Bennelongia Environmental Consultants

Roy Hill Iron Ore Pty Ltd

Monitoring short range endemic invertebrates at the Roy Hill 1 Mine April to July 2013

Final Report

Prepared for Roy Hill Iron Ore Pty Ltd
by Bennelongia Pty Ltd

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Monitoring short range endemic invertebrates at the Roy Hill 1 Mine, April to July 2012

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Front cover: Photo of the Fortescue River floodplain

Client – Roy Hill Iron Ore Pty Ltd

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EXECUTIVE SUMMARY

Roy Hill Iron Ore Pty Ltd operates, and is the proponent for, the Roy Hill Iron Ore Mining Project Stage 1 (the Project) on the southern slopes of the Chichester Range, 110 km north of Newman in the Pilbara. Environmental approval for the Project was given on 23 December 2009, subject to a series of Ministerial Conditions (Ministerial Statement 824). The Ministerial Conditions relating to short range endemic invertebrates (SREs) were changed in December 2012 (Ministerial Statement 902).

SREs are species of invertebrates with ranges of less than 10,000 km^2. Seven groups of invertebrates occurring in the Pilbara are currently recognised as containing high proportions of SREs. Surveys at the Project have recognized five potential SRE species. Condition 9 of Ministerial Statement 902 requires a program of triennial habitat monitoring outside the Project Area for each of the five potential SRE species during the life of the mining operation. The biologically important subsection of Condition 9 is:

> **Condition 9-1.** The proponent shall identify suitable habitat monitoring sites outside the mining tenement boundaries shown in Figure 6 of Schedule 1 of Ministerial Statement 824, for each of the species *Missulena* sp. (`MYG252-DNA`), *Synothele* `MYG127`, *Aganippe* `MYG126`, *Idiommata* `MYG128`, and *Beierolpium* sp. The proponent shall identify no fewer than three habitat monitoring sites for each of these species, unless otherwise agreed with the CEO.

This report addresses Condition 9-1 and the other four subsections of Condition 9. At present, *Idiommata* `MYG128` has been recorded only from site 1106_13 within the Project. One objective of the monitoring was to undertake surveys and find three habitat monitoring sites outside the Project where *Idiommata* `MYG128` occurs. The other four species (*Missulena* sp. (`MYG252-DNA`), *Synothele* `MYG127`, *Aganippe* `MYG126`, *Idiommata* `MYG128` and *Beierolpium* sp.) are known from outside the Project and the second objective of monitoring was to survey at least three sites for each species and determine condition targets against which the ecological character of the sites could be assessed in future years.

As a result of the surveys of sites where *Missulena* sp. (`MYG252-DNA`), *Synothele* `MYG127`, *Aganippe* `MYG126`, *Idiommata* `MYG128` and *Beierolpium* sp. occur, three types of habitat monitoring are proposed to identify and confirm whether any significant decline in site condition occurs:

- Habitat targets for the litter index, plant species richness and percentage cover,
- nMDS analysis of sites based on percentage cover of middle storey species, and
- Photo points provide a visual picture of site condition and a check on the results of the other two monitoring methods.

It is possible that the habitat targets proposed in this report will require future modification, and that interpretation of nMDS plots may become more quantified, as more monitoring data become available. However, all monitored sites currently appear to be in suitable condition to support the SRE species occurring within them.

No additional specimens of *Idiommata* `MYG128` were collected in 2013, despite 40 wet-pit traps being set during each of the two periods of sampling for the species and additional foraging being undertaken. Examination of results from 2013 and previous attempts to re-collect the species, which is known from a single male within the Project, suggest that more than 1000 wet-pit traps would need to be set for a period of 42 days to be likely to catch a single specimen of *Idiommata* `MYG128`. Given the likelihood that *Idiommata* `MYG128` does not currently occur at site 1106_13, based on intensive searches during the past three years, it is recommended to seek the agreement that no habitat monitoring sites are required for *Idiommata* `MYG128`.

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1. INTRODUCTION

Roy Hill Iron Ore Pty Ltd operates, and is the proponent for, the Roy Hill Iron Ore Mining Project Stage 1 (the Project) on the southern slopes of the Chichester Range, 110 km north of Newman in the Pilbara. Environmental approval for the Project was given on 23 December 2009, subject to a series of Ministerial Conditions (Ministerial Statement 824).

This report deals with the monitoring of short-range endemic (SRE) invertebrates that is required under Ministerial Statement 824. Seven groups of arthropods that are currently recognised as containing high proportions of SREs occur in the Pilbara. These are millipedes, centipedes, spiders, pseudoscorpions, scorpions, slaters and land snails (Harvey 2002; Crews & Harvey 2011). SRE species are a focus for conservation because they usually occur in small patches of habitat within an overall range <10,000 km^2. Their small ranges and patchy distributions make them potentially susceptible to substantial population reduction from single anthropogenic habitat changes, such as mine development.

As part of the environmental impact assessment conducted for the Roy Hill Stage 1 Mine, surveys for SREs were undertaken at the mine site in 2006 using a combination of foraging and trapping techniques (ecologia 2006). Trapping consisted of five days of dry-pit trapping at six sites (five traps per site), supplemented by dry-pit trapping for vertebrate fauna. An isopod (*Laevophiloscia* sp.), two scorpion species (*Urodacus* sp. and *Lychas* sp.) and seven species of centipede were captured (none was considered to be an SRE; ecologia 2008). This result was queried by the Department of Environment and Conservation (DEC) and ecologia undertook extra surveys in October 2008 using hand foraging, collecting one mygalomorph specimen (*Conothele* sp.). ecologia then conducted further surveys between May and July 2009, using wet-pit trapping, and collected at least 10 species belonging to SRE groups, although only two of these were identified to species level (ecologia 2009). None of the 10 species was considered to be a potential SRE species. The animals were subsequently submitted to the Western Australian Museum (WAM) for identification and a number of the species were determined to be potential SREs (Framenau and Harvey 2009). Ministerial Statement 824, which was published in December 2009, required the proponent to protect and annually monitor five of these potential SRE species at the Roy Hill 1 mine site. ecologia returned to Roy Hill in 2010 to conduct additional survey outside the Project area to document the wider occurrence of the five potential SRE species. Using wet-pit trapping between March and April 2010, three of the five species listed in the Ministerial Statement, *Missulena* sp. (`MYG252-DNA`), *Synothele* `MYG127` and *Beierolpium* sp., were located outside the mine.

Formal monitoring to meet Condition 9 of Ministerial Statement 824 began in 2011. Bennelongia has undertaken the monitoring work in 2011, 2012 and 2013. Following the monitoring in 2012, Condition 9 of Ministerial Statement 824 was replaced by Condition 9 of Ministerial Statement 902, which was published on 6 July 2012. This report provides the results of the monitoring undertaken between April and July 2013 to meet requirements of the new Condition 9.

1.1. Condition 9

Condition 9 of Ministerial Statement 902 requires a program of triennial habitat monitoring outside the Project Area for each of the five potential SRE species during the life of the mining operation. Condition 9 states:

> **Condition 9-1.** The proponent shall identify suitable habitat monitoring sites outside the mining tenement boundaries shown in Figure 6 of Schedule 1 of Ministerial Statement 824, for each of the species *Missulena* sp. (`MYG252-DNA`), *Synothele* `MYG127`, *Aganippe* `MYG126`, *Idiommata*

`MYG128`, and *Beierolpium* sp. The proponent shall identify no fewer than three habitat monitoring sites for each of these species, unless otherwise agreed with the CEO.

Condition 9-2. The proponent shall monitor the habitat condition at the sites identified in accordance with Condition 9-1 triennially, until such time as the CEO authorises monitoring to cease. The first monitoring event shall occur not more than 12 months after the date of this statement.

Condition 9-3. The proponent shall submit the results of the monitoring required by Condition 9-2 to the CEO not more than 6 months after each monitoring event.

Condition 9-4. In the event that monitoring required by Condition 9-2 indicates a decline in the habitat condition at the sites identified in accordance with Condition 9-1:

1. the proponent shall report such findings to the CEO within 21 days of the decline being identified;
2. the proponent shall provide evidence which allows determination of the cause of the decline;
3. if determined by the CEO to be a result of activities undertaken in implementing the proposal, the proponent shall submit actions to be taken to remediate the decline to the CEO; and
4. the proponent shall implement actions to remediate the decline upon approval of the CEO and shall continue until such time as the CEO determines that the remedial actions may cease.

Condition 9-5. The proponent shall make the monitoring reports required by Condition 9-3 publicly available in a manner approved by the CEO.

2. FRAMEWORK FOR MONITORING IN 2013

Monitoring in 2013 was undertaken to address Condition 9-1 and 9-2. There were two components to this work.

