OB29, 30, 35 Expansion
Short-range Endemic Invertebrate Fauna Survey

Report to BHP West Australian Iron Ore

7 May 2024

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4	Nihara Gunawardene		Trent Betts	07/05/2024

Executive Summary

BHP Western Australian Iron Ore (BHP WAIO) commissioned Biologic Environmental Survey Pty Ltd (Biologic) to undertake a detailed two-season short-range endemic (SRE) invertebrate fauna survey in the Orebody 29, 30, 35 expansion area (hereafter referred to as the Study Area). The Study Area is located approximately 6 km south-west of Newman and covers an area of approximately 610 ha. The purpose of this survey was to inform future environmental approvals across the Study Area by assessing the occurrence and potential occurrence of significant environmental values pertaining to terrestrial invertebrate fauna species with restricted geographic ranges.

From the database searches and literature review, 146 taxa representing five Confirmed SRE and 141 Potential SRE taxa have been recorded from within 40 km of the Study Area. The Confirmed SRE species were represented by one mygalomorph spider, *Aname watsoni,* one selenopids spider, *Karaops morganoconnelli*, one pseudoscorpion, *Feaella callani*, and two millipedes – *Antichiropus verutus* and *Antichiropus cristatus*. Only *Aname watsoni* is considered Highly Likely to occur in the Study Area, the remaining Possible or Unlikely to occur. The only records of Potential SRE within the Study Area were *Indolpium* sp. indet.

The two season SRE invertebrate survey was undertaken within the Study Area in April and November of 2023. Habitat assessments were carried out at 37 sites across the Study Area. From a combination of visual assessment, adjacent mapping information, and satellite imagery, five habitat types were recorded and mapped across the Study Area. The majority (>98%) of the Study Area consists of habitats of Low significance to SRE invertebrate fauna, or were cleared. The Breakaway/ Cliff habitat is of High significance for SRE invertebrates, but only covers 0.27% of the Study Area. A small portion (1.82%) of the Study Area was Hillcrest/ Hillslope, which is Moderately suitable for SRE invertebrate fauna.

Short-range endemic invertebrate sampling was conducted at 25 of the 37 sites assessed and 21 taxa from SRE groups were identified from the combination of morphological and molecular identification. Of the 14 named taxa, nine are considered Potential SRE and the remaining five are considered Widespread. Currently, six Potential SRE taxa are known only from the Study Area, though only three taxa were recorded only in Moderately suitable SRE habitat Hillcrest/ Hillslope. These were Olpiidae `sp. Biologic-PSEU164`, Geophilidae `sp. Biologic-CHIL064` and *Buddelundia* `sp. Biologic-ISOP139`. Taxa within these groups have not historically been sampled during SRE surveys and continuing molecular work has revealed a highly diverse fauna. Further work needs to be done to better understand the taxonomy, distribution and SRE status of these groups in the region.

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1 Introduction

1.1 Background

BHP Western Australian Iron Ore (BHP WAIO) commissioned Biologic Environmental Survey Pty Ltd (Biologic) to undertake a desktop assessment and a detailed two-season short-range endemic (SRE) invertebrate fauna survey in the Orebody 29, 30, 35 expansion area (hereafter referred to as the Study Area). The Study Area is located approximately 6 km south-west of Newman (Figure 1.1) and covers an area of approximately 610 ha.

1.2 Scope and objectives

The objective of this survey was to identify the occurrence of SRE invertebrate fauna species and their habitats within the Study Area, by combining the information gathered during a desktop assessment and a two-season detailed SRE invertebrate fauna survey. Specifically, the key objectives of the report were to:

- Describe and map significant and SRE invertebrate fauna habitat values of the Study Area; and
- Compile an inventory of significant and SRE invertebrate fauna present or potentially present within the Study Area.

This report may be used to inform the environmental assessment and approvals process and may also assist in the preparation of Environmental Impact Assessment documentation.

1.3 Short-range endemic invertebrate fauna

Endemism refers to the restriction of a species to a particular area, whether it is at the continental, national, or local scale (Allen *et al.*, 2002). Endemism at a local scale is referred to as short-range endemism (Harvey, 2002). Short-range endemism of a species is influenced by several factors including life history, physiology, habitat requirements, dispersal capabilities, biotic and abiotic interactions and historical conditions which not only influence the distribution of a species, but also the tendency for differentiation and speciation (Ponder & Colgan, 2002).

Harvey (2002) proposed a range criterion for terrestrial SRE invertebrate species at less than 10,000 km^2 (or 100 km x 100 km), which has been adopted by regulatory authorities in Western Australia (EPA, 2016b). SRE invertebrate species often share similar biological, behavioural, and life history characteristics that influence their restricted distributions and limit their wider dispersal (Harvey, 2002). For example, burrowing taxa such as mygalomorph spiders and *Urodacus* scorpions may only leave their burrows (or a narrow home territory near the burrow) as juveniles dispersing from the maternal burrow, or when males search for a mate (Rix *et al.*, 2017). Taxa such as terrestrial isopods, millipedes and snails are dispersal-limited because of their slow movement and cryptic habitat (Car *et al.*, 2019), while some taxa can be limited by very specific habitat requirements, such as selenopid spiders within fractured rocky outcrops (Crews, 2013).

Several taxonomic groups of invertebrates are currently understood to have a high proportion of species with restricted ranges and, as such, are given additional consideration in terrestrial fauna assessments. These include mygalomorph spiders (Castalanelli *et al.*, 2014), selenopid spiders (Crews, 2013), scorpions (Volschenk *et al.*, 2010), pseudoscorpions (Harvey *et al.*, 2016), millipedes (Car *et al.*, 2019), land snails (Johnson *et al.*, 2004), and terrestrial isopods . The Environmental Protection Authority (EPA) considers the existence of SRE invertebrate fauna to be a significant biodiversity issue and that SRE fauna "may be at a greater risk of changes in conservation status as a result of habitat loss or other threatening processes" (EPA, 2016b).

1.4 Conservation legislation

Protection for significant invertebrate species and ecological communities (i.e. Threatened and Priority Ecological Communities (TECs and PECs)) is provided under State and Federal legislation, comprising:

- *Environmental Protection Act 1986* (*EP Act 1986*) (WA).
- *Biodiversity Conservation Act 2016* (*BC Act 2016*) (WA).
- *Environment Protection and Biodiversity Conservation Act 1999* (*EPBC Act 1999*) (Commonwealth).

The majority of SRE invertebrate species and communities are not currently protected under this legislation, due in large part to incomplete taxonomic and ecological knowledge, and as such the assessment of conservation significance for SRE invertebrates is guided primarily by advice provided by the Western Australian Museum (WAM) and other taxonomic experts, and under technical guidance from the EPA, including:

- EPA (2016a) *Environmental Factor Guideline: Terrestrial Fauna.*
- EPA (2016b) *Technical Guidance: Sampling of Short-range Endemic Invertebrate Fauna.*
- EPA (2016c) *Technical Guidance: Terrestrial Fauna Surveys.*

The survey was also carried out in a manner consistent with the following document developed by BHP WAIO:

- BHP (2022) *BHP WAIO's Short-range Endemic Invertebrate Fauna Assessment Methods: Technical Process Instruction (SPR-IEN-EMS-013).*

LEGEND

Study Area

Rail

Biologic

Scale 1:15,000

0 200 400 Meters

Coordinate System: GDA 1994 MGA Zone 50
Projection: Transverse Mercator
Datum: GDA 1994 Created 29/04/2024

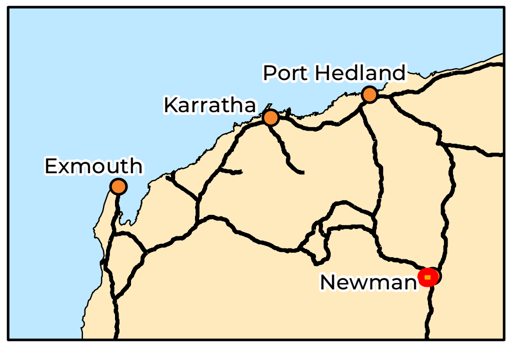

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Figure 1.1: Study Area and regional context

2 Existing Environment

2.1 Biogeography

The Study Area is located within the Pilbara bioregion of Western Australia, as defined by the Interim Biogeographic Regionalisation of Australia (IBRA) (Thackway & Cresswell, 1995). The Study Area wholly occurs within the Hamersley subregion (PIL3) of the Pilbara region. The Hamersley subregion is the southernmost section of the Pilbara Craton and is a mountainous area of Proterozoic sedimentary ranges and plateaux, dissected by basalt, shale and dolerite gorges (Kendrick, 2001). Vegetation in the subregion is defined by mulga low woodland over bunch grasses in the valley floors, and *Eucalyptus leucophloia* over *Triodia brizoides* on the ranges (Kendrick, 2001).

2.2 Climate

The region has a semi-desert to tropical climate, with rainfall occurring sporadically throughout the year, although mostly during summer (Thackway & Cresswell, 1995). Summer rainfall is usually the result of tropical storms in the north or tropical cyclones that impact upon the coast and move inland (Leighton, 2004). The winter rainfall is generally lighter and is the result of cold fronts moving north easterly across the state (Leighton, 2004). The average annual rainfall ranges from 200-350 mm, although there are significant fluctuations between years, with some locations receiving up to 1,200 mm in some years (McKenzie *et al.*, 2009). Temperatures vary significantly throughout the year with average maximum summer temperatures reaching 35°C to 40°C and winter maximum temperatures generally fluctuating between 22°C and 30°C (BoM, 2023).

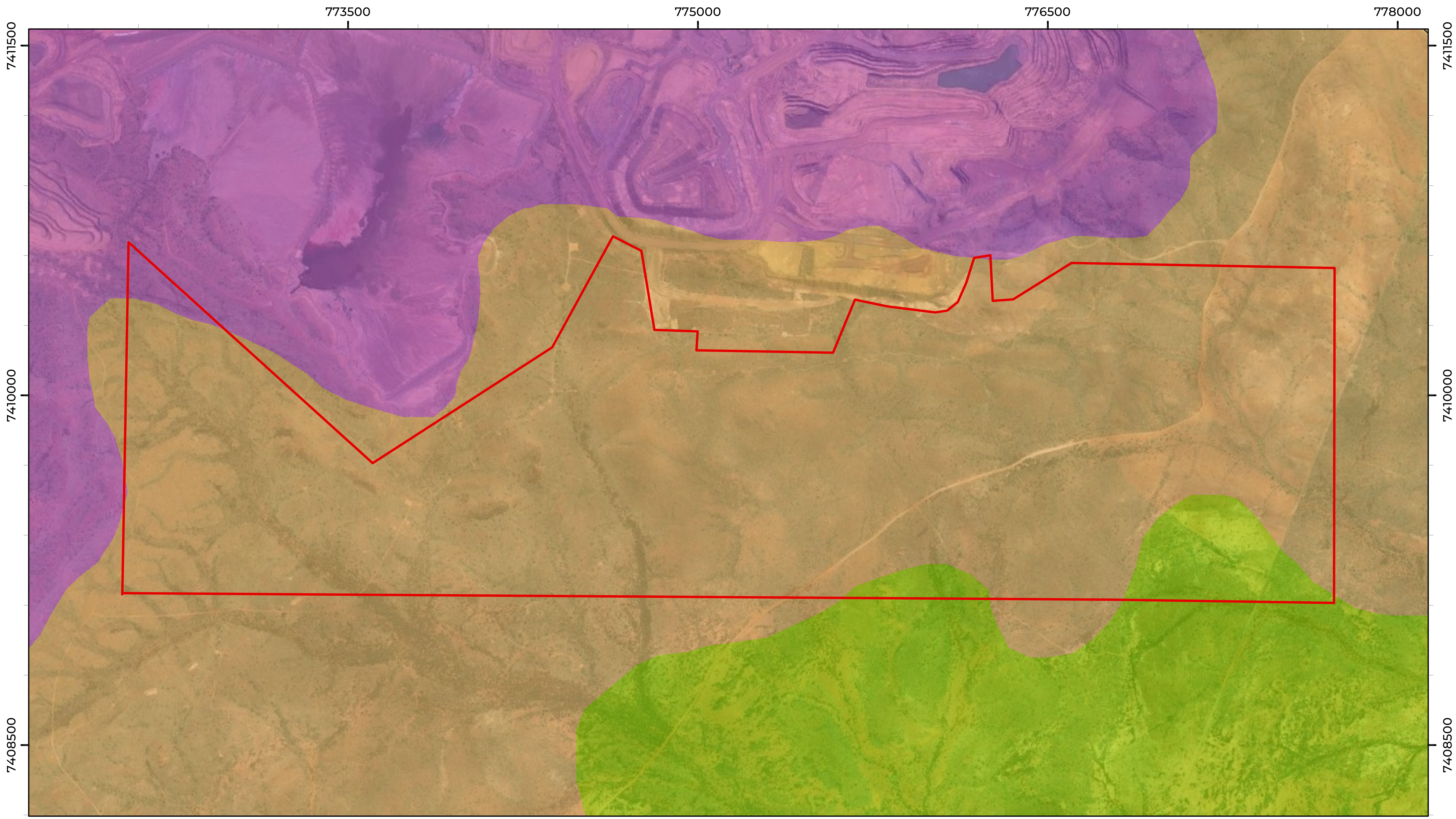
2.3 Land systems

Work undertaken by a joint team from the Department of Primary Industries and Regional Development (DPIRD) and the Department of Planning, Lands and Heritage classified the pastoral areas of Western Australia (Pringle *et al.*, 1994). The purpose of the surveys were to provide a comprehensive description and mapping of the biophysical resources of the pastoral areas, together with an evaluation of the pastoral potential and the condition of the soils and vegetation (Pringle *et al.*, 1994).

A total of three land systems have been mapped as occurring within the Study Area: Elimunna, Rocklea and Newman. The description and extent of these land systems are listed Table 2.2 and shown in Figure 2.1.The dominant land system is the Rocklea System, covering 571 ha of the Study Area.

Table 2.1: Land systems of the Study Area

Land System	Description	Extent in the Survey Area	
		ha	%
Elimunna	Stony plains on basalt supporting sparse acacia and cassia shrublands and patchy tussock grasslands.	34	5.41
Rocklea	Basalt hills, plateaux, lower slopes and minor stony plains supporting hard spinifex and occasionally soft spinifex grasslands with scattered shrubs.	571	93.60
Newman	Rugged jaspilite plateaux, ridges and mountains supporting hard spinifex grasslands.	5	0.99
Total		**610**	**100**



LEGEND

Study Area

Local Road

Land System

Elimunna System

Newman System

Rocklea System

Biologic

Scale 1:15,000

0 200 400 Meters

Coordinate System: GDA 1994 MGA Zone 50
Projection: Transverse Mercator
Datum: GDA 1994 Created 29/04/2024

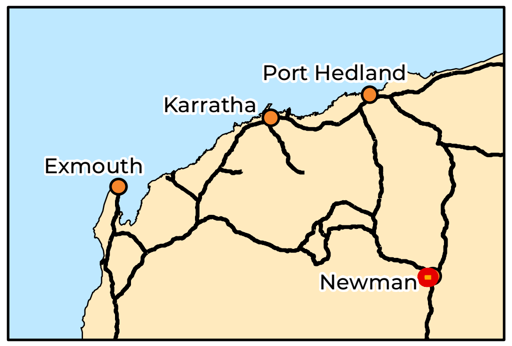


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Figure 2.1: Land systems of the Study Area

3 Methods

3.1 Desktop Assessment

A desktop assessment, comprising database searches and a literature review, was undertaken prior to the field survey. The purpose of the desktop assessment was to identify SRE invertebrate fauna occurring, or potentially occurring, in the Study Area.

