Ministers North to Yandi Corridor

SRE Invertebrate Fauna Survey

Biologic Environmental Survey

BHP Billiton Iron Ore Pty Ltd

July 2018

DOCUMENT STATUS				
Revision No.	**Author**	**Review / Approved for Issue**	**Approved for Issue to**	
			Name	**Date**
1	Brad Durrant Dean Main Nihara Gunawardene	Brad Durrant	David Mickle	30/07/2018
2	Claire Brooks Brad Durrant	Brad Durrant	David Mickle	21/08/2018
Final				

"IMPORTANT NOTE"

We have prepared this report for the sole purposes of BHP Billiton Pty Ltd ("Client") for the specific purpose only for which it is supplied. This report is strictly limited to the Purpose and the facts and matters stated in it, and does not apply directly or indirectly and will not be used for any other application, purpose, use or matter.

In preparing this report we have made certain assumptions. We have assumed that all information and documents provided to us by the Client or as a result of a specific request or enquiry were complete, accurate and up-to-date. Where we have obtained information from a government register or database, we have assumed that the information is accurate. Where an assumption has been made, we have not made any independent investigations with respect to the matters the subject of that assumption. We are not aware of any reason why any of the assumptions are incorrect.

This report is presented without the assumption of a duty of care to any other person (other than the Client) ("Third Party"). The report may not contain sufficient information for the purposes of a Third Party or for other uses. Without the prior written consent of Biologic:

a) This report may not be relied on by a Third Party; and

b) Biologic will not be liable to a Third Party for any loss, damage, liability or claim arising out of or incidental to a Third Party publishing, using or relying on the facts, content, opinions or subject matter contained in this report.

If a Third Party uses or relies on the facts, content, opinions or subject matter contained in this report with or without the consent of Biologic, Biologic disclaims all risk and the Third Party assumes all risk and releases and indemnifies and agrees to keep indemnified Biologic from any loss, damage, claim or liability arising directly or indirectly from the use of or reliance on this report.

In this note, a reference to loss and damage includes past and prospective economic loss, loss of profits, damage to property, injury to any person (including death) costs and expenses incurred in taking measures to prevent, mitigate or rectify any harm, loss of opportunity, legal costs, compensation, interest and any other direct, indirect, consequential or financial or other loss.

TABLE OF CONTENTS

TABLES

FIGURES

APPENDICES

EXECUTIVE SUMMARY

BHP Western Australian Iron Ore (BHP WAIO) commissioned Biologic Environmental Survey Pty Ltd (Biologic) to undertake a two season (Level 2) short-range endemic (SRE) invertebrate fauna survey covering the Ministers North to Yandi Corridor area (hereafter referred to as the Study Area), located approximately 90 km north west of the town of Newman in the Pilbara region of Western Australia. The Study Area is located between the southern boundary of BHPBIO Yandi mining operations and the northern boundary of the BHPBIO Ministers North exploration tenement and covers an area of approximately 2025 ha. This SRE invertebrate fauna report will be used to inform future environmental approvals across the area.

A desktop assessment was carried out in a manner consistent with the Western Australian (WA) Environmental Protection Authority (EPA) and BHPBIO's requirements for the environmental surveying and reporting of fauna. A review of databases (two online databases, three Western Australian Museum (WAM) databases and BHPBIO's SRE fauna database) and all publicly available literature relevant to the Study Areas and surrounding areas (within a 20 km radius), and additional reports commissioned and held by BHPBIO, was undertaken for the desktop assessment.

The database searches revealed a total of 102 records of invertebrate fauna representing seven higher taxa known to contain SRE, namely pseudoscorpions, scorpions, mygalomorph spiders, selenopid spiders, gastropods, isopods and millipedes.

Habitats considered suitable for SRE terrestrial invertebrates in the Pilbara were targeted for the baseline SRE survey, namely Gorges/ deep gullies, Shallow/ open gullies, Ridges/ breakaways, Drainage foci and Vegetation groves. Representation was also given to the other habitat types present (despite their lower SRE suitability), including Drainage lines, Woodlands, and Plains. Thirty seven sites were sampled for SRE fauna including habitat assessments, with an additional site opportunistically sampled for SRE fauna (no habitat assessment).

Invertebrate samples were collected from microhabitats in leaf litter, topsoil, under rocks, and woody debris at 38 sites in two trips (9th – 13th October 2017, and 14th – 24th June 2018). Almost all sites yielded invertebrate specimens - 18 out of 20 sites in Trip 1 and 17 out of 18 sites from Trip 2. A total of 205 invertebrate specimens, representing groups known to contain SRE invertebrate taxa, were collected from the 38 sites.

A total of 21 invertebrate taxa representing five target groups known to contain SRE; namely selenopid spiders, pseudoscorpions, scorpions, millipedes and isopods. Six of

these taxa have been regarded as widespread, nine considered 'Data Deficient' with the remaining six regarded as Potential SRE. The Potential SRE fauna comprised;

***Karaops* sp. indet.**

All *Karaops* specimens collected during the survey were either juvenile or female resulting in higher level identifications (mature males are required for species-level IDs). While the uncertain taxonomic resolution attributed to taxa being classified as 'Data Deficient' SRE status, habitat indicators (known from multiple habitat types extending beyond the Study Area) suggest that it is unlikely that the specimen would be restricted to the Study Area. The *Karaops* specimens could potentially be aligned with one of four species (*Karaops* sp. `nov. Area C`, *Karaops* `ARA001-DNA`, *Karaops* `ARA002-DNA` and *Karaops banyjima*), known from within 20km of the Study Area, two of which, *K.*`ARA001-DNA` and *K.* `ARA002-DNA` are known from Yandi Mine, immediately bordering the Study Area to the north.

***Lychas* '*bituberculatus* complex'**

This species complex is currently regarded as likely to contain SRE species and three Potential SRE *Lychas* species (*L*. 'sp.2', sp.3 and sp.4) occur 13 km to the south east of the Study Area. Additionally, three records of *L*. '*bituberculatus*' occur within 10 km of the Study Area and may represent the same taxa.

One specimen was recorded in gorge/gully and the other in drainage area/floodplain, which indicates that the species is unlikely to be restricted to the Study Area and likely disperses through drainage habitats.

***Lychas* 'hairy tail complex'**

This species complex is currently regarded as likely to contain SRE species and three Potential SRE *Lychas* species (*L*. 'sp.2', sp.3 and sp.4) occur 13 km to the south east of the Study Area. Additionally, three records of *L*. 'hairy tail complex' occur within 13 km of the Study Area to the south and may represent the same taxa.

Two specimens were recorded in gorge/gully and the other in hillcrest/hillslope habitat, which indicates that the species is unlikely to be restricted to the Study Area and may prefer rocky habitats which extend beyond the Study Area.

***Buddelundia* sp. '10ma'**

While this species is known from up to 60 km from the Study Area, this still indicates a potential distribution of less than 10,000 km^2 and therefore is regarded as a Potential SRE. With further sampling of isopods in the Pilbara, this species may be found beyond this

distribution or it may be confirmed to be restricted to its current known range and be regarded as a Confirmed SRE species.
This species has been recorded in several different habitat types and can therefore be regarded as unlikely to be restricted to the Study Area.

***Buddelundia* sp. '49'**

While this species is known from up to 80 km from the Study Area, this still indicates a potential distribution of less than 10,000 km^2 and therefore is regarded as a Potential SRE; however, these specimens represent two disjunct populations and there is some possibility that a taxonomic review of the species will confirm two separate species.
This species has been recorded in three different habitat types, all moderate to low suitability, and can therefore be regarded as unlikely to be restricted to the Study Area.

Philosciidae sp. indet.

This family is rarely collected in the Pilbara and therefore difficult to assess; however, all known species in the Pilbara are currently regarded as Potential SRE.

These specimens were all collected from gorge/gully habitats in the southern part of the Study Area which indicates a strong preference for these high suitability habitats. The gorge gully habitats do extend beyond the Study Area; however, the ability of these species to utilise other habitat types for dispersal is unclear and they may be highly restricted.

Habitats within the Study Area were classified into seven habitat zones; basalt outcrop, breakaway/cliff, gorge/gully, hillcrest/hillslope, major drainage line, minor drainage line and drainage area/floodplain. These zones were based on differences in the major landform features, drainage features and vegetation features that influence SRE occurrence.

Only one habitat zone within the Study Area is regarded to be of high suitability for SRE fauna, and therefore of high significance, gorge/gully. The remaining six habitat zones are either moderate (breakaway/cliff), moderate to low (hillslope/hillcrest, basalt outcrop and minor drainage) or low (major drainage and drainage area/floodplain).

None of the high or moderate suitability habitats are restricted to the Study Area. The occurrences of gorge/gully habitats are well connected to the breakaway/cliff, drainage area/floodplain and major drainage habitats which would provide suitable microhabitats for dispersal and protection for any species that require and are able to utilise these microhabitats.

1 INTRODUCTION

BHP Billiton Iron Ore Pty Ltd (BHPBIO) commissioned Biologic Environmental Survey Pty Ltd (Biologic) to undertake a two season (Level 2) short-range endemic (SRE) invertebrate fauna survey covering the Ministers North to Yandi Corridor area (hereafter referred to as the Study Area), located approximately 90 km north west of the town of Newman in the Pilbara region of Western Australia. The Study Area is located between the southern boundary of BHPBIO Yandi mining operations and the northern boundary of the BHPBIO Ministers North exploration tenement and covers an area of approximately 2025 ha (Figure 1.1). This SRE invertebrate fauna report will be used to inform future environmental approvals across the area.

1.1 Short-range endemic fauna

Endemism refers to the restriction of a species to a particular area, whether it is at the continental, national or local scale, the latter being commonly referred to as short-range endemism (Allen *et al.* 2002). Short-range endemism in a species is determined by several factors including life history, physiology, dispersal capabilities and opportunities as well as the tendency for differentiation and speciation. Other biotic and abiotic interactions both historical and current can also restrict the distribution of a species. (Ponder and Colgan 2002).

While many vertebrate fauna have been identified as restricted in geographical distribution, in recent years a number of invertebrate taxa have been highlighted as being comprised of a high proportion of species likely to be regarded as short-range endemics (SREs) (Harvey 2002). These taxa include freshwater snails (Ponder and Colgan 2002), land snails (Johnson *et al.* 2004) and mygalomorph spiders (Main *et al.* 2000). This restriction in geographical distribution has led to SRE invertebrate fauna becoming an important component of the environmental impact assessment process providing a focal point for survey work aimed at protecting species of high conservation value.

Figure 1.1: Location of the Study Area

705000 710000 715000 720000 725000

7485000 7480000 7475000

Yandi Mine

Phils Creek Mi

Port Hedland
Roebourne
Marble Bar
Millstream-Chichester National Park
Tom Price
Karijini National Park
HAMERSLEY RANGE
Newman

Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, © OpenStreetMap contributors, and the GIS User Community

Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Legend

- Study Area
- BHP Tenements
- Railway
- Major Resource Projects

biologic Environmental Survey

1:60,000

N

0 1 2 4 km

BHP - Ministers North to Yandi Corridor
SRE Invertebrate Fauna Survey
Fig. 1.1: Location of the Study Area

Coordinate System: GDA 1994 MGA Zone 50
Projection: Transverse Mercator
Datum: GDA 1994

Size A3. Created 14/09/2018

2 ENVIRONMENT

2.1 Vegetation

The 2,025 hectare (20.25 km^2) Study Area is located within the Hamersley Botanical District, which is part of the Eremaean Province (Beard 1990). It is dominated by tree and shrub - steppe communities consisting mainly of *Eucalyptus* and *Acacia* species. *Triodia pungens, Triodia wiseana* and some Mulga (*Acacia aneura*) occur within valley areas and short grass plains occur on alluvia. The vegetation within the Study Area is classified as the following two vegetation associations, as mapped by Beard (1975) and later refined by Shepherd *et al.* (2001):

- 82: Hummock grasslands, low tree steppe; Snappy gum over *Triodia wiseana*; and
- 18: Low woodland; mulga (*Acacia aneura*).

While the Pre-European extent for each vegetation association is close to 100 percent (Table 2.1), less than 10 percent of each association occurs within formal or informal reserves (Shepherd *et al*. 2001).

Table 2.1: Pre-European extent of vegetation associations occurring within the Study Area

Vegetation Association	Description	Pre-Euro. Extent Remaining (ha)	Remaining area (ha) in IUCN Class I-IV Reserves	% remaining Other Reserves	% remaining in DBCA Managed PL
Hamersley - 82	Hummock grasslands, low tree steppe; Snappy gum over *Triodia wiseana*	2,290,910 (100%)	8.9	0.2	1.0
Hamersley - 18	Low woodland; mulga (*Acacia aneura*)	24,659,110 (99.9%)	2	0.3	2.5

2.2 Geology

The regional geology has been described and mapped by the Geological Survey of Western Australia at a scale of 1:250,000 (Tyler *et al*. 1991). The geology within the Study Area belongs to the Hamersley Group of the Hamersley Basin, a late Archaean to early Proterozoic (2765-2470 Ma) basin which occurs over the southern part of the Pilbara Craton (Thorne and Tyler 1997). The geology of the Study Area is broadly classified as metamorphosed banded iron stone, chert, mudstone, siltstone, rhyolite, and numerous dolerite sills.