Addressing Condition 9-1. *Idiommata* `MYG128` has not been collected since the 2009 survey by ecologia, when it was recorded in site 1106_13 (exclusion site 13 in Ministerial Statement 824). Condition 9-1 requires identification of three sites outside the mining area where *Idiommata* `MYG128` occurs and a program of wet-pit trapping was implemented with the objective of identifying such sites.

In addition to the monitoring undertaken to address Condition 9-1 directly, site 1106_13 was surveyed by hand foraging in an attempt to re-collect *Idiommata* `MYG128` where it was originally found.

Addressing Condition 9-2. A program of habitat monitoring was implemented at selected sites where *Missulena* `MYG252-DNA` (3 sites), *Synothele* `MYG127` (5 sites), *Aganippe* `MYG126` (5 sites) and *Beierolpium* sp. (3 sites) occur.

3. SRE MONITORING ISSUES

Persistence of ground-dwelling invertebrates, especially mygalomorph spiders, in woodland habitats is strongly affected by disturbance, as measured by factors such as reduced ground and shrub cover and increased weed cover and grazing intensity (Abensperg-Traun *et al*. 1996; Clark *et al.* 2005). The premise underlying the program of habitat monitoring undertaken to meet Condition 9-2 is that the mygalomorph spiders and pseudoscorpions will persist at sites where they currently occur unless there is significant change in habitat at those sites.

Monitoring habitat is less time-consuming and will create less disturbance to the target SRE species than foraging and trapping surveys. However, in order to interpret the results of habitat monitoring, there must be an explicit relationship between SRE persistence and some habitat targets. Given the limited

information about the biology of SRE species in general (Harvey *et al*. 2002), and for the Project SRE species in particular, selection of relevant habitat parameters for monitoring is difficult. Identifying the habitat targets (minimum values for maintenance of SRE species) is also likely to be difficult.

SRE species tend to occur in patches of the landscape containing more moisture than surrounding areas (EPA 2009). Thus, on the flat Fortescue floodplain around the Project, SRE species mostly occur along drainage lines that support trees and shrubs rather than in spinifex-covered areas. Habitat targets that reflect drainage line conditions are likely to reflect occurrence of suitable habitat for SRE species. However, rainfall and vegetation condition are very variable in rangelands and there is a need to take account of the likely high inter-annual variability in conditions within drainage lines when setting habitat targets (Friedel *et al*. 1993).

4. METHODS

Monitoring fieldwork occurred during three field trips. During the first field trip (15 – 19 April 2013), habitat was monitored at 10 sites outside the mine lease where the SRE species nominated in Ministerial Statement 902 have been recorded. Wet-pit traps were also set at 10 sites outside the mine lease for *Idiommata* `MYG128`. During a second field trip (27 – 30 May 2013) the wet pit traps were retrieved and new traps set at the same 10 sites, with a number of traps re-positioned within sites to sample the various microhabitats. During a third field trip (23 – 24 July 2013), the second lot of wet pit traps were retrieved.

Details of habitat monitoring are given below, followed by a general description of the sites sampled and their locations, and then a description of sampling for *Idiommata* `MYG128`.

4.1. Habitat Monitoring

Habitat condition was monitored at 10 sites where *Missulena* `MYG252-DNA`, *Synothele* `MYG127`, *Aganippe* `MYG126` or the pseudoscorpion *Beierolpium* sp. have been recorded (Table 4-1). The purpose of monitoring was to compare habitat condition against a set of habitat targets to examine whether environmental conditions had remained suitable for the SRE species identified in Condition 9 of Ministerial Statement 902.

Sites were approximately 0.5 ha in extent and defined (at least on two sides) by the extent of drainage line vegetation. At each site, two field staff undertook a thorough walk through and around the site and then independently estimated the extent or condition site of each parameter listed in Table 4-1. The estimates were averaged to provide a score for each attribute at the site.

Habitat condition was assessed on the basis of three parameters: the amount of litter present, plant species richness and percentage plant cover. In addition, photographs were taken from photo points to provide an overall record of habitat condition, sites were assigned to a landform and the intensity of disturbance was quantified by estimating grazing intensity and fire history. Habitat targets associated with each parameter are derived for the first time, for most sites, in this report.

Landform and level of disturbance were estimated to help explain variations in the abundance of SRE species. Of the parameters specifically monitoring habitat condition, plant species composition was chosen to reflect the type of site and its overall ecological condition. Percentage plant cover was chosen to measure the density of vegetation because relatively dense vegetation (in relation to the surrounding

Table 4-1. Sites surveyed for habitat monitoring in 2013 and attributes scored.

				Parameters scored				
					Plant		Disturbance	
Site	Latitude	Longitude	SRE species code[1]	Litter index	Species richness	Percentage cover	Fire	Grazing
TR06	22°31`21.30"S	119°55`07.10"E	2	✓	✓	✓	✓	✓
TR08	22°39`04.00"S	120°07`04.00"E	1 & 3	✓	✓	✓	✓	✓
TR11	22°25`50.30”S	119°53`08.40”E	1 & 3	✓	✓	✓	✓	✓
TR12	22°37`47.70"S	120°07`21.30"E	2 & 3	✓	✓	✓	✓	✓
TR17	22°32`34.90”S	119°54`58.90”E	1 & 3	✓	✓	✓	✓	✓
TR19	22°31`13.50"S	119°54`43.70"E	1 & 3	✓	✓	✓	✓	✓
TR21	22°31`20.90”S	119°55`06.90”E	1 & 2	✓	✓	✓	✓	✓
1215_17	22°30`18.36"S	119°54`51.48"E	4	✓	✓	✓	✓	✓
1215_18	22°30`18.36"S	119°54`51.48"E	4	✓	✓	✓	✓	✓
1215_19	22°31`02.75"S	119°55`53.08"E	4	✓	✓	✓	✓	✓

[1] SRE species: 1, *Aganippe* `MYG126`; 2, *Missulena* `MYG252-DNA`, 3, *Synothele* `MYG127`, 4, *Beierolpium* sp.

landscape) is characteristic of drainage lines. Litter cover was measured to reflect plant productivity and lack of ground disturbance.

Parameters were estimated in the following ways. An index for the amount of litter was derived by visually estimating the areal extent of each of three litter categories (depth ≥5 cm, 1-5 cm, <1 cm). The estimates for each category were weighted by factors of 8, 3 and 0.1, respectively, and the sum of the weighted estimates provided the litter index. All plant species observed on the site were recorded to provide an estimate of plant species richness. Plant species cover was estimated separately for each species (as the percentage coverage) and the percentages were summed to provide an overall estimate of percentage plant cover (see ESCAVI 2003). Two types of disturbance were recognised, with the impact of fire and grazing by herbivores visually assessed using the categories in Table 4-2. Sites were assigned to a landscape category based on basic geomorphology.

Table 4-2. Disturbance categories for fire and grazing animals (see Bennelongia 2012).

Disturbance		
Category	Grazing	Fire
0	No tracks and all understorey vegetation intact	No fire scars
1	Less than 25% of area with either old tracks and/or understorey vegetation removal	Occasional burnt tree
2	25 - 50% of area with tracks and/or understorey vegetation removal	Many old burnt trees and post fire regeneration
3	Over 50% of area with well-worn tracks and/or understorey vegetation removal	Over 25% of area burnt or with fresh post fire regeneration

4.2. Sites

The 16 sites surveyed in 2013 (10 for habitat monitoring and 10 for *Idiommata* `MYG128`, with four common to both lists), plus site 1106_13, were all located on drainage lines and their vegetation consisted of thickets over tussock grasslands (Tables 4-1 and 4-3). All sites were broadly located within the Fortescue Valley, although sites TR25 and TR26 were within the foothills of the Chichester Range on drainage lines. The other eight sites were on the valley floor, north of Fortescue Marsh, in an area where numerous drainage lines meander southwards towards the Marsh (Figure 4-1). The area surrounding the drainage lines comprises very open plains supporting few scattered trees. Site photos are provided in Appendix 1.