3.1.1 Database searches

Five databases were searched for SRE invertebrate fauna records within and surrounding the Study Area (Table 3.1). Records of mygalomorph spiders, selenopid spiders, pseudoscorpions, scorpions, centipedes, millipedes, land snails, and terrestrial isopods were extracted. Indeterminate records were excluded, except where generic level characters and distribution information indicated a high likelihood of short-range endemism.

Table 3.1: Details of database searches conducted.

Database	Retrieval date	Search area
ALA (2023)	12/09/2023	40 km buffer surrounding the Study Area
DBCA (2023)	15/10/2023	
WAM (2023a) Arachnida & Myriapoda Database	12/09/2023	
WAM (2023b) Crustacea Database	12/09/2023	
WAM (2023c) Mollusca Database	12/09/2023	

3.1.2 Literature review

A review of relevant available literature was undertaken to record previously surveyed habitat types present within the Survey Area and to locate any additional records of significant and SRE invertebrate fauna not captured in the database searches. Fifteen publicly available and client-provided assessments were reviewed in total (Table 3.2).

Table 3.2: Literature sources used for the review.

Report title	Survey type	Distance from Study Area
ENV (2008)OB024/OB025 Short-Range Endemic Study, Case Study Pseudoscorpions	Single-Season Targeted SRE Invertebrate Survey	~14 km north-east
Outback Ecology (2008) Orebody 24/25 Upgrade Terrestrial Invertebrate Short-Range Endemic Assessment	Single-Season SRE Invertebrate Survey One targeted mygalomorph trip	~14 km north-east
Ninox (2009) A Fauna Survey of the Proposed Hope Downs 4 Mining Area, Near Newman, Western Australia	Two-Season Vertebrate and SRE Invertebrate Survey	30 km north-west

Report title	Survey type	Distance from Study Area
AMBS (2011) Assessment of Terrestrial Short-Range Endemic Invertebrates in the OB35- Western Ridge Area near Newman, Western Australia	Two-Season Vertebrate and SRE Invertebrate Survey	Adjacent
Biologic (2011) OB35 Short-Range Endemic Invertebrates Environmental Impact Assessment	EIA	Within and West of Study Area
Biologic (2012) Orebody 35 Short-Range Endemic Invertebrate Survey Report	One Season SRE Invertebrate Survey	Within and north west of Study Area
Biologic (2013) OB17/18 Short-Range Endemic Invertebrate Impact Assessment	One Season SRE Habitat Survey	~35 km east-north-east of Study Area
Biologic (2014a) Orebody 19-31 Short-Range Endemic Invertebrate Survey	Two Season SRE Invertebrate Survey	~30 km east-north-east
Biologic (2014b) Orebody 24/25 Short-Range Endemic Invertebrate Survey	Two season Detailed SRE Invertebrate Fauna Survey	~6 km north
Biologic (2015) Orebody 32 East AWT Terrestrial Short-Range Endemic Fauna Environmental Impact Assessment	EIA	~8 km north-east
Biologic (2019) Shearer's West Targeted Vertebrate and Short-Range Endemic Invertebrate Fauna Assessment	One-Season Vertebrate and SRE Invertebrate Survey	~42 km east
Biologic (2020) Jimblebar North Short-Range Endemic Invertebrate Fauna Survey	Two Season SRE Invertebrate Survey	~50 km east
Biologic (2021) Jimblebar North SRE Sequencing Report	NA	~50 km east
Bennelongia (2021a) Coombanbunna SRE field Survey Report	Two Season SRE Invertebrate Survey	13 km south-west of Newman
Bennelongia (2021b) Western Ridge Short-Range Endemic Invertebrate Fauna Survey	One Season SRE Invertebrate Survey	Adjacent West – 11 km SW of Newman

3.1.3 SRE status categorisation

The SRE categorisation used in this report follows the Western Australian Museum (WAM) revised classification system for SRE invertebrates, based upon the 10,000 km^2 range criterion proposed by Harvey (2002), and uses three categories (Confirmed SRE, Potential SRE, and Widespread) to describe the degree of certainty with which a species can be considered to be SRE or not (Table 3.3).

Table 3.3. SRE categorization used by WAM, adapted from Harvey (2002)

Distribution	Taxonomic Certainty	Taxonomic Uncertainty
Species range < 10,000 km^2	**Confirmed SRE** A known distribution of < 10,000 km^2. The taxonomy is well known. The group is well represented in collections and/or has been comprehensively sampled.	**Potential SRE** Patchy sampling has resulted in incomplete knowledge of geographic distribution. Incomplete taxonomic knowledge. The group is not well represented in collections. Any other significant knowledge gaps occur. **SRE Sub-categories may apply:** A: Data Deficient B: Habitat Indicators C: Morphology Indicators D: Molecular Evidence E: Research & Expertise
Species range > 10,000 km^2	**Widespread** A known distribution of > 10,000 km^2. The taxonomy is well known. The group is well represented in collections and/or has been comprehensively sampled.	

Confirmed SRE species are those for which sufficient evidence exists, from both taxonomic certainty and extent of sampling, to confirm that the species is restricted to a range of less than 10,000 km^2, whereas Widespread species are confirmed to have a range greater than 10,000 km^2. For taxa belonging to groups known to include SRE species, unless sufficient evidence exists to denote Confirmed SRE or Widespread status, the default categorisation is Potential SRE. This is usually due to lack of taxonomic knowledge and extensity of sampling.

Potential SRE status is sub-categorised by what information does currently exist about the taxon. Generally, all Potential SRE taxa are considered to be data deficient (sub-category A); however, where there are habitat indicators (B), morphological indicators (C), molecular evidence (D), or general expert knowledge and experience with the taxonomic group (E), there is usually a greater likelihood that the taxon is an SRE, and the more sub-categories that apply, the greater the likelihood.

3.1.4 Assessment of likelihood of occurrence

The likelihood of occurrence within the Survey Area for significant and SRE invertebrate taxa identified in the desktop assessment was assessed using a decision matrix (Table 3.4). The occurrence assessment was based on known information relating to species distribution, known habitat requirements, and locality records from database searches and previous studies within the Desktop Study Area. The assessment assigned each taxon one of five ratings, ranging from Present to Highly Unlikely to occur (Table 3.4). Where connectivity and widespread habitat exist within the Survey Area, more distant taxa have a higher likelihood to occur than where habitats are fragmented and isolated, as demonstrated in the differing likelihoods between 'Habitat available (widespread)' and 'Habitat available (restricted)'.

Table 3.4: Significant and SRE invertebrate species likelihood of occurrence in Survey Area.

		Habitat		
		Habitat available (widespread)	**Habitat available (restricted)**	**Habitat not available**
Range	**Recorded with Survey Area**	Present	Present	Present
	Recorded within < 2 km	Highly Likely	Likely	Possible
	Recorded within 2-5 km	Likely	Possible	Possible
	Recorded within 5-20 km	Possible	Possible	Unlikely
	Recorded > 20 km	Possible	Unlikely	Highly Unlikely

3.2 Field survey methods

Sampling sites were chosen to align with recommendations by the EPA (2016b) technical guidance, that is targeting of sheltered habitats and microhabitats, and habitat isolates. A total of 37 sites were visited and assessed for SRE habitat suitability. Of these, 25 were sampled for invertebrate fauna. Sites were placed to ensure that all relevant habitat types within the Study Area were sampled, and that good geographical coverage was achieved. Visual inspection for trapdoor spider burrows was conducted while moving through the Study Area and surrounds during the field survey.

3.2.1 Survey timing and weather

A two-season SRE invertebrate survey was undertaken within the Study Area in the wet season from the 26th to the 28th of April 2023 and the dry season 1st to the 3rd of November 2023. The closest Bureau of Meteorology (BoM) weather station at Newman Aero (station 007176), approximately 8 km to the south-west of the Study Area (BoM, 2023). Minimum and maximum temperatures at Newman Aero in the 12 months prior to the survey were generally typical for the location. During the wet season survey the maximum temperature ranged from 26.5°C to 28.9°C. During the dry season survey, maximum temperature ranged from 39.0°C to 40.6°C. No rainfall was recorded at Newman Aero during either survey. However, total rainfall in the month prior to the wet season survey was 118.4 mm, which is considerably higher than the long-term average (40.8mm). Almost all of this rainfall fell, 86.5 mm, on the 30th of March (Figure 3.1) (BoM, 2023).

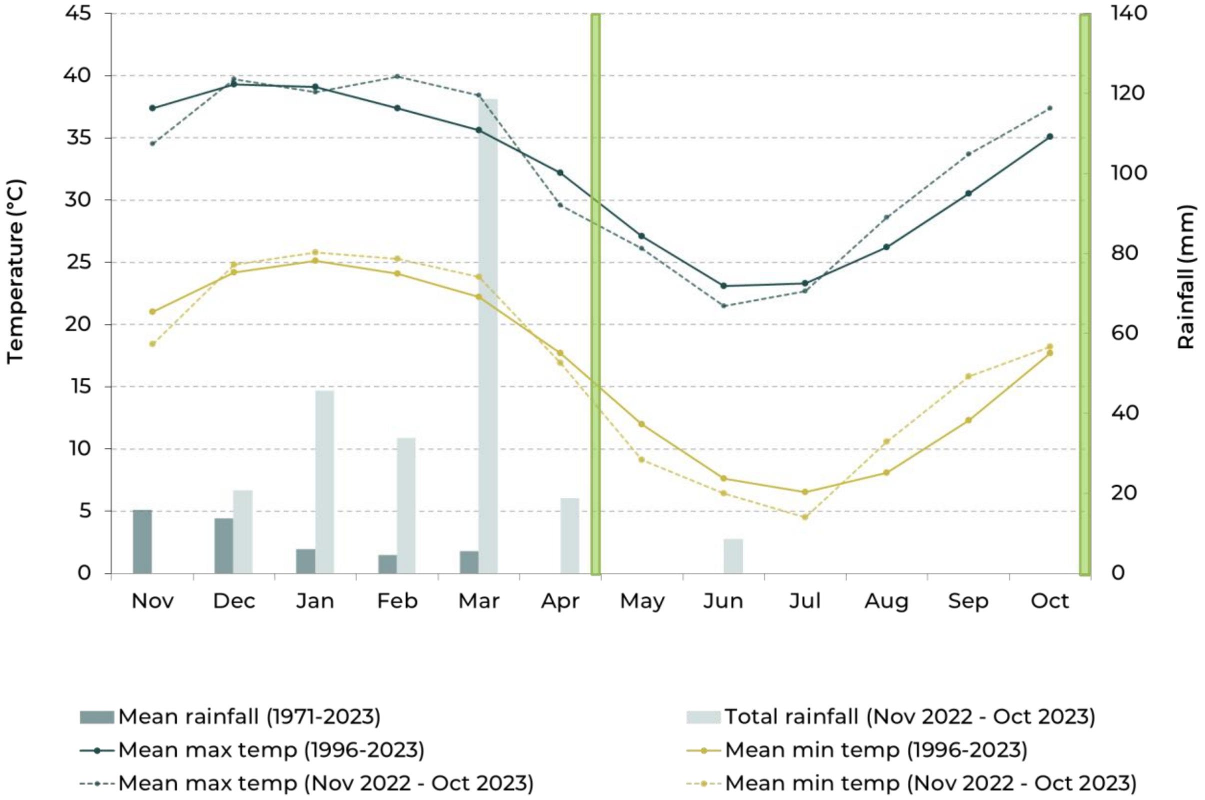


Figure 3.1: Long and short-term mean rainfall and temperature recorded at Newman Aero (station 07176); (BoM, 2023). Green shading indicates the survey timing.

3.2.2 Survey team and licensing

The fauna sampling for this survey was conducted under a DBCA Regulation 27 "Fauna Taking (Biological Assessment) License" (BA27000820) issued to Michael Curran (Appendix A).

The assessment was conducted by Principal Zoologist Nihara Gunawardene and Zoologists Isabelle Johansson and David Symons, all of whom have extensive experience with invertebrate fauna survey in the region.

3.2.3 Habitat assessment

Habitat assessments were undertaken at 37 sites by observation of the physical characteristics of the site. The broad habitat type in which the site occurred was observed and any site-specific landform characteristics were recorded. Physical characteristics at each site that were of relevance to significant and SRE invertebrate fauna were recorded, including major vegetation type and structure, vegetation condition, leaf litter cover, shade cover, and evidence of disturbance. The broad habitat type is used for mapping the habitats found in the Study Area, while the physical characteristics are used to provide an overall picture of the habitat value.

The suitability of each site for significant and SRE invertebrate fauna was assessed. The assessment considered three factors influencing suitability: isolation, protection, and complexity (see section 3.2.4). Each site was designated as being either High, Moderate or Low suitability for significant and SRE invertebrate fauna (Table 3.5).

Table 3.5: Significant and SRE invertebrate fauna habitat suitability assessment factors

Suitability	Requirement
High	A habitat with high isolation (e.g., mountaintops, islands, remnant vegetation) will likely be significant for SRE invertebrates as such fauna are usually characterised by limited dispersal ability. Protection from exposure and disturbance can support a variety of invertebrate species. Habitat complexity, such as leaf litter volume, rocky substrates, loose rocks and crevices, vegetation variation and soil depth and structural variation drives species richness and often abundance.
Moderate	Long mountain ranges and large plateaus with undulating hills may be isolated in a larger landscape scale and can support unique species. Moderate protection in shallow gullies and hillcrests/hillslopes where rocky crevices may offer some protection from the elements. Moderate complexity is often found in areas of vegetation and leaf litter.
Low	No isolation occurs in habitats such as sandy/stony plains. These areas are often vast and continuous through a landscape with no barriers to dispersal for species adapted to occurring. Very little protection from exposure and disturbance from the elements occurs in these plains and drainage areas. Low complexity characterises many plains and drainage areas, areas dominated by invasive plant species or prone to disturbance.

3.2.4 SRE fauna habitat suitability assessment

SRE habitat suitability assessment is undertaken by observation of landform characteristics of relevance to SRE invertebrate fauna, including major vegetation type and structure, vegetation condition, leaf litter cover, shade cover, and evidence of disturbance. SRE habitat suitability considers three factors: isolation, protection, and habitat complexity, as briefly outlined here:

- *Isolation* is the degree of connectivity between sites of similar habitat, or which share similar habitat characters. Degree of isolation is the most important factor when assessing the level of risk to SRE invertebrate fauna. SRE fauna have poor dispersal abilities so, if suitable habitat for a species is removed and other suitable habitat is some distance away, they may have no ability to survive to find other suitable habitat.

Habitats which may have a high degree of isolation include remnant vegetation, rocky outcrops, gorges, and the tops of ranges. Lower lying habitats such as plains, hills and drainage areas are likely to have a lower degree of isolation.