2.3 Soil

The CSIRO's Atlas of Australian Soils described and mapped the soils of Australia following Northcote et al. (1960-1968). The broad soil type mapped following Northcote et

al. (1960-1968) is soil type Fa13 – Ranges of banded jaspilite and chert along with shales, dolomites, and iron ore formations; some areas of ferruginous duricrust as well as occasional narrow winding valley plains and steeply dissected pediments. This unit is largely associated with the Hamersley and Ophthalmia Ranges. The soils are frequently stony and shallow and there are extensive areas without soil cover: chief soils are shallow stony earthy loams along with some soils on the steeper slopes. Associated are (Dr2.33, Dr2.32) soils on the limited areas of dissected pediments, while (Um5.52) and (Uf6.71) soils occur on the valley plains.

Tille (2006) collated the most recent and detailed mapping of Western Australia's Rangelands and Arid Interior. The Project Area falls within the Hamersley Plateaux zone of the Fortescue Province, which is said to comprise, "Hills and dissected plateaux (with some stony plains and hardpan wash plains) on sedimentary and volcanic rocks of the Hamersley Basin (Ophthalmia Fold Belt)" Tille (2006). The soils of this province are described as, "Stony soils with Red shallow loams and some Red/brown non-cracking clays and Red loamy earths" (Tille 2006).

Extensive hills and ridges occurring within the Study Area support areas with poorly formed skeletal soils or in some cases a complete lack of soil cover (where surface expression of the Robe pisolite are found). The hill slopes support uniform medium or fine textured soils consisting of loams and sands that are generally shallow, stony and lack nutrients. There are small areas of stony plains where the soils are better developed and deeper, represented most commonly as hard alkaline red-brown loams. The soils in the major drainage lines are alluvial sands and gravels with banks formed by a combination of alluvial sediments and duplex soils (Tille 2006).

2.4 Topography

The Study Area occurs within the central Hamersley Ranges which, together with the Ophthalmia Ranges, comprise the majority of the Hamersley Plateau. The dominant landform features are rocky hills with scree slopes and minor outcropping and rolling stony plains (Tille 2006). The topography of the Study Area is variable with a series of hills, breakaways, plateaux, and strike ridges dissected by gullies and drainage lines (Thorne and Tyler 1997). This landscape also extends beyond the Study Area to the north and south. The tallest mountains occur in the north east, known as the "Three Sisters".

2.5 Drainage and Groundwater

The average annual rainfall in the region is approximately 324.1 mm (as measured at Marillana Station), which occurs mainly as tropical summer storms associated with low

pressure systems, thus annual totals can vary widely. The minor and major drainage lines within the Study Area feed into the Marillana Creek which meanders roughly through the adjacent north of the Study Area, flowing west to east. Flows are sporadic and only occur after prolonged heavy rainfall as short-duration flooding with rapid peaks and slightly less rapid declines. Water rarely persists for long after flooding, tending to permeate down as a source of groundwater recharge into the underlying CID aquifer (BHP Billiton Iron Ore 2011a). Occasional persistent surface water occurs within small portions of major drainage lines with exposed rock.

2.6 Land systems

A total of 102 land systems were defined in the Pilbara at a scale of 1: 250,000 (Van Vreeswyk *et al.* 2004). The Study Area lies across four of these land systems (Figure 2.1). The northern and southern halves of the study area are primarily comprised of ranges associated with the McKay and Newman land systems respectively. A localised area within the central sector of the Study Area supports mesas characteristic of the Robe land system, with stony plains of the Boolgeeda land system represented in the south-east corner of the Study Area (Figure 2.1).

Figure 2.1: Land Systems of the Study Area

710000
712500
715000
717500
7480000
7477500

Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Legend

Study Area

Land Systems

- Disturbed Land
- Boolgeeda
- McKay
- Newman
- River
- Robe

biologic Environmental Survey

N

1:30,000

0 0.5 1 2 km

BHP - Ministers North to Yandi Corridor

SRE Invertebrate Fauna Survey

Fig. 2.1: Land Systems of the Study Area

Coordinate System: GDA 1994 MGA Zone 50
Projection: Transverse Mercator
Datum: GDA 1994

Size A3. Created 17/09/2018

3 METHODS

3.1 Desktop Assessment

A desktop assessment was carried out in a manner consistent with the Western Australian (WA) Environmental Protection Authority (EPA) and BHPBIO's requirements for the environmental surveying and reporting of fauna, including the following documents:

- EPA Guidance No. 56, Terrestrial Fauna Surveys for Environmental Impact Assessment in Western Australia (EPA 2016a);
- EPA Guidance Statement No. 20, Sampling of Short Range Endemic Invertebrate Fauna for Environmental Impact Assessment in Western Australia (EPA 2016b), Technical Guidance Sampling of short range endemic invertebrate fauna);
- BHPBIO Short-range Endemic Assessment Methods (SPR-IEN-EMS-013); and
- BHPBIO Biological Survey Spatial Data and Digital Photography Requirements (SPR-IEN-EMS-015).

3.2 Review of databases

Two online databases and three Western Australian Museum (WAM) databases were searched for terrestrial SRE records, as well as BHP Billiton Iron Ore's SRE fauna database:

- Department of Biodiversity, Conservation and Attractions (DBCA) NatureMap;
- Atlas of Living Australia (ALA);
- WAM Arachnida/ Myriapoda database;
- WAM Crustacea database;
- WAM Mollusca database; and
- BHP Billiton Iron Ore's SRE fauna database

The search parameters for each of these databases are detailed in Table 3.1.

Table 3.1: Databases searched for the review of previous records

Database	Parameters
NatureMap (accessed July 2018)	20 km radius around 22°47'04"S and 119°05'06"E
ALA (accessed July 2018)	Bounding box (40 km^2) Northwest 22°36'24.5"S, 118°53'45.5"E Southeast 22°58'26.3"S, 119°17'12.2"E
BHP SRE fauna (accessed July 2018)	Bounding box (40 km^2) Northwest 22°36'24.5"S, 118°53'45.5"E Southeast 22°58'26.3"S, 119°17'12.2"E
WA Museum Databases (accessed July 2018)	20 km radius around 22°47'04"S and 119°05'06"E

Figure 3.1: Previous BHP fauna surveys within 30 km of the Study Areas

660000 680000 700000 720000 740000 760000

7500000

7480000

7460000

Legend

Study Area

Previous SRE Surveys

- Ministers North Short-range Endemic Invertebrate Survey (Biologic 2015)
- Yandi Tenement Short-range Endemic Invertebrate Survey (Biologic 2015)
- Area C West to Yandi (Biota 2013a)
- Targeted Survey for Short Range Endemic Fauna in the Marillana Survey Area (Biota 2013b)
- Mainline Rail Expansion Project Short Range Endemic Invertebrate Fauna Survey (Subterraenean Ecology 2012)
- A survey of Short Range Endemic Invertebrate fauna in the Jinidi to Mainline Corridor (Biota 2012)
- Jinidi Lease and Jinidi to Mainline Rail SRE Review (Biota 2011)

biologic Environmental Survey

1:300,000

0 5 10 20 km

BHP - Ministers North to Yandi Corridor

SRE Invertebrate Fauna Survey

Fig. 3.1: Previous BHP fauna surveys within 30 km of the Study Areas

Coordinate System: GDA 1994 MGA Zone 50
Projection: Transverse Mercator
Datum: GDA 1994

Size A3. Created 17/09/2018

3.3 Review of previous studies

A review of all publicly available literature relevant to the Study Areas and surrounding areas (within a 30 km radius), and additional reports commissioned and held by BHPBIO, was undertaken for the desktop assessment (Figure 3.1).

No previous SRE surveys have been conducted within the Study Area. However, a number have been conducted in the immediate vicinity including two at Yandi (bordering the Study Area to the north) and most recently Ministers North (bordering the Study Area to the south), as well as a number of other SRE surveys within a 30 km radius. The results of these survey reports were reviewed in addition to database results, as listed below:

- Ministers North Short-range Endemic Invertebrate Survey (Biologic 2016)
- Yandi Tenement Short-range Endemic Invertebrate Survey (Biologic 2015);
- Area C West to Yandi Biota (2013a)
- Targeted Survey for Short Range Endemic Fauna in Marillana Survey Area (Biota 2013b)
- Mainline Rail Expansion Project SRE Inv Fauna Survey (Subterranean Ecology 2012)
- A Survey of Short Range Endemic Invertebrates in the Jinidi to Mainline Rail Corridor (Biota 2012); and
- Jinidi Lease and Jinidi to Mainline Rail SRE Review (Biota 2011)

These areas are not covered on the map in Figure 3.1 but were included in the review:

- Yandi Mine SRE Invertebrate Survey and Impact Assessment (Biologic 2013);
- Area C Mining Operation Environmental Management Plan (Revision 4) A, D, P1 and P3 Deposits: Terrestrial Invertebrate Short-range Endemic Assessment (Outback Ecology 2008);
- Assessment of Terrestrial Short-range Endemic Invertebrates, from Area C to Jinayri to Mount Newman Railway (AMBS 2010);
- Yandicoogina Junction South West and Oxbow Fauna Survey (Biota 2010).

3.4 Field survey

3.4.1 Field team

The field team consisted of Principal Zoologist; Morgan O'Connell, Senior Zoologists; Thomas Rasmussen and Ray Lloyd and Zoologist; Brighton Downing.

3.4.2 Survey timing and weather conditions

In order to satisfy a two-season (Level 2) survey, field surveys were undertaken during two phases as follows;

- **Phase 1:** 9th – 13th October 2017 (Morgan O'Connell and Thomas Rasmussen)

- **Phase 2:** 14th – 24th June 2018 (Ray Lloyd and Brighton Downing)

Long-term climatic data is not available for the Study Area (or nearest weather station - Barimunya); however, the BoM weather station at Marillana (Station 5009) and BHP's Barimunya station (Station 505053, located 15 km to the north-west) can be used as reference points for climatic observations in the Study Area (BoM 2018). The average monthly temperatures at Barimunya and rainfall observations at Marillana for a 12-month period covering both survey phases (August 2017 – July 2018) are plotted against the longer-term averages in Figure 3.2 below.

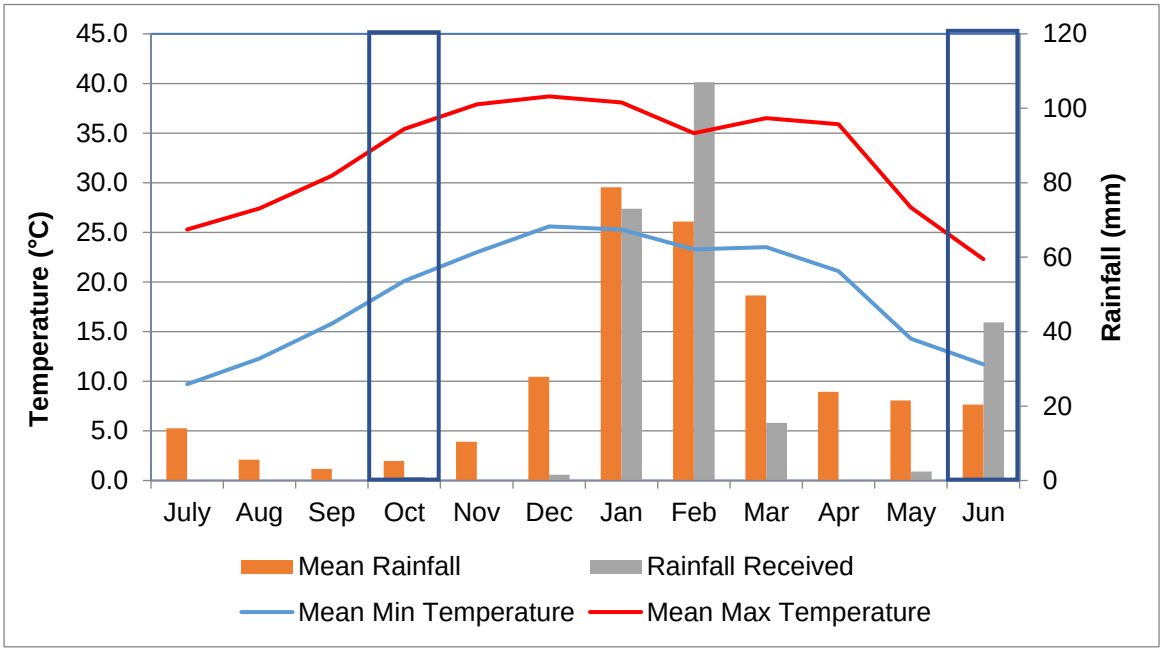


Figure 3.2: Long-term average rainfall plotted against recent rainfall observations (blue boxes indicate survey months) at Marillana (station 5009), and average monthly temperatures from Barimunya (station 505053).

As the activity of SRE invertebrate fauna can be dependent on rain events, rainfall in the month (and months prior) to each survey phase was considered. Timing for the Phase 1 survey (October 2017) was typical of the Pilbara dry-season, with the 3 months prior to Phase 1 (July - September 2017) recording no rainfall at Marillana and only 1 mm falling in October (BoM 2018).