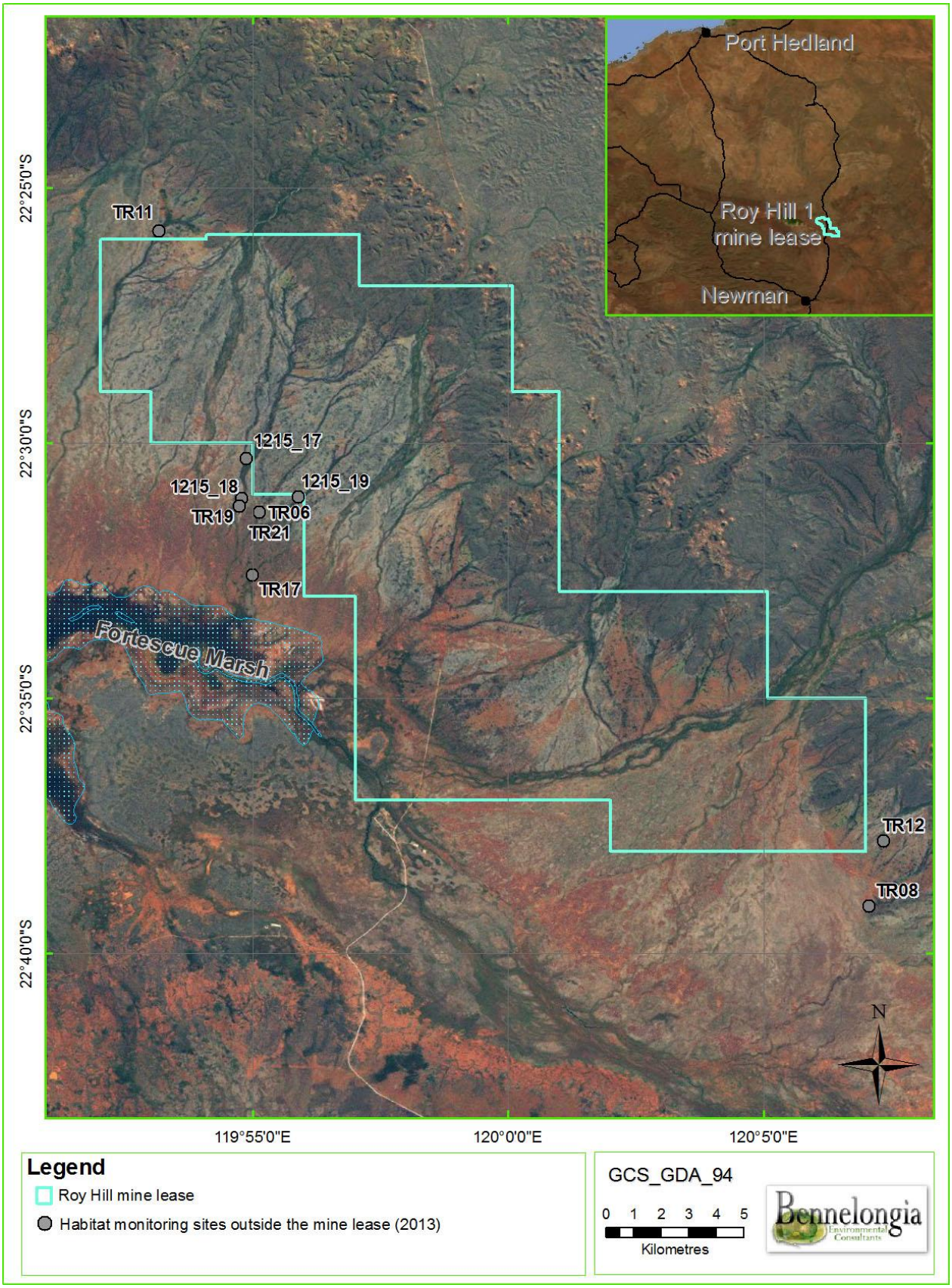


Figure 4-1. Sites where habitats of the four SRE species were monitored.

4.3. Idiommata `MYG128` Survey

All 10 sites sampled for *Idiommata* `MYG128` (Table 4-3, Figure 4-2) were searched intensively during the first two field trips to find possible burrows of this species. Some additional searching for *Idiommata* `MYG128` was conducted at site 1106_13 to confirm results from previous monitoring showing that the species no longer occurs there. Shapes of the burrow and lid (or the absence of a lid) were used to identify burrows as belonging to other species (see Bennelongia 2012). Possible *Idiommata* `MYG128` burrows were excavated to retrieve the spiders within them, which were preserved in 100% ethanol below a temperature of 4°C for four days prior to identification in the laboratory and, if required, DNA sequencing.

Table 4-3. Sites surveyed for *Idiommata* `MYG128`.

		Sample type			
Site	**Location**	**Wet-pit trapping**	**Hand foraging**	**Latitude**	**Longitude**
1106_13	Exclusion zone	×	✓	22°28`44.10"S	119°56`31.70"E
1215_17	Outside mine	✓	✓	22°30`18.36"S	119°54`51.48"E
1215_19	Outside mine	✓	✓	22°31`02.75"S	119°55`53.08"E
TR11	Outside mine	✓	✓	22°25`50.30”S	119°53`08.40”E
TR15	Outside mine	✓	✓	22°35`09.50”S	119°56`32.20”E
TR17	Outside mine	✓	✓	22°32`34.90”S	119°54`58.90”E
TR18	Outside mine	✓	✓	22°28`07.50”S	119°51`53.10”E
TR21	Outside mine	✓	✓	22°31`20.90”S	119°55`06.90”E
TR25	Outside mine	✓	✓	22°26`50.30"S	119°57`05.80"E
TR26	Outside mine	✓	✓	22°26`52.70"S	119°58`37.60"E
TR27	Outside mine	✓	✓	22°30`23.50"S	119°53`51.40"E

The focus of sampling, however, was wet-pit trapping and four wet-pit traps were set at each site surveyed for *Idiommata* `MYG128`. Wet pit traps spaced at distances of 20 to 100 m were dug into soil and left in place for six weeks or eight weeks (first and second sampling rounds, respectively). Each trap comprised a vertical 300 mm length of cylindrical PVC tube (110 mm diameter) with a white plastic bucket lid for a roof, which was attached to and raised 10-20 mm above the trap using metal brackets. The lid minimised the drift of debris and allowed access by vertebrates into the traps. A tight-fitting polypropylene jar inside the trap was filled with 800 ml of propylene glycol to preserve all invertebrates that fell into the trap. The traps were distributed among the microhabitats present in the drainage line habitat at each site, which included areas of accumulated litter in shady microhabitats or near logs, litter in open areas and bare open areas.

4.3.1. Laboratory Processing

The contents of the wet-pit traps were washed and sieved using a base sieve of 90 µm to remove the propylene glycol and debris. Retained samples were sorted under a dissecting microscope to extract fauna.

All mygalomorph spiders dug up via hand foraging or picked from wet pit trap samples were identified to species level using published and unpublished keys, unless damaged or otherwise unsuitable for identification. Specimens were dissected as required and viewed under dissecting and compound microscopes.