- *Protection* is the amount of protection from exposure to heat, direct sunlight and desiccation a site provides. Protection from disturbance is also considered as it is important for the long-term viability of SRE habitats and communities. The degree of protection a site provides is considered by examining characters such as aspect, slope, shade availability, soil and litter availability, and rocky outcropping amount. Habitats with high degrees of protection can include south-facing cliffs, rockpiles, and dense vegetation groves. Habitats with a lower degree of protection may include open plains, north facing slopes and drainage lines.
- *Habitat complexity* is the diversity of microhabitats provided due to the structure and biological characters of a site. Characters examined included depth and structural variation of leaf litter, diversity of rock size and crevices in rocky substrate, richness and structural variation of vegetation, and depth and availability of soil. Habitat complexity drives species richness and abundance. This is important for both predatory species, as having an abundance and richness of prey species is critical to their survival, as well as detritivore and herbivore species that rely upon the presence of vegetation and the accumulation of litter, woody debris, and organic matter for survival.

3.2.5 Additional habitat mapping for areas not surveyed

Two areas added post-survey to the north of the Study Area were not visited during the field survey and thus their habitat suitability was not assessed from visual observation. These areas make up approximately 28 ha (4.6% of the total Study Area). Satellite imagery in conjunction with adjacent habitat information was used to extrapolate probable SRE invertebrate habitat types for these additional areas.

3.2.6 Sampling techniques

Invertebrate fauna was sampled at 25 of the 37 sites across the Study Area. The sampling techniques employed for significant and SRE invertebrate fauna sampling included active foraging of rocks, trees and debris, leaf litter and soil sifting, ground searches for spider and scorpion burrows, and cup trapping of scorpion burrows. The target taxonomic groups were arachnids (spiders, scorpions, and pseudoscorpions), myriapods (millipedes, centipedes, and symphylans), land snails, and terrestrial isopods. The sampling methods adopted were carried out in accordance with EPA guidelines (EPA, 2016b), and are detailed below:

Active foraging

Active foraging was undertaken at each sampling site for up to two person hours and involved various techniques, depending on the characters of the site:

- Presence of rocky outcropping and loose rocks: suitably sized rocks were overturned, and rocky microhabitats (cracks, crevices, and boulders) were actively searched for rock-dwelling species (selenopid spiders, pseudoscorpions, scorpions, centipedes, millipedes, isopods, and snails).
- Presence of woody debris: larger logs and woody debris were overturned and actively searched for detritivore species (millipedes and isopods).
- Presence of trees and larger vegetation: trees such as *Banksia*, *Eucalyptus, Corymbia,* and *Casuarina* were actively searched, including underneath bark and in tree hollows, for bark dwelling species (scorpions and pseudoscorpions).
- Presence of flat ground: active searching of open ground and beneath leaf litter was conducted for burrow-dwelling species (generally mygalomorph spiders and scorpions, but also wolf spiders and tiger beetles in salt lakes).

Leaf litter and soil sifting

Leaf litter, humus, and soil (to approximately 15 cm below surface where possible) was placed in a sieve at the site and agitated to sift invertebrates into a white tray. The sifted litter was then thoroughly searched for target species such as pseudoscorpions, springtails, millipedes, snails, and isopods. Up to eight sifts (approximately 3L of material) were conducted at sampled sites where sufficient leaf litter and humus was available.

Burrow excavation

When a mygalomorph burrow was encountered, a photo with a relative scale (usually forceps) was taken of the burrow both open and closed (if relevant). The excavation of the burrow included digging into the ground immediately adjacent to the spider burrow and slowly scraping around the silken burrow lining until the spider is uncovered. The spider is then extracted from its burrow using forceps and placed within a vial. The vial is then cooled on ice in an esky before placing it into a fridge to slow the spider's activity. Once immobile the spider is then frozen for a number of hours before the vial is filled with 100% ethanol for euthanasia and preservation. When a *Urodacus* scorpion burrow is encountered, if cup pitfall-trapping is not practicable, the burrow may be excavated. This is done by carefully digging along the burrow with a soil scoop until the scorpion is uncovered. The same extraction and euthanasia method is used as with mygalomorph spiders.

Specimen preservation and identification

All small invertebrate specimens were euthanized in 100% ethanol on site (except for mygalomorph spiders and scorpions). Morphological identification of all specimens was performed in-house by invertebrate taxonomists Morgan Lythe, Isabelle Johansson and Ruby McKenna using available keys and expertise.

3.2.7 Molecular analysis

DNA extraction and sequencing methods followed Cullen and Harvey (2017, 2018). Subsampled tissue/specimen was placed directly into ATL buffer for extraction using the *QIAGEN DN-easy* Blood and Tissue extraction kit, and DNA extraction followed the manufacturer's protocols. DNA extractions were amplified by Polymerase Chain Reaction (PCR) using Folmer PCR primers (LCO1490, HCO2198; Folmer *et al.*, 1994) to assess the variability of cytochrome c oxidase I (COI).

The resulting PCR product was cleaned up and sequenced by the Australian Genomic Research Facility (AGRF) Perth node. Molecular laboratory workflows were managed using GENEIOUS Prime (Kearse *et al.*, 2012) with the Biocode plugin (http://www.mooreabiocode.org). Raw sequence data were edited and assembled in GENEIOUS, and final consensus sequences were then available for downstream analysis.

Comparative sequences were taken from different sources and analysed using two separate methods.

Sources

- Biologic Sequence Library: sequences produced from previous jobs undertaken by Biologic, which is comprised of 5,764 quality assured DNA sequences.
- GenBank: Annotated open access sequence database of all publicly available nucleotide sequences and their protein translations.

Methods

- Basic Local Alignment Search Tool (BLAST): a method for rapidly searching a DNA sequence library to identify similar sequences. Sequences were searched using the "blastn" function, which returns similar matches.
- Taxonomic Curation: BLAST occasionally fails to identify sequences that could be considered useful for comparison, such as species that might be genetically distant, but are required to be included in the analysis for comparison. Taxonomically relevant specimens were identified using the available taxonomic classifications and identifications in those databases.

For each taxonomic group, the selected sequences were aligned using the Multiple Alignment using Fast Fourier Transform (MAFFT) algorithm (Katoh *et al.*, 2002). Trees were constructed on resulting alignments using the RaxML plugin in GENEIOUS (Stamatakis, 2014), with 1,000 bootstrap replicates, and the GTR+G substitution model.

To delimit taxonomic units using molecular data, a genetic distance-based threshold method was applied, combined with Biologic's morphological identifications. Fauna-specific genetic distance thresholds for delimiting species and Operational Taxonomic Units (OTUs) were used wherever possible, based on published literature and available previous reports. Where these thresholds were not available, the assessment used average divergence thresholds for related groups or higher taxa developed by broad-level studies (e.g. Hebert *et al.*, 2003).

In general, ≤8% COI divergence is seen as appropriate to determine OTUs (Hebert et al., 2003a); however, higher or lower divergences are sometimes justified depending on the organism studied. Unless otherwise stated within this report, sequences that exhibited COI divergences ≤8% are considered to belong to the same OTU.

The analysis was constrained by the breadth of data available to undertake comparisons, the accessibility of pre-existing regional sequences, and the success rate of genetic sequencing, which can be affected by specimen collection, preservation, storage methods and contamination. Best practices were followed during specimen collection, preservation, and storage, prior to specimens arriving at Biologic's laboratories. All care was taken to ensure that the risks of laboratory contamination, data handling issues, and specimen management issues were minimised within Biologic's laboratories throughout the subsampling, processing and genetic analysis.

The databases used for regional comparisons included GenBank, which is a dynamic database, and the addition of new sequences and altered taxonomic classifications could not be included into this report if they occurred after the 8th of December 2023.

DNA barcoding using the mitochondrial gene COI, while useful for explaining genetic differences between closely related or moderately related species, is limited in its ability to resolve deeper phylogenetic relationships among taxa at higher taxonomic levels (e.g. genus, family, order). In the current study, phylogenetic relationships among species/OTUs at >25% COI divergence are treated with caution (Simon *et al.*, 1994).

4 Results

4.1 Desktop assessment

The database searches gathered records of arachnids, myriapods, terrestrial isopods, and land snails from within 40 km of the Study Area. These represented 146 taxa from SRE invertebrate groups, including indeterminate records (Appendix B). Most records were of arachnids, namely mygalomorph spiders, pseudoscorpions and scorpions. Five of these taxa are Confirmed SRE; one mygalomorph spider – *Aname watsoni* (1.47 km away), one selenopid spider – *Karaops morganoconnelli* (8.85 km away), one pseudoscorpion – *Feaella callani* (12.5 km away), and two *Antichiropus* millipedes – *Antichiropus verutus* (2.81 km away) and *Antichiropus cristatus* (6.3 km away). The remaining 141 taxa are deemed Potential SRE based on the records available and knowledge of higher taxonomy where species designation is indeterminate.

The likelihood of occurrence for the Confirmed SRE species identified in the desktop assessment was measured using the decision matrix found in Table 3.4, which takes into consideration proximity to the Study Area and the extent of habitat in which these taxa occur The likelihood of occurrence analysis found that the Confirmed SRE mygalomorph spider, *Aname watsoni,* is considered Highly Likely to occur. Records exist in close proximity (minimum of 1.57 km away), however, little is known about the species habitat as most records are males collected from pitfall traps (Castalanelli *et al.*, 2020).

The selenopid spider *Karaops morganoconnelli* and millipedes *Antichiropus verutus* and *Antichiropus cristatus* are considered Possible to occur within the Study Area. *Karaops morganoconnelli* is currently only known from the region of the Ophthalmia range within the Pilbara and tends to be collected from under rocks in gullies, ridges or hillslopes (Crews, 2023). Both *Antichiropus verutus* and *Antichiropus cristatus* have very restricted distributions within the Pilbara (Car *et al.*, 2019) and all known records were collected over 2 km from the Study Area. . *Antichiropus verutus* has primarily been collected from pitfall traps within habitats such as rocky slopes, gorges, gullies and ridge bases, and was more recently collected within a steep gully in the Bennelongia SRE survey of Western Ridge (Bennelongia, 2021b). The species has also been recorded from lower-suitability habitats such as stony plain, but it is likely these specimens were caught during traverses to more suitable habitat, or in the process of finding mates. *Antichiropus cristatus* has limited habitat data available from pitfall trap collections during the Pilbara Biological Survey (SSE of Wheelara Hill) (Car *et al.*, 2019), but has been previously collected from gully and steep slope habitats (AMBS, 2011) (identified in the report as *Antichiropus* \`OB35_2\`) and slope habitats (BHP, 2023; Car *et al.*, 2019). Antichiropus millipedes are generally considered to inhabit restricted habitat types, such as rocky outcrops or deep gorges, and are limited by narrow time periods where the moisture levels allow above ground activity such as foraging and mating (Car *et al.*, 2013). Due to this, they are less likely to occur than other species that may have more widespread habitat needs, as demonstrated by a 'Possible' occurrence likelihood within the Study Area, even when recorded as close as 2.81 km. *Faealla callani* is considered Unlikely to occur in the Study Area due to its restricted distribution in major gorge habitat. This species has only been collected once in 2013 (Biologic, 2014b). This habitat type does not occur within the Study Area.

One Potential SRE pseudoscorpion has been previously recorded from within the Study Area. It has only been identified to genus level as *Indolpium* sp. indet. Disregarding 32 indeterminate taxa, a total of 21 Potential SRE taxa are considered Highly Likely to occur in the Study area, nine Likely to occur, 80 Possible to occur, and three Unlikely to occur within the Study Area. As the Newman area and its environs have been surveyed extensively, there are numerous records (27) of taxa occurring <2 km from the Study Area.

Table 4.1: Database search records of Confirmed SRE species from within 40km of the Study Area

Family	Lowest ID	Likelihood of occurrence	Closest record (km)
Anamidae	*Aname watsoni*	Highly Likely	1.57
Selenopidae	*Karaops morganoconnelli*	Possible	8.85
Feaellidae	*Feaella callani*	Unlikely	12.50
Paradoxosomatidae	*Antichiropus cristatus*	Possible	6.30
	Antichiropus verutus	Possible	2.81

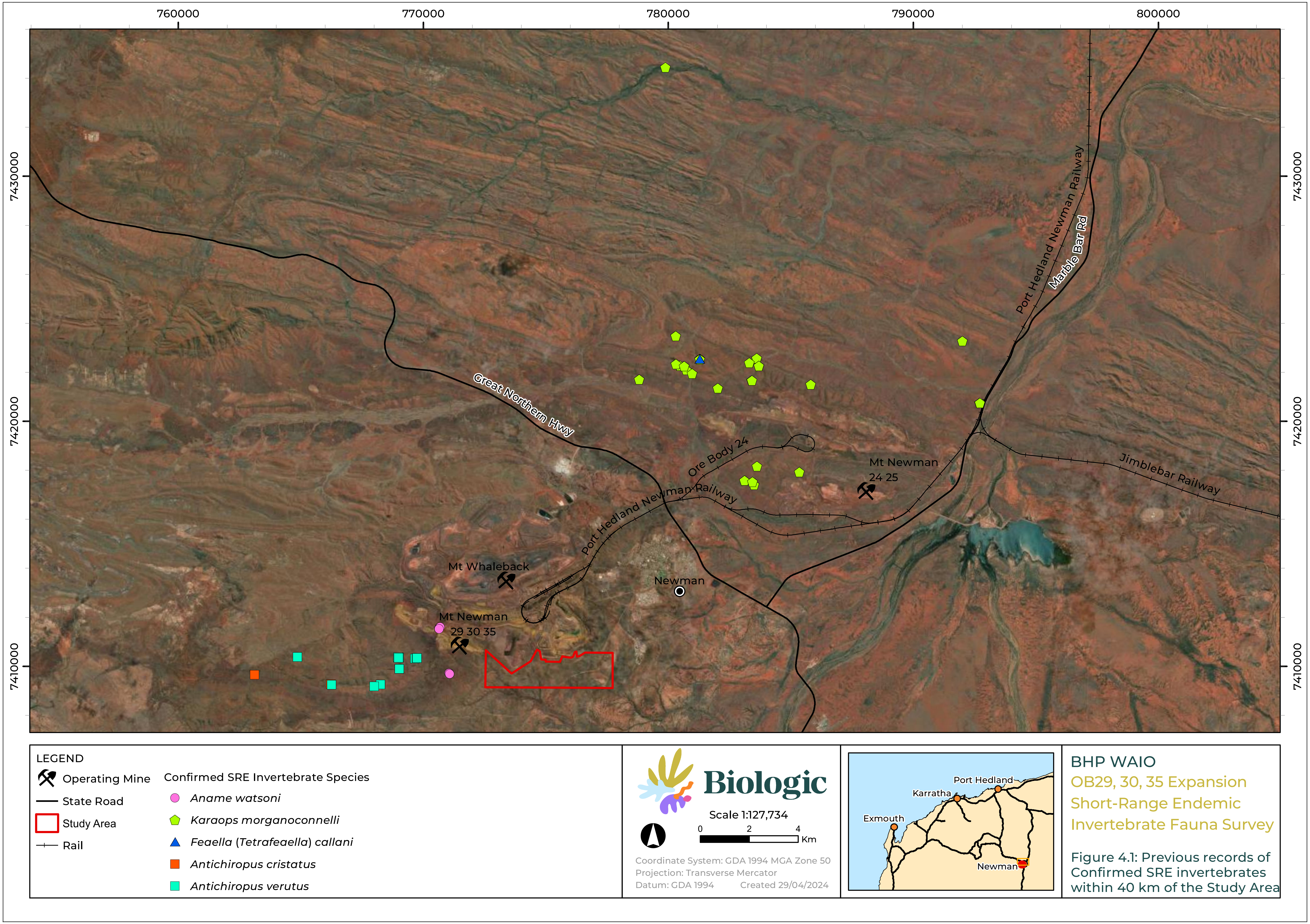


Figure 4.1: Previous records of Confirmed SRE invertebrates within 40 km of the Study Area