Timing for the Phase 2 survey (June 2018) proceeded the typical Pilbara wet-season months. Rainfall observations at Marillana station in the 3-months prior to the survey (March-May) were lower than the long-term averages (Figure 3.2). However, June 2018 experienced significantly higher than average rainfall with 83 mm recorded in a three-day window (6 - 8 June) approximately 1 week prior to the survey. This amount of rainfall is consistent with wet-season averages for the area (56.5 mm; December - March long-term rainfall average) and as such, climatic conditions leading up to and during the survey were considered suitable for a wet season SRE survey. Temperatures were considered average for the seasons surveyed and it is considered unlikely that these were a limiting factor for the faunal results (BoM 2018).

3.4.3 Sampling site selection

Sites were chosen according to Guidance Statement 20 (EPA 2009) and BHP Billiton Iron Ore's Guidance for Short-Range Endemic Invertebrate Surveys in the Pilbara Region (SPR-IEN-EMS-013) (BHP Billiton Iron Ore 2009). Sampling and assessment sites data is shown in Appendix A.

Habitats considered suitable for SRE terrestrial invertebrates in the Pilbara were targeted for the baseline SRE survey, namely gorges/ deep gullies, shallow/ open gullies, ridges/ breakaways, drainage foci and vegetation groves. Representation was also given to the other habitat types present (despite their lower SRE suitability), including drainage lines, woodlands, and plains. Thirty seven sites were sampled for SRE fauna including habitat assessments (Figure 3.3), with an additional site opportunistically sampled for SRE fauna (no habitat assessment).

3.4.4 Habitat assessment

Thirty seven SRE invertebrate fauna habitat assessments were conducted during the survey (Figure 3.3) in accordance with BHP Billiton Iron Ore's Guidance for Short-Range Endemic Invertebrate Surveys in the Pilbara Region (SPR-IEN-EMS-013) (BHP Billiton Iron Ore 2009). The habitat assessments were aimed at determining the significance of each site as Potential SRE habitat, and hence the likelihood that each site may contain SRE fauna. The habitat assessment was based on three major factors influencing the significance of habitats for SRE species; isolation, protection and habitat complexity, as briefly outlined below and illustrated in Figure 3.4.

Figure 3.3: Survey effort in the Study Area

708000 710000 712000 714000 716000 718000

7482000 7480000 7478000 7476000

MNY24 MNY29 MNY31 MNY32 MNY38 MNY30 MNY18 MNY25 MNY07 MNY06 MNY09 MNY37 MNY17 MNY26 MNY01 MNY08 MNY19 MNY20 MNY05 MNY36 MNY35 MNY16 MNY13 MNY11 MNY22 MNY03 MNY02 MNY21 MNY33 MNY34 MNY12 MNY10 MNY27 MNY14 MNY04 MNY15 MNY23 MNY28

Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Legend

Study Area

SRE Sampling Sites

biologic Environmental Survey

1:30,000

0 0.5 1 2 km

BHP - Ministers North to Yandi Corridor

SRE Invertebrate Fauna Survey

Fig. 3.3: Survey effort in the Study Area

Coordinate System: GDA 1994 MGA Zone 50
Projection: Transverse Mercator
Datum: GDA 1994

Size A3. Created 17/09/2018

***Isolation*:** based on the level of connectivity between sites, which share similar habitat characteristics. Isolation is the most important factor when it comes to the level of risk, as any fauna with limited dispersal characteristics, regardless of the habitat preference, will likely be, at least, an isolated population. Examples include islands and mountaintops; in the Pilbara, peaks like Mt Meharry have been shown to harbour significant SRE species (Durrant 2011).

***Protection*:** this primarily relates to protection from solar exposure; however, protection from disturbance is also very important for the long term viability of SRE habitats and communities, *i.e.* protection from fire, flood and invasive species.

Protection is provided at two levels; the site level where the structural composition of the site (aspect, slope *etc.*) can provide protection from exposure and disturbance by providing physical barriers (*e.g.* gorges and gullies); and the habitat level where certain microhabitat characteristics, associated with habitat complexity, provide more direct protection, particularly from exposure (*i.e.* leaf litter, rocky substrates, canopy cover and soil depth).

***Habitat complexity*:** this factor drives species richness and often abundance at a site, *i.e.* the more complex a site is, the more species and individuals it is likely to contain. This is particularly important, as a number of SRE groups are predators; therefore the richness and abundance of prey species are critical to their survival.

Complexity, with respect to SREs, is based around a number of microhabitat types:

- Leaf litter: both depth and structural variation;
- Rocky substrates: loose rocks and crevices;
- Vegetation variation: flora richness and structural variation; and
- Soil: depth and structural variation.

Likewise, the complexity of the habitat is important to detritivore SRE taxa (such as isopods, millipedes and some snails) which rely upon decaying leaf litter, woody debris and organic matter for survival. Examples in the Pilbara include deep gullies and gorges, where many of these areas contain most of the above microhabitat types, and therefore tend to be the richest areas.

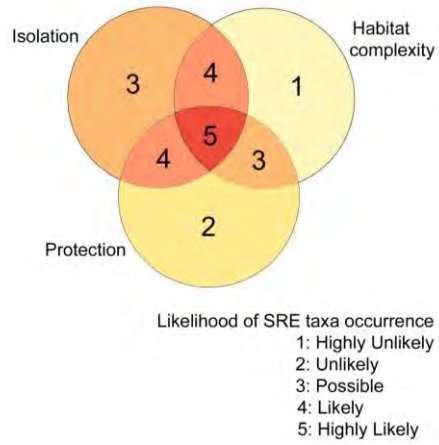


Figure 3.4: Habitat assessment diagram

3.4.5 Sampling techniques

The sampling techniques employed for the baseline SRE sampling included active foraging, leaf litter sifting, soil sifting and targeted searches for spider and scorpion burrows. The target taxonomic groups were mygalomorph spiders, selenopid spiders, scorpions, millipedes, pseudoscorpions, land snails and isopods.

The sampling methods adopted were carried out in accordance with the following documents:

- Environmental Protection Authority (EPA) Position Statement No. 3 'Terrestrial Biological Surveys as an Element of Biodiversity Protection' (EPA 2002);
- Guidance Statement No. 56 'Terrestrial Fauna Surveys for Environmental Impact Assessment in Western Australia' (EPA 2004);
- Guidance Statement No. 20 'Sampling of Short Range Endemic Fauna for Environmental Impact Assessment in Western Australia' No. 20 (EPA 2009); and
- BHP Billiton Iron Ore Guidance for SRE Invertebrate Surveys in the Pilbara Region (SPR-IEN-EMS-013) (BHP Billiton Iron Ore 2009).

Active foraging (baseline SRE sampling only)

Active foraging was undertaken at each sampling site for 1.5 person hours during the survey, and involved various techniques relevant to the following microhabitats:

- Under rocks, within cracks and crevices: suitably sized rocks were over turned, and rocky microhabitats were actively searched for rock dwelling species;
- Woody debris: larger logs and woody debris were investigated and over turned searching for detritivores;
- Vegetation and tree bark: significant vegetation (*e.g.* Mulga, and fig trees) were actively searched, including underneath sheets of bark; and

- Burrow searching: active searches were undertaken for mygalomorph spider and scorpion burrows within suitable habitats. Note: searches for burrows are undertaken during foraging time and also whilst walking through the Study Area, but time taken to excavate burrows is additional to foraging time.

Leaf litter searching (baseline SRE sampling and targeted sampling)

At each site, leaf litter, humus and soil (to approximately 15 cm below surface) was placed in a sieve at the site and agitated to divide the sample into three grades (>7 mm, >3 mm, >1.4 mm). Each grade was thoroughly searched for target SRE species such as pseudoscorpions, millipedes, snails, and small scorpions. The maximum volume of litter in the sieve was approximately 4808 cm^3, and up to two sifts were conducted at each site, providing sufficient leaf litter and humus was available.

Specimen preservation and taxonomy

All specimens were preserved in 100% ethanol to preserve DNA for sequencing. Isopods were transferred to 70% ethanol for storage at the request of Dr Simon Judd.

All isopods were sent directly to Dr Simon Judd for identification and Arachnida (excluding Araneomorphae) and Myriapoda specimens were identified by Dr Erich Volshcenk. Araneomorph specimens were identified by Brad Durrant.

3.5 Limitations of the survey

EPA Guidance Statement No. 56 (EPA 2004) outlines several potential limitations to fauna surveys, which are presented and discussed in Table 3.2. It was considered that there were no material limitations to the survey.

Table 3.2: Survey limitations and constraints

Potential limitation or constraint	Applicability to this survey
Experience of personnel.	All field personnel involved have extensive fauna survey experience in the Pilbara, all with specific terrestrial invertebrate experience (15+ years total).
Scope (what faunal groups were sampled and whether any constraints affect this).	All target fauna groups were sampled. No constraint.
Proportion of fauna identified.	All fauna were identified by relevant experts. No constraint.
Sources of information (recent or historic) and availability of contextual information.	All previous surveys relevant to the planning of the survey were available and consulted.
Proportion of the task achieved.	A two-season SRE invertebrate survey was completed for the Study Area.
Disturbances (e.g. fire or flood).	No constraint (no discernible disturbances were noted during surveys of the Study Area).
Intensity of survey.	Based on Study Area size and knowledge of previous SRE sampling in the Pilbara, SRE sampling and habitat

Potential limitation or constraint	Applicability to this survey
	assessments were adequate throughout the entire Study Area.
Completeness of survey.	Considering the current two-season survey effort, the Study Area has been adequately surveyed.
Resources (e.g. degree of expertise available).	All resources required to complete the survey were available.
Remoteness or access issues.	Vehicle and track access was limited within the Study Area though helicopter access ensured all targeted habitats/sites were sampled therefore not considered limiting factors.
Timing of survey, weather, seasonality	Survey timing (two-season) did not follow traditional Pilbara 'wet-season' months (Dec-Mar), though rainfall observations prior to Phase 2 were consistent with long-term 'wet-season' rainfall averages for the area, and as such, not considered a limiting factor.

3.6 Assessment of species' conservation significance

The SRE status categories used in this report broadly follow the WAM's revised categorisation for SRE invertebrates. This system is based upon the 10,000km^2 range criterion proposed by Harvey (2002), and uses three broad categories to deal with varying levels of taxonomic certainty that may apply to any given taxon (Table 3.3).

Table 3.3: SRE categorisation used by WAM taxonomists

	Taxonomic Certainty	Taxonomic Uncertainty
Distribution < 10 000km^2	Confirmed SRE • A known distribution of < 10,000km^2. • The taxonomy is well known. • The group is well represented in collections and/ or via comprehensive sampling.	Potential SRE • Patchy sampling has resulted in incomplete knowledge of geographic distribution. • Incomplete taxonomic knowledge. • The group is not well represented in collections. • Category applies where there are significant knowledge gaps. **SRE Sub-categories may apply:** A) Data Deficient B) Habitat Indicators C) Morphology Indicators D) Molecular Evidence E) Research & Expertise
Distribution > 10 000km^2	Widespread (not an SRE) • A known distribution of > 10,000km^2. • The taxonomy is well known. • The group is well represented in collections and/ or via comprehensive sampling.	

Under this system, "Potential SRE" status is the default categorisation for species within the typical SRE taxonomic groups including mygalomorph spiders, selenopid spiders, land snails, pseudoscorpions, scorpions, and isopods, unless sufficient evidence exists to confirm widespread or confirmed SRE status.

Potential SRE status is sub-categorised by what is currently known about the species in question; *i.e.* whether there are B) habitat indicators, C) morphology indicators, D) molecular evidence, or E) a weight of general knowledge and experience with the group that suggests a reasonable likelihood that the species could be SRE. In terms of SRE likelihood, the more evidence that exists under sub categories 'B', 'C', 'D', and 'E', the greater the likelihood that further investigation would confirm that the species is a SRE; however, the Potential SRE category 'A' - data deficient is unique. This category indicates that the current information is insufficient to adequately assess the SRE status of the species in question. In such cases, where the SRE status cannot be confirmed, a conservative approach would be unable to consider the SRE risk to be higher than average where the taxonomy of the genus (or family) requires significant review in order to make any statement on SRE status, and/or the genus is not known to include any confirmed SRE species within the region (subject to the extent of prior sampling/ taxonomic effort).

To avoid confusion with other Potential SRE species for which there is some certainty and/or some precedent for their SRE status, this report represents the WAM's "Potential SRE - category 'A' - data deficient" only as "data deficient". The results from taxonomists are also presented within the broader context of the results from habitat assessment, habitat connectivity, and other ecological information collected during the survey. This approach aims to provide a more holistic assessment of SRE likelihood at scales relevant to the project, as well as the standard SRE range criterion of <10,000km^2 (Harvey 2002).

4 RESULTS

4.1 Database searches

Database searches containing records of target SRE fauna groups (mygalomorph spiders, selenopid spiders, land snails, pseudoscorpions, scorpions, isopods and millipedes), were compiled from all known previous surveys within a 20 km radius of the Study Area, providing an up-to-date SRE invertebrate fauna list for the Study Area and surrounds. The database searches (Table 3.1) revealed a total of 102 records of invertebrate fauna representing seven higher taxa known to contain SRE, namely pseudoscorpions, scorpions, mygalomorph spiders, selenopid spiders, gastropods, isopods and millipedes.

