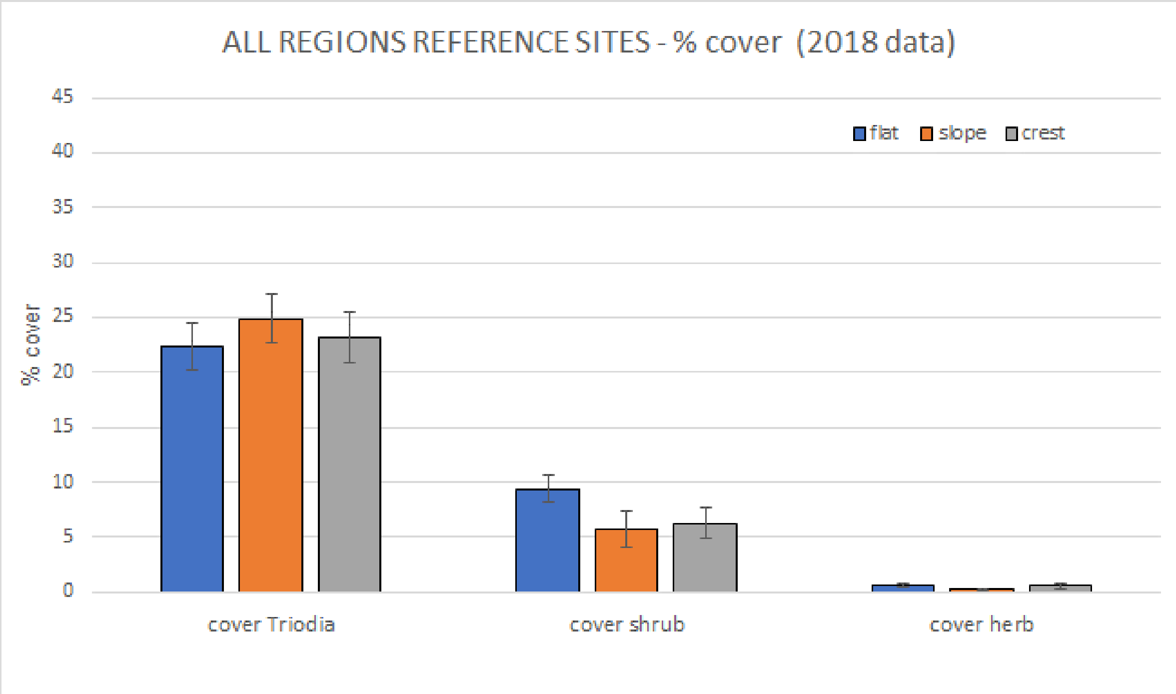

*No. of sites: All regions = 41; Central region = 12; Eastern region=21; Northern region = 8*