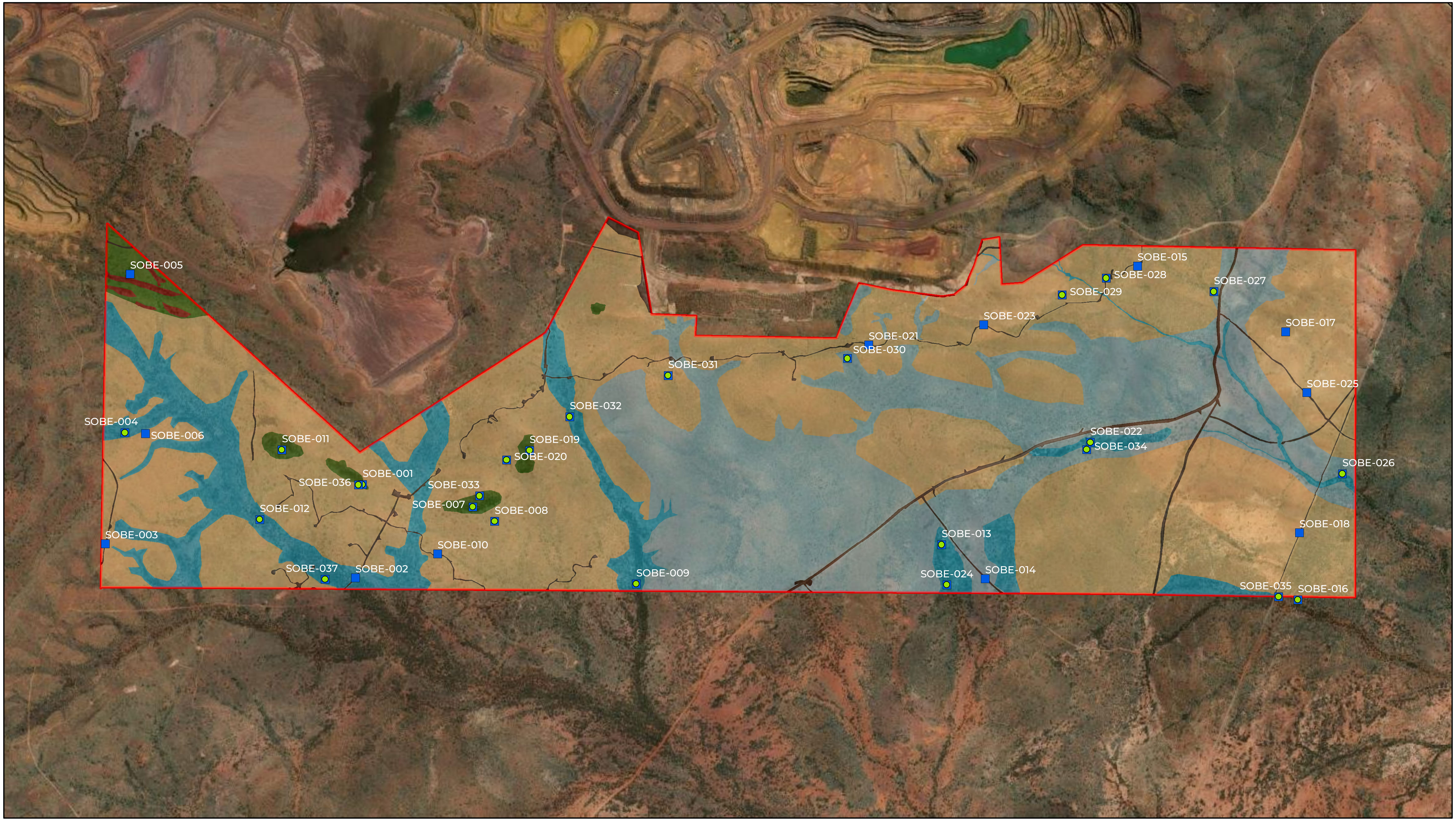
4.2 Habitat assessment

Habitat was assessed at a total of 37 sites within the Study Area (Figure 4.2). Previous habitat mapping from vertebrate fauna surveys had been developed across most of the Study Area for Western Ridge and Coombanbunna project areas. From this, the current habitat mapping was refined in accordance with SRE invertebrate fauna habitats identified during the survey. Two additional areas not assessed during the field survey were mapped from the adjacent habitat mapping information, in conjunction with satellite imagery. This portion of the Study Area constituted approximately 4.6% of the total Study Area. A total of five broad fauna habitat types were delineated within the Study Area (Figure 4.2); in decreasing order of extent, these were:

- Undulating Low Hills – 361.72 ha (59.33%);
- Drainage Area/ Floodplain – 163.13 ha (26.76%);
- Medium Drainage Line – 61.79 ha (10.14%);
- Hillcrest/Hillslope – 10.2 ha (1.67%); and
- Breakaway/ Cliff – 1.64 ha (0.27%)

A proportion of the Study Area was disturbed and was designated as Cleared/ Disturbed (11.14 ha or 1.83%). Including the cleared areas, a vast majority (>98%) of the Study Area was comprised of low significance habitats for SRE invertebrate taxa (Undulating Low Hills, Drainage Area/ Floodplain and Medium Drainage Line), or was completely unsuitable (Cleared/ Disturbed). These areas were widespread and/or interconnected and while they may be used by SRE invertebrate taxa for dispersal they do not offer the isolation and protection of habitats that SRE invertebrate taxa are often found in. Medium Drainage Line habitat is considered low significance; however, these open riparian woodland areas can support important microhabitats such as leaf litter accumulations, woody debris, small hollows, peeling bark, and a thick upper canopy. The Medium Drainage habitat is distinguished further by the fact that it would hold water for periods of time following rainfall and is a linear feature within the landscape, often providing connectivity for invertebrates across the landscape.

Hillcrest/ Hillslope habitat (1.67 %) was considered moderately suitable for SRE taxa. This habitat was characterised by open slopes with a rocky substrate and scattered trees and shrubs over low hummock grasslands. Important habitat features include old-growth spinifex, fallen boulders and outcropping ironstone containing overhangs and crevices. Instances of Breakaway/ Cliff habitats were contained within the Hillcrest/ Hillslope habitat and comprised microhabitats that were uncommon in other habitat types, such as rocky overhangs, caves and crevices. This significant habitat, however, only encompassed 0.27% of the Study Area, and was not accessed due active mining in the area. Due to this access limitation, the far north-west portion of the Study Area containing Breakaway/ Cliff habitat was assessed via visual inspection from a safe location. Both these habitat types were restricted in the landscape providing the isolation that is often associated with SRE taxa.



LEGEND

Study Area

Local Road

Sampling Type

Habitat Assessment

Sample Site and Habitat Assessment

Fauna Habitat

Breakaway/ Cliff

Cleared/ Disturbed

Drainage Area/ Floodplain

Hillcrest/ Hillslope

Medium Drainage Line

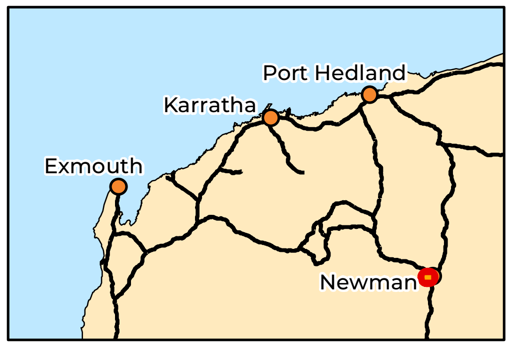
Undulating Low Hills

Biologic

Scale 1:15,000

0 200 400 Meters

Coordinate System: GDA 1994 MGA Zone 50
Projection: Transverse Mercator
Datum: GDA 1994 Created 29/04/2024



BHP WAIO

OB29, 30, 35 Expansion Short-Range Endemic Invertebrate Fauna Survey

Figure 4.2: SRE sample sites and habitats in the Study Area

Table 4.2: Habitat types within the Study Area with description and explanation of significance for SRE fauna.

Habitat type, extent, and suitability	Description	Extent	Potential SRE groups and explanation of significance	Representative photo
Undulating Low Hills Extent in Study Area: 361.72 ha (59.33%) SRE suitability: Low	These habitats are often comprised of gentle, open hill slopes with shallow gullies and with a mantles of gravel and larger rocks. The habitat supports hard spinifex (*Triodia* spp.) with scattered *Eucalyptus* trees and *Acacia*, *Eremophila* and/or *Grevillea* shrubs. These areas rarely feature dense vegetation and present limited complex sheltered habitats.	The Undulating Low Hills habitat occurs throughout the Study Area, usually associated with the lower elevation areas. Undulating Low Hills habitat is a characteristic habitat type of the Pilbara region. Its occurrence throughout the region is widespread and common.	**Mygalomorph spiders, selenopid spiders, pseudoscorpions, scorpions, and terrestrial isopods.** Low levels of habitat complexity, protection and isolation generally make these areas unsuitable for SRE species. Undulating low hills are unlikely to support SRE species due to high exposure, low complexity, and low isolation. The hills occasionally contain small rockpiles, outcropping and breakaways, providing limited shelter and isolation for SRE fauna.	

Habitat type, extent, and suitability	Description	Extent	Potential SRE groups and explanation of significance	Representative photo
Drainage Area/ Floodplain Extent in Study Area: 163.13 ha (26.76%) SRE suitability: Low	These habitats comprise predominantly flat areas with vegetation comprised of vegetation groves and various grasses and scattered patches of small to medium shrub species on gravelly clay loam or sandy substrates. These areas are mostly extensive, open plains that are adjacent to medium and major drainage lines	The Drainage Area/ Floodplain habitat occurs in low lying drainage areas and is common throughout the Study Area. Drainage Area/ Floodplain habitat is associated closely with drainage landforms of the Pilbara as it is caused by sediment overflow during flooding events.	**Mygalomorph spiders, pseudoscorpions, scorpions, land snails, terrestrial isopods.** Burrowing species may be found as they often occur on patches of deeper clay-loam soils, and for detritivore species that rely on dense leaf litter; however, the low levels of habitat complexity, protection and isolation generally make these areas unsuitable for most SRE species.	

Habitat type, extent, and suitability	Description	Extent	Potential SRE groups and explanation of significance	Representative photo
Medium Drainage Line Extent in Study Area: 61.79 ha (10.14%) SRE suitability: Low	Mid-sized drainage lines can be densely or sparsely vegetated, and extensive, but tend to be prone to impacts from flooding. Vegetation is often *Corymbia*, *Eucalyptus*, *Acacia aneura* or other *Acacia* over shrubby understory and patchy cover of hummock and/or tussock grasses on stony or gravelly substrates. Much of the Medium Drainage within the Study Area was overrun with invasive grasses.	Medium Drainage Line habitat occurs in a few pockets across the Study Area. These are associated with drainage systems that run through the area, and usually include surrounding Drainage Area/ Floodplain habitat. This fauna habitat is widespread throughout the Pilbara bioregion, though its structure and condition is variable as a result of rainfall events and susceptibility to degradation from cattle grazing.	**Mygalomorph spiders, pseudoscorpions, scorpions, land snails, terrestrial isopods.** Habitat complexity and exposure protection can be quite high in areas of dense vegetation; however, isolation is generally low as drainage lines form an interconnected network of vegetation-based habitats. Drainage lines may provide dispersal corridors for some SRE fauna.	

Habitat type, extent, and suitability	Description	Extent	Potential SRE groups and explanation of significance	Representative photo
Hillcrest/ Hillslope Extent in Study Area: 10.20 ha (1.67%) SRE suitability: Moderate	This habitat comprises rocky outcrops and ridges within the Study Area. A common feature of Hillcrest/ Hillslope habitat is a rocky substrate, often with exposed bedrock, and skeletal red soils. These can contain cracks and crevices. Instances of Breakaway/ Cliff is contained within this habitat. This habitat is usually dominated by open *Eucalyptus* woodlands, *Acacia* and *Grevillea* scrublands and *Triodia* low hummock grasslands.	Rocky Hillcrest/ Hillslope habitat makes up most of the higher ground throughout the Study Area. The habitat type in the Study Area was limited to very small discontinuous hills and were very open and exposed at the top.	**Selenopid spiders, pseudoscorpions, millipedes, terrestrial isopods.** While generally unsuited to SRE fauna due to high exposure and lack of complexity, small microhabitats of deeper soils and leaf litter can be important for some species, as is the case with the Priority 1 species *Antichiropus pendiculus* and *A. cirratus* at Mining Area C and South Flank (Biologic, 2016, 2018). High ranges are often isolated, acting as terrestrial islands for some species. South-facing steep slopes may also provide some protection.	

Habitat type, extent, and suitability	Description	Extent	Potential SRE groups and explanation of significance	Representative photo
Breakaway/ Cliff Extent in Study Area: 1.64 ha (0.27%) SRE suitability: High	Breakaway/ Cliffs are rugged, incised rocky hills and ranges. They tend to contain large rock fragments and more rock outcropping than other fauna habitats. Significant habitat features such as caves are sometimes encountered in this habitat type. Vegetation can be dense and complex in areas of soil deposition or sparse and simple where erosion has occurred.	Breakaway/ Cliff habitat occurs wholly within the Hillcrest/ Hillslope habitat. It occurs only in the upper north-west corner of the Study Area in a small, isolated pocket, where hydrology action has carved into the Hillcrest/Hillslope face over time.	**Selenopid spiders, pseudoscorpions, millipedes, land snails, terrestrial isopods.** These habitats are often highly suitable for SRE fauna owing to the protection from exposure, high complexity and moisture retention, and inherent isolation due to discontinuous landforms. South-facing cliffs and breakaways tend to have a higher degree of protection while north-facing cliffs and breakaways tend to be more exposed.	

Habitat type, extent, and suitability	Description	Extent	Potential SRE groups and explanation of significance	Representative photo
Cleared/ Disturbed Extent in Study Area: 11.14 ha (1.83%) SRE suitability: N/A	Cleared or recently disturbed areas devoid of vegetation or heavily disturbed, due to mining and pastoralism activities.	The disturbed habitat occurs throughout the Study Area, in smaller strips and patches primarily associated with drilling activity (with drill lines, drill pads and access tracks).	Generally unsuitable for SRE invertebrate fauna.	

4.3 SRE invertebrate fauna

SRE invertebrate fauna sampling was conducted at 25 of the 37 sites assessed across the two surveys. A total of 40 invertebrate specimens from targeted groups were collected during the two sampling periods (wet and dry seasons). These specimens were morphologically identified by in-house taxonomists, and 19 representative specimens were sequenced for DNA barcoding and compared to available regional sequences. In total, 21 taxa from SRE groups were represented from the combination of morphological and molecular identification, including seven with indeterminate species designation (Table 4.3). These taxa were represented by four Araneae, five Pseudoscorpiones, two Scorpiones, two Chilopoda, two Gastropoda and six Isopoda. Of these 21 taxa, 13 are considered Potential SRE while the remaining eight are considered Widespread (not including one Widespread species observed by burrow morphology alone) (Table 4.3).

