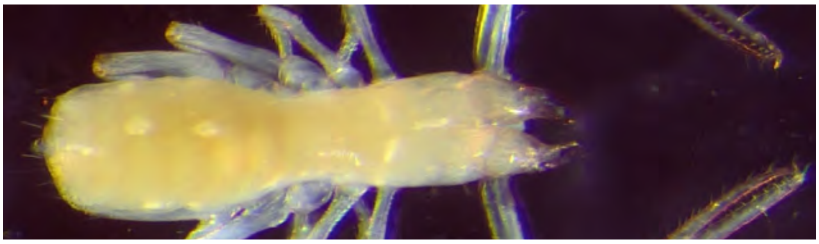
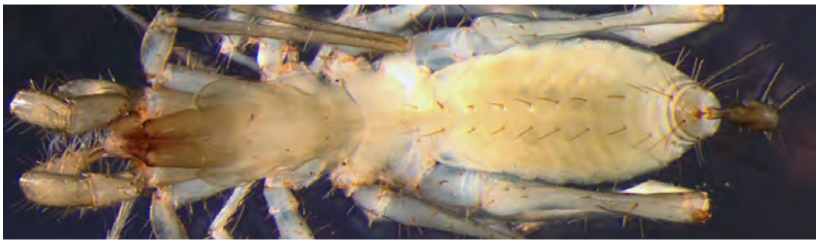
Biota Environmental Sciences

Baby Hope Downs Troglofauna Survey Phase 2





Prepared for Rio Tinto

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Baby Hope Downs Troglofauna Phase 2

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1.0 Executive Summary

The Baby Hope Downs deposit, located approximately 79 km northwest of Newman in the Pilbara, is currently in the process of undergoing environmental approvals to develop the site into an iron ore mine. Developments that may be constructed in the Baby Hope Downs project area comprise mine pits, waste dumps, topsoil stockpiles and other related infrastructure. As troglobitic fauna are known from the locality and may be impacted by the proposed mining developments, Rio Tinto is investigating the troglofauna community that exists in the project area. One phase of troglofauna sampling has been completed and this report documents the results of the second phase, in addition to collating all data on known conservation significant taxa from the study area.

This survey was completed under “Licence to Take Fauna for Scientific Purposes” No. SF010266, using methods consistent with those outlined in the EPA Guidance Statement No. 54a and EPA Environmental Assessment Guideline (EAG) No. 12. Sampling methods included 117 troglofauna colonisation traps placed in 43 drillholes, and scraping at 12 drillholes using weighted haul nets.

Thirty-two specimens collected during Phase 2 were identified as being potential troglobites or troglophiles from six orders. Genetic studies completed in the Pilbara have indicated that the orders Blattodea and Polyxenida tend not to display short-range endemism and are likely troglophilic, and were therefore not considered further in this report.

Singleton records were collected from the orders Palpigradi (drillhole RC14HD10022) and Pseudoscorpiones (family Chthoniidae; species *Lagynochthonius* sp.’PSE096’; drillhole RC13HD10336). Four specimens were collected from the hexapod order Diplura and eight from the arachnid order Schizomida. The specimens from the orders Diplura and Palpigradi were unable to be identified further due to poor resolution of their wider taxonomic framework.

Genetic analysis of Schizomida collected during Phase 2 revealed the presence of three distinct lineages (equivalent to species), *Draculoides* sp. BHD3, *Draculoides* sp. BHD4 and *Draculoides* sp. BHD5. None of these species are restricted to the Baby Hope Downs project area.

When the Phase 2 data were collated with Phase 1 and historical records from the study, 19 specimens of troglobitic schizomid have now been collected. These specimens represent six distinct species, with sequence divergences of 5.5% - 13.7%. These specimens were predominantly collected from Colluvium, Marra Mamba and Brockman Iron Formation surface geological units. Of the four schizomid species collected from multiple drillholes, two were also collected in more than one geological unit. *Draculoides* sp. BHD4 was collected from both Brockman Iron Formation in the south of the study area and from two drillholes in Colluvium within the proposed pit outline. *Draculoides* sp. CI1, which thus far only occurs outside of the proposed pit outlines, has also been collected over a greater range (1,518 ha) and from three locations in three geological units.

Two recorded taxa, *Draculoides* sp. BHD2 and Palpigradi sp., are currently restricted to the project area and have only been recorded from sites within proposed pit outline. However habitat mapping completed for this study suggest that suitable troglofauna habitat extends north of the project area boundary. Given that the record of *Draculoides* sp. BHD2 came from close to the northern margin of the project area, this may suggest the species would also occur further to the north.

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2.0 Introduction

2.1 Project Background

The Baby Hope Downs iron ore deposit is located adjacent to the existing Hope Downs 1 iron ore mine, approximately 79 km northwest of Newman in the Pilbara region of Western Australia (Figure 2.1). Rio Tinto has undertaken an Order of Magnitude study of the Baby Hope Downs iron ore deposit, as well as extensive drilling in the area, and is in the process of seeking environmental approval to develop the site. Future developments that may be constructed in the area comprise mine pits, waste dumps, topsoil stockpiles and other general infrastructure.

A preliminary desktop review conducted by Biota (2009) concluded that it was likely that potential Short-Range Endemic (SRE) and troglobitic fauna occur within both the existing Hope Downs operations area and adjacent areas that had not been previously surveyed. As mining developments have the potential to impact subterranean fauna (EPA 2013), Rio Tinto commissioned targeted troglobitic fauna surveys of the Baby Hope Downs project area (Figure 2.1).

An initial phase of troglobitic fauna sampling was completed in the project area by Biota Environmental Sciences (Biota) in 2013 (Biota 2015). To support the environmental approvals process, a second survey phase was completed in 2015, which is the subject of this report.