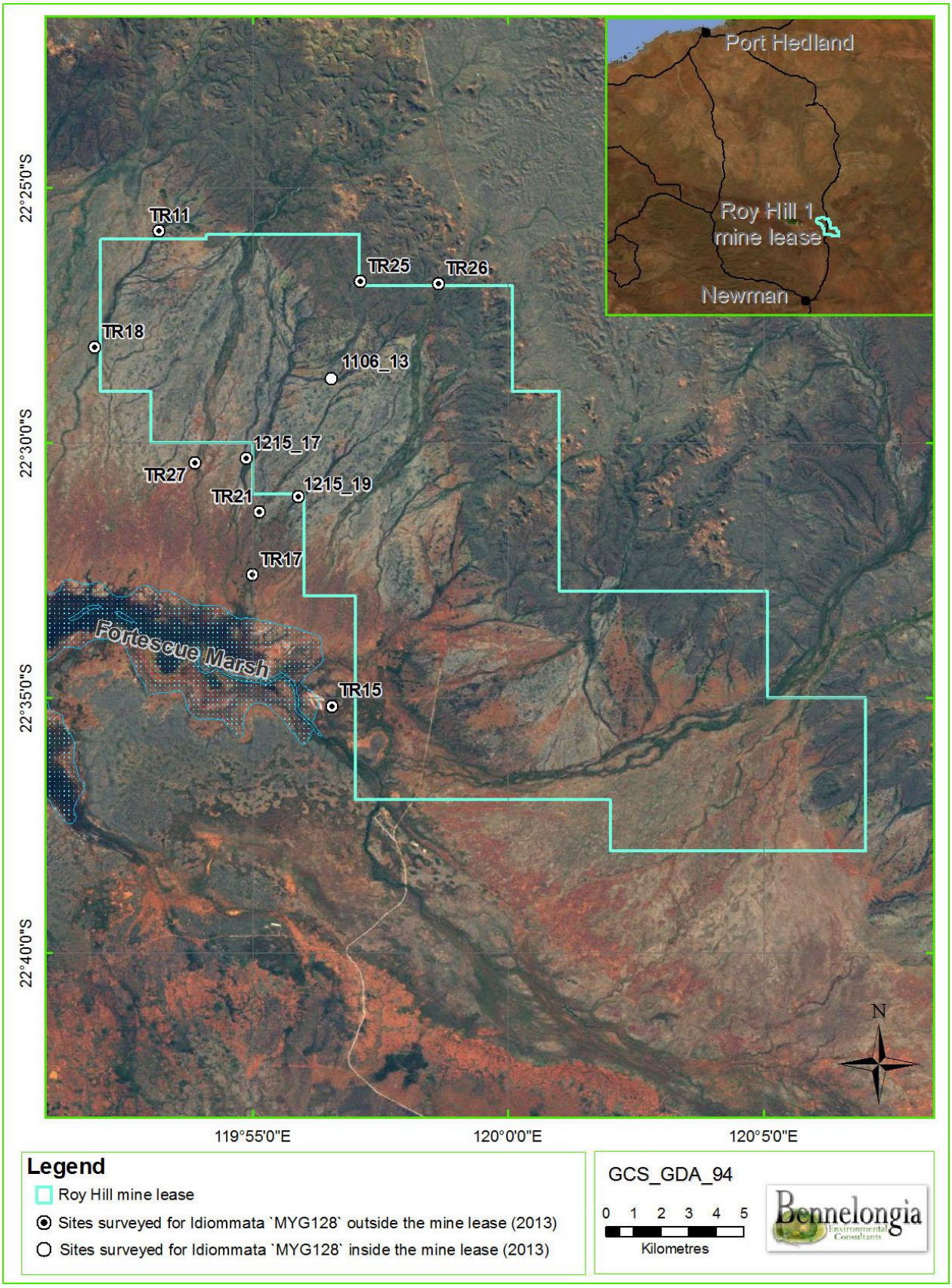


Figure 4-2. Sites where *Idiommata* `MYG128` surveys were conducted.

4.3.2. Multivariate analyses

In order to examine whether the sites surveyed for *Idiommata* `MYG128` were a close match for the one site where the species has been recorded (site 1106_13), plant species composition of selected sites on different dates were plotted using non-metric multi-dimensional scaling (nMDS). Plant composition (as a measure of the ecological characteristics of sites) was plotted for site 1106_13 in 2012 and 2013 (*Idiommata* `MYG128` was recorded here in 2009), the 10 sites sampled for *Idiommata* `MYG128` in 2013, and for the habitat monitoring sites scored in 2013. nMDS and principal components analysis routines in the Gingko software package were used to determine the similarity of sites and to examine which plant species were responsible for any patterns seen (principal component analysis). Percentage cover scores were square-root transformed.

4.3.3. Antecedent Rainfall

Conditions were relatively wet during the period of survey, with 130.8 mm of rain recorded at Bonney Downs (60 km north of Roy Hill) during the survey and 300.1 mm during the five weeks prior to survey. Annual rainfall is provided in Appendix 2.

4.4. Personnel

Fieldwork in 2013 was undertaken by Michael Curran and Sean Bennett. Sample sorting was carried out by Michael Curran, Sean Bennett, Jeremy Quartermaine and Jim Cocking. Identifications were made by Michael Curran.

4.5. Limitations

There were no logistic or other constraints on the survey, other than the sample effort for *Idiommata* `MYG128`, which is discussed further in section 5.

5. RESULTS

5.1. Habitat Monitoring

Habitat monitoring in 2013 showed variability in condition between sites (Table 5-1). This confirmed earlier results at Roy Hill, which also showed high spatial variability. Some results from 2011 and 2012 are also presented here to highlight that the variability is temporal as well as spatial (Table 5-2). This spatial and temporal variability matches the results of other published rangeland studies and is discussed further in section 6. The remainder of section 5.1 provides information on the extent of the variability.

Litter index values varied by a factor of 3.4 across sites, although variation was less between most sites (index varied from 16-32). Litter was more extensive at sites TR12 and 1215_17, with index values of 61.7 and 41.5, respectively (Table 5-1). Results from seven sites previously scored in 2011 or 2012 showed greater within-year variation and the litter index at site 11 was 5.3 times higher in 2011 than in 2013, which highlights the possible extent of temporal variability (Table 5-2).

Plant species richness varied across sites by a factor of 2.3 in 2013 (Table 5-1). This variability was driven principally by site 1215_17, which had 21 species. The other sites had between nine and 15 species. While plant species richness was mostly higher in 2013 than 2011 or 2012, site TR19 had 50% more species in 2012. The largest interannual variation in richness was at site 12, where species richness increased by a factor of 3.3 between 2012 and 2013.

Table 5-1. Scores for habitat attributes at the 10 monitoring sites in 2013.

Site	Litter index	Species richness	Percentage cover	Fire	Grazing	SRE Code*
TR06	28.4	15	96.5	0	2	2
TR08	28.4	9	70	0	2	1 & 3
TR11	19.7	13	107	0	1	1 & 3
TR12	57.4	10	105.5	0	2	2 & 3
TR17	16.8	15	80.5	0	2	1 & 3
TR19	28.4	10	104	0	2	1 & 3
TR21	28.4	14	106	0	2	1 & 2
1215_17	41.5	21	90	0	2	4
1215_18	28.4	9	73.5	0	2	4
1215_19	32.4	13	87	0	2	4

*SRE species codes: 1, *Aganippe* `MYG126`; 2, *Missulena* `MYG252-DNA`; 3, *Synothele* `MYG127`; 4, *Beierolpium* sp.

Table 5-2. Habitat parameter scores in 2011, 2012 and 2013 at sites with multiple measurements.

	Litter index			Species richness			Percentage cover		
Site	2013	2012	2011	2013	2012	2011	2013	2012	2011
TR06	28.4		32.4	15		7	96.5		79
TR08	28.4		32.4	9		7	70		62.5
TR11	19.7		104	13		12	107		132
TR12	57.4	78.5		10	3		105.5	90	
TR17	16.8	29.5		15	8		80.5	112	
19	28.4	107.5		10	15		104	185	
21	28.4	93		14	13		106	104	

Percentage cover was the most stable parameter across sites in 2013 and varied by a factor of only 1.5 (Table 5-1). Cover ranged from 70 to 107%. Results from 2011 and 2012 for the seven sites previously scored showed slightly more between-site variability because of higher maximum cover values, such as 185% at TR19 in 2012, but reflected the greater stability of percentage cover as a habitat measurement (Table 5-2).

Despite rainfall and grazing typically being regarded as the major factors affecting habitat condition in rangelands, neither appeared responsible for the patterns at the Project. Rainfall records from nearby Bonney Downs (Appendix 2) did not correlate particularly well with the conditions observed on-site from 2011 to 2013, although this may reflect the importance of localised rainfall events not recorded at Bonney Downs.

All sites other than TR11 exhibited moderate level grazing disturbance. Site TR11 exhibited minor grazing impacts (Table 5-1).

No site appeared to be disturbed by fire in 2013 (Table 5-1).

5.1.1. Species Habitat Preferences

There were no obvious differences in habitat parameter measurements at the sites monitored for different species (Table 5-3), which is perhaps not surprising when in some cases sites were monitored for multiple species. The data suggest, however, that it may be appropriate to use a single management target for all SRE species covered by Condition 9-2.

Table 5-3. Mean species scores (±SE) in 2013 for habitat parameters.

	N	Litter index	Species richness	Percentage cover
Aganippe `MYG126`	5	24.3±2.5	12.2±1.2	93.5±7.6
Missulena `MYG252-DNA`	3	38.1±7.5	13.0±1.2	102.7±2.4
Synothele `MYG127`	5	30.1±7	11.4±1.1	93.4±7.6
Beierolpium sp.	3	34.1±3.0	14.3±2.7	83.5±3.9

Table 5-4. Sites at which non-target mygalomorph spiders were collected in 2013.

	Hand foraging							Wet trap
	1106_13 (EX13)	**1215_17**	**TR11**	**TR15**	**TR17**	**TR18**	**TR21**	**1215_19**
Actinopodidae								
Missulena sp.	1							
Barychelidae								
Synothele `MYG127`	2		1		1			
Aurecocrypta sp. B04[1]	1							
Ctenizidae								
Conothele sp. B01		1		1	1			
Idiopidae								
Aganippe `MYG126`						1	1	1
Eucyrtops sp.			1					

[1] Male specimen and likely to be given a Western Australian Museum code.

5.2. Survey for Idiommata `MYG128`

No specimens of *Idiommata* `MYG128` were trapped and no potential burrows of the species were found during the survey in 2013.

The characteristics of site 1106_13 in 2009, when *Idiommata* `MYG128` was collected, are unknown. There was considerable variability in the characteristics of other sites but many sites with the same characteristics as 1106_13 in 2012 and 2013 (Figure 5-1) were sampled for *Idiommata* `MYG128` by foraging in 2012 without success. Site TR17, which was sampled in 2013, had characteristics intermediate between 1106_13 in 2012 and 2013.