Several *Gaius tealei* burrows, some abandoned/dead and some aestivating, were observed in multiple drainage line sites (Table 4.3). As this is a widespread species, Biologic are confident that the burrows in these weed invaded drainage line sites represent this species. Given this, no burrows were excavated and hence no specimen obtained. As such this species is not included in the specimen count as no specimen was collected. Other mygalomorph spider burrows were observed during the survey but not excavated, as they were in close proximity to other specimens collected and likely to represent species collected nearby, e.g. *Aname mellosa*. Each taxon is elaborated on further in the following sections, with the terminology of *dissimilarity* being used for OTUs to indicate the degree of relatedness of specimens to each other genetically. The lower the dissimilarity the greater the chance that the two specimens are the same species.

Table 4.3. Invertebrate fauna collected within the Study Area from target groups during the survey. Red text indicates Potential SRE taxa that have not been recorded beyond the Study Area to date.

Higher taxon	Taxon	SRE status	Number individuals	Linear range (km)	Identification method	Habitat type
ARACHNIDA: ARANEAE						
Actinopodidae	*Missulena davidi*	Widespread	1	~300	Molecular	MD
Anamidae	*Aname mellosa*	Widespread	2	>200	Molecular	DA/F, MD
Barychelidae	Barychelidae sp. indet.	Potential	1	N/A	Morphological	MD
	Synothele `MYG334`	Widespread	1	259.4	Molecular	H/H
Idiopidae	*Gaius tealei*	Widespread	-	>200	Burrows only	DA/F, MD
ARACHNIDA: PSEUDOSCORPIONES						
Atemnidae	*Anatemnus* `sp. Biologic-PSEU081`	Widespread	1	217	Molecular	MD
	Atemnidae sp. indet.	Widespread	7	N/A	Morphological	MD
Olpiidae	*Indolpium* sp. indet.	Potential	4	N/A	Morphological	DA/F, H/H, ULH
	Olpiidae `sp. Biologic-PSEU164`	Potential	1	Singleton	Molecular	H/H
	Olpiidae `sp. Biologic-PSEU165`	Potential	3	2.4	Molecular	H/H, MD
ARACHNIDA: SCORPIONES						
Buthidae	*Lychas* sp. indet.	Potential	1	N/A	Morphological	DA/F
Urodacidae	*Urodacus* `sp. Biologic-SCOR023`	Widespread	1	237.2	Molecular	MD
CHILOPODA: GEOPHILOMORPHA						
Geophilidae	Geophilidae `sp. Biologic-CHIL064`	Potential	1	Singleton	Molecular	H/H
CHILOPODA: SCOLOPENDROMORPHA						
Cryptopidae	*Cryptops* `sp. Biologic-CHIL063`	Potential	1	Singleton	Molecular	MD
GASTROPODA: STYLOMMATOPHORA						
Pupillidae	*Gastrocopta* sp. indet.	Widespread	2	N/A	Morphological	MD
	Pupoides sp. indet.	Widespread	1	N/A	Morphological	MD
MALACOSTRACA: ISOPODA						

Higher taxon	Taxon	SRE status	Number individuals	Linear range (km)	Identification method	Habitat type
Armadillidae	Buddelundiinae sp. indet.	Potential	1	N/A	Morphological	ULH
	Buddelundia `OBE001`	Potential	2	N/A	Morphological	DA/F, ULH
	Buddelundia `OBE002`	Potential	4	N/A	Morphological	H/H
	Buddelundia `sp. Biologic-ISOP138`	Potential	2	0.74	Molecular	MD
	Buddelundia `sp. Biologic-ISOP139`	Potential	2	0.82	Molecular	H/H
	Buddelundia `sp. SJ_10ts_DNA`	Potential	1	87.9	Molecular	ULH
TOTAL			**40**			

Habitat Types are DA/F (Drainage Area/ Floodplain), MD (Medium Drainage Line), H/H (Hillcrest/ Hillslope and ULH (Undulating Low Hills).

4.3.1 Arachnida: Araneae

Actinopodidae

One *Missulena* specimen was collected at Medium Drainage Line site SOBE-022 (Table 4.3). It was preliminarily identified morphologically and through burrow type (Plate 1) to the Widespread species *Missulena davidi*, which was confirmed with molecular analysis. *Missulena davidi* has a current range of almost 300 km in the Pilbara (Greenberg *et al.*, 2021).

Plate 1: *Missulena davidi* with its typical two-door burrow entrance.

Anamidae

Two *Aname* specimens were collected from burrows in Medium Drainage Line (SOBE-022) and Drainage Area/ Floodplain (SOBE-034) sites (Plate 2, Table 4.3). Both specimens underwent molecular analysis as they were female and could not be identified to species reliably. This resulted in a match to the OTU for Widespread species *Aname mellosa*, found throughout central Pilbara and into the Midwest region of Western Australia (Harvey *et al.*, 2012). The sequenced specimens were dissimilar from regional *A. mellosa* sequences by up to 13.8%, but this taxon is found to have high genetic variation (Castalanelli *et al.*, 2014; Harvey *et al.*, 2018), and so they remain *Aname mellosa*.

Plate 2: *Aname mellosa* burrow and spider hunting at the entrance during night work.

Barychelidae

Two Barychelidae spiders were collected during the survey (Table 4.3, Figure 4.3). One live barychelid specimen was excavated from a burrow in the Hillcrest/ Hillslope site SOBE-036. This specimen underwent molecular analysis, which matched it with the OTU for *Synothele* `sp. MYG334` (0.5-7.5% dissimilarity). The project sequence was most related (0.5-1.4% dissimilarity) to sequences from specimens collected in the neighbouring Coombanbunna project (Bennelongia, 2020). These sequences have also been recorded as *Synothele* `xkarara` (Bennelongia, 2020, 2021b; Castalanelli *et al.*, 2014). However, the genus requires substantial taxonomic revision and *Synothele* `xkarara` also aligns with sequences named *Synothele* sp. MYG313, *S.* sp. MYG335 and *S.* sp. MYG127. Sequence variation is up to 7.7% dissimilarity and if they do all represent the same OTU then *Synothele* `sp. MYG334` has a linear range of greater than 200 km in the central Pilbara, making it a Widespread taxon (Table 4.3). A second Barychelidae burrow was excavated at Medium Drainage Line site SOBE-024. The silk was relatively fresh, but the burrow lid was degraded, and the only remains of the spider were a few legs at the bottom of the burrow. These legs were distinctly Barychelidae, but there was not enough tissue to sequence. The specimen remains Barychelidae sp. indet, Potential SRE (WAM Categories 'A' Data Deficient and 'E' Research and Expertise).

Idiopidae

A number of *Gaius tealei* burrows were observed in two main habitat types, Medium Drainage Line site SOBE-009 and Drainage Area/ Floodplain site SOBE-037 (Plate 3). In the former site the burrows were mainly dead burrows with only one burrow observed as possibly active. In the latter site, there were more burrows but were all capped with aestivating caps. *Gaius tealei*, is widespread in the Pilbara (Rix *et al.*, 2018) and are often found in drainage areas.

Plate 3: *Gaius tealei* burrows, dead and capped with aestivating cap.

4.3.2 Arachnida: Pseudoscorpiones

<u>Atemnidae</u>

Eight Atemnidae specimens were collected from Medium Drainage Line sites (Table 4.3). One specimen was sequenced and matched to the OTU for *Anatemnus* `sp. Biologic-PSEU081`, which is a Widespread taxon with a current linear distance of 217 km. All Atemnidae are generally considered widespread species, and the molecular result supports this.

<u>Olpiidae</u>

A total of eight Olpiidae specimens were collected during the survey (Table 4.3, Figure 4.3). These were morphologically identified to seven *Indolpium* and one juvenile Olpiidae sp. indet. Four individuals originally identified to *Indolpium* were sequenced and compared to regional sequences. The specimens fell into two OTU groupings, and none matched existing sequences.

Three of the sequenced olpiids matched each other (0.9-2.4% dissimilarity) and were assigned the novel OTU Olpiidae `sp. Biologic-PSEU165`. These specimens were found in Hillslope/ Hillcrest (SOBE-019 and SOBE-036) and Medium Drainage Line (SOBE-013) habitats. These were closely related to sequenced specimens from neighbouring Coombanbunna project at 7.3-8.1% dissimilarity (Indolpium `sp. BPS261`, Bennelongia, 2020). However, as the similarity ranged around the 8% difference, with the project sequences being much more similar to each other, the project sequences have conservatively been kept as a separate OTU till further molecular analysis is available for olpiid pseudoscorpions. The remaining sequenced specimen, collected at Hillcrest/ Hillslope habitat SOBE-001, was 8.7% dissimilar to a sequence from a Coombanbunna sequence, *Indolpium* `sp. BPS238`. However, it was more than 14% different to all other regional specimens in the analysis and was designated the OTU Olpiidae `sp. Biologic-PSEU164`.

Olpiidae taxonomy is poorly developed, making identification even to genus difficult, and molecular analysis has shown genera such as *Indolpium* to be polyphyletic. Due to this, a number of specimens originally morphologically identified to *Indolpium* sp. indet. were left at family level when establishing OTU designations. While it is thought that the likelihood for short-range endemism for Olpiidae is low, molecular sequencing continues to find a high diversity for OTUs, many with seemingly restricted range. All specimens that underwent molecular analysis are considered Potential SRE (WAM Categories 'A' Data Deficient, 'D' Molecular Evidence and 'E' Research and Expertise). The remaining four *Indolpium* sp. indet. specimens are also considered Potential SRE (WAM Categories 'A' Data Deficient and 'E' Research and Expertise). Two of these were collected from the same site as Olpiidae `sp. Biologic-PSEU165`, and likely represent this taxon, but further molecular analysis would be necessary to elucidate taxonomic relationships of the remaining Olpiidae taxa.

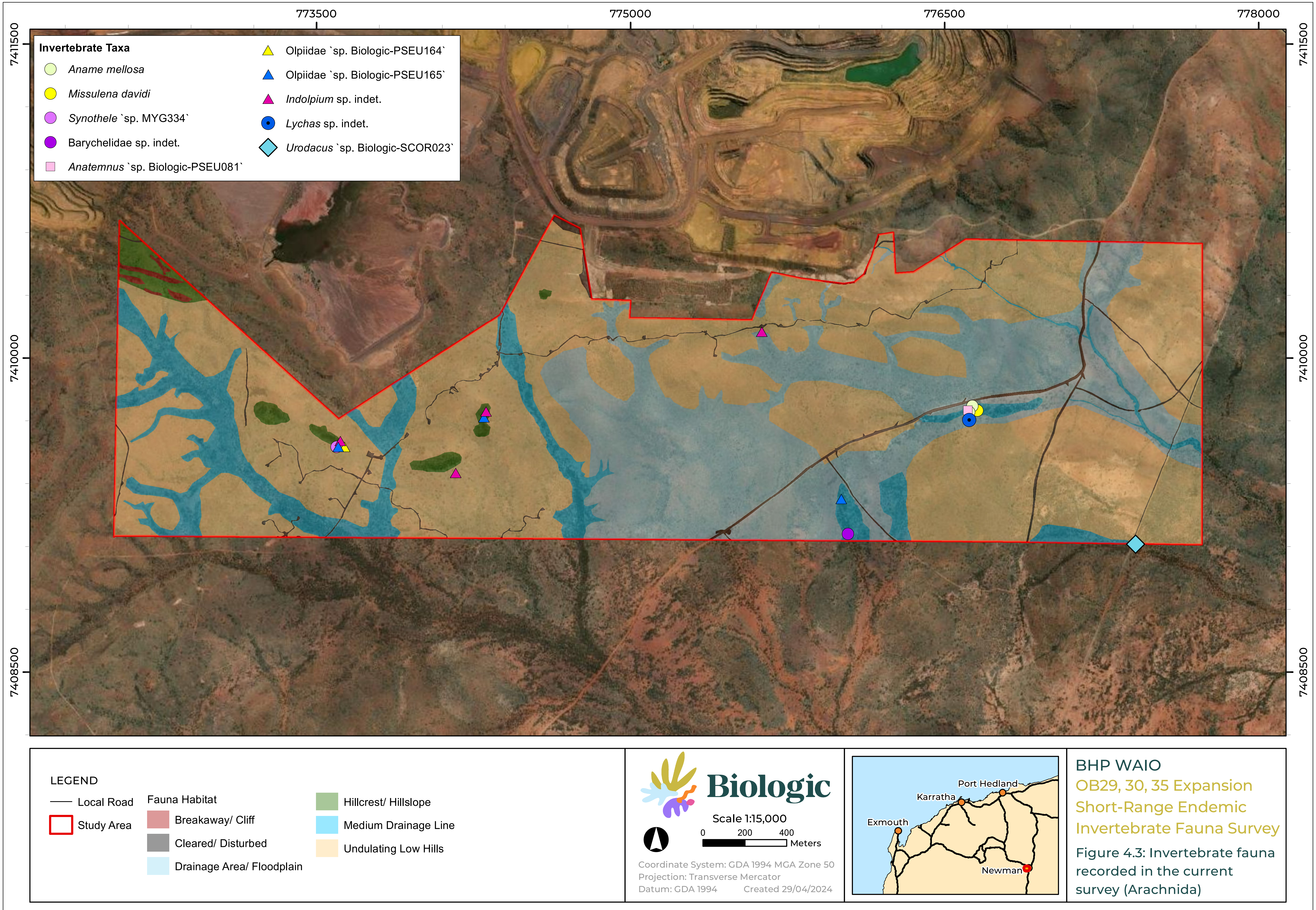
4.3.3 Arachnida: Scorpiones

Buthidae

One *Lychas* specimen was collected during a night search at Drainage Area/ Floodplain site SOBE-034 (Table 4.3, Figure 4.3). The specimen was sequenced, but the sequence was not viable for analysis. A second attempt yielded the same result, and the specimen remains indeterminate. The *Lychas* sp. indet. is currently considered Potential SRE (WAM Categories 'A' Data Deficient and 'E' Research and Expertise).

Urodacidae

One *Urodacus* specimen was excavated from a burrow at Medium Drainage Line site SOBE-035 (Table 4.3). Molecular analysis showed the specimen matched the OTU *Urodacus* `sp. Biologic-SCOR023` found at West Turner Syncline and *Urodacus* `BSCO046` found at Coombanbunna and Western Ridge projects (Bennelongia, 2020, 2021b). Biologic's OTU designation will continue to be used to reduce multiple naming conventions as it has been published in the public domain. *Urodacus* `sp. Biologic-SCOR023` has a linear distribution of over 237 km and is considered Widespread.



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OB29, 30, 35 Expansion
Short-Range Endemic
Invertebrate Fauna Survey

Figure 4.3: Invertebrate fauna recorded in the current survey (Arachnida)

4.3.4 Chilopoda: Geophilomorpha

Geophilidae

One Geophilidae specimen was collected during the wet season survey from Hillcrest/ Hillslope site SOBE-007 (Table 4.3, Figure 4.4). The specimen was sequenced and found to be over 14.9% dissimilar from all sequences analysed. It was assigned the novel OTU Geophilidae `sp. Biologic-CHIL064`. Most geophilomorph genera and species are undescribed, and species designation is primarily via molecular analysis, although due to a very small dataset there is currently little confidence in species level designations. The degree of short-range endemism in this group is unknown, and Geophilidae `sp. Biologic-CHIL064` is currently considered Potential SRE (WAM Categories 'A' Data Deficient, 'D' Molecular Evidence and 'E' Research and Expertise).