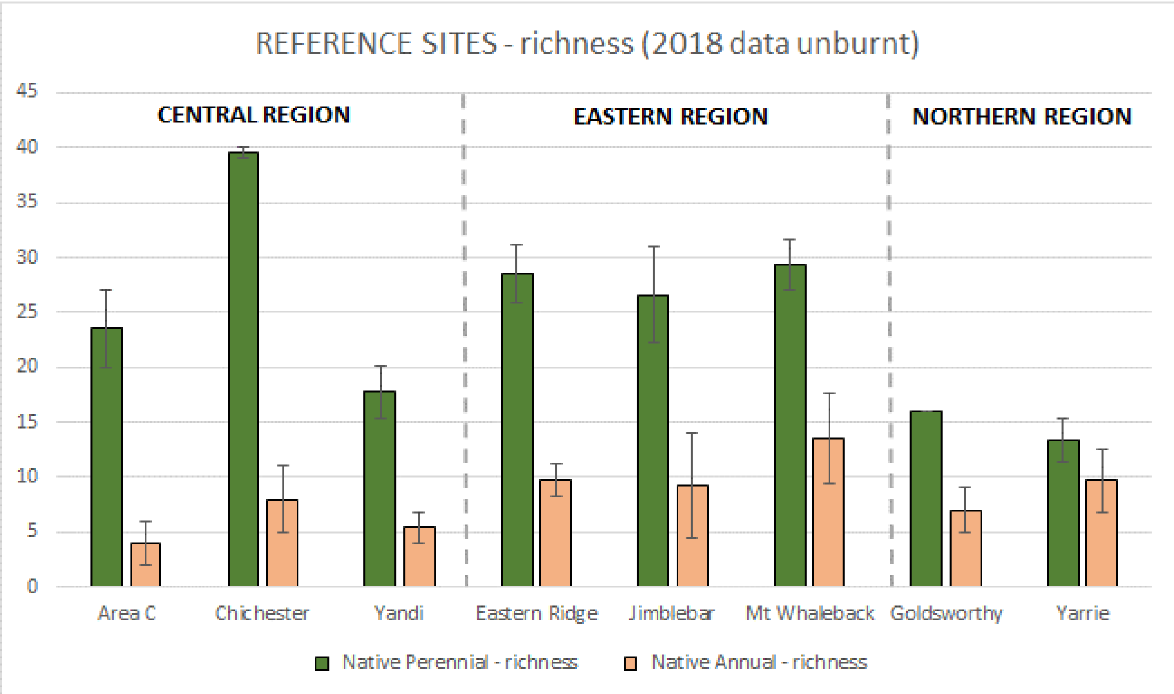

REFERENCE SITES - richness (2018 data unburnt)
45
40
35
30
25
20
15
10
5
0
CENTRAL
EASTERN
NORTHERN
ALL REGIONS
Native Perennial - richness
Native Annual - richness