Without information about the characteristics of site 1106_13 in 2009, which may differ considerably from those in 2012 and 2013, it is difficult to select sites more likely to support *Idiommata* `MYG128`. The nMDS plot shows that, in the absence of much information about *Idiommata* `MYG128` distribution, the 2013 trapping was focussed on sites considered to be prospective for mygalomorphs generally (Figure 5-1).

5.2.1. Non-target mygalomorph spiders

Thirteen specimens of mygalomorph spider, comprising six non-target species were collected during searches for *Idiommata* `MYG128` (Table 5-4). The specimens have been lodged with the Western Australian Museum.

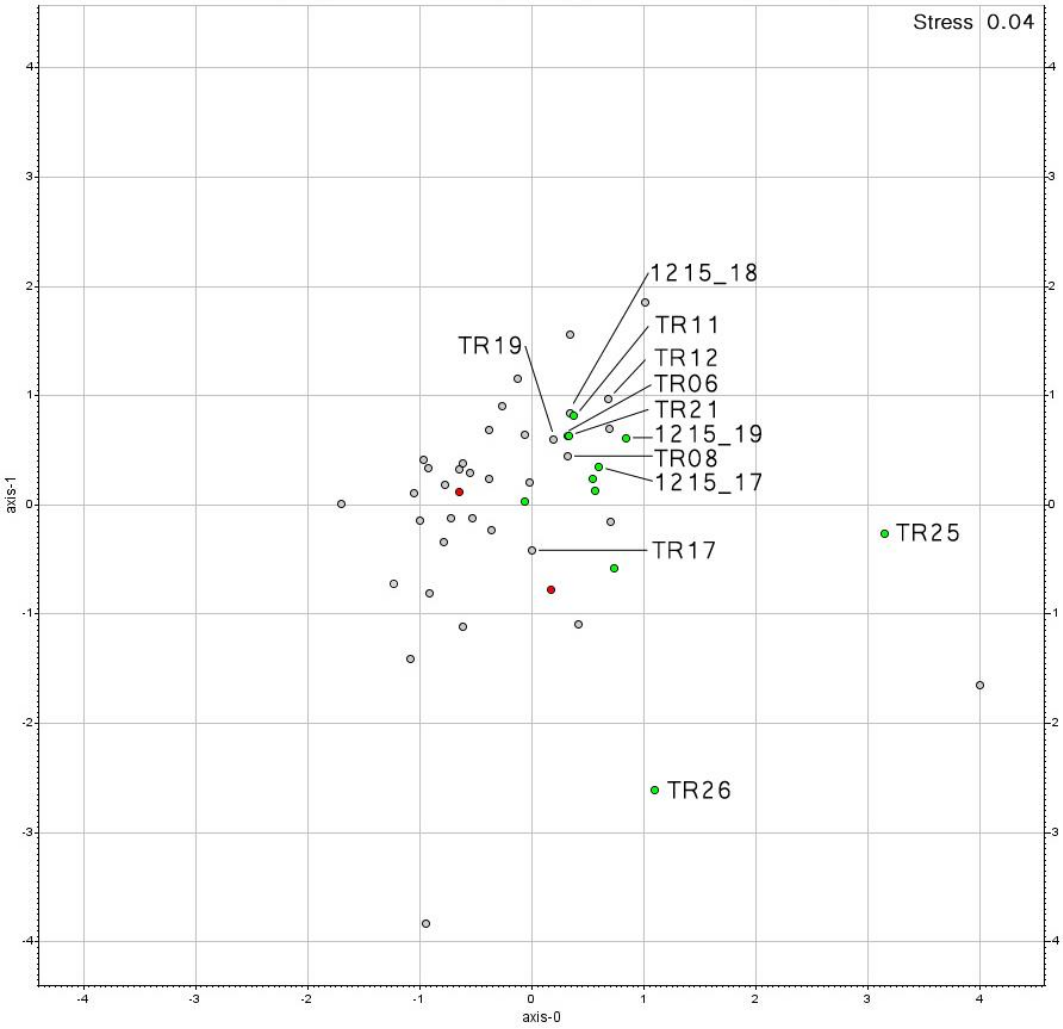


Figure 5-1. Two dimensional nMDS, based on plant composition, for sites sampled at Roy Hill for SRE species.

Site 1106_13 in 2012 and 2013 (red), *Idiommata* survey sites in 2013 (green), sites surveyed for SRE species by foraging in 2012 and or monitored for habitat in 2013 (labelled) (grey). Sites TR25 and 26 are also labelled (see text).

6. DISCUSSION

6.1. Habitat Monitoring

Under Ministerial Statement 902, no further population monitoring is required for the mygalomorph spiders and pseudoscorpion within the Project mine lease. Instead, habitat condition of selected sites where the five species are known to occur outside the Project should be monitored to provide assurance that the species are unlikely to be at risk from mining. In the case of *Idiommata* `MYG128`, sites where the species occurs are yet to be identified (see section 5.2).

Interim habitat targets for litter index, plant species richness and percentage cover were proposed by Bennelongia (2012). The targets are revised here, and the proposed complexity of the monitoring program is expanded, for two reasons. First, some of the sites monitored in 2013 differed from those listed in 2012. Second, examination of interannual variability suggested a more traditional rangeland habitat monitoring approach to setting targets is required than proposed by Bennelongia (2012) (see Friedel 1991; Ludwig and Tongway 1992). The new targets are aimed at recognising when habitat at a site has undergone a threshold change likely to result in impacts on target species that are independent of normal habitat changes associated with variation in annual rainfall and minor disturbances.

It is proposed that habitat should be monitored in three ways to determine with confidence whether any threshold changes in habitat condition (rather than natural fluctuations) have occurred. The three types of monitoring are:

- Compliance with target values. Habitat targets for the litter index, plant species richness and percentage cover parameters are proposed in Table 6-1. These targets represent the minimum values of the habitat parameters that can be considered to represent no change,
- Characterisation of habitat type. nMDS analysis of sites based on percentage cover of middle storey species will enable sites to put into broad habitat categories (Figure 6-1), and
- Photo points will illustrate any changes in a site over time to provide a visual record of overall site changes and a check on the validity of the other two types of monitoring (Appendix 1a).

Table 6-1. Proposed habitat targets for habitat attributes.

Site	Litter index	Species richness	Percentage cover
Missulena `MYG252-DNA`			
TR06	>15	>5	>60
TR12	>15	>5	>60
TR21	>15	>5	>60
Aganippe `MYG126`			
TR08	>15	>5	>60
TR11	>15	>5	>60
TR17	>15	>5	>60
TR19	>15	>5	>60
TR21	>15	>5	>60
Synothele `MYG127`			
TR08	>15	>5	>60
TR11	>15	>5	>60
TR12	>15	>5	>60
TR17	>15	>5	>60
TR19	>15	>5	>60
Beierolpium sp.			
1215_17	>15	>5	>60
1215_18	>15	>5	>60
1215_19	>15	>5	>60

*21 species in baseline survey

Monitoring sites (grey), floodplain sites (blue), degraded drainage line sites (red). Percentage cover at floodplain and degraded sites is shown beside sites. As a monitoring site becomes degraded, it will move down or to the left in the nMDS.

6.1.1. Habitat Targets

Habitat targets for three parameters have been derived for selected sites where *Missulena* `MYG252-DNA`, *Synothele* `MYG127`, *Aganippe* `MYG126` and *Beierolpium* sp. occur (Table 5-1). The targets are intended to identify the threshold at which habitat condition in the drainage line sites undergoes a change that will permanently alter the ecological character of the sites such that they are similar to the surrounding floodplain landscape, which is mostly bare ground and open tussock grassland with very low percentage cover. This means, for example, that habitat targets will not be met if the litter index at site TR06 is 10 (i.e. below the target of >15) and percentage cover is 40% (i.e. below the target of >60). It is suggested that sites should be regarded as meeting habitat targets overall if two of the three targets are met.

6.1.2. nMDS Analysis

Ordination of plant species data, using percentage cover values, is an efficient way of representing habitat change in response to disturbance (see Figure 3 in Friedel 1992). A simulated framework for monitoring of selected sites where *Missulena* `MYG252-DNA`, *Synothele* `MYG127`, *Aganippe* `MYG126` and *Beierolpium* sp. occur is provided in Figure 6-1. The analysis is based on mid-storey vegetation only. Drainage line sites where the SRE species occur are clearly separated from sites typical of the surrounding floodplain (blue circles) and from drainage sites where the effect of extreme disturbance has been simulated (red circles).

6.1.3. Photo Points

Taking photographs over several years from fixed monitoring points within a site, or using a series of available photographs, is a widely used technique for rapidly assessing vegetation change (Hussey 2001; Pickard 2002). The technique can also be used to assess more holistic site changes that determine ecological character. However, in this case it is proposed that photographs are used to check on the accuracy of conclusions about site condition derived from use of habitat targets and nMDs plots. Photographs should be taken looking upstream and downstream from the site centroid (coordinates given in Table 4-1). Photographs of baseline condition are shown in Appendix 1a.