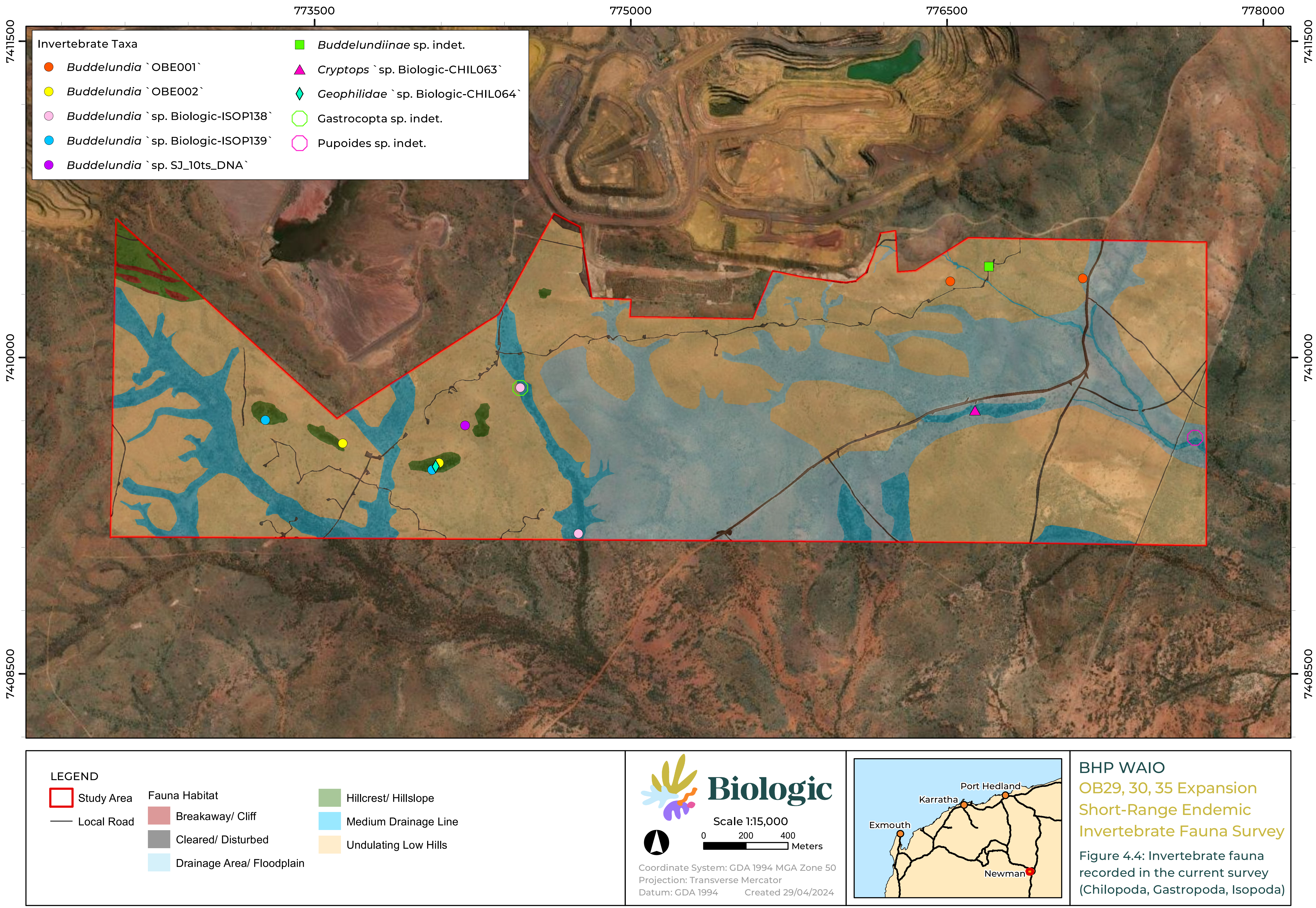
4.3.5 Chilopoda: Scolopendromorpha

Cryptopidae

Cryptopidae centipedes in the genus *Cryptops* are occasionally encountered in subterranean surveys; these are eyeless and pigmentless centipedes whose status as a SRE group is uncertain. However, sequence data often yield unique OTUs, pointing either to a high diversity or high degree of range restriction. One *Cryptops* specimen was collected from Medium Drainage Line site SOBE-022 (Table 4.3, Figure 4.4), which was subjected to molecular analysis. The sequence did not match any existing regional sequences at over 16.4% dissimilarity, and the specimen was assigned the novel OTU *Cryptops* `sp. Biologic-CHIL063`. This taxon is considered Potential SRE (WAM Categories 'A' Data Deficient, 'D' Molecular Evidence and 'E' Research and Expertise).

4.3.6 Gastropoda

Two empty *Gastrocopta* and one *Pupoides* shell were collected from two Medium Drainage Line sites (Table 4.3) (SOBE-032 and SOBE-026, respectively). Species from these genera are generally considered to be Widespread.



BHP WAIO
OB29, 30, 35 Expansion Short-Range Endemic Invertebrate Fauna Survey

Figure 4.4: Invertebrate fauna recorded in the current survey (Chilopoda, Gastropoda, Isopoda)

4.3.7 Malacostraca: Isopoda

Armadillidae

A total of twelve Armadillidae isopods were collected over the wet and dry season surveys from a variety of habitat types (Table 4.3, Figure 4.4). The specimens were first identified morphologically, which three morphotypes within the *Buddelundia* genus and one specimen that was designated Buddelundiinae sp. indet. The morphotypes were based on shape and relative size of the lobes of pereonite I and II, as well as the presence and features of any dorsum projections and the general shape and colouration of the animal. The five *Buddelundia* representatives from the three morphotypes and the one Buddelundiinae specimen were subjected to molecular analysis, resulting in 2 novel OTUs, one regionally matched OTU and one unviable sequence.

Of the four *Buddelundia* morphologically identified to `OBE001`, two were sequenced and matched each other at 0.2% dissimilarity. These two specimens were over 7.8% dissimilar from all other isopod sequences analysed and were designated the novel OTU *Buddelundia* `sp. Biologic-ISOP138`. Despite falling 0.2% under the 8% threshold of dissimilarity to *Buddelundia* `sp. Biologic-ISOP014`, in the absence of any intermediate sequences or further evidence, molecular designation erred on the side of caution and specimens were assigned a unique OTU. It is likely the remaining un-sequenced *Buddelundia* `OBE001` specimens also represent this taxon, but this would need to be confirmed with molecular analysis. All *Buddelundia* `sp. OBE001`, including those reclassified as `sp. Biologic-ISOP138` were found in Drainage Area/ Floodplain, Medium Drainage Line and Undulating Low Hills habitats. Six of the Armadillidae all found in Hillcrest/ Hillslope habitat were grouped into the morphotype *Buddelundia* `OBE002`. Two of these underwent molecular analysis and matched each other with 1.8% dissimilarity. These specimens were assigned the novel OTU *Buddelundia* `sp. Biologic-ISOP139`, 9.1% dissimilar from all other isopod sequences analysed. One of the un-sequenced *Buddelundia* `OBE002` specimens was collected from the same site as *Buddelundia* `sp. Biologic-ISOP139 (SOBE-007). This specimen, along with the remaining un-sequenced specimens morphotyped to *Buddelundia* `OBE002` likely represent *Buddelundia* `sp. Biologic-ISOP139` but this would require confirmation with molecular analysis. *Buddelundia* `sp. Biologic-ISOP138` and *Buddelundia* `sp. Biologic-ISOP139` are only found within the Study Area and represent Potential SRE taxa (WAM Categories 'A' Data Deficient, 'D' Molecular Evidence and 'E' Research and Expertise). *Buddelundia* `OBE001` and *Buddelundia* `OBE002` are also considered Potential SRE (WAM Categories 'A' Data Deficient and 'E' Research and Expertise).

One of the *Buddelundia* specimens collected from the Undulating Low Hills site SOBE-020 was considered a distinct morphotype. Molecular analysis uncovered a match to the OTU *Buddelundia* `sp. SJ_10ts_DNA` (4% dissimilarity). *Buddelundia* `sp. SJ_10ts_DNA` has been found outside of the Study Area and has a linear distance of 87.9 km. This taxon is considered Potential SRE (WAM Categories 'A' Data Deficient, 'D' Molecular Evidence and 'E' Research and Expertise).

The Buddelundiinae specimen was collected from Undulating Low Hills habitat site SOBE-028. Though the specimen was deceased on collection, enough features were present to identify it to the subfamily Buddelundiinae. Unfortunately, molecular analysis did not yield a viable sequence and this taxon is considered Potential SRE (WAM Categories 'A' Data Deficient and 'E' Research and Expertise).

4.4 Constraints and limitations

The EPA (2016c) outlines several potential limitations to fauna surveys. These aspects are assessed and discussed in Table 4.4. The identification of SRE species, the interpretation of species' distributions and the resulting categorisation of their respective SRE status is dependent on the current state of taxonomic and ecological knowledge of the target groups at the time of survey. Owing to ongoing developments in regional sampling coverage and taxonomic information, the SRE status, distributions and habitat preferences of the taxa described herein may be subject to change over time. It is not considered that the survey suffered from any specific constraints in relation to the number of samples, the coverage of SRE habitat types or the sampling and preservation methods used to detect the target fauna.

Table 4.4: Survey limitations and constraints.

Potential limitation or constraint	Limitation to current survey	Applicability to this survey
Experience of personnel.	No	The field personnel involved in the survey were experienced in undertaking SRE fauna surveys of similar nature.
Scope (faunal groups sampled and whether any constraints affect this)	No	The scope of a two-season survey was conducted adequately with survey methods comprising active foraging, leaf litter and soil sifting, and burrow searching. A small proportion of the Study Area (far north-west) was inaccessible due to active mining operations.
Proportion of fauna identified	No	Sufficient identification of all invertebrate specimens was completed by relevant taxonomic experts following the field survey and molecular analysis was undertaken on a representative proportion of the specimens.

Potential limitation or constraint	Limitation to current survey	Applicability to this survey
Sources of information (recent or historic) and availability of contextual information	No	Other surveys undertaken within, and in the vicinity of, the Study Area provided sufficient baseline data relevant to the survey.
Proportion of the task achieved	No	A two-season survey of the Study Area was completed and related to the results of surveys in the broader area identified in the desktop assessment.
Timing / weather / season / cycle	No	Rainfall for the months preceding the wet season survey was atypical and moisture retention would have been low, possibly resulting in lower numbers of taxa collected.
Disturbances (e.g., fire or flood)	No	There was significant weed invasion around the Medium Drainage Line and Drainage Area/ Floodplain habitat types. This would likely have affected the available habitat for SRE invertebrates.
Intensity of survey	No	A total of 37 habitat assessments and 25 sample sites were completed across the Study Area resulting in an appropriate intensity of surveying for the survey scope.
Completeness of survey	No	The proposed two-season survey was completed in full within the Study Area. The survey achieved sufficient coverage of all SRE habitats within the Study Area.
Resources (e.g., degree of expertise available)	No	All relevant resources and expertise required to complete the survey were available and utilised. All species recorded during the survey were identified by experienced taxonomists.
Remoteness or access issues	No	As mentioned previously, the far north-west section of the Study Area was not safe to access due to mining operations in the area. This area was assessed for SRE suitability via habitat assessment from afar.

5 Discussion

Only one of the five Confirmed SRE species identified in the desktop assessment, *Aname watsoni,* was considered Highly Likely to occur within the Study Area. Confirmed SREs *Karaops morganoconnelli*, *Antichiropus cristatus* and *Antichiropus verutus* were considered Possible to occur and *Feaella* (*Tetrafeaella*) *callani* was considered Unlikely to occur due to the habitats where the holotype specimens were collected from.

The majority of the Study Area (>98%) was of Low suitability for SRE invertebrates or not suitable in the case of Cleared/ Disturbed areas. Moderately suitable habitat, Hillcrest/ Hillslope represented 1.67% of the Study Area and highly suitability habitat, Breakaway/ Cliff covered 0.27% only. This area was adjacent to an active mining area and represents the remnants of a larger, but currently mined, ridge system.

None of the Confirmed SRE taxa identified in the desktop assessment were found during the surveys. Thirteen of the 21 taxa collected during the survey were Potential SRE. Of these 13 taxa, six were novel and have only been recorded from within the Study Area to date: Olpiidae \`sp. Biologic-PSEU164\`; Olpiidae \`sp. Biologic-PSEU165\`; Geophilidae \`sp. Biologic-CHIL064\`; *Cryptops* \`sp. Biologic-CHIL063\`; *Buddelundia* \`sp. Biologic-ISOP138\`; and *Buddelundia* \`sp. Biologic-ISOP139\`. Of these, Olpiidae \`sp. Biologic-PSEU164\`, Geophilidae \`sp. Biologic-CHIL064\` and *Buddelundia* \`sp. Biologic-ISOP139\` were collected exclusively in moderately suitable SRE invertebrate habitat Hillcrest/ Hillslope. Taxa within these groups have either not historically been sampled during SRE surveys and/or continuing molecular work has revealed a highly diverse fauna. Further work needs to be done to better understand the taxonomy, distribution and SRE status of these groups in the region. Olpiidae \`sp. Biologic-PSEU165\`, *Cryptops* \`sp. Biologic-CHIL063', and *Buddelundia* \`sp. Biologic-ISOP138\` were found in Medium Drainage Line sites and are unlikely to be restricted to the Study Area. Taxa collected from Moderate suitability habitat Hillcrest/ Hillslope are more likely to represent SRE species than those collected from Low suitability habitats, such as Major Drainage or Undulating Low Hills.

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Appendix A: DBCA License

Department of **Biodiversity, Conservation and Attractions**

GOVERNMENT OF WESTERN AUSTRALIA

FAUNA TAKING (BIOLOGICAL ASSESSMENT) LICENCE

Regulation 27, Biodiversity Conservation Regulations 2018

Licence Number: BA27000820

Licence Holder: Mr Michael Curran
Biologic Environmental Survey
24 – 26 Wickham Street
EAST PERTH WA 6004

Date of Issue: 30/03/2023

Date Valid From: 26/04/2023
Date of Expiry: 25/04/2024

LICENSED ACTIVITIES

Subject to the terms and conditions on this licence, the licence holder may –

1. Take or disturb fauna for Short-Range Endemic (SRE) Invertebrate Fauna Survey of Orebody 29 expansion area in the Pilbara region to inform future detailed and targeted SRE surveys and support future environmental approvals processes. Survey to be undertaken using dry pit traps small beverage cups (6 cm diameter) will be used to trap scorpions at their burrow entrances. These will be deployed overnight and checked in the morning and hand capture techniques active searching / opportunistic sampling, specimens SRE invertebrates will be kept at the Biologic office before being lodged with the WA Museum for identification and storage.

LOCATIONS

1. Orebody 29 expansion area, located approximately 6 km south-west of Newman and covering an area of approximately 581 hectares.

AUTHORISED PERSONS

The following persons or persons of the specified class may assist in carrying out the licensed activities:

1. Nihara Gunawardene
2. David Symons

CONDITIONS

1. Fauna must not be taken on CALM land, (as defined in the Conservation and Land Management Regulations 2002*)*, unless authorised by a written notice of a lawful authority issued under regulations 4 and 8 of the Conservation and Land Management Regulations 2002.
2. If persons, other than the licence holder, are authorised to carry out/assist in carrying out the activities under the licence, the licence holder must ensure those persons have read and understand the licence terms and conditions.
3. The written authorisation of the person in possession or occupation of the land accessed and upon which fauna is taken, as required under regulation 101(2) and referred to in "Additional information" below, must:

1

Department of **Biodiversity, Conservation and Attractions**

a) state location details (including lot or location number, street/road, suburb and local government authority);

b) state land owner or occupier name, and contact phone number;

c) specify the time period that the authorisation is valid for;

d) be signed and dated; and

e) be attached to this licence at all times.