## SCALE OF ASSESSMENT: REGIONS

### Comparison of reference sites within different landforms

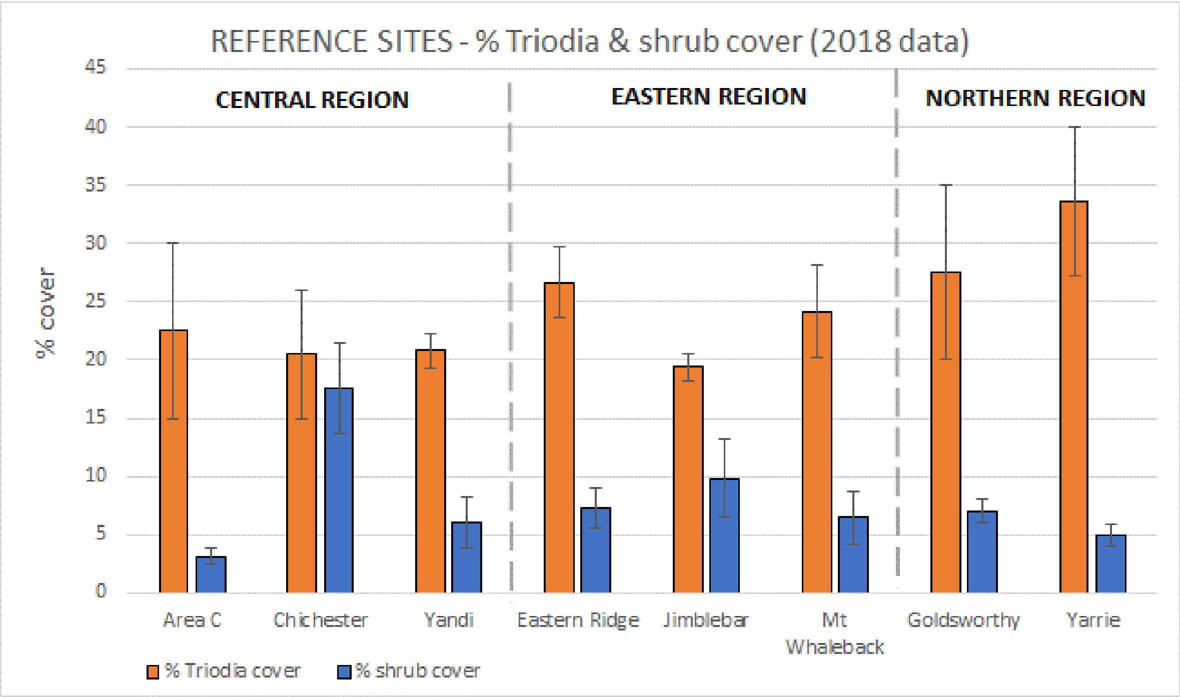



*No. of sites: flats = 28; slope = 14; crest=13.*



## SCALE OF ASSESSMENT: HUBS

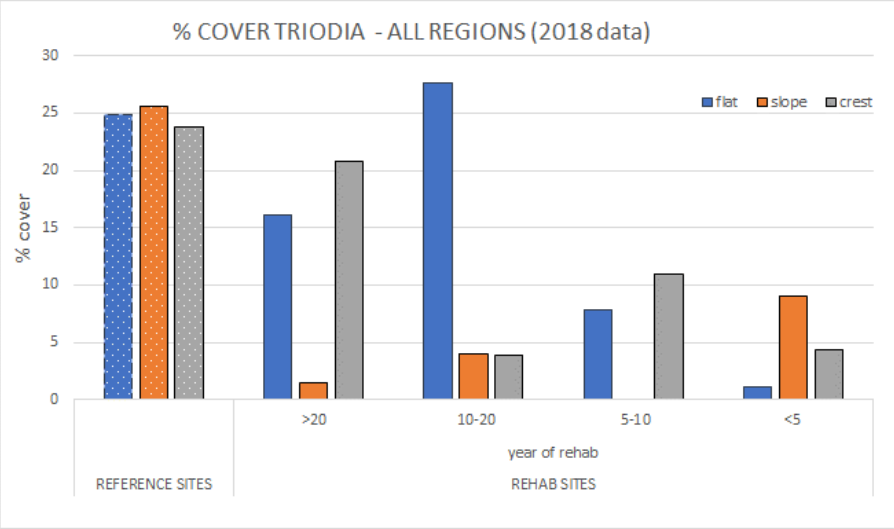
### Comparison of reference sites within hubs

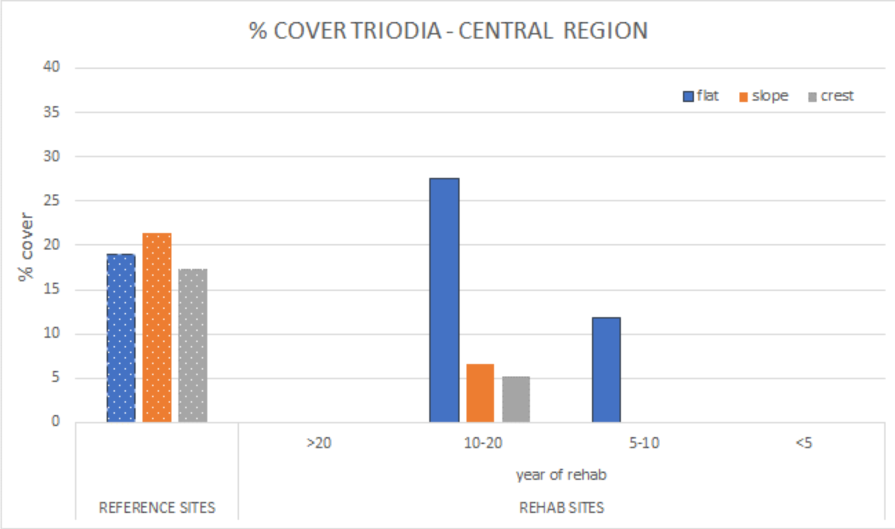


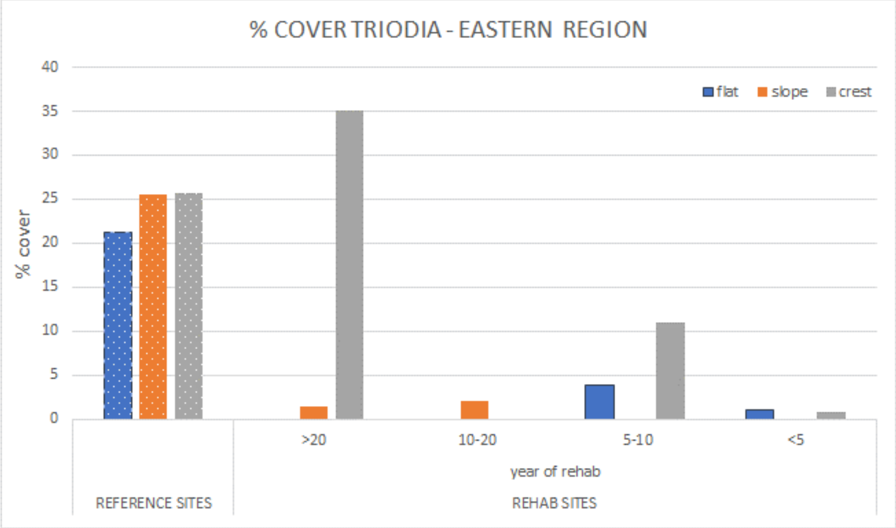

*No. of sites: Area C = 2; Chichester Rail = 2; Yandi = 8; Eastern Ridge = 9; Jimblebar = 5; Mt Whaleback = 7; Goldsworthy =9;. Yarrie = 6. Note, sites included in analysis are those with no recent evidence of fire.*