2.2 Objectives and Report Aims

In 2013, Biota was commissioned to carry out Phase 1 of the troglobitic fauna survey (Biota 2015). The Phase 2 2015 survey targeted a variety of drilled, geological units adjacent to as well as within the 1,652 ha project area (see Figure 2.1).

The objectives of the Phase 2 troglobitic fauna survey were to:

- sample a representative subset of available drillholes for troglofauna within the project area and surrounds, in order to collect additional specimens to and data on species distributions and habitats;
- morphologically identify the collected troglobitic and troglophilic specimens to lowest taxonomic level possible; and
- discuss current conservation significance of the recorded troglobitic and troglophilic species.

This report provides a description of the methodology used during the second phase. It also documents the results of the most recent phase and collates data from both troglobitic fauna sampling phases (Section 4.0) in the discussion (Section 6.0).

Its intended use is as a supporting document for the environmental impact assessment of the proposed development, under Section 38 of the *Environmental Protection Act 1986.* Both the field survey and report are subject to specific limitations that are discussed in Section 3.3.

2.3 Terminology

For the purposes of this report, the following terms are used as defined below:

Study area – the area encompassing all sampled drillholes from Baby Hope Downs and troglobitic fauna record locations from Phase 2 and historic (reference) collections.

Project area – the outline supplied by Rio Tinto as the extent of the Baby Hope Downs project.

Proposed pit outline – the outline supplied by Rio Tinto as the proposed extent of mining operations.

Other terms are detailed in the glossary provided in Section 7.0.

2.4 Troglobitic Fauna Background

Australia was historically thought to lack habitat suitable for subterranean fauna. Studies in recent decades however, mostly with an emphasis on environmental impact assessment, have revealed Australia to be highly diverse in subterranean fauna with numerous areas of interest throughout the continent (Guzik et al. 2010). In Western Australia these zones of subterranean biodiversity can be found at the Nullarbor, Yilgarn, Cape Range, Barrow Island and the Pilbara bioregion (Humphreys 2001, Page et al. 2008, Guzik et al. 2010).

Subterranean fauna can be categorised into two distinct ecological groups based on habitat, troglobitic fauna (troglofauna) and stygobitic fauna (stygofauna). Troglofauna are a suite of fauna that survive only in air-filled cavities and interstices between the surface and the water table. Troglobites are obligatory subterranean habitat dwellers, and while they may occur close to surface environments, are strongly adapted to subterranean environments. This makes such fauna unable or highly unlikely to survive surface conditions. A range of similarly adapted fauna occur that opportunistically use subterranean habitats but are able to survive outside these stable environments. Studies from the Pilbara bioregion have demonstrated that these latter suites of fauna; troglophiles, trogloxenes and edaphobites, are not similarly restricted in range and therefore unlikely to be impacted at taxon level by small scale developments (Biota and Helix 2011, Helix 2012).

Troglofauna in northern Western Australia have been known for some time from karstic limestone systems on Cape Range and Barrow Island. Surveys in the Pilbara over the past decade or more have collected subterranean fauna from other geological units such as banded iron formations, channel iron deposits, unconsolidated alluvium and sedimentary basalt (Marmonier et al. 1993, Biota 2004, 2006a, 2010a, 2011a, 2013), indicating that the suitability of a formation as habitat for troglobitic fauna is mostly a function of the availability of habitable space (Marmonier et al. 1993, Humphreys 1999, Biota 2006a), rather than a specific rock type.

Subterranean habitats are characterised by shared physical parameters that include a lack of light, stable temperature, limited nutrient infiltration from surface environments and a constant humidity (Juberthie 2001, Romero 2009). These habitat characteristics have resulted in convergence in body morphology evolution amongst many subterranean fauna.

Morphological characteristics common to most subterranean fauna include reduced or lack of pigmentation, reduced or lack of eyes, and elongate body morphology and appendages adapted for sensory movement (Culver and Pipan 2009, Romero 2009).

Troglofauna in semi-arid Australia are thought to be relictual rainforest fauna. Fauna adapted to humid environments, which retreated underground to subterranean environments during the aridification of Australia (in the late Miocene; Humphreys 1993). This is inferred from affinities of the taxonomic groups represented amongst the troglofauna with other extant taxa in tropical climates. Some invertebrate groups with troglobitic representatives include the Arachnida (e.g. Schizomida, Pseudoscorpiones and Araneae), Chilopoda (e.g. Scolopendrida), Diplopoda (e.g.

Polydesmida and Haplodesmida), and Insecta (e.g. Diplura, Thysanura, Coleoptera and Blattodea). A single troglobitic vertebrate species of blind snake (*Anilios longissimus,* formerly *Ramphotyphlops longissimus*) is known from Australia, collected from Barrow Island (Aplin 1998, Humphreys et al. 2013)

Due to their dependence on constant humidity, dispersal and distribution of troglobitic fauna species tends to remain limited to individual blocks of inter-connected habitat, leading to long periods of population isolation and localised speciation. As a result, troglobitic fauna are considered to be of conservation significance, given species often display extreme short-range endemism and species may therefore be affected by relatively small-scale developments such as mining and construction.