6.1.4. Interpreting Monitoring Results

Very little is known about the biology of any of the four SRE species being monitored. This means that determining what site conditions are suitable for the persistence of the species should be an iterative process and some adjustment of habitat targets and nMDS interpretations may be necessary over time. Additional monitoring is required before it will be possible to quantify the boundary between site types in the nMDS plots. Therefore, it is proposed that a formal review of both habitat targets and nMDS plot boundaries between site types should be undertaken after each of the next two monitoring events.

As an overarching premise on which to base an interpretation of monitoring results while baseline information is improved in the next monitoring events, it can reasonably be assumed that while conditions at the monitored sites remain within their natural range, the four SRE species will continue to use these sites.

As has already been pointed out, temporal variability in condition is naturally high in drainage lines around the Project and the currently proposed habitat targets in Table 6-1 reflect this. Similarly, sites

are expected to show significant variation in position in nMDS plots between years and any boundaries between site types derived in future for nMDS plots should reflect this. Sites should be seen as having declined in condition (see Condition 9-4) only if there is evidence of a shift to an alternative kind of habitat (see Suding *et al*. 2004). Examples of shits to alternative habitats are a shift from riparian vegetation along a drainage line to open tussock grass floodplain or a shift from functional riparian vegetation to a permanent loss of most of this vegetation.

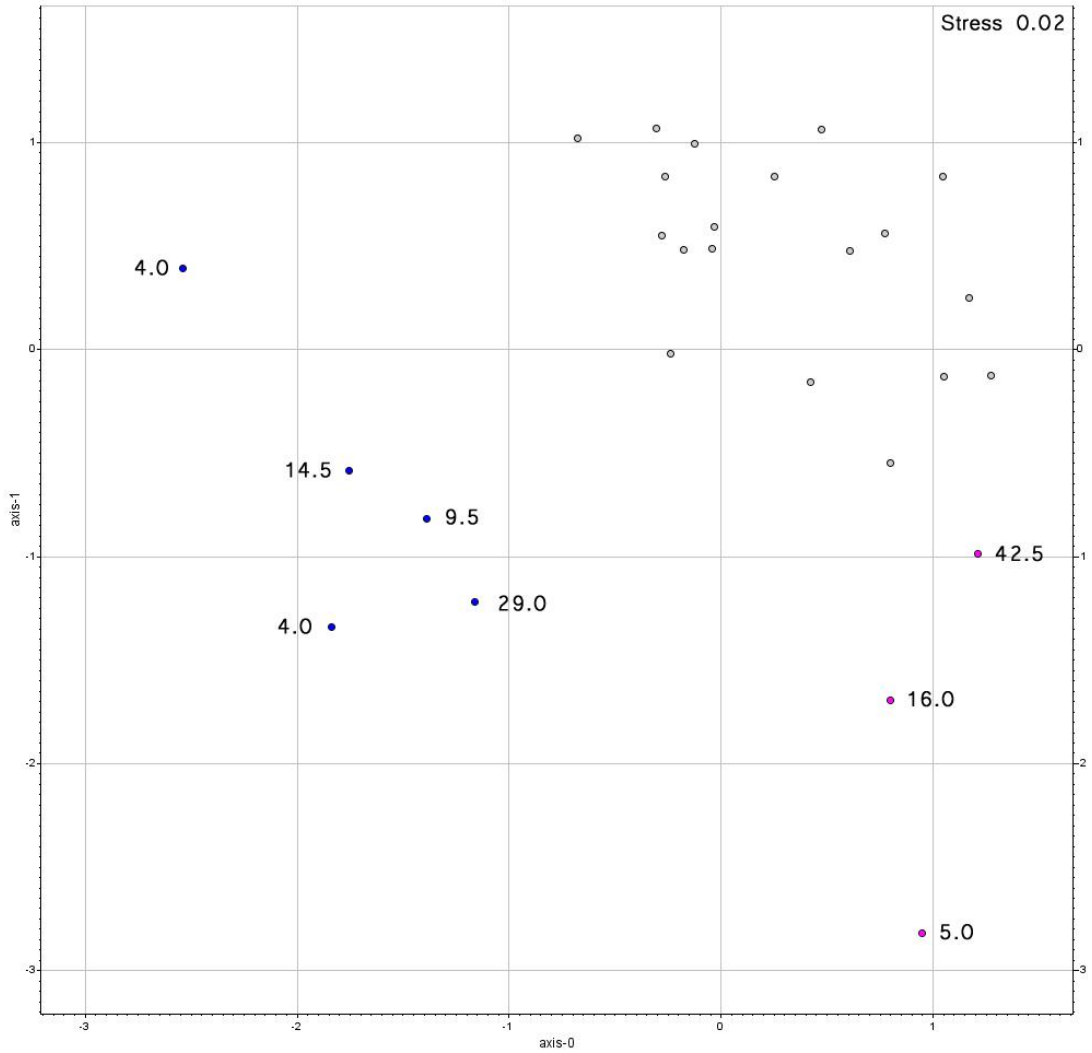


Figure 6-1. Simulated framework for habitat monitoring based on percentage cover of species.

6.1.5. Current Condition

It is concluded from examination of the data collected in 2013 that all sites currently appear in suitable condition to support the species occurring there.

6.1.6. Responding to Decline in Condition

Condition 9-4 of Ministerial Statement 902 provides no information about the proportion of sites that may decline in condition before a management response is required. Accordingly, the CEO of the Office of the Environmental Protection Authority should be notified of a decline at any site within 21 days of identification of the decline.

Condition 9-4 requires that evidence is provided to determine the cause of decline in site condition. Collection of rainfall data and scoring of grazing intensity and fire intensity should continue to be part of the monitoring program because the information will assist in explaining changes in condition. However, declines in condition recognized by the monitoring program are more likely to result from vegetation clearing, earthworks or movements by heavy vehicles within the site. While evidence regarding these activities may be apparent during fieldwork, and may also be apparent from the photo point monitoring, identification of the causes of decline will usually require assistance from mine staff.

6.2. Idiommata *`MYG128`*

Habitat monitoring sites have not been identified for *Idiommata* `MYG128` because of the failure to re-collect the species since its original collection as a single male at site 1106_13 between May and June 2009 (ecologia 2009). Greater trapping effort in 2010, foraging in 2011 and 2012, and wet-pit trapping and foraging in 2013 have failed to re-collect the species, although weather conditions in 2012 were similar to 2009 (Appendix 2).

The most likely explanation for the failure to re-collect *Idiommata* `MYG128` is that the species occurs in low abundance and has cryptic burrows, so that it has not been detected by foraging, and that insufficient wet-pit trapping has been conducted to collect the species through trapping. It is pertinent that during initial surveys of Roy Hill in 2006 and 2008 using foraging and dry-pit traps, ecologia (2008) recorded a single mygalomorph spider. In 2009, ecologia collected 10 mygalomorph spiders (including the one *Idiommata* `MYG128`) from a combination of 160 wet-pit traps set for 54 days each and foraging. Another 10 mygalomorphs were collected in 2010 from a combination of 190 wet-pit traps set for 40 – 50 days and foraging. It appears from the reports that seven animals were trapped in 2009 and between two and five animals were trapped in 2010.

The 2011 and 2012 surveys by Bennelongia (2011, 2012) used only foraging and recorded 824 mygalomorphs. During the survey in 2013, 40 wet-pit traps were set for a period of 42 days followed by a second period of 56 days and one mygalomorph was trapped. Additional spiders were collected when foraging to ensure they were not *Idiommata* `MYG128`.

While relatively little is known about the biology of the genus *Idiommata*, advice from the Western Australian Museum in 2012 suggested *Idiommata* is comprised of widespread but very low abundance species because it represents less than five per cent of mygalomorph specimens in the Museum collection. Nearly all have been collected in wet-pit traps. Assuming that about 10 species of mygalomorph spider occur at Roy Hill and that *Idiommata* `MYG128` occurs at only half the average abundance, existing data suggest more than 1000 wet-pit traps set for 42 days each may be required to catch a single specimen of *Idiommata* `MYG128`.

6.2.1. Site 1106_13

The very high collecting effort required to be likely to catch *Idiommata* `MYG128` means it is possible that the species still occurs at site 1106_13 and has simply not been re-collected. However, this seems unlikely. Apart from the earlier surveys of ecologia, intensive hand foraging was conducted by Bennelongia at this site in 2011, 2012 and 2013 without any evidence of species burrows. Furthermore, two wet-pit traps for eight weeks in 2012 at the site (not reported in the main summary of sampling effort above, Table 4-3) failed to collect the species. The most likely scenario is that the male animal collected in 2009 was dispersing from an unknown area in the vicinity of site 1106_13, where the species still persists.