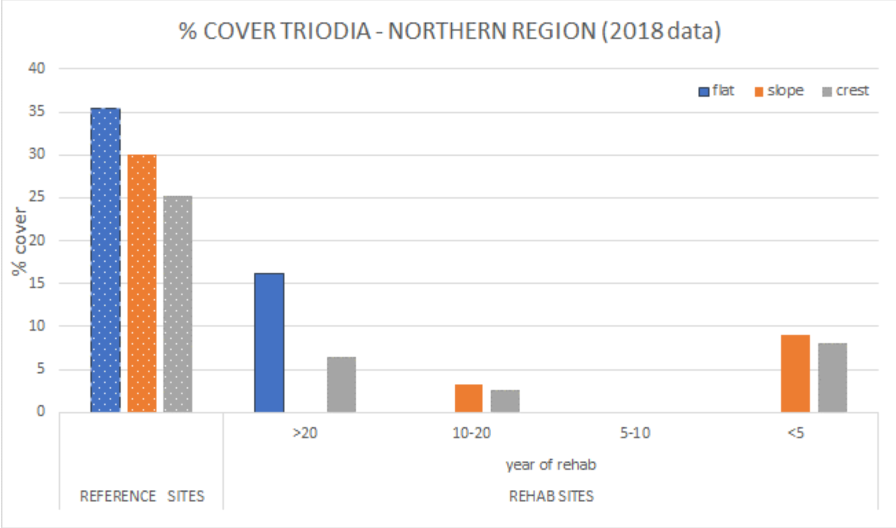
## SCALE OF ASSESSMENT: REGIONS

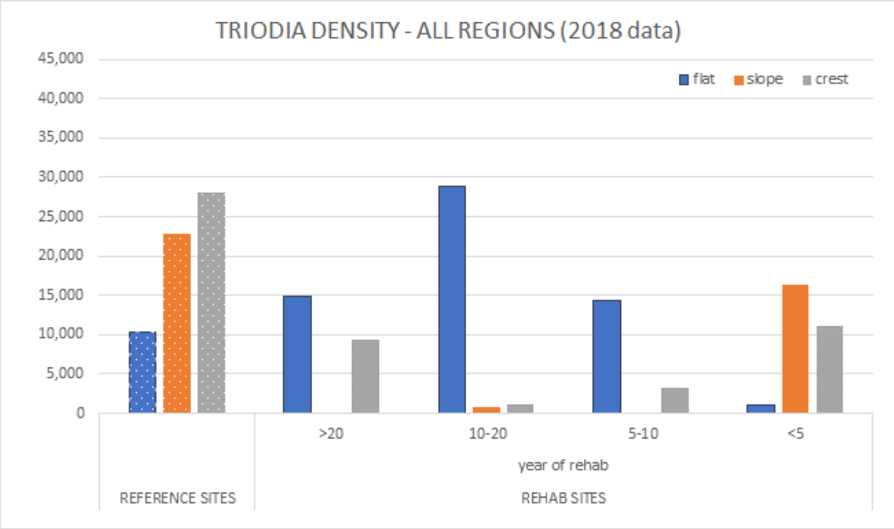
### Comparison of rehabilitation sites

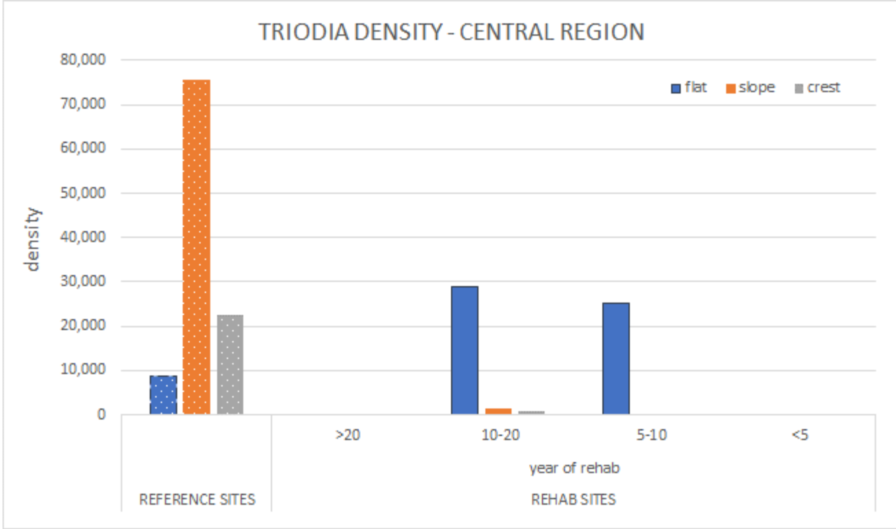


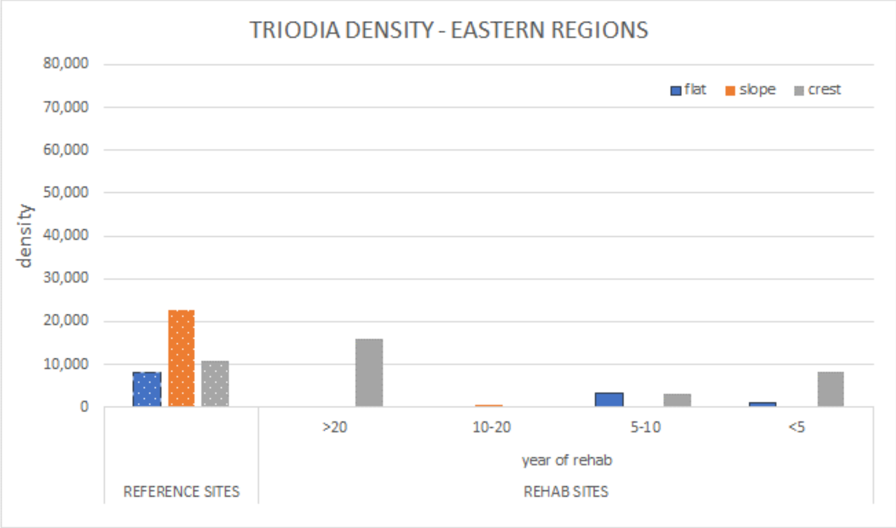