Pseudoscorpions accounted for 29 morphospecies belonging to five families; Atemnidae, Chernetida, Garypidae, Garypinidae, and Olpiidae. Eleven of these were identified as potential SRE with a further four taxa recognised as confirmed SRE species.

A total of nine morphospecies of scorpions were recorded from families Buthidae (5 species) and Urodacidae (4 species). Of these, five were identified as potential SRE with two taxa, *Urodacus* `firetail` and *Urodacus* `pilbara 8`, currently known as a confirmed SRE species.

The mygalomorph spiders were the most abundant of the SRE groups with 48 morphospecies belonging to five families; Actinopodidae, Barychelidae, Halonoproctidae, Idiopidae, and Nemesiidae. These comprised of a total of thirteen potential SRE and 21 confirmed SRE taxa.

All of the selenopid spiders identified were known from the single genus *Karaops*. While none of the five morphospecies were confirmed SRE, four were identified as potential SRE and a further taxon, *Karaops* sp. indet., as 'data deficient' owing to its low taxonomic resolution.

Seven millipede morphospecies belonging to two families were recorded from the database searches. Each family (Paradoxosomatidae and Trigoniulidae) comprised of three morphospecies from single genera, *Antichiropus* and *Austrostrophus*, respectively. All known species of *Antichiropus* from the Pilbara currently represent confirmed SRE fauna while a further two *Austrostrophus* species were identified as potential SRE.

The current SRE status of 34 records (from all target SRE groups) potentially representing SRE, could not be determined due to poor taxonomic resolve (higher level identifications). This may be attributed to specimen being damaged, juvenile or the wrong sex for species-level identifications. Where the SRE status of taxa could not be determined due to poorly resolved taxonomy, their status is classified as 'Data Deficient' and therefore cannot be

regarded further in this assessment. Amongst the data deficient records were 13 pseudoscorpions, two scorpions, 14 mygalomorph spiders, and single representatives of selenopid spider, gastropod, isopod and millipede. A further isopod taxon, Philosciidae sp. indet., was identified as a Potential SRE.

Table 4.1: Database search results for SRE target groups within 20 km of the Study Area

Higher Taxon	Family	Species/ morphospecies	SRE Status
Pseudoscorpiones			
	Atemnidae	*Oratemnus* sp. indet.	Data Deficient
	Chernetidae	Chernetidae sp. indet.	Data Deficient
		Haplochernes sp. indet.	Data Deficient
		Haplochernes `sp. 1`	Potential SRE
		Haplochernes `sp. 2`	Potential SRE
		Nesidiochernes sp. indet.	Data Deficient
		Sundochernes `PSE090`	Potential SRE
		Troglochernes sp. indet.	Data Deficient
	Garypidae	*Synsphyronus* sp. indet.	Data Deficient
		Synsphyronus `long hand 2`	Confirmed SRE
		Synsphyronus `PSE014 long hand 2`	Confirmed SRE
	Garypinidae	*Solinus* sp. indet.	Data Deficient
	Olpiidae	Olpiidae sp. indet.	Data Deficient
		Olpiidae sp. `7/4`	Confirmed SRE
		Olpiidae `gen. nov. 7/4` sp. indet.	Confirmed SRE
		Olpiidae `PSEAAA` sp. indet.	Potential SRE
		Austrohorus sp. indet.	Data Deficient
		Austrohorus `M1`	Potential SRE
		Austrohorus `M2`	Potential SRE
		Austrohorus `pilbara`	Potential SRE
		Beierolpium sp. indet.	Data Deficient
		Beierolpium `sp. 1`	Potential SRE
		Beierolpium `sp. 7/2`	Data Deficient
		Euryolpium sp. indet.	Data Deficient
		Indolpium sp. indet.	Data Deficient
		Xenolpium sp. indet.	Data Deficient
		Xenolpium `PSE033`	Potential SRE
		Xenolpium `sp. 1`	Potential SRE
		Xenolpium `sp. 2`	Potential SRE
Scorpiones			
	Buthidae	Buthidae sp. indet.	Data Deficient
		Lychas 'sp. 1`	Potential SRE
		Lychas 'sp. 2`	Potential SRE
		Lychas 'sp. 3`	Potential SRE
		Lychas 'sp. 4`	Potential SRE
	Urodacidae	*Urodacus* sp. indet.	Data Deficient

Higher Taxon	Family	Species/ morphospecies	SRE Status
		Urodacus `sp. 9`	Potential SRE
		Urodacus `firetail`	Confirmed SRE
		Urodacus `pilbara 8`	Confirmed SRE
Mygalomorphae			
	Actinopodidae	*Missulena* sp. indet.	Data Deficient
		Missulena faulderi	Confirmed SRE
		Missulena langlandsi	Potential SRE
		Missulena sp. `A3`	Potential SRE
		Missulena `nov. newman`	Potential SRE
	Barychelidae	Barychelidae sp. indet.	Data Deficient
		Aurecocrypta sp. indet.	Data Deficient
		Aurecocrypta sp. `chichester`	Potential SRE
		Aurecocrypta `MYG316-DNA`	Confirmed SRE
		Aurecocrypta `MYG317-DNA`	Potential SRE
		Idiommata sp. indet.	Data Deficient
		Synothele sp. indet.	Data Deficient
		Synothele `MYG309-DNA`	Confirmed SRE
		Synothele `MYG311-DNA`	Confirmed SRE
	Halonoproctidae	Ctenizidae sp. indet.	Data Deficient
		Conothele `MYG525`	Potential SRE
		Conothele `MYG533`	Potential SRE
		Conothele `MYG534`	Potential SRE
		Conothele `MYG539`	Potential SRE
		Conothele `MYG279-DNA`	Confirmed SRE
		Conothele `MYG282-DNA`	Confirmed SRE
	Idiopidae	Idiopidae sp. indet.	Data Deficient
		Aganippe? sp. indet.	Data Deficient
		Idiosoma `MYG083`	Confirmed SRE
		Idiosoma? sp. indet.	Data Deficient
	Nemesiidae	Nemesiidae sp. indet.	Data Deficient
		Aname? sp. indet.	Data Deficient
		Aname sp. indet.	Data Deficient
		Aname `MYG098`	Confirmed SRE
		Aname `MYG104`	Confirmed SRE
		Aname `MYG321-DNA`	Confirmed SRE
		Aname `MYG324-DNA`	Potential SRE
		Aname `MYG378-DNA`	Potential SRE
		Kwonkan `MYG006`	Confirmed SRE
		Kwonkan `MYG088`	Potential SRE
		Kwonkan `MYG195`	Confirmed SRE
		Kwonkan `MYG325-DNA`	Confirmed SRE
		Kwonkan `MYG337-DNA`	Confirmed SRE
		Kwonkan `MYG338-DNA`	Confirmed SRE
		Kwonkan `MYG339-DNA`	Confirmed SRE

Higher Taxon	Family	Species/ morphospecies	SRE Status
		Kwonkan `MYG379-DNA`	Confirmed SRE
		Teyl sp. indet.	Data Deficient
		Teyl sp. `nov. Area C`	Potential SRE
		Teyl `MYG027`	Confirmed SRE
		Yilgarnia sp. indet.	Data Deficient
		Yilgarnia `MYG033`	Confirmed SRE
		Yilgarnia `MYG197`	Confirmed SRE
		Yilgarnia `MYG324-DNA`	Confirmed SRE
Araneomorphae			
	Selenopidae	*Karaops* sp. indet.	Data Deficient
		Karaops sp. `nov. Area C`	Potential SRE
		Karaops `ARA001-DNA`	Potential SRE
		Karaops `ARA002-DNA`	Potential SRE
		Karaops banyjima	Potential SRE
Gastropoda			
	Placostylidae	*Bothriembryon* sp. indet.	Data Deficient
Isopoda			
	Armadillidae	*Buddelundia* sp. indet.	Data Deficient
	Philosciidae	Philosciidae sp. indet.	Potential SRE
Myriapoda			
	Paradoxosomatidae	*Antichiropus* sp. indet.	Confirmed SRE
		Antichiropus `DIP006`	Confirmed SRE
		Antichiropus `DIP007`	Confirmed SRE
	Trigoniulidae	*Austrostrophus* sp. indet.	Data Deficient
		Austrostrophus stictopygus	Potential SRE
		Austrostrophus `DIP018`	Potential SRE

4.2 Previous Surveys

While no previous SRE sampling has been conducted within the Study Area, several surveys have been undertaken in the immediate vicinity (Yandi to the north, and Ministers North to the south) and wider sub-regional area, as summarised below. Several of the reports identified morphospecies of mygalomorph spiders using DNA analyses without reference to the WAM's established 'MYG' morphospecies system, which may have affected the ability of these reports to make regional comparisons and assess SRE status. Subsequent recent work by WAM taxonomists has successfully aligned the majority of these genetically derived taxa (M. Castalanelli WAM pers. comm. 2014); therefore, the taxa shown in Table 4.2 reflects the identifications from WAM databases, rather than the identifications reported in the surveys below.

Table 4.2: Results of previous SRE surveys conducted in the vicinity of the Study Area

Report Reference	SRE Species	Habitat
Ministers North SRE Invertebrate Survey (Biologic 2016)	*Karaops* sp. `indet.`	Mostly within Gorge/Deep Gully and Ridge/Breakaway
	Barychelidae sp. `indet.	Drainage Foci
	Lychas `hairy tail grp`	Hillslope/Footslope and Ridge/Breakaway
	Buddelundia `49`	Mostly within Gorge/Deep Gully and Drainage Foci
	Philosciidae sp. `indet.`	Mostly within Gorge/Deep Gully and Shallow Gully
	Chilenophilidae sp. `indet.`	Gorge/Deep Gully and Ridge/Breakaway
	Australoschendyla sp. `indet.`	Gorge/Deep Gully
	Cryptops sp. `indet.`	Hillslope/Footslope
Yandi Tenement SRE Invertebrate Survey (Biologic 2015)	*Karaops* `ARA001-DNA`	Wide range of SRE habitats
	Succinea `sp. indet.`	Drainage Line
	Troglochernes `sp. indet.`	Drainage Line
	Sundochernes `PSE090`	Drainage Line
	Yilgarnia `MYG197`	Mostly within Ridge/ Breakaway
Yandi Mine SRE Invertebrate Survey and Impact Assessment (Biologic 2013)	*Karaops* `ARA001-DNA`	Ridges/ breakaways, gorges, and gullies
Area C and Surrounds SRE Survey (Biota 2011)	*Aname* `MYG104`	Mulga groves and drainage lines
	Yilgarnia `MYG197`	Ridge/ Breakaway and drainage lines
	Antichiropus `Area C sp. 2` (now A. `DIP007`)	Hill crests featuring *Corymbia* mallee
	Gen. `indet.` sp. `indet.` (now *Austrostrophus* `DIP018`)	Gorges, gullies, Ridge/ Breakaway
	Synsphyronus `long hand 2` (now S. PSE014)	Shallow gullies/ drainage lines
	Karaops banyjima	Gorges
Area C Mining Operation Environmental Management Plan (Revision 4) A, D, P1 and P3 Deposits: Terrestrial Invertebrate SRE Assessment (Outback Ecology 2008)	*Aname* sp. (now *Chenistonia* `MYG088`)	South facing ridges and gullies
	Antichiropus sp. nov. `Area C` (now A. `DIP006`)	South facing ridges and gullies
Assessment of Terrestrial SRE Invertebrates, from Area C to Jinayri to Mount Newman Railway (AMBS 2010)	*Aname* `MYG098`	Open plains
A Survey of SRE Invertebrates in the Jinidi to Mainline Rail Corridor (Biota 2012)	*Missulena* sp. 'A1'	Mulga dominated groves, valley floors
	Conothele sp. 'C6'	Mulga open shrubland
	Conothele sp. 'C13'	Acacia spp. shrubland over open hummock grassland
	Aganippe sp. 'I1'	Valley floors, Drainage Lines, alluvial fans
	Idiopid sp. 'I9'	Acacia habitats
	Kwonkan sp. 'N38'	Eucalyptus open woodland, Acacia shrubland
	Kwonkan sp. 'N42'	Hill ranges
	Kwonkan sp. 'N43'	Acacia open woodland over hummock grassland
	Kwonkan sp. 'N44'	Weeli Wolli Creek
	Aname sp. 'N1', *Aname* sp. 'N16'	Acacia habitats
	Aname sp. N18'	Drainage floors, low slopes and plains
Yandicoogina Junction South West and Oxbow Fauna Survey (Biota 2010)	None	N/A

4.3 SRE Fauna results

4.3.1 Baseline Survey

Invertebrate samples were collected from microhabitats in leaf litter, topsoil, under rocks, and woody debris at 38 sites in two trips. In Trip 1, habitat assessments and invertebrate sampling was carried out at 20 sites. A further 17 sites were habitat assessed and sampled for invertebrates in Trip 2, with an additional site opportunistically sampled for invertebrates. Almost all sites yielded invertebrate specimens - 18 out of 20 sites in Trip 1 and 17 out of 18 sites from Trip 2. A total of 205 invertebrate specimens, representing groups known to contain SRE, were collected from the 38 sites. The fauna included Arachnida, Gastropoda, Isopoda, and Myriapoda. A number of individuals in each group were identified as being potential SRE and others were confirmed as SRE species (Table 4.3, Table 4.4). Each taxon is discussed below and the locations of all potential and confirmed SRE fauna recorded are shown in Figure 4.1. The full survey data is shown in Appendix 2.