6.2.2. Future monitoring for Idiommata `MYG128`

Based on existing information, it is considered unlikely that *Idiommata* `MYG128` continues to occur at site 1106_13. It may occur in other parts of the Project but there are no records of it doing so.

The level of sampling required to collect *Idiommata* `MYG128` at three locations outside Project in order to identify suitable habitat monitoring sites, as proposed under Condition 9-1, is sufficiently high to be outside the expectations of a monitoring program. Given the likelihood that *Idiommata* `MYG128` does not occur at site 1106_13, it is recommended to seek the agreement of the CEO of the Office of the Environmental Protection Authority that no habitat monitoring sites are required for *Idiommata* `MYG128`.

7. REFERENCES

Abensperg-Traun, M., Smith, G.T. and Arnold, G.W. (1996) The effects of habitat fragmentation and livestock-grazing on animal communities in remnants of gimlet woodland in the Western Australian wheatbelt. I. Arthropods. *Journal of Applied Ecology* **33**, 1281-1301.

Bennelongia (2011) Monitoring short range endemic invertebrates at the Roy Hill 1 Mine. Report 2011/115, Bennelongia Pty Ltd, Jolimont, 37 pp.

Bennelongia (2012) Monitoring short range endemic invertebrates at the Roy Hill 1 Mine Feb 2012. Report 2012/155, Bennelongia Pty Ltd, Jolimont, 38 pp.

Clarke, P.J., Latz, P.K., and Albrecht, D.E. (2005) Long-term changes in semi-arid vegetation: Invasion of an exotic perennial grass has larger effects than rainfall variability. *Journal of Vegetation Science* **16**, 237-248.

Crews, S., and Harvey, M.S. (2011) The spider family Selenopidae (Arachnida, Araneae) in Australia and Asia. *ZooKeys* **99**, 1-103.

ecologia Environment (2006) Roy Hill Iron Ore Project short range endemic survey. ecologia Environment, West Perth, 46 pp.

ecologia Environment (2008) Roy Hill additional SRE survey report. ecologia Environment, West Perth, 22 pp.

ecologia Environment (2009) Roy Hill Iron Ore Project. Interim short-range endemic invertebrate report. ecologia Environment, West Perth, 43 pp.

ecologia Environment (2010) Roy Hill additional short range endemic invertebrate survey. ecologia Environment, West Perth, 55 pp.

EPA (2009) Roy Hill 1 iron ore mining project stage 1, Report and recommendations of the Environmental Protection Authority 1342, 28 pp plus appendices.

EPA (2012) Roy Hill 1 Iron Ore Mining Project Stage 1 – Section 46 change to Condition 9 of Ministerial Statement 824 – short range endemic invertebrates. Report and recommendations of the Environmental Protection Authority 1439, 5 pp.

ESCAVI (2003) Australian vegetation attribute manual: national vegetation information system, version 6.0. Department of the Environment and Heritage, Canberra.

Friedel, M.H. (1991) Range condition assessment and the concept of thresholds: a viewpoint. *Journal of Range Management* **44**, 422-426.

Friedel, M.H., Pickup, G., and Nelson, D.J. (1993) The interpretation of vegetation change in a spatially and temporally diverse arid Australian landscape. *Journal of arid environments* **24**, 241-260.

Framenau, V.W. and Harvey, M.S. (2009) The short-range endemic invertebrate fauna of Roy Hill (ecologia project 1106) (Western Australia). Report to ecologia Environment. Western Australian Museum, Welshpool, 10 pp.

Harvey, M.S. (2002) Short-range endemism amongst the Australian fauna: some examples from non-marine environments. *Invertebrate Systematics* **16**, 555-570.

Hussey, B.M.J. (2001) Photographic monitoring of vegetation. Wildlife Notes 9. Department of Conservation and Land Management, Kensington, 6 pp.

Ludwig, J.A., and Tongway, D.J. (1992) Monitoring the condition of Australian arid lands: linked plant-soil indicators. In D McKenzie, DE Hyatt and VJ McDonald (eds), Ecological Indicators. Springer, New York, pp. 765-772.

Pickard, J. (2002) Assessing vegetation change over a century using repeat photography. *Australian Journal of Botany* **50**, 409-414.

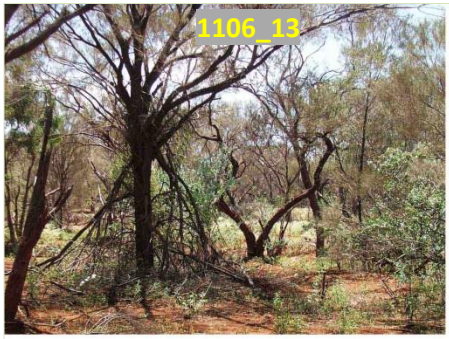
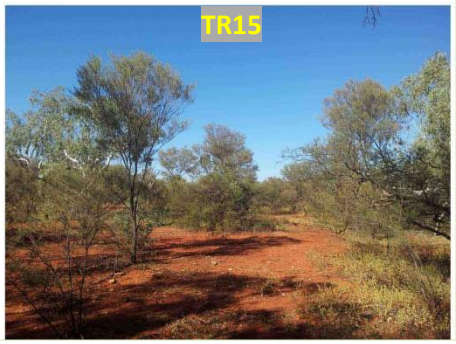
Suding, K.N., Gross, K.L., and Houseman, G.R. (2004) Alternative states and positive feedbacks in restoration ecology. *Trends in Ecology & Evolution* **19**, 46-53.

Appendix 1a. Photos of 2013 habitat monitoring sites.

Site	Site	Site
 TR06	 TR08	 TR08
 TR11	 TR11	 TR12
 TR17	 TR17	 TR19
 TR19	 TR21	 TR21
 1215_17	 1215_17	 1215_18

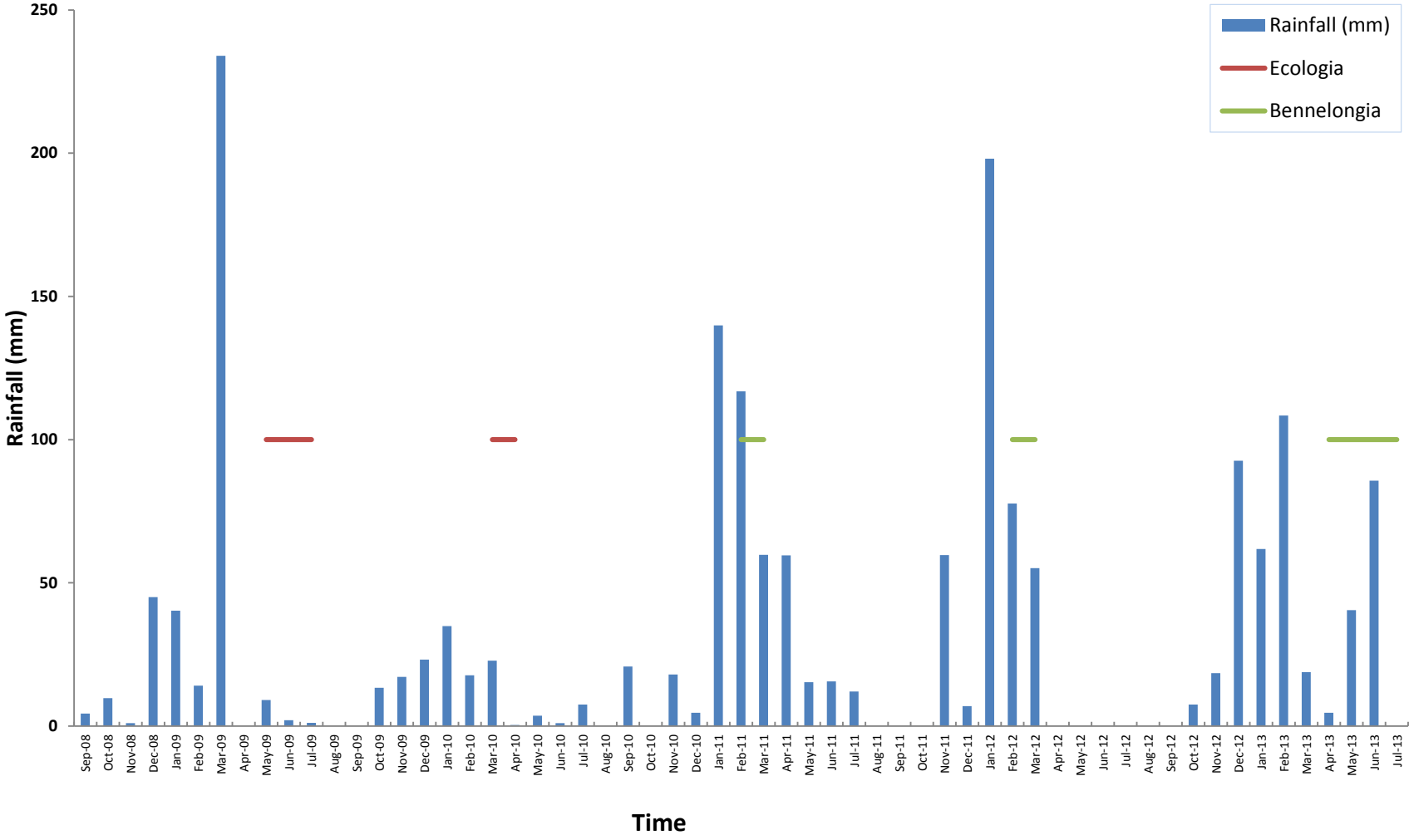
Site	Site	Site
 1215_18	 1215_19	 1215_19

Appendix 1b. Photos of sites surveyed for*Idiommata *`MYG128` in 2013.