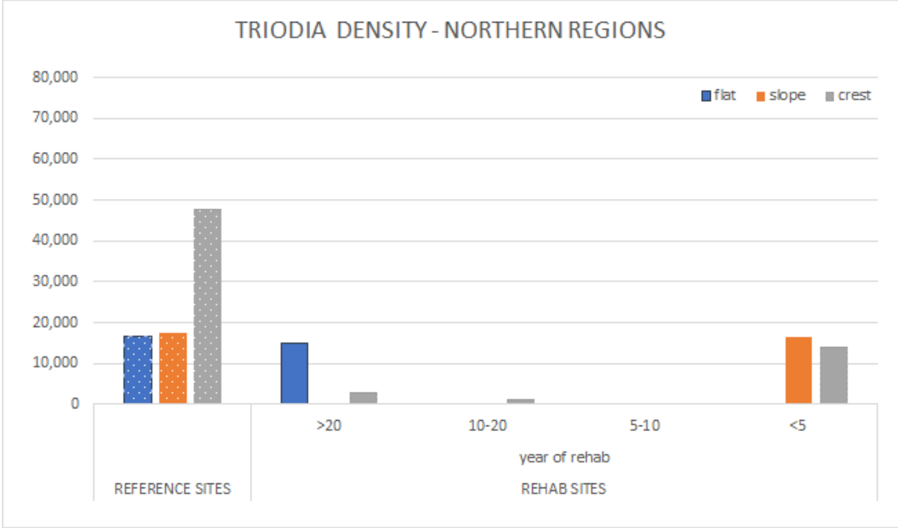



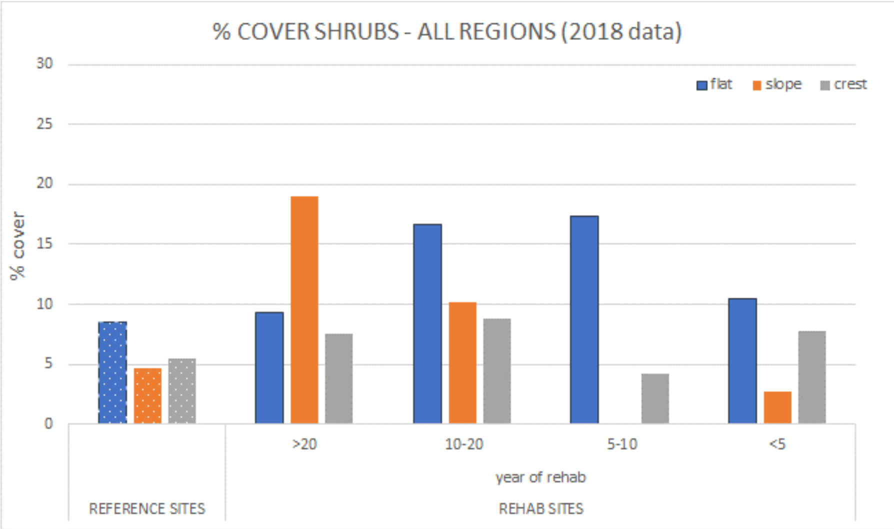



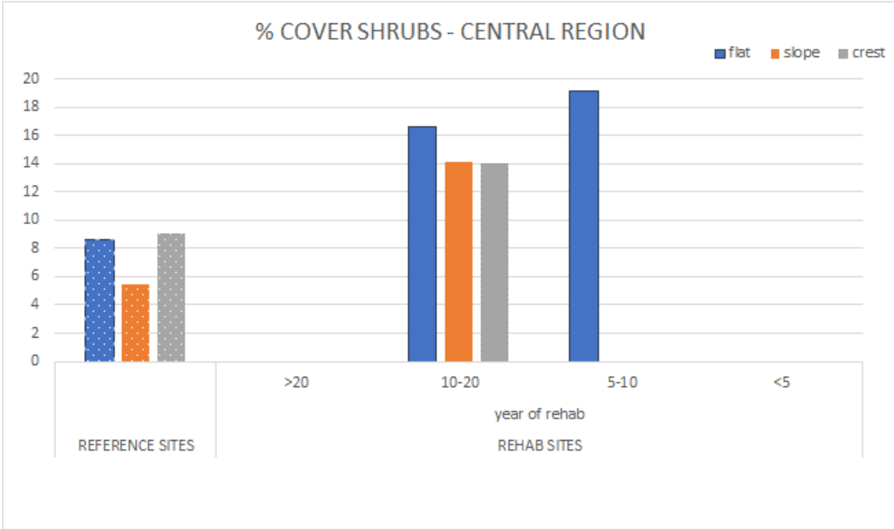

TRIODIA DENSITY - ALL REGIONS (2018 data)
45,000
40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
flat
slope
crest
>20
10-20
5-10
<5