Arachnida

Araneomorphae: Selenopidae

Karaops sp. indet.

Twenty three selenopid specimens were collected from 15 sites across both Trip 1 and Trip 2. All 23 specimens were identified as being in the genus *Karaops*; however, further taxonomic clarification was not possible as all specimens were juvenile. These individuals were collected on rocks and boulders in a variety of habitats; basalt outcrops, breakaway/cliff, gorge/gully, hillcrest/hillslope and minor drainage line habitats, which may indicate that they were dispersing.

This taxon is regarded as a Potential SRE (WAM Categories ‘A’ Data deficient and ‘E’ Research and experience) and molecular analysis could further resolve this deficiency.

Pseudoscorpiones

Atemnidae: *Oratemnus* sp. indet.

One juvenile specimen from this genus was recorded from one minor drainage line site. There is limited taxonomic knowledge of this genus in the Pilbara, so further taxonomic resolution would require molecular analysis.

As such, this taxon is regarded as Data deficient.

Chthoniidae

Austrochthonius sp. indet.

Six specimens of this genus were recorded from two gorge/gully sites, one hillcrest/hillslope and one minor drainage line site, of which five were females and one juvenile.

Due to the lack of taxonomic resolution, this taxon is regarded as Data deficient.

Tyrannochthonius aridus

Two male specimens of this species were collected from two hillcrest/hillslope sites.

Tyrannochthonius. aridus is a widespread species found throughout the Pilbara, up to 320 km north west of the Study Area and is therefore regarded as Widespread.

Garypidae: *Synsphyronus* 'PSE093'

One male and three juvenile specimens were collected of this species from two sites (MNY02 and MNY06), one gorge/gully and one hillcrest/hillslope site.

Synsphyronus 'PSE093' is a widespread species found throughout the Pilbara and adjacent regions, up to 400 km to the west and east of the Study Area and is therefore regarded as Widespread.

Olpiidae

Austrohorus sp. indet.

Four specimens (three females and one juvenile) of this genus were recorded from two sites (MNY17 and MNY32) with two habitat types, gorge/gully and minor drainage line. There is little taxonomic knowledge of this genus, so further taxonomic resolution would require molecular analysis.

As such, this taxon is regarded as Data deficient.

Beierolpium sp. '8/3'

All six specimens of this taxon were female and were collected from one breakaway/cliff site.

This taxon is known from throughout the Pilbara, up to 370 km north west of the Study Area and is therefore regarded as Widespread.

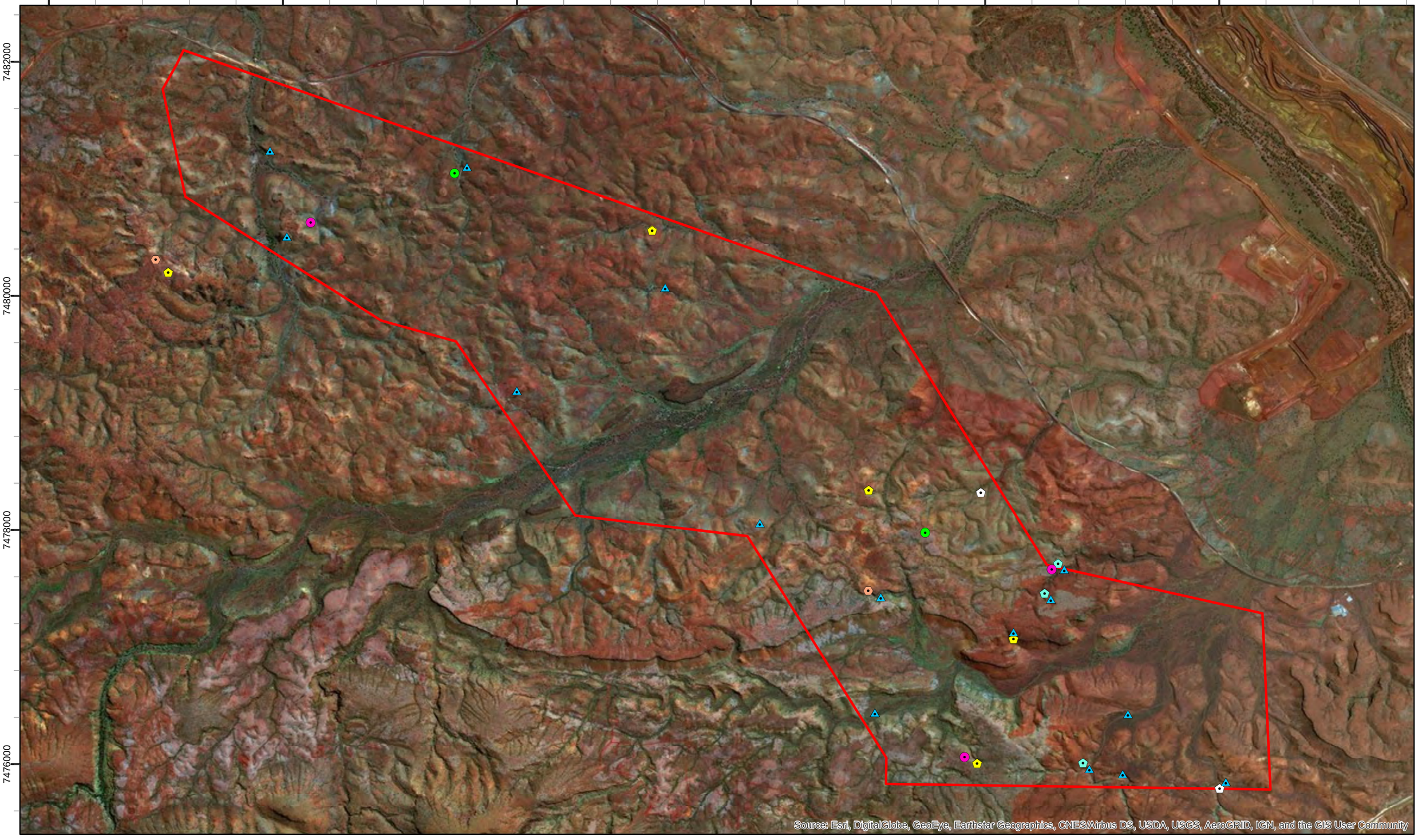
Beierolpium sp. '8/4 (small)'

One female specimen of this taxon was recorded from one site in a major drainage line. This taxon is known from throughout the Pilbara, up to 140 km north west of the Study Area and is therefore regarded as Widespread

Figure 4.1: SRE fauna (Potential and Confirmed) recorded from survey of the Study Area

708000 710000 712000 714000 716000 718000

7482000 7480000 7478000 7476000



Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Legend

Study Area

Potential SRE Specimens Collected

Aranae

- *Karaops* sp. indet.

Pseudoscorpiones

- *Synsphyronus* sp. indet.

Scorpiones

- *Lychas* sp. 'bituberculatus complex'
- *Lychas* sp. 'hairy tail complex'

Isopoda

- *Buddelundia* sp. '10ma'
- *Buddelundia* sp. '49'
- Philosciidae sp. Indet

biologic Environmental Survey

N

1:30,000

0 0.5 1 2 km

BHP - Ministers North to Yandi Corridor

SRE Invertebrate Fauna Survey

Fig. 4.1: Potential SRE fauna recorded during the survey

Coordinate System: GDA 1994 MGA Zone 50
Projection: Transverse Mercator
Datum: GDA 1994

Size A3. Created 17/09/2018

Beierolpium sp. indet.

One juvenile specimen of this genus was recorded from a minor drainage line site and is not able to be resolved further without molecular analysis.

As such, this taxon is regarded as Data deficient.

Euryolpium sp. indet.

One male specimen was collected from one site in basalt outcrops habitat (MNY08).

There is limited taxonomic knowledge of this genus in the Pilbara, so further taxonomic resolution would require molecular analysis.

As such, this taxon is regarded as Data deficient.

Indolpium sp. indet.

Twelve specimens (one male, two females and nine juveniles) from this genus were collected at eight sites in a variety of habitat types; these were breakaway/cliff, gorge/gully, hillcrest/hillslopes and minor drainage line habitats.

There is limited taxonomic knowledge of this genus in the Pilbara, so further taxonomic resolution would require molecular analysis.

As such, this taxon is regarded as Data deficient.

Olpiidae sp. '7/4'

Eleven (four males, two females and five juveniles) specimens were collected from three different habitats; these were breakaway/cliff, gorge/gully and hillcrest/hillslope.

This species is known from throughout the Pilbara, up to 270 km north of the Study Area and is therefore regarded as Widespread.

Scorpionida

Buthidae

Lychas 'bituberculatus complex'

Two specimens (a male and a juvenile) were collected from two sites, one in a gorge/gully habitat (MNY32) and the other in a drainage area/ floodplain habitat (MNY11).

This complex is currently regarded as likely to contain SRE species (E. Volschenk pers. comm.), therefore this taxon is regarded as a Potential SRE (WAM Categories 'A' Data deficient and 'E' Research and experience).

Lychas 'hairy tail complex'

Three specimens (one male and two females) were collected from three sites, two gorge/gully habitats and a hillcrest/hillslope habitat.

This complex is currently regarded as likely to contain SRE species (E. Volschenk pers. comm.), therefore this taxon is regarded as a Potential SRE (WAM Categories 'A' Data deficient and 'E' Research and experience).

Lychas sp. indet.

One juvenile specimen from an ironstone outcrop site was recorded.

Due to the lack of taxonomic resolution, this taxon is regarded as Data deficient.

Myriapoda

Diplopoda: Trigoniulidae:

Austrostrophus sp. indet.

Eight specimens of *Austrostrophus* (one male, two females and five juveniles) were recorded from six sites in three habitat types; breakaway/cliff, ironstone outcrops and gorge/gully.

Recent investigations into *Austrostrophus* have indicated the potential for rich diversity within the genus and possible significant genetic structure within this species.

Due to the lack of taxonomic resolution, this taxon is regarded as Data deficient.

Isopoda

Armadillidae

Buddelundia sp. '10ma'

Eight specimens (four males, two females and two juveniles) were collected from five sites across a variety of habitats; breakaway/cliff, gorge/gully, hillcrest/hillslopes and minor drainage line habitats. Several records of this species are known to the north, north east and south of the Study Area; however, the species has not been recorded greater than 60 km from the Study Area.

As such, this species is regarded as a Potential SRE (WAM Categories 'A' Data deficient and 'E' Research and experience).

Buddelundia sp. '16'

Thirty four specimens (eight males, 13 females and 13 juveniles) were collected from 12 sites in a variety of habitats; breakaway/cliff, gorge/gully, hillcrest/hillslopes and major drainage line habitats.

This species is known throughout most of the south eastern Pilbara, up to 110 km south east of the Study Area and is therefore regarded as Widespread.

Buddelundia sp. '49'

Five female specimens from two sites were collected in hillcrest/hillslope (MNY28) and minor drainage line habitat (MNY35). This species is small and difficult to determine from other small species and is tentatively known from 80 km to the south east of the Study Area; however, because of this uncertainty, it is possible these records represent two distinct species (S. Judd pers. comm.).

As such, this species is regarded as a Potential SRE (WAM Categories 'A' Data deficient and 'E' Research and experience).

Buddelundia sp. indet.

One indeterminate female specimen was collected from one gorge/gully site and is not regarded as representing any of the other species of *Buddelundia* recorded.

Due to the lack of taxonomic resolution, this taxon is regarded as Data deficient.

Philosciidae

Philosciidae sp. indet.

Four specimens (two males and two females) and multiple fragments were collected from three sites in gorge/gully habitats. Philosciids are rarely collected in the Pilbara and information on the taxonomy and distribution is lacking; however, they are currently all considered Potential SRE species in the Pilbara (S. Judd, pers. comm.).

As such, this species is regarded as a Potential SRE (WAM Categories 'A' Data deficient and 'E' Research and experience).

Table 4.3: Arachnid taxa recorded during the SRE invertebrate survey.

Higher Taxon	Taxa	SRE Status	Basalt Outcrops	Breakaway/ Cliff	Gorge/Gully	Hillcrest/Hill Slope	Major Drainage Line	Minor Drainage Line	Drainage Area/Flood plain	Total
Araneae										
Selenopidae										
	Karaops sp. indet.	Potential SRE	3	5	11	3		1		23
Pseudoscorpiones										
Atemnidae										
	Oratemnus sp. indet.	Data deficient						1		1
Chthoniidae										
	Austrochthonius sp. indet.	Data deficient			4	1		1		6
	Tyrannochthonius aridus	Widespread				2				2
Garypidae										
	Synsphyronus sp. 'PSE093'	Potential SRE			1	3				4
Olpiidae										
	Austrohorus sp. indet.	Data deficient			3			1		4
	Beierolpium sp. '8/3'	Widespread		6						6
	Beierolpium sp. '8/4 small'	Widespread					1			1
	Beierolpium sp. indet.	Data deficient						1		1
	Euryolpium sp. indet.	Data deficient	1							1
	Indolpium sp. indet.	Data deficient		3	3	5		1		12
	Olpiidae sp. 7/4	Widespread		6	3	2				11
Scorpiones										
Buthidae										
	Lychas 'bituberculatus complex'	Potential SRE			1				1	2
	Lychas 'hairy tail complex'	Potential SRE			2	1				3
	Lychas sp. indet.	Data deficient				1				1

Table 4.4: All other taxa recorded during the SRE invertebrate survey.