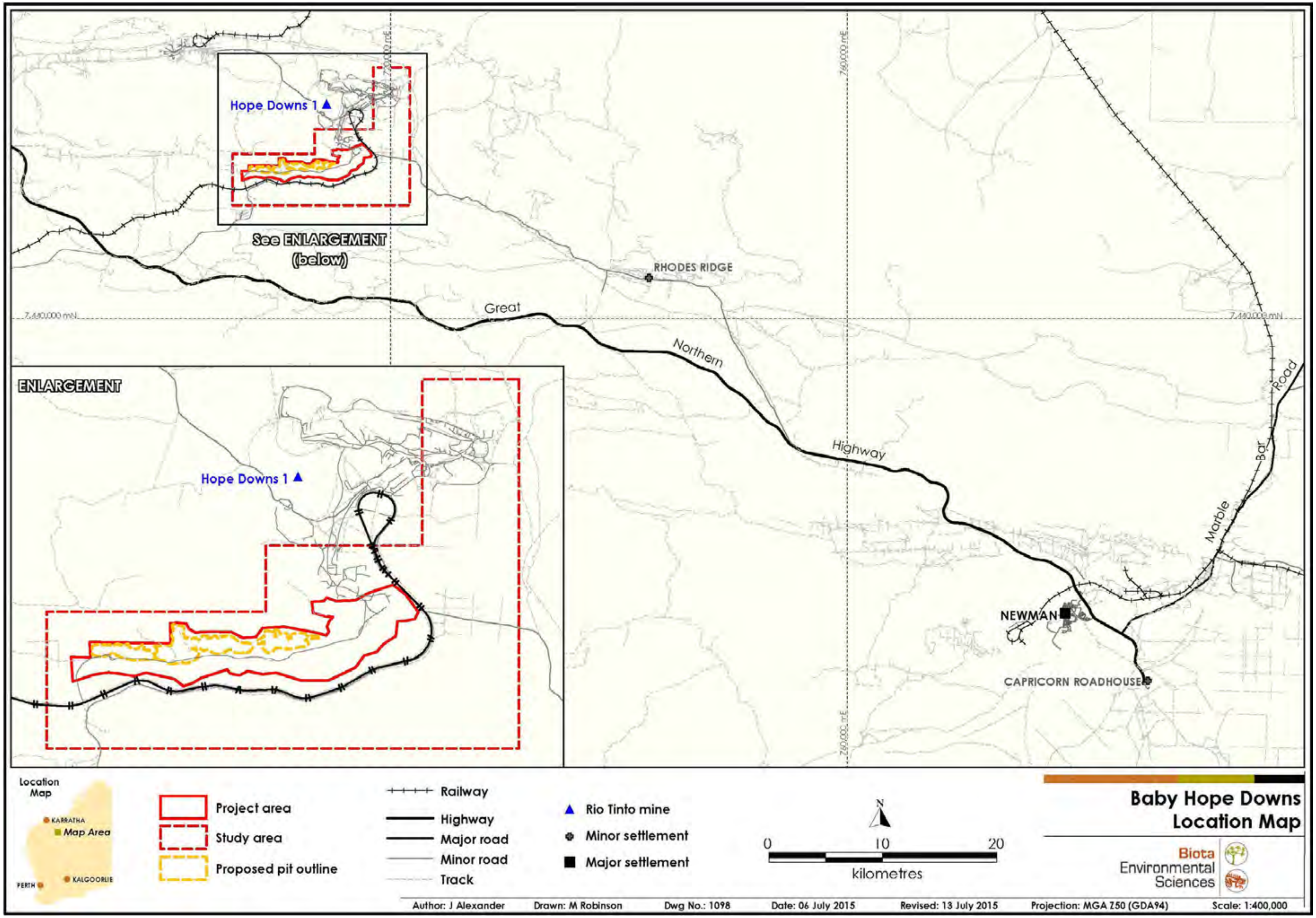

Figure 2.1: Location of the Baby Hope Downs project and study areas.

3.0 Methodology

This survey was completed under "Licence to Take Fauna for Scientific Purposes" No. SF010266 issued to Jason Alexander (Appendix 1). Methodology and approach were consistent with those outlined in the EPA Guidance Statement No. 54a (EPA 2007) and EPA Environmental Assessment Guideline (EAG) No. 12 (EPA 2013).

3.1 Sampling Methodology

Troglobitic fauna were sampled for using two methods; baited colonisation traps and scraping with haul nets.

3.1.1.1 Colonisation Trapping

Custom-built litter colonisation traps were suspended at intervals within drillholes located within the study area. Traps were constructed from 60 mm internal diameter PVC irrigation pipe cut to a length of 180 mm. Each trap had a series of 20 mm holes drilled into the side, and traps remained open at the upper end. Up to three traps were installed at each site, such that they were in contact with the interior of the sampled drillhole, facilitating fauna entry into the trap.

Leaf litter was gathered locally from the ground surface in the study area, particularly from the bases of *Acacia* shrubs. The collected litter was soaked in water and irradiated in a microwave oven for two minutes on maximum power setting. The microwave acted to kill any surface invertebrates present and assisted in the breaking down of organic matter. Wet litter was added to the traps, which were kept in sealed containers until immediately prior to insertion into the drillholes to avoid desiccation of leaf litter. After the installation of traps, the opening of each drillhole was sealed to maintain humidity and to minimise entry of surface fauna.

Traps were recovered from each drillhole after seven weeks and stored in labelled zip lock bags in order to maintain humidity and prevent desiccation of potential troglofauna specimens during transport to Perth.

Fauna specimens were recovered from the traps using specially designed Tullgren funnel units. Leaf litter from each trap was placed in a sieve under an aluminium lamp containing a 25-watt globe. This created a temperature of approximately 30°C at the surface of the leaf litter. A funnel situated below the leaf litter collected the fauna as they fell, directing them into an attached vial of 100% ethanol. Leaf litter was left in the Tullgren funnels for a period of 24 hours, or until dry, after which time the bulked invertebrate sample removed.

3.1.1.2 Troglofauna Scraping

Troglofauna were also sampled by using reinforced stygofauna haul nets. These nets were constructed from 70 µm plankton mesh and had 100 mm apertures attached to a weighted catch jar.