year of rehab
REFERENCE SITES
REHAB SITES

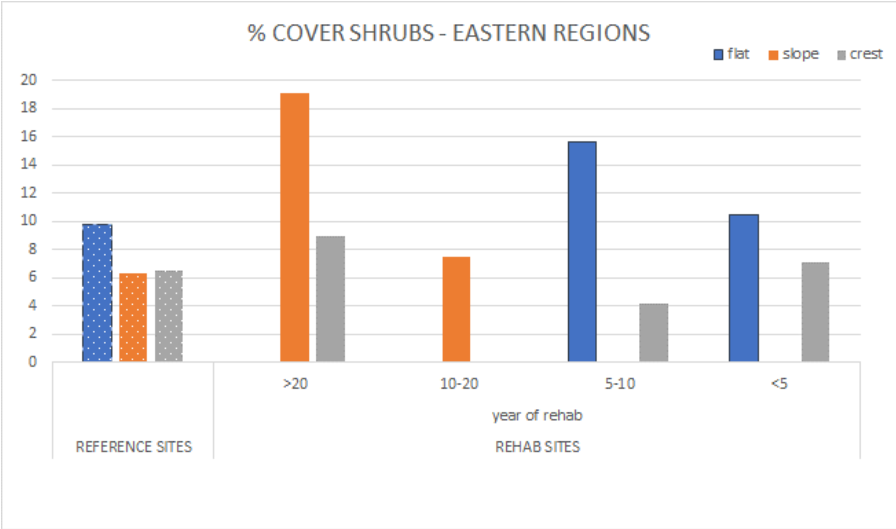

TRIODIA DENSITY - CENTRAL REGION
density
80,000
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
flat
slope
crest
>20
10-20
5-10
<5
year of rehab
REFERENCE SITES
REHAB SITES