Higher Taxon	Taxa	SRE Status	Basalt Outcrop	Breakaway/ Cliff	Gorge/Gully	Hillcrest/Hill slope	Major Drainage Line	Minor Drainage Line	Drainage Area/Flood Plain	Total
Myriapoda										
Trigoniulidae										
	Austrostrophus sp. indet.	Data deficient		3	5					8
Isopoda										
Armadillidae										
	Buddelundia sp. '10ma'	Potential SRE		1	1	5		1		8
	Buddelundia sp. '16'	Widespread		12	17	4	1			34
	Buddelundia sp. '49'	Potential SRE				2		3		5
	Buddelundia sp. indet.	Data deficient			1					1
Philosciidae										
	Philosciidae sp. indet.	Potential SRE			10					10
Total			4	36	62	29	2	10	1	**144**

4.4 Habitat assessment

4.4.1 Habitats zones

At the landscape scale, the habitats within the Study Area were classified into seven habitat zones; basalt outcrop, breakaway/cliff, gorge/gully, hillcrest/hillslope, major drainage line, minor drainage line and drainage area/floodplain. These zones were based on differences in the major landform features, drainage features and vegetation features that influence SRE occurrence. Figure 4.2 shows the location and indicative extent of the habitat zones within the Study Area, and their characteristics and SRE suitability are described below:

- **Basalt outcrop** – These habitat zones often comprise smaller, more discontinuous outcrops and boulder piles occurring on plains or open hill slopes. Inherently more isolated and generally less sheltered than Ridges/ breakaways. These areas rarely feature dense vegetation and present limited complex habitats. As such, these habitat zones are generally considered moderate-low SRE suitability.
- **Breakaway/cliff** – Complex rocky, mountainous habitats featuring extensive breakaway or cliff face. These tend to differ from Rocky outcrops and Hillslopes by being taller and larger, and by having steeper faces that generally provide more shelter and habitat complexity, and therefore considered moderate suitability for SRE fauna. These habitat zones can be isolated or occur in connected networks, as is the case in the Study Area.
- **Gorge/gully -** This habitat zone comprises deeply incised rocky landforms with low to moderate gorges carved by moderate or major drainage lines, where the base of the gorge is relatively flat, and the vertical or near vertical faces offer consistent shade. This habitat zone can form in highly mountainous areas at the base of steep slopes, or in deeply incised rolling hills, as observed within the Study Area. The habitat types within this zone may include gorges/ deep gullies, drainage lines, drainage foci, and ridges/ breakaways in areas where one face is more deeply incised than another. The overall SRE suitability of this habitat zone is high and is not as variable depending on slope and aspect as the more mountainous major gorge/ gully systems. This is because the narrower, more meandering course of river gorges provides plenty of sheltered aspects, complex microhabitats within rocks, dense vegetation, and higher persistence of moisture.
- **Hillcrest/hillslope** - This habitat zone comprises the remaining rocky habitats on open (exposed) slopes and hill crests that do not feature major outcrops, ridges, or gullies. Such areas are not highly complex and generally have skeletal soils and

sparse open vegetation (often Triodia hummock grassland with scattered *Corymbia*/ *Eucalyptus* spp.) that can provide pockets of protection from exposure. Steeper, south-facing hill slopes can also provide some protection. These areas generally have a moderate- low suitability for SRE fauna, unless there is another landform or vegetation feature providing a more complex microhabitat within this habitat type. While these habitat zones are not usually considered to be suitable for SRE fauna, they can contain suitable microhabitats, as is the case with *Antichiropus* 'DIP006' and 'DIP007' (Biologic 2018).

- **Drainage lines (major and minor)** – Major and minor drainage areas that can be densely vegetated, and extensive, but tend to be prone to disturbances from flooding. These areas are dominated by dense shrubland and groves/ thickets of *Acacia* (Mulga and other *Acacia* species) and *Eucalyptus*/ *Corymbia* species; therefore the majority of SRE habitats are based on vegetation and detritus. Slope and aspect are more or less irrelevant to SRE suitability here; instead, the density and structure of vegetation influences complexity of detrital microhabitats, and amount of shelter available. Isolation is generally low, as the groves and drainage line habitats form an interconnected network of vegetation-based habitats along the course of the drainage line and flood plains. These types of habitats are generally considered to provide dispersal opportunities for some SRE fauna the suitability of this habitat zone considered moderate-low.
- **Drainage area/floodplain** – this habitat zone is characterised by mostly flat, extensive, open areas that may feature pockets of shrubland or open woodland. Similar to drainage lines, slope and aspect are less relevant to SRE suitability but rather the density and structure of vegetation influences complexity of detrital microhabitats, and amount of shelter available. Limited detrital microhabitats can be present though are generally thought unlikely to support SRE species due to high exposure, low complexity, and low isolation.

Figure 4.2: SRE habitats of the Study Area

710000 712000 714000 716000 718000 720000

7482000

7480000

7478000

7476000

Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Legend

Study Area

Fauna Habitats

- Basalt Outcrops
- Breakaway/ Cliff
- Drainage Area/ Floodplain
- Gorge/ Gully
- Hillcrest/ Hillslope
- Major Drainage Line
- Minor Drainage Line

biologic Environmental Survey

N

1:30,000

0 0.5 1 2 km

BHP - Ministers North to Yandi Corridor

SRE Invertebrate Fauna Survey

Fig. 4.2: SRE habitats within the Study Area

Coordinate System: GDA 1994 MGA Zone 50
Projection: Transverse Mercator
Datum: GDA 1994

Size A3. Created 17/09/2018

5 DISCUSSION

5.1 Discussion of habitat results

Only one habitat zone within the Study Area is regarded to be of high suitability for SRE fauna, and therefore of high significance- gorge/gully. The remaining six habitat zones are either moderate (breakaway/cliff), moderate to low (hillslope/hillcrest, basalt outcrop and minor drainage) or low (major drainage and drainage area/floodplain).

None of the high or moderate suitability habitats are restricted to the Study Area. The occurrences of gorge/gully habitats are well connected to the breakaway/cliff, drainage area/floodplain and major drainage habitats which would provide suitable microhabitats for dispersal and protection for any species that require these microhabitats.

5.2 Discussion of fauna results

Current SRE fauna surveys of the Study Area recorded a total of 21 invertebrate taxa representing five target groups known to contain SRE; namely selenopid spiders, pseudoscorpions, scorpions, millipedes and isopods. Six of these taxa have been regarded as widespread, nine considered 'Data Deficient' with the remaining six regarded as Potential SRE. The Potential SRE fauna are listed below and discussed further;

***Karaops* sp. indet.**

All *Karaops* specimens collected during the survey were either juvenile or female resulting in higher level identifications (mature males are required for species-level IDs). While the uncertain taxonomic resolution attributed to taxa being classified as 'Data Deficient' SRE status, habitat indicators (known from multiple habitat types extending beyond the Study Area) suggest the specimen would be unlikely to be restricted to the Study Area. The *Karaops* specimens could potentially be aligned with one of four species (*Karaops* sp. `nov. Area C`, *Karaops* `ARA001-DNA`, *Karaops* `ARA002-DNA` and *Karaops banyjima*), known from within 20km of the Study Area, two of which, *K.*`ARA001-DNA` and *K.* `ARA002-DNA` are known from Yandi Mine, immediately bordering the Study Area to the north.

***Lychas* '*bituberculatus* complex'**

This species complex is currently regarded as likely to contain SRE species (E. Volschenk pers. comm.) and three Potential SRE *Lychas* species (*L*. 'sp.2', sp.3 and sp.4) occur 13 km to the south east of the Study Area. Additionally, three records of '*bituberculatus*' occur within 10 km of the Study Area, and may represent the same taxa.

One specimen was recorded in gorge/gully and the other in drainage area/floodplain, which indicates that the species is unlikely to be restricted to the Study Area and likely disperses through drainage habitats.

***Lychas* 'hairy tail complex'**

This species complex is currently regarded as likely to contain SRE species (E. Volschenk pers. comm.) and three Potential SRE *Lychas* species (*L*. 'sp.2', sp.3 and sp.4) occur 13 km to the south east of the Study Area. Additionally, three records of '*hairy tail* complex' occur within 13 km of the Study Area to the south, and may represent the same taxa.

Two specimens were recorded in gorge/gully and the other in hillcrest/hillslope habitat, which indicates that the species is unlikely to be restricted to the Study Area and may preference rocky habitats which extend beyond the Study Area.

***Buddelundia* sp. '10ma'**

While this species is known from up to 60 km from the Study Area, this still gives it a known distribution of less than 10,000 km^2 and therefore is regarded as a Potential SRE. With further sampling of isopods in the Pilbara, this species may be found beyond this distribution or it may be confirmed to be restricted to its current known range and be regarded as a Confirmed SRE species.

This species has been recorded in several different habitat types and can therefore be regarded as unlikely to be restricted to the Study Area.

***Buddelundia* sp. '49'**

While this species is known from up to 80 km from the Study Area, this still gives it a known distribution of less than 10,000 km^2 and therefore is regarded as a Potential SRE; however, these specimens represent two disjunct populations and there is some possibility that a taxonomic review of the species will confirm two separate species (S. Judd pers. comm.). This species has been recorded in three different habitat types, all moderate to low suitability, and can therefore be regarded as unlikely to be restricted to the Study Area.

Philosciidae sp. indet.

This family is rarely collected in the Pilbara and therefore difficult to assess; however, all known species in the Pilbara are currently regarded as Potential SRE (S. Judd, pers. comm.).

These specimens were all collected from gorge/gully habitats in the southern part of the Study Area which would indicate a strong preference for these high suitability habitats. The gorge gully habitats do extend beyond the Study Area; however, their ability to utilise

other habitat types for dispersal is unclear and they may represent a highly restricted species.

6 REFERENCES

Allen, G.R., Midgley, S.H. and Allen, M. (2002). Field Guide to the Freshwater Fishes of Australia. CSIRO Publishing, Melbourne, Vic.

AMBS (2010). Assessment of Terrestrial Short-range Endemic Invertebrates, from Area C to Jinayri to Mount Newman Railway. Unpublished report for BHP Billiton Iron Ore Pty Ltd, Perth WA.

Beard, J. S. (1975). Map and Explanatory Notes to Sheet 5: The Vegetation of the Pilbara Area. Nedlands, Western Australia: University of Western Australia Press.

Beard, J. S. (1990). Plant Life of Western Australia. Kenthurst, Kangaroo Press.

BHP Billiton Iron Ore (2009) BHP Billiton Iron Ore's Guidance for Short-Range Endemic Invertebrate Surveys in the Pilbara Region (SPR-IEN-EMS-013); Central Pilbara Region Short-Range Endemic Assessment Scope, Approach and Methods. BHP Billiton Iron Ore, 20 March 2009.

BHP Billiton Iron Ore (2011a) Yandi Mine Surface Water and Groundwater Management Plan. Revision 2, August 2011. Unpublished report for BHP Billiton Iron Ore Pty Ltd, Perth WA.

Biologic (2013). Yandi Mine SRE Invertebrate Survey and Impact Assessment. Unpublished report for BHP Billiton Iron Ore Pty Ltd, Perth WA.

Biologic (2015). Yandi Tenement Short-range Endemic Invertebrate Survey. Unpublished report for BHP Billiton Iron Ore Pty Ltd, Perth WA.

Biologic (2016). Ministers North Short-range Endemic Invertebrate Survey. Unpublished report for BHP Billiton Iron Ore Pty Ltd, Perth WA.

Biota (2010) Yandicoogina Junction South West and Oxbow Fauna Survey. Unpublished report for Rio Tinto Iron Ore, Perth WA.

Biota (2011) Jinidi Lease and Jinidi to Mainline Rail SRE Review. Report to BHP Billiton Iron Ore, Perth.

Biota (2011) Area C and Surrounds Short Range Endemic Survey. Unpublished report for BHP Billiton Iron Ore Pty Ltd, Perth WA.

Biota (2012). A Survey of Short Range Endemic Invertebrates in the Jinidi to Mainline Rail Corridor. Unpublished report for BHP Billiton Iron Ore Pty Ltd, Perth WA.

Biota (2013a) A Survey of the Short Range Endemic Invertebrate Fauna of Area C West to Yandi. Report to BHP Billiton Iron Ore, Perth.

Biota (2013b) Targeted Survey for Short Range Endemic Fauna in the Marillana Survey Area. Report to BHP Billiton Iron Ore, Perth.

Bureau of Meteorology (BoM) (2018). Online Climate Data. Database: http://www.bom.gov.au/. Last accessed July 2018.

Durrant, B.J. (2011) Short-range endemism in the Central Pilbara. Unpublished report to BHP Billiton Iron Ore. Perth, WA.

Environmental Protection Authority (EPA) (2002) Position Statement No. 3 Terrestrial Biological Surveys as an Element of Biodiversity Protection. Perth, WA.

Environmental Protection Authority (EPA) (2004) Guidance for the Assessment of Environmental Factors (in accordance with the Environmental Protection Act 1986). Terrestrial Fauna Surveys for Environmental Impact Assessment in Western Australia. No. 56. Perth, WA.