Sampling took place by lowering the net to the bottom of the drillhole before being slowly hauled up to the surface whilst scraping the edge of the drillhole. This dislodged any fauna on the vertical surface of the drillhole interior. Each site was hauled a minimum of four times, scraping each side of the drillhole. On completion of scraping each site, any observed fauna specimens were preserved in-situ in 100% ethanol and individually labelled. The contents of the net, which included dry soil and root matter, were emptied into a uniquely labelled container. The container was then filled with 100% ethanol to preserve any specimens that may have been in the soil and root matter for transport to Perth and sorting in the laboratory.

3.1.2 Data Management

Field site and collection data were captured using custom-built forms in the mobile tablet application, Fulcrum.

Preliminary identification of subterranean fauna involved identification of specimens to order level, where possible, or separating specimens out into distinct morphotypes. Sorting was completed using dissecting microscopes (Olympus SZ40 and SZ61, magnification up to 40x). Specimens were then assigned a unique number based on drillhole name, date and method of collection. Specimens were re-preserved in 100% ethanol once separated out into morphotypes, which allows for both morphological and molecular analyses.

Once all sampling and preliminary sorting had been completed, data were exported from Fulcrum into Excel format and into Biota's internal database.

3.2 Survey Design

3.2.1 Timing and Personnel

Phase 2 of sampling at Baby Hope Downs was managed by Jason Alexander, with directional input from Garth Humphreys, both of Biota. Jason Alexander and Mike Delaney (Biota) completed troglofauna sampling between the 8th of April and 21st of May 2015.

Sorting and preliminary identification of specimens (to order level) was completed by Jason Alexander, Tim Sachse and Andrew Sheppard, all of Biota. Specimens were then grouped by order and selected specimens sent for further analysis. Collected Schizomida specimens were forwarded to Helix Molecular Solutions (Helix) for genetic analysis (Appendix 2). Specimens belonging to the orders Pseudoscorpiones, Palpigradi, Blattodea and Diplura were forwarded onto the Western Australian Museum (WAM) for further morphological analysis, where possible.

Melissa Robinson and Kylie Webster of Biota prepared maps for field surveys and reporting purposes.

3.2.2 Sampling Effort

A total of 43 sites were sampled for troglofauna using haul nets and colonisation traps during Phase 2. Sampling included 43 sites sampled using colonisation traps and 12 sites using haul net scraping techniques (Table 3.1). Sites were selected to provide a spatial coverage of the study areas and to target prospective geological units where accessible. Blockages in two sites, RC13HD10230 and RC13HD10331 prevented the recovery of four traps. A total of 117 traps were installed and 113 were recovered (Table 3.1).

Table 3.1: Summary of site locations sampled and sampling effort per site for Phase 2 of troglofauna sampling at Baby Hope Downs (coordinates in Zone 50, datum GDA94).

Site Name	Easting (m E)	Northing (m N)	Scrape	Number Installed	Number Recovered	Trap Depths
GD13HD10016	716087	7454116		2	2	10, 20
RC07H1S198	715491	7454213	Y	2	2	10, 15
RC07H1S356	715543	7454208	Y	2	2	15, 20
RC07H1S374	715699	7454403	Y	1	1	10
RC07H1S390	715795	7454250		3	3	10, 20, 30
RC07H1S395	715803	7454501		3	3	10, 20, 30
RC07H1S422	716241	7454589	Y	2	2	10, 20
RC07H1S439	716004	7454497		2	2	10, 20
RC07H1S554	716148	7454397		3	3	10, 20, 30
RC07H1S559	716389	7454288		3	3	10, 20, 30
RC07H1S613	715485	7454223	Y	2	2	15, 30

Site Name	Easting (m E)	Northing (m N)	Scrape	Number Installed	Number Recovered	Trap Depths
RC10H1SW039	708665	7453041		3	3	15, 30, 45
RC11H1SW0008	708064	7452787		3	3	15, 30, 40
RC12H1SW0005	709160	7452800		3	3	15, 30, 45
RC12H1SW0120	711561	7452791		2	2	10, 20
RC12H1SW0137	712155	7453550	Y	2	2	10, 25
RC12H1SW0203	714913	7450889		3	3	15, 30, 45
RC13HD10011	710056	7452890		3	3	15, 30, 45
RC13HD10055	710658	7452791		3	3	15, 30, 45
RC13HD10066	710650	7453601		3	3	10, 20, 30
RC13HD10151	711061	7453239		3	3	15, 30, 45
RC13HD10169	711959	7453145		3	3	15, 30, 45
RC13HD10230*	713957	7453242		3	2	15, 30, 45
RC13HD10277	710459	7452485		3	3	15, 30, 45
RC13HD10298	713708	7450585		3	3	15, 30, 45
RC13HD10299	713708	7450791	Y	3	3	15, 30, 45
RC13HD10319	713162	7453392	Y	2	2	15, 30
RC13HD10327	713309	7450792		3	3	10, 20, 30
RC13HD10331*	713310	7450392	Y	3	0	15, 30, 45
RC13HD10336	713716	7450225	Y	2	2	15, 30
RC13HD10339	716312	7450593		3	3	15, 30, 45
RC13HD10342	716510	7450691		3	3	15, 30, 45
RC13HD10344	716713	7450589		3	3	15, 30, 45
RC13HD10356	716313	7450290		3	3	15, 30, 45
RC13HD10359	716101	7450071		3	3	15, 30, 45
RC13HD10362	715520	7450320		3	3	15, 30, 45
RC14HD10022	714759	7453338	Y	3	3	10, 20, 30
RC14HD10195	713414	7453337		3	3	15, 30, 40
RC14HD10674	711313	7453588	Y	3	3	10, 15, 20
RC14HD10933	710214	7453243		3	3	15, 30, 45
RC14HD10968	709107	7452938		3	3	10, 20, 30
RC14HD11114	714405	7450784		3	3	15, 30, 45
RD13HD10020	712571	7453141		3	3	15, 30, 45
		Total	12	117	113	

* Denotes blockage in site – unable to retrieve all traps.