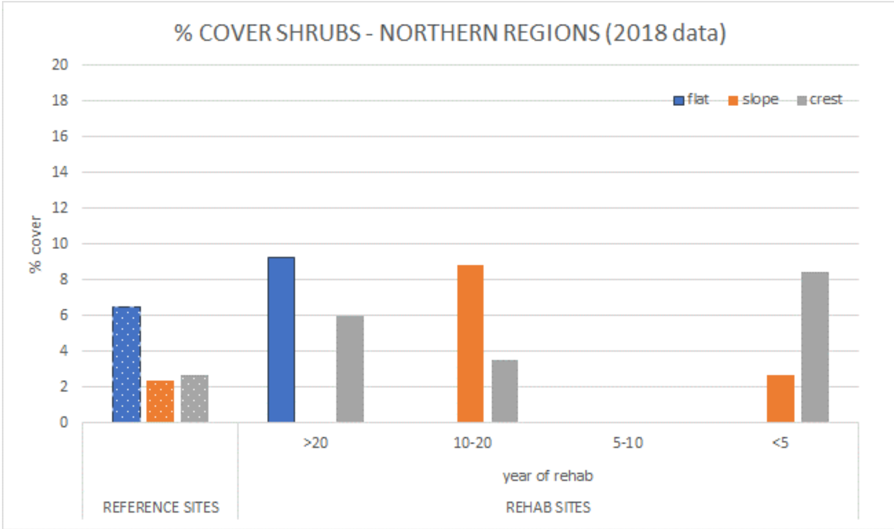

TRIODIA DENSITY - EASTERN REGIONS
density
80,000
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
flat
slope
crest
>20
10-20
5-10
<5
year of rehab
REFERENCE SITES
REHAB SITES

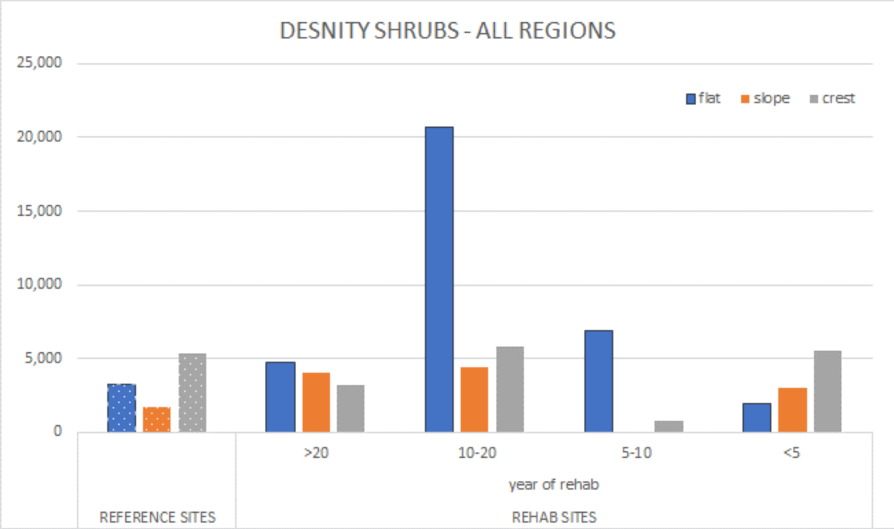

TRIODIA DENSITY - NORTHERN REGIONS
80,000
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
flat
slope
crest
>20
10-20
5-10
<5
year of rehab
REFERENCE SITES
REHAB SITES

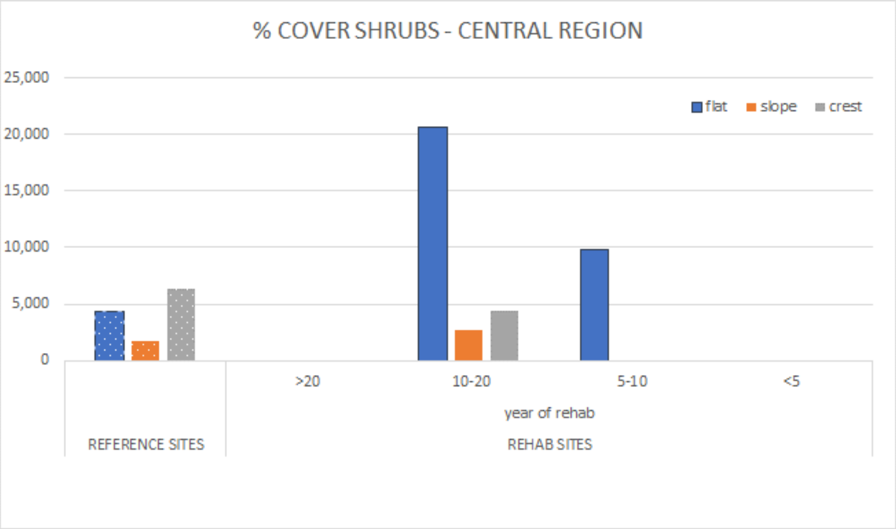

% COVER SHRUBS - ALL REGIONS (2018 data)
flat
slope
crest
% cover
30
25
20
15
10
5
0
>20
10-20
5-10
<5
year of rehab
REFERENCE SITES
REHAB SITES