4. This licence, and any written authorisation or lawful authority which authorises the take of fauna on specified locations must be carried at all times while conducting licensed activities and be produced on demand by a wildlife officer.

5. If a species of fauna listed as a threatened species under Section 19 of the *Biodiversity Conservation Act 2016* is inadvertently captured, that species is to be released immediately at the point of capture. If the fauna is injured or deceased, the licence holder shall contact the DBCA Wildlife Licensing Section (wildlifelicensing@dbca.wa.gov.au) for advice on treatment or disposal. Details of any capture of threatened fauna must be included in the "Return of Fauna Taken."

6. The licence holder must not:

a) release any fauna in any area where it does not naturally occur;

b) transfer fauna to any other person or authority (other than the Western Australian Museum) unless approved in writing by the CEO; or

c) dispose of the remains of fauna in any manner likely to interfere the natural or present day distribution of the species.

7. The licence holder must not take and remove more than ten specimens of any one protected species of fauna from any location less than 20km apart. Where exceptional circumstances make it necessary to take a larger number of specimens from a particular location in order to obtain adequate statistical data, the collector must proceed with circumspection and justify their actions to the Director General in advance.

8. All holotypes and syntypes and a half share of paratypes of species or subspecies permitted to be permanently taken under this licence must be donated to the Western Australian Museum. Duplicates (one pair in each case) of any species collected, which represents a significant extension of geographic range must be offered to the Western Australian Museum.

9. All specimens and material retained under the authority of this licence must be offered to the Western Australian Museum for loan, for inclusion in its collection, or on request be made available to other persons involved in relevant scientific studies.

10. The licence holder must create, compile and maintain records and information as required in a DBCA approved "Return of Fauna Taken" of all fauna taking activities as they occur.

11. A DBCA approved "Return of Fauna Taken" must be completed in full (including nil taking details) and submitted to DBCA Wildlife Licensing Section (wildlifelicensing@dbca.wa.gov.au) prior to the end of each annual period of the licence (from the valid from date) (refer to "Additional Information" section

Danny Stefoni
LICENSING OFFICER
WILDLIFE PROTECTION BRANCH

2

Department of Biodiversity, Conservation and Attractions

Delegate of CEO

ADDITIONAL INFORMATION

1. It is an offence to take any species of fauna listed as a threatened species under Section 19 of the *Biodiversity Conservation Act 2016* unless the person is authorised under Section 40. The penalty ranges between $300 000 and $500 000; Section 150 Biodiversity Conservation Act 2016.
2. Regulation 82 empowers the CEO to add, substitute or delete a term or condition of a licence or to correct errors. Such power may be exercised on application of a licence holder or by the CEO's own initiative. If an amendment to a licence term or condition is required, please contact the CEO or the Licensing Section on wildlifelicensing@dbca.wa.gov.au in the first instance. The licence holder, if adversely affected by a condition imposed in this licence, may apply to the State Administrative Tribunal for review of the decision of the CEO to impose that condition on a licence: regulation 89(2) Biodiversity Conservation Regulations 2018.
3. A person must not contravene a condition of a licence. The penalty for an offence involving the contravention of a condition of a licence is a fine of $10 000: regulation 84 of the Biodiversity Conservation Regulations 2018.
4. It is an offence for persons authorised by this licence to enter land that is not in their possession or under their control without first having the *prior* written authorisation of the current owner or occupier of the land to:

   a) enter the land; and

   b) carry out the activity authorised by this licence.

   The penalty for this offence is a fine of $5 000: regulation 101(2) of the Biodiversity Conservation Regulations 2018.
5. The licence holder must be able to produce for inspection upon request any information or records required by regulation 85(2) of the Biodiversity Conservation Regulations 2018 Penalty $10 000. It is an offence to knowingly include false or misleading information or make statements in records: regulation 85(3) of the Biodiversity Conservation Regulations 2018 Penalty $10 000. It is an offence to include any information or make any statement in a return that the licence holder knows to be false or misleading in a material particular: regulation 86 (2) of the Biodiversity Conservation Regulations 2018 Penalty $10 000.
6. The approved DBCA "Return of Fauna Taken" data file can be downloaded from the DBCA webpage (https://www.dpaw.wa.gov.au/plants-and-animals/licences-and-authorities).
7. The issuing of a licence under the Biodiversity Conservation Regulations 2018 does not constitute an animal ethics approval or a licence to use animals for scientific purposes as required under the *Animal Welfare Act 2002,* Animal Welfare (Scientific Purposes) Regulations 2003. It is the responsibility of a licence applicant / licence holder to ensure that they comply with the requirements of all applicable legislation. Enquiries relating to the Animal Welfare Act licences and animal ethics approvals are to be directed to the Department of Primary Industries and Regional Development (https://www.agric.wa.gov.au/animalwelfare).
8. Threatened fauna can only be taken under a *Biodiversity Conservation Act 2016* Section 40 authorisation, Occurrences of threatened species must be reported to the CEO. For more information please see https://www.dpaw.wa.gov.au/plants-and-animals/threatened-species-and-communities/threatened-animals.
9. Any interaction involving Nationally Listed Threatened Fauna that may be invasive and/or harmful to the fauna may require approval from the Commonwealth Department of the Environment and Energy http://www.environment.gov.au/about-us/business-us/permits-assessments-licences. Interaction with

such species is controlled by the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* and Environment Protection and Biodiversity Conservation Regulations 2000 as well as the *Biodiversity Conservation Act 2016* and Biodiversity Conservation Regulations 2018.

Appendix B: Database search records of Potential and Confirmed SRE species from within 40 km of the Study Area

Family	Lowest ID	SRE Status	Minimum Distance from Study Area (km)	Likelihood of occurrence
ARACHNIDA: Araneae				
Actinopodidae	*Missulena* `sp. Biologic-ARAN038`	Potential	12.45	Possible
	Missulena `sp. Biologic-ARAN054`	Potential	21.49	Unlikely
	Missulena sp. indet.	Potential	13.20	Possible
Anamidae	*Aname* `MYG205`	Potential	1.49	Highly Likely
	Aname `MYG206`	Potential	1.47	Highly Likely
	Aname sp. indet.	Potential	2.11	Likely
	Aname watsoni	Confirmed	1.47	Highly Likely
	Kwonkan `MYG006`	Potential	5.61	Possible
	Kwonkan `MYG098`	Potential	1.46	Highly Likely
	Kwonkan `MYG651`	Potential	5.61	Possible
	Kwonkan `sp. Biologic-ARAN055`	Potential	24.90	Possible
	Teyl? sp. indet.	Potential	4.86	Likely
Barychelidae	*Aurecocrypta* `MYG315`	Potential	8.94	Possible
	Idiommata `MYG128`	Potential	38.30	Possible
	Synothele sp. indet.	Potential	0.10	Highly Likely
Euagridae	*Cethegus* `MYG299`	Potential	10.76	Possible
	Cethegus sp. indet.	Potential	1.70	Highly Likely
Halonoproctidae	*Conothele* `MYG279`	Potential	39.57	Possible
	Conothele `MYG385`	Potential	9.58	Possible
	Conothele `MYG558`	Potential	7.33	Possible
	Conothele `MYG575`	Potential	7.99	Possible
	Conothele `sp. Biologic-ARAN056`	Potential	18.45	Possible
Idiopidae	*Idiosoma* `MYG085`	Potential	39.41	Possible

Family	Lowest ID	SRE Status	Minimum Distance from Study Area (km)	Likelihood of occurrence
	Idiosoma `sp. Biologic-ARAN039`	Potential	9.02	Possible
	Idiosoma `sp. Biologic-ARAN040`	Potential	8.02	Possible
	Idiosoma `sp. Biologic-ARAN044`	Potential	12.79	Possible
Selenopidae	*Karaops* `ARA003`	Potential	17.93	Possible
	Karaops `sp. Biologic-ARAN042`	Potential	7.99	Possible
	Karaops morganoconnelli	Confirmed	8.85	Possible
	Karaops sp. indet.	Potential	9.15	Possible
ARACHNIDA: Pseudoscorpiones				
Chthoniidae	*Austrochthonius* `BPS264`	Potential	1.87	Highly Likely
	Austrochthonius `PSE135, pilbara`	Potential	30.69	Possible
	Austrochthonius sp. indet.	Potential	3.87	Likely
	Lagynochthonius sp. indet.	Potential	12.38	Possible
	Tyrannochthonius `sp. Biologic-PSEU059`	Potential	7.49	Possible
	Tyrannochthonius sp. indet.	Potential	9.45	Possible
Cthoniidae	Cthoniidae `sp. Biologic-PSEU120`	Potential	30.07	Possible
Feaellidae	*Feaella (Tetrafeaella) callani*	Confirmed	12.50	Unlikely
Garypidae	*Synsphyronus* `BPS258`	Potential	5.12	Possible
	Synsphyronus `PSE086`	Potential	26.79	Unlikely
	Synsphyronus `PSE129`	Potential	7.99	Possible
	Synsphyronus sp. `long chelal hand`	Potential	3.56	Possible
	Synsphyronus sp. `nov. 8/1 Pilbara`	Potential	11.85	Possible
	Synsphyronus sp. `nov. long chelal hand`	Potential	3.58	Possible
	Synsphyronus sp. indet.	Potential	3.55	Possible
Garypinidae	*Amblyolpium* `BPS273`	Potential	5.40	Possible

Family	Lowest ID	SRE Status	Minimum Distance from Study Area (km)	Likelihood of occurrence
	Garypinidae sp. indet.	Potential	2.25	Likely
Olpiidae	*Austrohorus* `BPS266`	Potential	5.86	Possible
	Austrohorus `sp. Biologic-PSEU060`	Potential	10.12	Possible
	Austrohorus sp. indet.	Potential	1.46	Highly Likely
	Beierolpium `BPS272`	Potential	5.95	Possible
	Beierolpium `sp. 7/4`	Potential	9.45	Possible
	Beierolpium `sp. 8/1`	Potential	10.09	Possible
	Beierolpium `sp. 8/2, BPS267`	Potential	4.83	Likely
	Beierolpium `sp. 8/2`	Potential	1.46	Highly Likely
	Beierolpium `sp. 8/3, BPS259`	Potential	0.02	Highly Likely
	Beierolpium `sp. 8/3`	Potential	2.38	Likely
	Beierolpium `sp. 8/4 small`	Potential	9.74	Possible
	Beierolpium `sp. 8/4`	Potential	8.02	Possible
	Beierolpium `sp. Biologic-PSEU061`	Potential	7.92	Possible
	Beierolpium `sp. Biologic-PSEU062`	Potential	13.50	Possible
	Beierolpium sp. indet.	Potential	1.28	Highly Likely
	Euryolpium `BPS271`	Potential	3.87	Likely
	Euryolpium `sp. Biologic-PSEU063`	Potential	12.80	Possible
	Euryolpium `sp. Biologic-PSEU064`	Potential	8.79	Possible
	Euryolpium `sp. Biologic-PSEU065`	Potential	10.97	Possible
	Euryolpium sp. indet.	Potential	2.45	Likely
	Indolpium `BPS238`	Potential	1.28	Highly Likely
	Indolpium `BPS260`	Potential	2.24	Likely
	Indolpium `BPS261`	Potential	6.68	Possible

Family	Lowest ID	SRE Status	Minimum Distance from Study Area (km)	Likelihood of occurrence
	Indolpium `sp. Biologic-PSEU066`	Potential	12.96	Possible
	Indolpium sp. indet.	Potential	0.00	Present
	Linnaeolpium sp. indet.	Potential	0.13	Highly Likely
	Olpiidae sp. indet.	Potential	2.11	Likely
	Xenolpium `PSE079`	Potential	37.62	Possible
ARACHNIDA: Scorpiones				
Buthidae	*Isometroides* sp. indet.	Potential	3.20	Likely
	Lychas `bituberculatus complex`	Potential	1.34	Highly Likely
	Lychas `BSCO040`	Potential	8.77	Possible
	Lychas `BSCO057`	Potential	0.10	Highly Likely
	Lychas `hairy tail complex`	Potential	2.41	Likely
	Lychas `harveyi complex`	Potential	2.11	Likely
	Lychas `jonesii`	Potential	18.93	Possible
	Lychas `SCO038`	Potential	33.30	Possible
	Lychas `SCO042`	Potential	12.27	Possible
	Lychas `SCO049`	Potential	15.02	Possible
	Lychas `sp. Biologic-SCOR012`	Potential	19.39	Possible
	Lychas `waldockae`	Potential	2.83	Likely
	Lychas sp. indet.	Potential	1.35	Highly Likely
Urodacidae	*Urodacus* `BSCO045`	Potential	1.87	Highly Likely
	Urodacus `BSCO046`	Potential	1.87	Highly Likely
	Urodacus `megamastigus complex`	Potential	0.10	Highly Likely
	Urodacus `SCO031`	Potential	11.40	Possible
	Urodacus `sp. Biologic-SCOR007`	Potential	9.26	Possible

Family	Lowest ID	SRE Status	Minimum Distance from Study Area (km)	Likelihood of occurrence
	Urodacus `sp. Biologic-SCOR016`	Potential	17.99	Possible
	Urodacus `sp. Biologic-SCOR017`	Potential	25.22	Possible
	Urodacus sp. indet.	Potential	8.41	Possible
MYRIAPODA: Chilopoda				
Chilenophilidae	Chilenophilidae sp. indet.	Potential	12.24	Possible
	Geomerinus `sp. Biologic-CHIL027`	Potential	9.05	Possible
	Geomerinus `sp. Biologic-CHIL030`	Potential	13.71	Possible
	Geomerinus sp. indet.	Potential	8.79	Possible
Mecistocephalidae	*Mecistocephalus* `sp. Biologic-CHIL026`	Potential	9.05	Possible
	Mecistocephalus `sp. Biologic-CHIL037`	Potential	20.87	Possible
	Mecistocephalus nr `sp. Biologic-CHIL037`	Potential	20.87	Possible
	Mecistocephalus sp. indet.	Potential	1.87	Highly Likely
Oryidae	Oryidae sp. indet.	Potential	8.86	Possible
Oryiidae	*Orphnaeus* sp. indet.	Potential	20.87	Possible
Cryptopidae	*Cryptops* `BSCOL067`	Potential	1.07	Highly Likely
	Cryptops `sp. Biologic-CHIL028`	Potential	9.46	Possible
	Cryptops `sp. Biologic-CHIL029`	Potential	8.79	Possible
MYRIAPODA: Diplopoda				
Paradoxosomatidae	*Antichiropus* `sp. Biologic-POLD003`	Potential	12.15	Possible
	Antichiropus cristatus	Confirmed	6.30	Possible
	Antichiropus sp. indet.	Potential	5.62	Possible
	Antichiropus verutus	Confirmed	2.81	Possible
	Paradoxosomatidae sp. indet.	Potential	11.42	Possible
Trigoniulidae	*Austrostrophus* sp. indet.	Potential	0.41	Likely