Environmental Protection Authority (EPA) (2009) Guidance for the Assessment of Environmental Factors (in accordance with the Environmental Protection Act

1986). Sampling of Short Range Endemic Fauna for Environmental Impact Assessment in Western Australia. No. 20. Perth, WA.

(EPA) Environmental Protection Authority (2016a) Guidance for the Assessment of Environmental Factors (in accordance with the *Environmental Protection Act 1986*). Terrestrial Fauna Surveys for Environmental Impact Assessment in Western Australia. No. 56. Western Australia.

(EPA) Environmental Protection Authority (2016b) Guidance for the Assessment of Environmental Factors (in accordance with the *Environmental Protection Act 1986*). Sampling of Short Range Endemic Fauna for Environmental Impact Assessment in Western Australia. No. 20. Western Australia.

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

Johnson, M.S., Hamilton, Z.R, Murphy, C. E., MacLeay, C. A., Roberts, B., & Kendrick, P.G. (2004). Evolutionary genetics of island and mainland populations of *Rhagada* (Gastropoda: Pulmonata) in the Pilbara Region, Western Australia. *Australian Journal of Zoology* 52: 341-355.

Main, B.Y., Sampey, A. and West, P.L.J. (2000) Mygalomorph spiders of the southern Carnarvon Basin, Western Australia. *Records of the Western Australian Museum* Supplement 61: 281-293.

Outback Ecology (2008). Area C Mining Operation Environmental Management Plan (Revision 4) A, D, P1 and P3 Deposits: Terrestrial Invertebrate Short-range Endemic Assessment. Unpublished report to BHP Billiton Iron Ore. Perth, WA.

Ponder, W.F. and Colgan, D.J. (2002). What makes a narrow-range taxon? Insights from freshwater snails. *Invertebrate Systematics* **16**: 571-582.

Shepherd, D. P., Beeston, G. R., & Hopkins, A. J. M. (2001). Native Vegetation in Western Australia, Extent, Type and Status. Resource Management Technical Report 249. Perth, Western Australia:

Subterranean Ecology (2012) Mainline Rail Expansion Project Short Range Endemic Invertebrate Fauna Survey. Report to BHP Billiton Iron Ore, Perth.

Thorne, A.M. and Tyler, I,M, (1997). Mt Bruce, Western Australia (2nd Edition). Map Sheet and explanatory notes. 1:250 000 geological series. Sheet SF50-11. Geological Survey of WA.

Tille, P. (2006) Soil-landscapes of Western Australia's Rangelands and Arid Interior. Resource Management Technical Report 313. Department of Agriculture and Food Western Australia. Perth, WA.

Tyler, I. M., Hunter, W. M. & Williams, I. R. (1991). Newman, Western Australia. 1:250,000 Geological Series – Explanatory Notes (2nd Edition). Geological Survey of Western Australia.

Van Vreeswyk, A. M. E., Payne, A. L., Leighton, K. A., & Hennig, P. (2004).

Appendix A: Sampling Site Data

Site	Habitat	Landform	Shade	Soil	Outcrop	Leaf Litter	Disturbance	Latitude	Longitude
01	Hillcrest/ Hillslope	Hillcrest/ Upper Hillslope	Low to Med 20-40%	Few Small Patches	Major Outcropping	Few Small Patches	None Discernible	-22.7804	119.0831
02	Gorge/ Gully	Gorge	Med to High 60-80%	Many Small Patches	Extensive Outcropping	Few Large Patches	None Discernible	-22.797	119.095
03	Gorge/ Gully	Gorge	Low to Med 20-40%	Many Small Patches	Extensive Outcropping	Few Large Patches	None Discernible	-22.794	119.1179
04	Gorge/ Gully	Gully	Low to Med 20-40%	Few Small Patches	Extensive Outcropping	Many Small Patches	Mining Exploration	-22.81	119.1126
05	Major Drainage Line	Major Drainage Line	Negligible <5%	Many Small Patches	Negligible	Few Small Patches	None Discernible	-22.7886	119.0674
06	Hillcrest/ Hillslope	Hillcrest/ Upper Hillslope	Negligible <5%	Scarce	Limited Outcropping	Scarce	None Discernible	-22.7722	119.0354
07	Hillcrest/ Hillslope	Hillcrest/ Upper Hillslope	Med to High 60-80%	Few Small Patches	Moderate Outcropping	Many Small Patches	Mining Exploration	-22.7699	119.0452
08	Basalt outcrops	Boulders/ Rockpiles	Negligible <5%	Scarce	Extensive Outcropping	Scarce	None Discernible	-22.7815	119.0645
09	Hillcrest/ Hillslope	Hillcrest/ Upper Hillslope	Negligible <5%	Scarce	Limited Outcropping	Scarce	None Discernible	-22.7715	119.0677
10	Breakaway/ Cliff	Breakaway	Low to Med 20-40%	Few Small Patches	Major Outcropping	Few Small Patches	None Discernible	-22.7915	119.0997
11	Drainage area/Floodplain	Sandy/ Stony Plain	Low 5-20%	Evenly Spread	Limited Outcropping	Many Large Patches	None Discernible	-22.8059	119.0947
12	Drainage area/Floodplain	Footslope	Low 5-20%	Scarce	Negligible	Scarce	Mining Exploration,Road	-22.8017	119.1245
13	Gorge/ Gully	Gorge	Med to High 60-80%	Few Large Patches	Extensive Outcropping	Many Large Patches	None Discernible	-22.8095	119.1035
14	Gorge/ Gully	Gorge	Med to High 60-80%	Few Large Patches	Extensive Outcropping	Many Large Patches	None Discernible	-22.8092	119.1032
15	Hillcrest/ Hillslope	Ironstone Outcrops	Negligible <5%	Scarce	Major Outcropping	Scarce	None Discernible	-22.7914	119.0849
16	Basalt outcrops	Granite Outcrops/ Domes	Low 5-20%	Few Small Patches	Major Outcropping	Few Small Patches	None Discernible	-22.7904	119.0788
17	Minor Drainage Line	Gully	Low to Med 20-40%	Few Small Patches	Minor Outcropping	Few Large Patches	None Discernible	-22.7763	119.0556
18	Minor Drainage Line	Medium Drainage Line	Low 5-20%	Few Small Patches	Limited Outcropping	Few Small Patches	None Discernible	-22.7679	119.0605
19	Breakaway/ Cliff	Breakaway	Low 5-20%	Scarce	Moderate Outcropping	Scarce	None Discernible	-22.7825	119.0748
20	Breakaway/ Cliff	Breakaway	Low 5-20%	Scarce	Moderate Outcropping	Scarce	None Discernible	-22.7831	119.0743

21	Gorge/ Gully	Gully	Med to High 60-80%	Few Small Patches	Major Outcropping	Few Large Patches	None Discernible	-22.797	119.1092
22	Gorge/ Gully	Gorge	High 80-100%	Scarce	Major Outcropping	Few Small Patches	None Discernible	-22.7947	119.1103
23	Gorge/ Gully	Gorge	High 80-100%	Scarce	Major Outcropping	Few Small Patches	Road/ Access Track	-22.8104	119.1154
24	Major Drainage Line	Major Drainage Line	Negligible <5%	Many Small Patches	Minor Outcropping	Evenly Spread	None Discernible	-22.7606	119.0423
25	Minor Drainage Line	Minor Drainage Line	Negligible <5%	Scarce	Limited Outcropping	Scarce	None Discernible	-22.7685	119.0756
26	Breakaway/ Cliff	Cliff	Low 5-20%	Scarce	Major Outcropping	Many Small Patches	None Discernible	-22.7778	119.0894
27	Hillcrest/ Hillslope	Cliff	Med to High 60-80%	Scarce	Major Outcropping	Scarce	None Discernible	-22.8058	119.1157
28	Hillcrest/ Hillslope	Gorge	Med to High 60-80%	Scarce	Major Outcropping	Scarce	None Discernible	-22.8109	119.1239
29	Breakaway/ Cliff	Breakaway	Med to High 60-80%	Many Small Patches	Major Outcropping	Many Small Patches	None Discernible	-22.7632	119.0437
30	Hillcrest/ Hillslope	Hillslope	Low to Med 20-40%	Scarce	Limited Outcropping	Scarce	None Discernible	-22.7687	119.0482
31	Breakaway/ Cliff	Hillcrest/ Upper Hillslope	Med to High 60-80%	Scarce	Major Outcropping	Few Small Patches	None Discernible	-22.7287	119.0102
32	Gorge/ Gully	Gorge	Low to Med 20-40%	Few Small Patches	Extensive Outcropping	Few Small Patches	None Discernible	-22.7643	119.0601
33	Drainage area/Floodplain	Sandy/ Stony Plain	Negligible <5%	Many Large Patches	Negligible	Many Small Patches	None Discernible	-22.7975	119.1173
34	Breakaway/ Cliff	Cliff	High 80-100%	Scarce	Major Outcropping	Few Large Patches	None Discernible	-22.7996	119.1061
35	Minor Drainage Line	Minor Drainage Line	Low 5-20%	Many Small Patches	Minor Outcropping	Few Large Patches	None Discernible	-22.7883	119.1037
36	Hillcrest/ Hillslope	Hillcrest/ Upper Hillslope	Negligible <5%	Few Small Patches	Minor Outcropping	Scarce	None Discernible	-22.7883	119.0939
37	Minor Drainage Line	Gully	Low 5-20%	Few Small Patches	Moderate Outcropping	Many Small Patches	Frequent Fire	-22.7734	119.0767
38	Minor Drainage Line	Minor Drainage Line	Low 5-20%	Few Large Patches	Minor Outcropping	Many Small Patches	None Discernible	-22.7684	119.0434

Appendix B: Survey Fauna Data

Site	Date	Invertebrate Group	Family	Genus	Species	No.	Habitat Type	Sex	Latitude	Longitude
MNY01	10/10/2017	Land Snail				1	Hillcrest/ Hillslope		-22.780365	119.083066
MNY01	10/10/2017	Isopod	Armadillidae	Buddelundia	sp. '16'	2	Hillcrest/ Hillslope		-22.780365	119.083066
MNY02	10/10/2017	Pseudoscorpion	Garypidae	Synsphyronus	sp. 'PSE093'	1	Gorge/ Gully	Male	-22.797011	119.095028
MNY02	10/10/2017	Land Snail				1	Gorge/ Gully		-22.797011	119.095028
MNY02	10/10/2017	Spider (non-mygal)	Selenopidae	Karaops	sp. indet.	1	Gorge/ Gully	Undetermined/ Immature	-22.797011	119.095028
MNY02	10/10/2017	Isopod	Armadillidae	Buddelundia	sp. '16'	4	Gorge/ Gully		-22.797011	119.095028
MNY03	10/10/2017	Pseudoscorpion	Olpiidae		sp. '7/4'	3	Gorge/ Gully		-22.79395	119.117922
MNY04	10/10/2017	Spider (non-mygal)	Selenopidae	Karaops	sp. indet.	2	Gorge/ Gully	Undetermined/ Immature	-22.810025	119.112577
MNY04	10/10/2017	Isopod	Philosciidae		sp. indet.	1	Gorge/ Gully	Female	-22.810025	119.112577
MNY05	10/10/2017	Land Snail				2	Major Drainage Line		-22.78856	119.067392
MNY06	10/10/2017	Pseudoscorpion	Garypidae	Synsphyronus	sp. 'PSE093'	2	Hillcrest/ Hillslope	Undetermined/ Immature	-22.772239	119.03537
MNY06	10/10/2017	Isopod	Armadillidae	Buddelundia	sp. '10ma'	1	Hillcrest/ Hillslope	Male	-22.772239	119.03537
MNY06	10/10/2017	Pseudoscorpion	Garypidae	Synsphyronus	sp. 'PSE093'	1	Hillcrest/ Hillslope	Undetermined/ Immature	-22.772239	119.03537
MNY07	11/10/2017	Spider (non-mygal)	Selenopidae	Karaops	sp. indet.	1	Hillcrest/ Hillslope	Undetermined/ Immature	-22.769852	119.045194
MNY08	11/10/2017	Spider (non-mygal)	Selenopidae	Karaops	sp. indet.	2	Basalt outcrops	Undetermined/ Immature	-22.78151	119.064513
MNY08	11/10/2017	Pseudoscorpion	Olpiidae	Euryolpium	sp. indet.	1	Basalt outcrops	Male	-22.78151	119.064513
MNY08	11/10/2017	Spider (non-mygal)	Selenopidae	Karaops	sp. indet.	1	Basalt outcrops	Undetermined/ Immature	-22.78151	119.064513
MNY08	11/10/2017	Land Snail				1	Basalt outcrops		-22.78151	119.064513
MNY09	11/10/2017	Pseudoscorpion	Olpiidae	Indolpium	sp. indet.	1	Hillcrest/ Hillslope	Female	-22.771462	119.067731
MNY10	11/10/2017	Spider (non-mygal)	Selenopidae	Karaops	sp. indet.	1	Breakaway/ Cliff	Undetermined/ Immature	-22.805934	119.094672
MNY10	11/10/2017	Spider (non-mygal)	Selenopidae	Karaops	sp. indet.	1	Breakaway/ Cliff	Undetermined/ Immature	-22.805934	119.094672
MNY11	11/10/2017	Scorpion	Buthidae	Lychas	bituberculatus complex'	1	Drainage Area/ Floodplain	Male	-22.791486	119.099681
MNY12	11/10/2017	Spider (non-mygal)				1	Drainage Area/ Floodplain		-22.8016893	119.1245232
MNY13	12/10/2017	Isopod	Armadillidae	Buddelundia	sp. '16'	2	Gorge/ Gully		-22.791445	119.084875