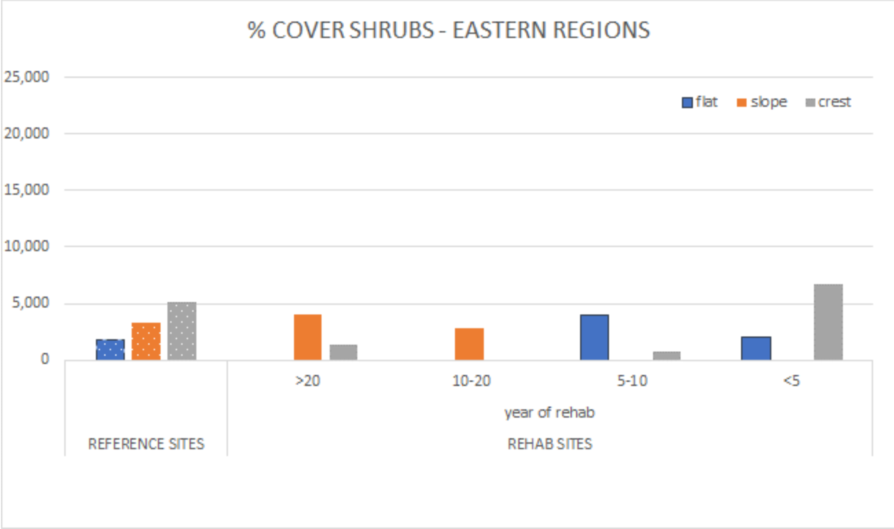

% COVER SHRUBS - CENTRAL REGION
flat
slope
crest
20
18
16
14
12
10
8
6
4
2
0
>20
10-20
5-10
<5
year of rehab
REFERENCE SITES
REHAB SITES

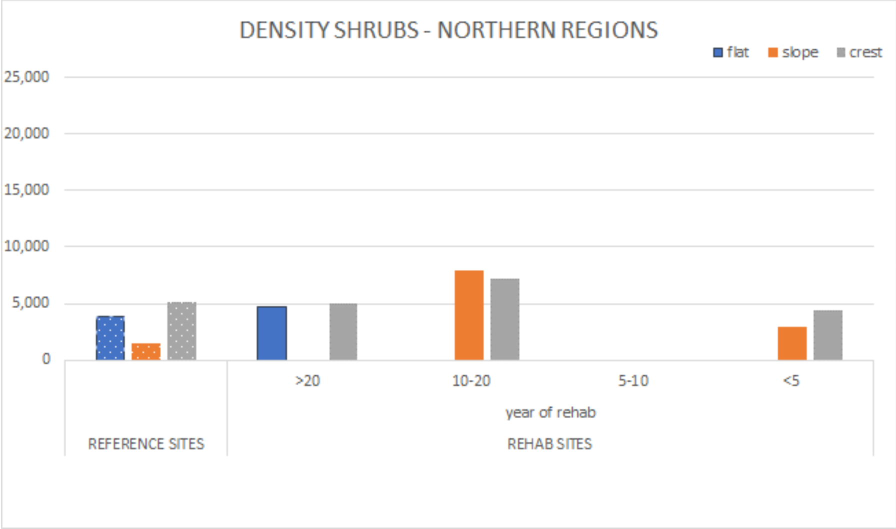

% COVER SHRUBS - EASTERN REGIONS
flat
slope
crest
20
18
16
14
12
10
8
6
4
2
0
>20
10-20
5-10
<5
year of rehab
REFERENCE SITES
REHAB SITES


% COVER SHRUBS - NORTHERN REGIONS (2018 data)
flat
slope
crest
% cover
20
18
16
14
12
10
8
6
4
2
0
>20
10-20
5-10
<5
year of rehab
REFERENCE SITES
REHAB SITES


DESNITY SHRUBS - ALL REGIONS
25,000
20,000
15,000
10,000
5,000
0
flat
slope
crest
>20
10-20
5-10
<5
year of rehab
REFERENCE SITES
REHAB SITES


% COVER SHRUBS - CENTRAL REGION
25,000
20,000
15,000
10,000
5,000
0
flat
slope
crest
>20
10-20
5-10
<5
year of rehab
REFERENCE SITES
REHAB SITES


% COVER SHRUBS - EASTERN REGIONS
25,000
20,000
15,000
10,000
5,000
0
flat
slope
crest
>20
10-20
5-10
<5
year of rehab
REFERENCE SITES
REHAB SITES


DENSITY SHRUBS - NORTHERN REGIONS
flat
slope
crest
25,000
20,000
15,000
10,000
5,000
0
>20
10-20
5-10
<5
year of rehab
REFERENCE SITES
REHAB SITES