3.3 Study Limitations

A number of limitations apply to the two phases of troglofauna sampling completed at Baby Hope Downs. Two of the taxa, Palpigradi sp. and Diplura sp., were unable to be identified due to poor resolution of their wider taxonomic framework. This limited the conclusiveness of some of the findings for these taxa in regards to both taxonomic placement and ecological status. Wider taxonomic reviews of these groups would be required to better determine their conservation status.

Mapping of hydrated geological units at depth was not available at the time of this study. Subterranean habitat was therefore primarily examined by reference to surface geology mapping data, which may not always reflect underlying formations. The use of preliminary cross-sections and selected drill log data assisted with offsetting this limitation.

Troglobitic fauna sampling at Baby Hope Downs has been limited to existing drill holes, which are focused on the resource development. Surveys targeting surrounding and continuous geological units would be beneficial to determine the wider extent of species' distributions and suitable subterranean habitats.

Local scale (1:4,000) geological mapping supplied by Rio Tinto was limited in extent to the northern portion of the project area, in the vicinity of the proposed pit outlines. This limited the extent to which potential troglofauna habitat could be mapped and this was not attempted in the southern portion of the project area.

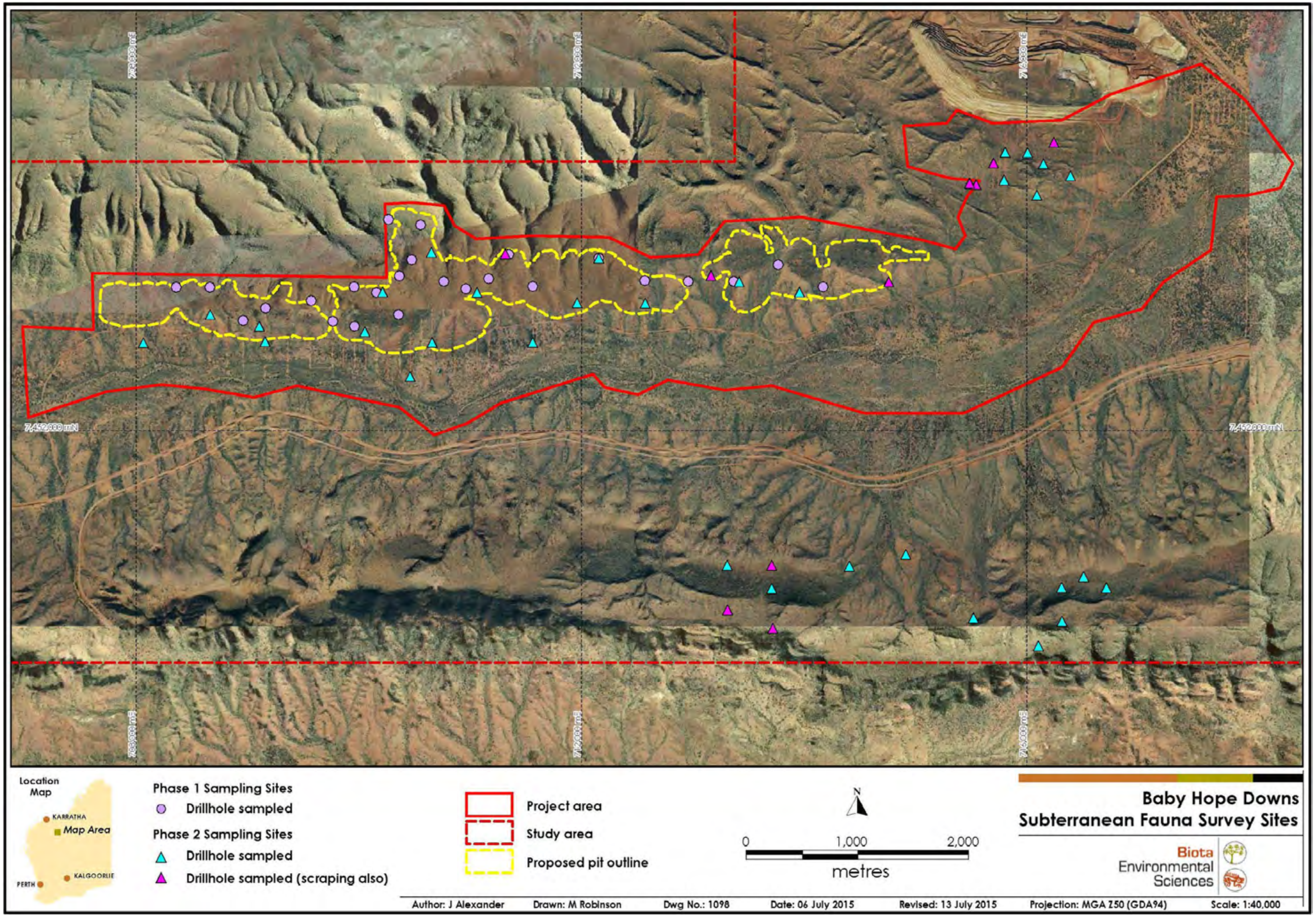

Figure 3.1: Location of Phase 2 sampling points in relation to Phase 1 and proposed mining pit.