Site	Site	Site
 1106_13	 1215_17	 1215_17
 1215_19	 1215_19	 TR11
 TR11	 TR15	 TR15

Site	Site	Site
 TR17	 TR17	 TR18
 TR18	 TR21	 TR21
 TR23	 TR23	 TR25
 TR25	 TR26	 TR26
 TR27	 TR27	No Image

Appendix 2. Monthly Rainfall Data (Bonney Downs) and Survey Timing.



Appendix 3. 2013 Habitat attributes for monitoring and Idiommata `MYG128` sites.

Table A. Floristics – species height and percentage cover per site.

Row Labels	1215_17	1215_18	1215_19	TR06	TR08	TR11	TR12	TR15	TR17	TR18	TR19	TR21	TR23	TR25	TR26	TR27
**Aerva javanica*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.5
**Bidens bipinnata*	0	0	0	0	0	0.5	0	0.5	0.5	0	0	0	0	0	0.5	0
**Cenchrus ciliaris*	1	0.5	0	0	10	0.5	0	1	1	30	0.5	0	0	0	20	15
Acacia aneura	40	40	40	65	45	55	35	25	65	75	75	75	75	0	0	25
Acacia atkinsiana	10	15	0	15	0	30	30	0	0	15	10	15	5	0	0	5
Acacia bivenosa	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Acacia pyrifolia var. *pyrifolia*	1	0	0	0.5	0	0	0	0.5	0.5	1	0	0.5	0.5	5	5	2
Acacia synchronicia	0	0	0	0.5	0.5	0	0	0	2	0	0	0	0	0	0	0.5
Acacia tetragonophylla	1	1	0.5	1	1	0	5	5	7	2.5	1	1	1	0	0	2
Acacia tumida	0	0	0	0	0	0	0	0	0	0	0	0	0	20	2	0
Acacia xiphophylla	2	0.5	1	0	0	5	1	0.5	0	0.5	0.5	0	0	0	0.5	1
Atalaya hemiglauca	0.5	0	0	0	0	0	0	2	0	2	0	0	0	0	2	0.5
Boerhavia repleta	0	0	0	0.5	0	0	0	0.5	0.5	0.5	0.5	0.5	0	0	0.5	0
Chrysopogon fallax	0.5	0.5	0.5	0.5	0	2	0	0	0.5	1	0.5	0.5	10	0	0	0.5
Cleome viscosa	0	0	0	0	0	0.5	0	0.5	0.5	0.5	0	0	0.5	0.5	0.5	0
Clerodendrum tomentosum var. *lanceolatum*	0.5	0	2	0.5	0	0	0	0	0	0	0	0.5	1	0	0	0
Corchorus lasiocarpus subsp. *lasiocarpus*	2	0	10	0	0	0	0	0	0	5	0	0	2	0	0.5	1
Corchorus sidoides	2	0	0.5	0	2	1	2	0.5	0.5	0	0	0	0	0.5	0.5	0
Corymbia hamersleyana	0.5	0	0	0	0	0	0	5	0	0.5	0	0	0	0.5	5	0.5
Cucumis maderaspatanus	0	0	0	0	0	0.5	0	0	0	0	0	0	0	0	0	0
Cymbopogon ambiguus	0	0	0	0	0	0	0	0	0	0	0	0	0	0.5	0	0
Cyperus vaginatus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Enteropogon ramosus	0	0	0	0	0	0	0	0.5	0.5	1	0	0	0.5	0	0	0
Eragrostis sp.	0	0	0	0	0	0	0	0	0	0.5	0	0	0.5	0	0	0
Eriachne mucronata?	25	15	30	10	10	10	30	0	0	25	15	10	50	10	0	5
Eucalyptus camaldulensis	0.5	0	0	0	0	0	0	20	0.5	0.5	0	0	0	5	1	2
Evolvulus alsinoides var. *villosicalyx*	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Gossypium robinsonii	0.5	0	0	0	0	0	0	0.5	0	0	0	0	0	1	1	0
Grevillea wickhamii	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Hakea lorea	0.5	0	0	0	0	0	0	0.5	0	0	0	0	0	0	0.5	0.5
Melaleuca eleuterostachya	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0
Melaleuca leucadendra	0	0	0	0	0	0	0	2	0	0	0	0	0	0	5	0
Mollugo molluginea	0	0	0	0	0	0	0	0	0	0	0	0	0	0.5	0	0

Row Labels	1215_17	1215_18	1215_19	TR06	TR08	TR11	TR12	TR15	TR17	TR18	TR19	TR21	TR23	TR25	TR26	TR27
Psydrax latifolia	0.5	0	0	0.5	0	0.5	1	0	0.5	0.5	0	0.5	0.5	0	0	0.5
Ptilotus calostachyus	0	0	0	0.5	0	0	0	0	0	0	0	0.5	0	0	0	0
Ptilotus obovatus	0	0.5	0.5	0.5	0.5	0	0.5	0	0	0.5	0.5	0.5	0.5	0	0	0.5
Salsola australis	0.5	0	0.5	0.5	0.5	0	0.5	1	0.5	0.5	0	0.5	0.5	0	0	0.5
Senna artemisioides subsp. *helmsii*	0.5	0	0.5	0	0	1	0	0.5	0	0	0	0	0	0.5	0.5	0
Senna artemisioides subsp. *oligophylla*	0.5	0	0.5	0.5	0	0	0	0.5	0	0.5	0	0.5	1	0	0.5	0.5
Senna glutinosa	0	0	0	0	0	0	0	0	0	0.5	0	0	0	0	0	0
Stemodia viscosa	0	0	0	0	0	0	0	0	0	0	0	0	0	0.5	0.5	0
Tephrosia rosea	0	0	0	0	0	0	0	0.5	0	0	0	0	0	1	0.5	0
Themeda triandra	0	0	0	0	0	0	0	0	0	0	0	0	0	2	1	0
Trioda wiseana?	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0
Triodia pungens	0	0	0	0	0	0	0	0	0	0	0	0	0	0	60	0
Total	**90**	**73.5**	**87**	**96.5**	**70**	**107**	**105.5**	**69.5**	**80.5**	**163.5**	**104**	**106**	**149**	**50**	**111**	**63.5**

*Alien to Western Australia.

Table B. Litter – depth and cover per site.

Site	Coverage of litter (%)			Litter index	Disturbance	
	<1 cm	1 – 5 cm	5 + cm		Fire	Grazing
1215_17	90	9.5	0.5	41.5	0	2
1215_18	94.5	5	0.5	28.45	0	2
1215_19	94	5	1	32.4	0	2
TR06	94.5	5	0.5	28.45	0	2
TR08	94.5	5	0.5	28.45	0	2
TR11	97.5	2	0.5	19.75	0	1
TR12	84.5	15	0.5	57.45	0	2
TR15	64	35	1	119.4	0	2
TR17	98.5	1	0.5	16.85	0	2
TR18	94	5	1	32.4	0	2
TR19	94.5	5	0.5	28.45	0	2
TR21	94.5	5	0.5	28.45	0	2
TR23	89	10	1	46.9	0	0
TR25	97.5	2	0.5	19.75	0	0
TR26	90	5	5	64	0	0
TR27	89	10	1	46.9	0	2

Appendix 4. Habitat attributes of monitoring sites surveyed in previous years.

	Litter index			Species richness			Percentage cover		
Site	**2013**	**2012**	**2011**	**2013**	**2012**	**2011**	**2013**	**2012**	**2011**
TR06	28.4		32.4	15		7	96.5		79
TR08	28.4		32.4	9		7	70		62.5
TR11	19.7		104	13		12	107		132
TR12	57.4	78.5		10	3		105.5	90	
TR17	16.8	29.5		15	8		80.5	112	
19	28.4	107.5		10	15		104	185	
21	28.4	93		14	13		106	104	