Family	Lowest ID	SRE Status	Minimum Distance from Study Area (km)	Likelihood of occurrence
	Austrostrophus stictopygus	Potential	1.07	Likely
MALACOSTRACA: Isopoda				
Armadillidae	*Acanthodillo* `BIS379`	Potential	1.07	Highly Likely
	Acanthodillo sp. indet.	Potential	7.67	Possible
	Armadillidae `sp. Biologic-ISOP060`	Potential	9.46	Possible
	Armadillidae `sp. SJ_WN_DNA`	Potential	19.00	Possible
	Armadillidae sp. indet.	Potential	9.01	Possible
	Buddelundia `BIS374`	Potential	3.52	Likely
	Buddelundia `BIS375`	Potential	1.87	Highly Likely
	Buddelundia `BIS376`	Potential	0.56	Highly Likely
	Buddelundia `BIS377`	Potential	1.87	Highly Likely
	Buddelundia `BIS380`	Potential	9.49	Possible
	Buddelundia `BIS381`	Potential	5.62	Possible
	Buddelundia `sp. 10NM`	Potential	17.28	Possible
	Buddelundia `sp. 14CR`	Potential	9.05	Possible
	Buddelundia `sp. 16`	Potential	0.05	Highly Likely
	Buddelundia `sp. 49`	Potential	1.37	Highly Likely
	Buddelundia `sp. 78`	Potential	8.56	Possible
	Buddelundia `sp. 79`	Potential	9.19	Possible
	Buddelundia `sp. 80`	Potential	11.76	Possible
	Buddelundia `sp. Biologic-ISOP014`	Potential	8.99	Possible
	Buddelundia `sp. Biologic-ISOP059 (SJ_78)`	Potential	12.00	Possible
	Buddelundia `sp. Biologic-ISOP111`	Potential	18.26	Possible
	Buddelundia `sp. Biologic-ISOP112`	Potential	17.99	Possible

Family	Lowest ID	SRE Status	Minimum Distance from Study Area (km)	Likelihood of occurrence
	Buddelundia `sp. SJ_10NM_DNA`	Potential	19.52	Possible
	Buddelundia `sp. SJ_14CR_DNA`	Potential	20.87	Possible
	Buddelundia `sp. SJ_49_DNA`	Potential	18.43	Possible
	Buddelundia sp. indet.	Potential	0.10	Highly Likely
	Buddelundiinae `sp. OB24`	Potential	9.85	Possible
	Buddelundiinae sp. indet.	Potential	14.32	Possible
Philosciidae	Philosciidae sp. indet.	Potential	8.39	Possible
MYRIAPODA: Symphyla				
Scutigerellidae	*Hanseniella* `BSYM099`	Potential	0.02	Highly Likely

Appendix C: Sites and habitat assessments from the current survey

Site	Habitat type	SRE suitability	Latitude	Longitude	Survey Date	% Shade	Soil Availability	% Litter cover
SOBE-001	Hillcrest/ Hillslope	Moderate	-23.4007498	119.6772055	26/04/2023	Low to Med 20-40%	Few Small Patches	Few Small Patches
SOBE-002	Medium Drainage Line	Low	-23.4042444	119.6769926	26/04/2023	Medium 40-60%	Many Large Patches	Few Large Patches
SOBE-003	Undulating Low Hills	Low	-23.4031462	119.6668379	26/04/2023	Negligible <5%	None Discernible	None Discernible
SOBE-004	Medium Drainage Line	Low	-23.398978	119.6675452	26/04/2023	Med to High 60-80%	Evenly Spread	Many Large Patches
SOBE-005	Hillcrest/ Hillslope	Moderate/Low	-23.39305417	119.6676449	26/04/2023	Low 5-20%	Few Small Patches	Scarce
SOBE-006	Undulating Low Hills	Low	-23.3989959	119.6683844	26/04/2023	Negligible <5%	None Discernible	None Discernible
SOBE-007	Hillcrest/ Hillslope	Moderate/High	-23.4015143	119.6816942	27/04/2023	Low to Med 20-40%	Many Small Patches	Few Small Patches
SOBE-008	Undulating Low Hills	Low	-23.4020367	119.6825936	27/04/2023	Low 5-20%	Scarce	Scarce
SOBE-009	Medium Drainage Line	Low	-23.40427489	119.6883712	27/04/2023	Med to High 60-80%	Many Large Patches	Many Large Patches
SOBE-010	Undulating Low Hills	Low	-23.4032937	119.6803015	27/04/2023	Low 5-20%	None Discernible	None Discernible
SOBE-011	Hillcrest/ Hillslope	Moderate	-23.3995082	119.6739244	27/04/2023	Low to Med 20-40%	Scarce	Few Small Patches
SOBE-012	Medium Drainage Line	Low	-23.4021304	119.6730744	27/04/2023	Low to Med 20-40%	Evenly Spread	Many Large Patches
SOBE-013	Medium Drainage Line	Low	-23.40259159	119.7007161	27/04/2023	Med to High 60-80%	Many Large Patches	Many Large Patches
SOBE-014	Drainage Area/ Floodplain	Low	-23.4038379	119.7024986	27/04/2023	Low 5-20%	Few Small Patches	None Discernible
SOBE-015	Undulating Low Hills	Low	-23.3920453	119.70843	27/04/2023	Negligible <5%	Scarce	None Discernible
SOBE-016	Medium Drainage Line	Low	-23.4044012	119.715179	28/04/2023	Low 5-20%	Many Small Patches	Scarce
SOBE-017	Undulating Low Hills	Low	-23.39439288	119.7144814	28/04/2023	Negligible <5%	Few Small Patches	None Discernible
SOBE-018	Undulating Low Hills	Low	-23.4018946	119.7151904	28/04/2023	Negligible <5%	Few Small Patches	None Discernible

Site	Habitat type	SRE suitability	Latitude	Longitude	Survey Date	% Shade	Soil Availability	% Litter cover
SOBE-019	Hillcrest/ Hillslope	Moderate	-23.3993575	119.6839538	28/04/2023	Medium 40-60%	Few Small Patches	Few Small Patches
SOBE-020	Undulating Low Hills	Low	-23.3997314	119.6830255	28/04/2023	Low 5-20%	Scarce	Scarce
SOBE-021	Undulating Low Hills	Low	-23.3951871	119.6976093	28/04/2023	Negligible <5%	Many Small Patches	Scarce
SOBE-022	Medium Drainage Line	Low	-23.398676	119.7066586	28/04/2023	Medium 40-60%	Many Large Patches	Many Large Patches
SOBE-023	Undulating Low Hills	Low	-23.3943476	119.7022495	27/04/2023	Negligible <5%	None Discernible	None Discernible
SOBE-024	Medium Drainage Line	Low	-23.40408676	119.700948	1/11/2023	Low to Med 20-40%	Evenly Spread	Many Small Patches
SOBE-025	Undulating Low Hills	Low	-23.3966502	119.7153802	1/11/2023	Negligible <5%	Scarce	None Discernible
SOBE-026	Medium Drainage Line	Low	-23.3996666	119.7168836	1/11/2023	Low to Med 20-40%	Few Small Patches	Few Large Patches
SOBE-027	Drainage Area/ Floodplain	Low	-23.39295126	119.7115476	1/11/2023	Low to Med 20-40%	Many Small Patches	Few Small Patches
SOBE-028	Undulating Low Hills	Low	-23.39252166	119.7071801	2/11/2023	Medium 40-60%	Few Small Patches	Many Small Patches
SOBE-029	Undulating Low Hills	Low	-23.393178	119.7054008	2/11/2023	Negligible <5%	Scarce	Scarce
SOBE-030	Drainage Area/ Floodplain	Low	-23.39569974	119.6967614	2/11/2023	Low 5-20%	Few Small Patches	Few Small Patches
SOBE-031	Undulating Low Hills	Low	-23.3964657	119.6895064	2/11/2023	Low to Med 20-40%	Few Small Patches	Many Large Patches
SOBE-032	Medium Drainage Line	Low	-23.39807043	119.6855478	2/11/2023	Low to Med 20-40%	Few Small Patches	Many Large Patches
SOBE-033	Hillcrest/ Hillslope	Moderate	-23.4010891	119.6819636	2/11/2023	Low 5-20%	Scarce	Few Small Patches
SOBE-034	Drainage Area/ Floodplain	Low	-23.39894107	119.7065155	2/11/2023	Low 5-20%	Many Small Patches	Few Small Patches
SOBE-035	Medium Drainage Line	Low	-23.4043035	119.7143995	2/11/2023	Low to Med 20-40%	Evenly Spread	Few Large Patches

Site	Habitat type	SRE suitability	Latitude	Longitude	Survey Date	% Shade	Soil Availability	% Litter cover
SOBE-036	Hillcrest/ Hillslope	Moderate	-23.40074576	119.6771767	3/11/2023	Low 5-20%	Few Small Patches	Few Small Patches
SOBE-037	Medium Drainage Line	Low	-23.4043198	119.6757694	3/11/2023	Medium 40-60%	Evenly Spread	Many Large Patches

Appendix D: Specimens collected from the current survey

Site	Habitat type	Date collected	Class	Order	Family	Lowest ID	SRE Status	No. of specimens
SOBE-001	Hillcrest/ Hillslope	26/04/2023	Arachnida	Pseudoscorpiones	Olpiidae	Olpiidae `sp. Biologic-PSEU164`	Potential	1
SOBE-001	Hillcrest/ Hillslope	26/04/2023	Malacostraca	Isopoda	Armadillidae	*Buddelundia* `OBE002`	Potential	2
SOBE-004	Medium Drainage Line	26/04/2023	Arachnida	Pseudoscorpiones	Atemnidae	Atemnidae sp. indet.	Widespread	2
SOBE-007	Hillcrest/ Hillslope	27/04/2023	Chilopoda	Geophilidae	Geophilidae	Geophilidae `sp. Biologic-CHIL064`	Potential	1
SOBE-007	Hillcrest/ Hillslope	27/04/2023	Malacostraca	Isopoda	Armadillidae	*Buddelundia* `sp. Biologic-ISOP139`	Potential	1
SOBE-007	Hillcrest/ Hillslope	27/04/2023	Malacostraca	Isopoda	Armadillidae	*Buddelundia* `OBE002`	Potential	2
SOBE-008	Undulating Low Hills	27/04/2023	Arachnida	Pseudoscorpiones	Olpiidae	*Indolpium* sp. indet.	Potential	1
SOBE-009	Medium Drainage Line	27/04/2023	Malacostraca	Isopoda	Armadillidae	*Buddelundia* `sp. Biologic-ISOP138`	Potential	1
SOBE-011	Hillcrest/ Hillslope	27/04/2023	Malacostraca	Isopoda	Armadillidae	*Buddelundia* `sp. Biologic-ISOP139`	Potential	1
SOBE-012	Medium Drainage Line	27/04/2023	Arachnida	Pseudoscorpiones	Atemnidae	Atemnidae sp. indet.	Widespread	1
SOBE-013	Medium Drainage Line	27/04/2023	Arachnida	Pseudoscorpiones	Atemnidae	Atemnidae sp. indet.	Widespread	1
SOBE-013	Medium Drainage Line	27/04/2023	Arachnida	Pseudoscorpiones	Olpiidae	Olpiidae `sp. Biologic-PSEU165`	Potential	1
SOBE-019	Hillcrest/ Hillslope	28/04/2023	Arachnida	Pseudoscorpiones	Olpiidae	*Indolpium* sp. indet.	Potential	1
SOBE-019	Hillcrest/ Hillslope	28/04/2023	Arachnida	Pseudoscorpiones	Olpiidae	Olpiidae `sp. Biologic-PSEU165`	Potential	1
SOBE-020	Undulating Low Hills	28/04/2023	Malacostraca	Isopoda	Armadillidae	*Buddelundia* `sp. SJ_10ts_DNA`	Potential	1
SOBE-022	Medium Drainage Line	28/04/2023	Arachnida	Araneae	Actinopodidae	*Missulena davidi*	Widespread	1
SOBE-022	Medium Drainage Line	27/04/2023	Arachnida	Araneae	Anamidae	*Aname mellosa*	Widespread	1
SOBE-022	Medium Drainage Line	1/11/2023	Arachnida	Pseudoscorpiones	Atemnidae	*Anatemnus* `sp. Biologic-PSEU081`	Widespread	1
SOBE-022	Medium Drainage Line	1/11/2023	Arachnida	Pseudoscorpiones	Atemnidae	Atemnidae sp. indet.	Widespread	1
SOBE-022	Medium Drainage Line	1/11/2023	Chilopoda	Scolopendromorpha	Cryptopidae	*Cryptops* `sp. Biologic-CHIL063`	Potential	1

Site	Habitat type	Date collected	Class	Order	Family	Lowest ID	SRE Status	No. of specimens
SOBE-024	Medium Drainage Line	1/11/2023	Arachnida	Araneae	Barychelidae	Barychelidae sp. indet.	Potential	1
SOBE-026	Medium Drainage Line	1/11/2023	Arachnida	Pseudoscorpiones	Atemnidae	Atemnidae sp. indet.	Widespread	1
SOBE-026	Medium Drainage Line	1/11/2023	Gastropoda	Stylommatophora	Pupillidae	*Pupoides* sp. indet.	Widespread	1
SOBE-027	Drainage Area/ Floodplain	1/11/2023	Malacostraca	Isopoda	Armadillidae	*Buddelundia* `OBE001`	Potential	1
SOBE-028	Undulating Low Hills	2/11/2023	Malacostraca	Isopoda	Armadillidae	Buddelundiinae sp. indet.	Potential	1
SOBE-029	Undulating Low Hills	2/11/2023	Malacostraca	Isopoda	Armadillidae	*Buddelundia* `OBE001`	Potential	1
SOBE-030	Drainage Area/ Floodplain	2/11/2023	Arachnida	Pseudoscorpiones	Olpiidae	*Indolpium* sp. indet.	Potential	1
SOBE-032	Medium Drainage Line	2/11/2023	Arachnida	Pseudoscorpiones	Atemnidae	Atemnidae sp. indet.	Widespread	1
SOBE-032	Medium Drainage Line	2/11/2023	Gastropoda	Stylommatophora	Pupillidae	Gastrocopta sp. indet.	Widespread	2
SOBE-032	Medium Drainage Line	2/11/2023	Malacostraca	Isopoda	Armadillidae	*Buddelundia* `sp. Biologic-ISOP138`	Potential	1
SOBE-034	Drainage Area/ Floodplain	2/11/2023	Arachnida	Araneae	Anamidae	*Aname mellosa*	Widespread	1
SOBE-034	Drainage Area/ Floodplain	2/11/2023	Arachnida	Scorpiones	Buthidae	*Lychas* sp. indet.	Potential	1
SOBE-035	Medium Drainage Line	2/11/2023	Arachnida	Scorpiones	Urodacidae	*Urodacus* `sp. Biologic-SCOR023`	Widespread	1
SOBE-036	Hillcrest/ Hillslope	3/11/2023	Arachnida	Araneae	Barychelidae	*Synothele* `sp. MYG334`	Widespread	1
SOBE-036	Hillcrest/ Hillslope	3/11/2023	Arachnida	Pseudoscorpiones	Olpiidae	*Indolpium* sp. indet.	Potential	1
SOBE-036	Hillcrest/ Hillslope	3/11/2023	Arachnida	Pseudoscorpiones	Olpiidae	Olpiidae `sp. Biologic-PSEU165`	Potential	1