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4.0 Results

A total of 1,822 invertebrate specimens were collected during the Phase 2 troglofauna sampling, representing 15 taxonomic orders (Appendix 3). As is common with troglofauna sampling, the majority of specimens collected were not troglobitic, but edaphobitic (deep-soil and litter dwelling). Edaphobitic taxa do not typically have restricted distributions and are not considered high risk for short-range endemism (e.g. orders Acarina, Collembola, Diptera) (Harvey 2002, Berry 2005, Biota and Helix 2011). The edaphobites collected during this survey are not discussed further in this report, as they are not relevant to the objectives of this study. For the purposes of this report we will focus on troglobitic and troglophilic specimens. Troglophiles display troglomorphic characteristics and will utilise subterranean environments but are not restricted to them. In general, troglophiles are less prone to short-range endemism and therefore at relatively low risk of taxon-level impacts due to local scale developments.

Thirty-two specimens collected during Phase 2 were identified as being potential troglobites or troglophiles from six orders (Table 4.1). Nine of these were collected with haul nets (scraping) and 23 via colonisation traps. The insect order Blattodea, or cockroaches, were most commonly recorded with 17 specimens collected from six sites. The arachnid orders Palpigradi and Pseudoscorpiones, and the diplopod order Polyxenida, were least commonly recorded, represented by one specimen each.

Table 4.1: Summary of troglobitic and troglophilic specimens recorded during Phase 2 of sampling at Baby Hope Downs.

Taxonomy			Number of	Sites
Phylum	Class	Order (Common Name)	Collected	Collected
Arthropoda	Arachnida	Schizomida (Schizomid)	8	GD13HD10016, RC07H15374, RC07H1S198, RC12H1SW0005, RC13HD10298, RC13HD10342, RC14HD10195
		Palpigradi (Palpigrades)	1	RC14HD10022
		Pseudoscorpiones (Pseudoscorpion)	1	RC13HD10336
	Diplopoda	Polyxenida (Pincushion Millipede)	1	RC07H1S422
	Insecta	Blattodea (Cockroach)	17	RC07H1S422, RC07H1S613, RC12H1SW0137, RC13HD10331, RC13HD10336, RC13HD10339
		Diplura (Earwig)	4	RC07H1S356, RC07H1S613, RC13HD10055, RC14HD11114
		Total:	32	

Molecular studies previously completed in the Pilbara have indicated that the orders Blattodea and Polyxenida tend not to display short-range endemism and are likely troglophilic (Biota 2011b, 2012a, 2012b, Biota and Helix 2011). These troglophiles removed, four potential troglobitic orders remain, Schizomida, Palpigradi, Pseudoscorpiones and Diplura.

These taxa will be discussed in detail in the following sections.

4.1 Account of Phase 2 Troglobitic Fauna

4.1.1 Order Palpigradi

A single palpigrade (WAM number; T137071) was collected from drillhole RC14HD10022 during the second phase of troglofauna sampling (Table 4.2, Figure 4.1). The order Palpigradi is rarely collected during subterranean fauna sampling and limited taxonomic expertise exists in Australia to identify the specimen (Kym Abrams, WAM, pers. comm. 2015). Genetic analysis completed on this specimen may help clarify the distribution of this species.

Table 4.2: Summary of Palpigradi collected during Phase 2 sampling at Baby Hope Downs.

Taxonomy		Number Collected	Sites
Family	Taxon		
Indet.	Palpigradi sp.	1	RC14HD10022 (n=1)
	Total	1	

4.1.2 Order Pseudoscorpiones

A single troglobitic pseudoscorpion was collected from site RC13HD10336, south of the project area (Table 4.3, Plate 4.1, Figure 4.1). This specimen was identified morphologically as troglobitic and belonging to the undescribed species *Lagynochthonius* sp.'PSE096' (WAM number: T137072; family Chthoniidae; Abrams and Harvey 2015 see Appendix 4). The species is previously unrecorded in the Pilbara and is considered an SRE species. Further specimens would need to be collected to ascertain the distribution of this species however currently this species is recorded from outside the proposed pit outlines and outside the project area.

Table 4.3: Summary of Pseudoscorpiones collected during Phase 2 sampling at Baby Hope Downs.

Taxonomy		Number Collected	Sites
Family	Taxon		
Chthoniidae	*Lagynochthonius* sp.'PSE096'	1	RC13HD10336 (n=1)
	Total	1	

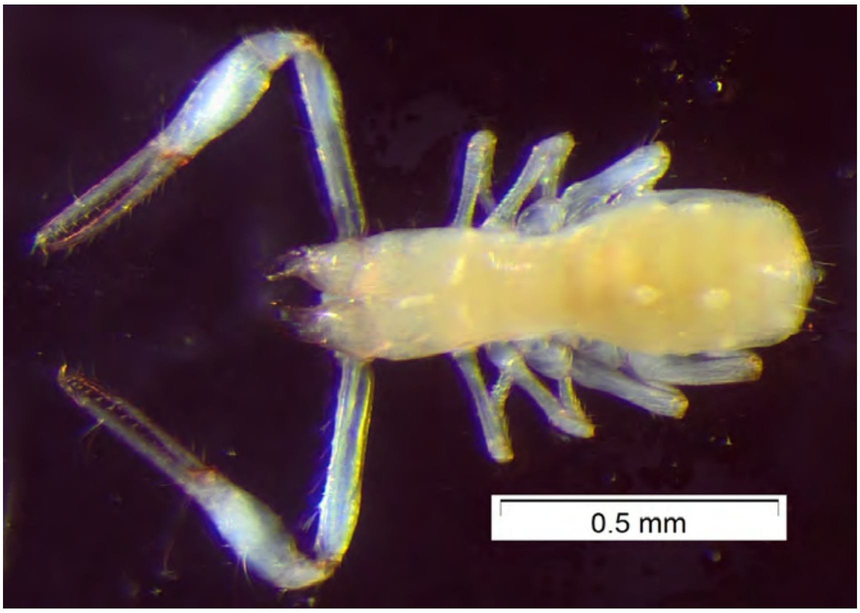


Plate 4.1: Dorsal view of Pseudoscorpiones species *Lagynochthonius* sp.'PSE096', collected from drillhole RC13HD10336.