MNY13	12/10/2017	Land Snail				3	Gorge/ Gully	Undetermined/ Immature	-22.791445	119.084875
MNY13	12/10/2017	Spider (non-mygal)	Selenopidae	Karaops	sp. indet.	1	Gorge/ Gully	Undetermined/ Immature	-22.791445	119.084875
MNY13	12/10/2017	Millipede	Trigoniulidae	Austrostrophus	sp. indet.	1	Gorge/ Gully	Undetermined/ Immature	-22.791445	119.084875
MNY14	12/10/2017	Millipede	Trigoniulidae	Austrostrophus	sp. indet.	1	Gorge/ Gully	Female	-22.809234	119.103227
MNY14	12/10/2017	Scorpion	Buthidae	Lychas	hairy tail complex'	1	Gorge/ Gully	Female	-22.809234	119.103227
MNY14	12/10/2017	Isopod	Armadillidae	Buddelundia	sp. '10ma'	1	Gorge/ Gully	Female	-22.809234	119.103227
MNY14	12/10/2017	Land Snail				1	Gorge/ Gully		-22.809234	119.103227
MNY17	12/10/2017	Pseudoscorpion	Olpiidae	Austrohorus	sp. indet.	1	Minor Drainage Line	Undetermined/ Immature	-22.776306	119.055641
MNY18	12/10/2017	Pseudoscorpion	Olpiidae	Indolpium	sp. indet.	1	Minor Drainage Line	Female	-22.767919	119.060545
MNY18	12/10/2017	Pseudoscorpion	Atemnidae	Oratemnus	sp. indet.	1	Minor Drainage Line	Undetermined/ Immature	-22.767919	119.060545
MNY19	12/10/2017	Land Snail				4	Breakaway/ Cliff	Undetermined/ Immature	-22.782543	119.074815
MNY20	12/10/2017	Isopod	Armadillidae	Buddelundia	sp. '16'	1	Breakaway/ Cliff	Undetermined/ Immature	-22.783077	119.074327
MNY21	17/06/2018	Millipede	Trigoniulidae	Austrostrophus	sp. indet.	2	Gorge/ Gully	Undetermined/ Immature	-22.796982	119.109165
MNY21	17/06/2018	Isopod	Philosciidae		sp. indet.	6	Gorge/ Gully	Undetermined/ Immature	-22.796982	119.109165
MNY21	17/06/2018	Isopod	Armadillidae	Buddelundia	sp. indet.	1	Gorge/ Gully	Female	-22.796982	119.109165
MNY21	17/06/2018	Pseudoscorpion	Olpiidae	Indolpium	sp. indet.	2	Gorge/ Gully	Undetermined/ Immature	-22.796982	119.109165
MNY21	17/06/2018	Spider (non-mygal)	Selenopidae	Karaops	sp. indet.	2	Gorge/ Gully	Undetermined/ Immature	-22.796982	119.109165
MNY22	17/06/2018	Scorpion	Buthidae	Lychas	hairy tail complex'	1	Gorge/ Gully	Male	-22.794673	119.11027
MNY22	17/06/2018	Millipede	Trigoniulidae	Austrostrophus	sp. indet.	1	Gorge/ Gully		-22.794673	119.11027
MNY22	17/06/2018	Spider (non-mygal)	Selenopidae	Karaops	sp. indet.	1	Gorge/ Gully	Undetermined/ Immature	-22.794673	119.11027
MNY22	17/06/2018	Isopod	Armadillidae	Buddelundia	sp. '16'	6	Gorge/ Gully		-22.794673	119.11027
MNY22	17/06/2018	Isopod	Philosciidae		sp. indet.	3	Gorge/ Gully		-22.794673	119.11027
MNY22	17/06/2018	Pseudoscorpion	Chthoniidae	Austrochthonius	sp. indet.	3	Gorge/ Gully		-22.794673	119.11027
MNY22	17/06/2018	Centipede				2	Gorge/ Gully		-22.794673	119.11027
MNY22	17/06/2018	Isopod	Armadillidae	Buddelundia	sp. '16'	3	Gorge/ Gully	Female	-22.794673	119.11027
MNY23	17/06/2018	Pseudoscorpion	Olpiidae	Indolpium	sp. indet.	1	Gorge/ Gully	Undetermined/ Immature	-22.810384	119.115356

MNY23	17/06/2018	Pseudoscorpion	Chthoniidae	Austrochthonius	sp. indet.	1	Gorge/ Gully	Female	-22.810384	119.115356
MNY23	17/06/2018	Isopod	Armadillidae	Buddelundia	sp. '16'	2	Gorge/ Gully	Male	-22.810384	119.115356
MNY23	17/06/2018	Spider (non-mygal)	Selenopidae	Karaops	sp. indet.	3	Gorge/ Gully	Undetermined/ Immature	-22.810384	119.115356
MNY24	18/06/2018	Pseudoscorpion	Olpiidae	Bierolpium	sp. '8/4 (small)'	1	Major Drainage Line	Female	-22.760567	119.042298
MNY24	18/06/2018	Land Snail				1	Major Drainage Line		-22.760567	119.042298
MNY24	18/06/2018	Isopod	Armadillidae	Buddelundia	sp. '16'	1	Major Drainage Line	Female	-22.760567	119.042298
MNY25	18/06/2018	Pseudoscorpion	Chthoniidae	Austrochthonius	sp. indet.	1	Minor Drainage Line	Female	-22.768471	119.07557
MNY25	18/06/2018	Land Snail				1	Minor Drainage Line		-22.768471	119.07557
MNY25	18/06/2018	Centipede				1	Minor Drainage Line		-22.768471	119.07557
MNY25	18/06/2018	Isopod	Armadillidae	Buddelundia	sp. '10ma'	1	Minor Drainage Line	Undetermined/ Immature	-22.768471	119.07557
MNY26	18/06/2018	Pseudoscorpion	Olpiidae		sp. '7/4'	6	Breakaway/ Cliff		-22.777809	119.089447
MNY26	18/06/2018	Centipede				1	Breakaway/ Cliff		-22.777809	119.089447
MNY26	18/06/2018	Pseudoscorpion	Olpiidae	Indolpium	sp. indet.	1	Breakaway/ Cliff	Undetermined/ Immature	-22.777809	119.089447
MNY26	18/06/2018	Pseudoscorpion	Olpiidae	Beierolpium	sp. '8/3'	6	Breakaway/ Cliff	Female	-22.777809	119.089447
MNY27	19/06/2018	Isopod	Armadillidae	Buddelundia	sp. '16'	1	Hillcrest/ Hillslope	Female	-22.805762	119.115723
MNY27	19/06/2018	Scorpion	Buthidae	Lychas	sp. indet.	1	Hillcrest/ Hillslope	Undetermined/ Immature	-22.805762	119.115723
MNY27	19/06/2018	Spider (non-mygal)	Selenopidae	Karaops	sp. indet.	1	Hillcrest/ Hillslope	Undetermined/ Immature	-22.805762	119.115723
MNY27	19/06/2018	Centipede				1	Hillcrest/ Hillslope		-22.805762	119.115723
MNY27	19/06/2018	Pseudoscorpion	Olpiidae	Indolpium	sp. indet.	2	Hillcrest/ Hillslope	Undetermined/ Immature	-22.805762	119.115723
MNY28	19/06/2018	Spider (non-mygal)	Selenopidae	Karaops	sp. indet.	1	Hillcrest/ Hillslope	Undetermined/ Immature	-22.81088	119.123949
MNY28	19/06/2018	Pseudoscorpion	Olpiidae		sp. '7/4'	2	Hillcrest/ Hillslope		-22.81088	119.123949
MNY28	19/06/2018	Isopod	Armadillidae	Buddelundia	sp. '49'	2	Hillcrest/ Hillslope	Female	-22.81088	119.123949
MNY28	19/06/2018	Pseudoscorpion	Olpiidae	Indolpium	sp. indet.	2	Hillcrest/ Hillslope	Undetermined/ Immature	-22.81088	119.123949
MNY28	19/06/2018	Pseudoscorpion	Chthoniidae	Austrochthonius	sp. indet.	1	Hillcrest/ Hillslope	Female	-22.81088	119.123949
MNY28	19/06/2018	Millipede	Polyxenidae			1	Hillcrest/ Hillslope		-22.81088	119.123949
MNY29	20/06/2018	Centipede				1	Breakaway/ Cliff		-22.763249	119.043689

MNY29	20/06/2018	Land Snail				38	Breakaway/ Cliff		-22.763249	119.043689
MNY29	20/06/2018	Centipede				1	Breakaway/ Cliff		-22.763249	119.043689
MNY29	20/06/2018	Isopod	Armadillidae	Buddelundia	sp. '16'	9	Breakaway/ Cliff		-22.763249	119.043689
MNY29	20/06/2018	Spider (non-mygal)	Selenopidae	Karaops	sp. indet.	2	Breakaway/ Cliff	Undetermined/ Immature	-22.763249	119.043689
MNY29	20/06/2018	Millipede	Trigoniulidae	Austrostrophus	sp. indet.	1	Breakaway/ Cliff	Undetermined/ Immature	-22.763249	119.043689
MNY30	20/06/2018	Scorpion	Buthidae	Lychas	hairy tail complex'	1	Hillcrest/ Hillslope	Female	-22.768714	119.048215
MNY30	20/06/2018	Dipluran				1	Hillcrest/ Hillslope		-22.768714	119.048215
MNY30	20/06/2018	Pseudoscorpion	Chthoniidae	Tyrannochthonius	aridus	1	Hillcrest/ Hillslope	Male	-22.768714	119.048215
MNY30	20/06/2018	Isopod	Armadillidae	Buddelundia	sp. '16'	1	Hillcrest/ Hillslope	Female	-22.768714	119.048215
MNY31	20/06/2018	Centipede				1	Breakaway/ Cliff		-22.728684	119.010167
MNY31	20/06/2018	Spider (non-mygal)				1	Breakaway/ Cliff		-22.728684	119.010167
MNY31	20/06/2018	Isopod	Armadillidae	Buddelundia	sp. '16'	2	Breakaway/ Cliff	Female	-22.728684	119.010167
MNY32	20/06/2018	Spider (non-mygal)	Selenopidae	Karaops	sp. indet.	1	Gorge/ Gully	Undetermined/ Immature	-22.764289	119.060112
MNY32	20/06/2018	Scorpion	Buthidae	Lychas	bituberculatus complex'	1	Gorge/ Gully	Undetermined/ Immature	-22.764289	119.060112
MNY32	20/06/2018	Pseudoscorpion	Olpiidae	Austrohorus	sp. indet.	3	Gorge/ Gully	Female	-22.764289	119.060112
MNY34	21/06/2018	Pseudoscorpion	Olpiidae	Indolpium	sp. indet.	2	Breakaway/ Cliff		-22.799575	119.106113
MNY34	21/06/2018	Millipede	Trigoniulidae	Austrostrophus	sp. indet.	2	Breakaway/ Cliff		-22.799575	119.106113
MNY34	21/06/2018	Isopod	Armadillidae	Buddelundia	sp. '10ma'	1	Breakaway/ Cliff	Undetermined/ Immature	-22.799575	119.106113
MNY34	21/06/2018	Centipede			sp. indet.	1	Breakaway/ Cliff		-22.799575	119.106113
MNY34	21/06/2018	Spider (non-mygal)	Selenopidae	Karaops	sp. indet.	1	Breakaway/ Cliff	Undetermined/ Immature	-22.799575	119.106113
MNY35	22/06/2018	Pseudoscorpion	Olpiidae	Bierolpium	sp. indet.	1	Minor Drainage Line	Undetermined/ Immature	-22.788332	119.103732
MNY35	22/06/2018	Isopod	Armadillidae	Buddelundia	sp. '49'	3	Minor Drainage Line	Female	-22.788332	119.103732
MNY35	22/06/2018	Land Snail				1	Minor Drainage Line		-22.788332	119.103732
MNY36	22/06/2018	Centipede				1	Hillcrest/ Hillslope		-22.788281	119.093887
MNY36	22/06/2018	Land Snail				1	Hillcrest/ Hillslope		-22.788281	119.093887
MNY36	22/06/2018	Pseudoscorpion	Chthoniidae	Tyrannochthonius	aridus	1	Hillcrest/ Hillslope	Male	-22.788281	119.093887
MNY36	22/06/2018	Isopod	Armadillidae	Buddelundia	sp. '10ma'	4	Hillcrest/ Hillslope		-22.788281	119.093887
MNY37	23/06/2018	Spider (non-mygal)	Selenopidae	Karaops		1	Minor Drainage Line	Undetermined/ Immature	-22.773373	119.076738

MNY37	23/06/2018	Land Snail				6	Minor Drainage Line		-22.773373	119.076738
MNY38	21/06/2018	Land Snail				1	Minor Drainage Line		-22.768361	119.043416