4.1.3 Order Diplura

Four specimens of the order Diplura were recorded during the Phase 2 sampling (Table 4.4, Plate 4.2, Figure 4.1), and were collected over a 763 ha area. These specimens were unable to be identified morphologically past the family Japygidae due to a lack of taxonomic expertise. Previous studies from the Robe Valley have indicated that Diplura, based on morphological characters, are unlikely to represent SRE species (Biota 2010b). The specimens collected from Baby Hope Downs are conservatively treated here as potential troglobitic fauna. Genetic analysis of these specimens, as well as specimens collected from the wider Pilbara area, would be required to determine the conservation significance of these specimens.

Table 4.4: Summary of collected Diplura from Phase 2 sampling at Baby Hope Downs.

Taxonomy		Number Collected	Sites
Family	Taxon		
Japygidae	Japygidae sp.	4	RC07H1S356 (n=1), RC07H1S613 (n=1), RC13HD10055 (n=1), RC14HD11114 (n=1, Plate 4.2)
	Total	4	

Plate 4.2: Dorsal view of Diplura sp. collected from drillhole RC14HD11114.

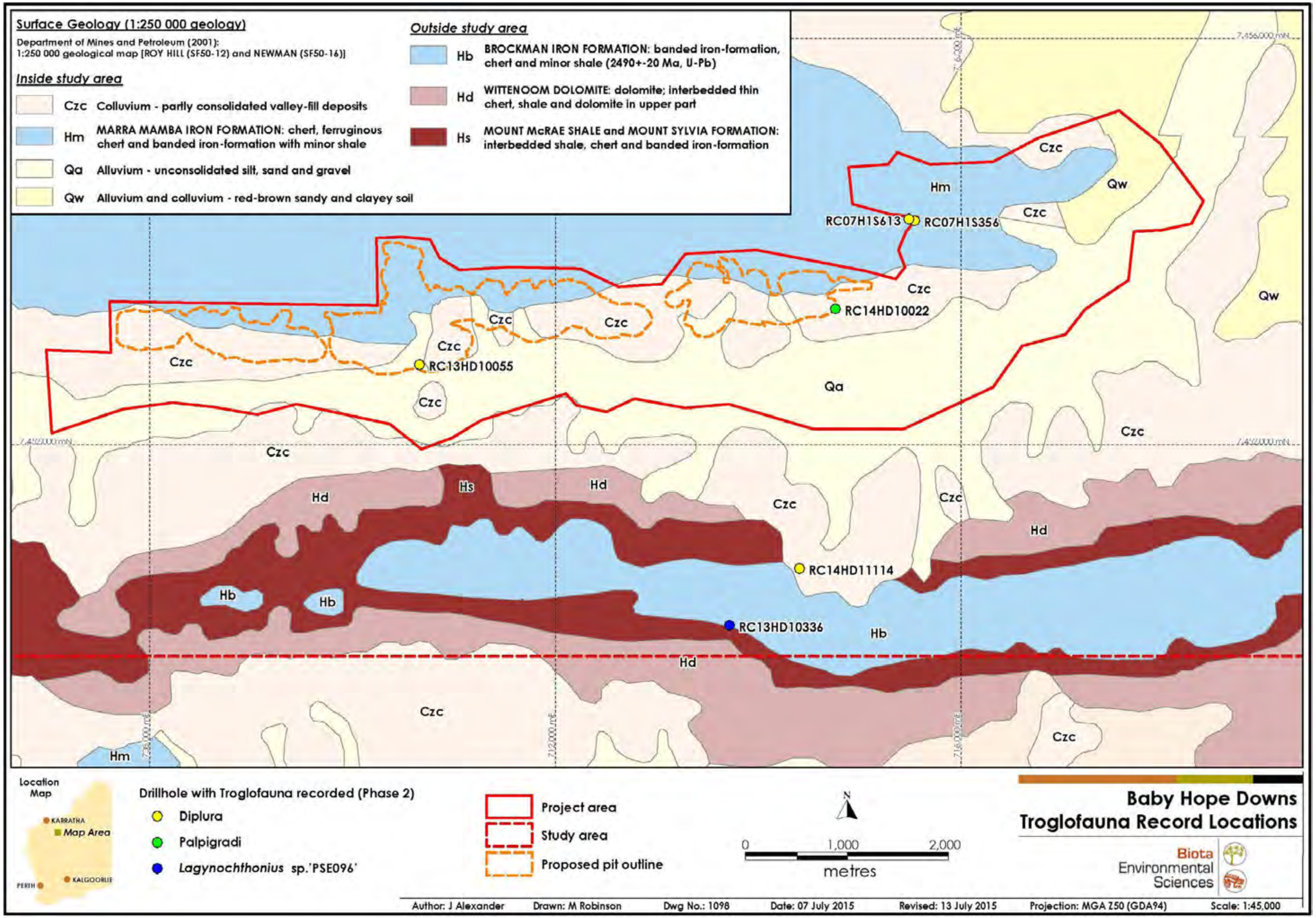


Figure 4.1: Locations and surface geology of Diplura, Palpigradi and Pseudoscorpiones collected during the Phase 2 sampling.

4.1.4 Order Schizomida

Eight Schizomida specimens were recorded during Phase 2 of troglofauna sampling in 2015. All specimens were sequenced, which revealed the presence of three distinct genetic lineages (Table 4.5), all belonging to the the genus *Draculoides* (family Hubbardiidae). For the purposes of this report, these lineages are synonymous with species level identifications (Appendix 2).

Four specimens of *Draculoides* sp. BHD3 (Table 4.5, Plate 4.3, Figure 4.2) were collected from three sites in the north of the project area. Two specimens of *D.* sp. BHD4 (Table 4.5, Plate 4.4, Figure 4.2) were collected from two sites within the proposed pit outlines, and also one site south of the project area. A singleton record was collected from south of the study area belonging to the species *D*. sp. BHD5 (Table 4.5, Plate 4.5, Figure 4.2).

Table 4.5: Taxonomy of Schizomida specimens collected from Phase 2 of sampling at Baby Hope Downs.

Taxonomy		Number	Sites
Family	Species / Lineage	Collected	
Hubbardiidae	*Draculoides* sp. BHD3 / BHD3 (Plate 4.3)	4	GD13HD10016 (n=1), RC07H1S198 (n=2), RC07H1S374 (n=1)
	Draculoides sp. BHD4 / BHD4 (Plate 4.4)	3	RC13HD10298 (n=1), RC12H1SW0005 (n=1), RC14HD10195 (n=1)
	Draculoides sp. BHD5 / BHD5 (Plate 4.5)	1	RC13HD10342 (n=1)
	Total	8	

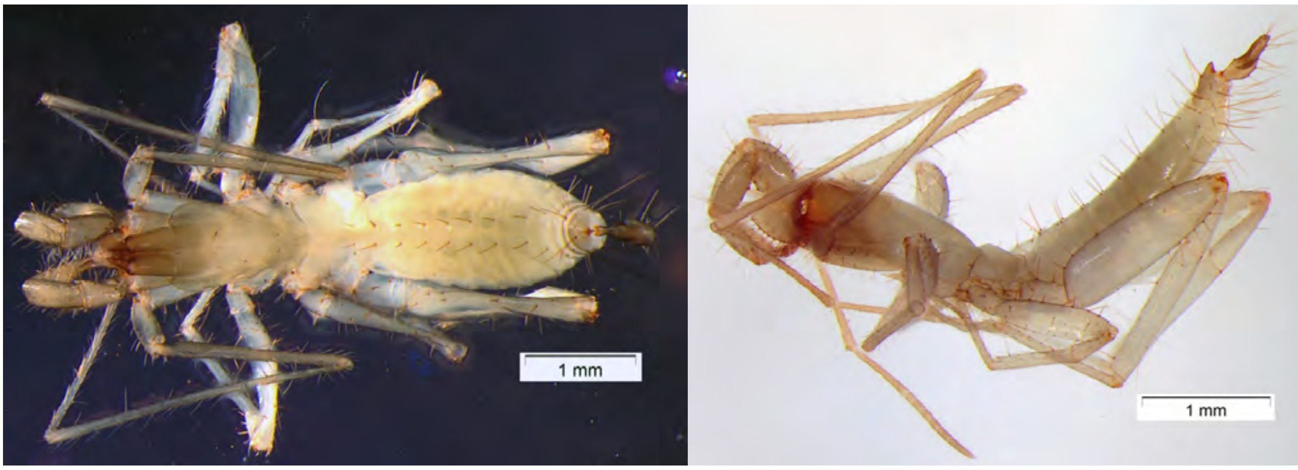


Plate 4.3: Dorsal view (left) and lateral view (right) of Schizomida species *Draculoides* sp. BHD3 collected from drillhole RC07H1S374.

Plate 4.4: Dorsal view of Schizomida species *Draculoides* sp. BHD4 collected from drillhole RC12H1SW0005.

Plate 4.5: Dorsal view of Schizomida species *Draculoides* sp. BHD5 collected from drillhole RC13HD10342.

4.2 Amalgamation of Schizomida Records

Two phases of sampling have been completed to date with five Schizomida specimens recorded from Phase 1 (Biota 2015) and eight recorded from Phase 2. All collected specimens were sequenced for genetic variation. Five lineages were recorded from sampling targeting Baby Hope Downs (CI1, and BHD2 – BHD5). Six reference specimens, representing one additional species (BHD1), were collected from the wider Hope Downs area are also incorporated into this amalgamation.

Nineteen specimens of troglobitic schizomid have been collected from Baby Hope Downs and surrounding areas, representing six distinct genetic lineages (Table 4.6, Figure 4.2). Genetic variation between species ranged from 5.5% (between BHD2 and BHD4) to 13.7% (Between BHD1/BHD4 and CI1) (Finston et al. 2015; see Appendix 2).

Table 4.6: Summary of recent and historical Schizomida collections from Baby Hope Downs and surrounds and their current distributions.

Species Name	Site Name	Surface Geology	Area (Ha)	n	Genetic differentiation (%)				
					BHD 1	BHD 2	BHD 3	BHD 4	BHD 5
Draculoides sp. BHD1	RC07H1S1048	• Colluvium - partly consolidated quartz and rock fragments; old valley-fill deposits	-	2					
Draculoides sp. BHD2	RC12H1SW0051, RC12H1SW0144	• Colluvium - partly consolidated quartz and rock fragments; old valley-fill deposits	8	3	10.9				
Draculoides sp. BHD3	GD13HD10016, RC07H1S198, RC07H1S374	• Marra Mamba - Chert, ferruginous chert and banded iron-formation	7	4	12.0	8.2			
Draculoides sp. BHD4	RC13HD10298, RC12H1SW0005 RC14HD10195	• Colluvium - partly consolidated quartz and rock fragments; old valley-fill deposits • Brockman Iron – Banded iron-formation, Chert and minor shale	593	3	8.7	5.5	9.8		
Draculoides sp. BHD5	RC13HD10342	• Brockman Iron – Banded iron-formation, Chert and minor shale	-	1	8.2	7.7	9.3	6.6	
Draculoides sp. CI1	RC12H1SW0026, 1218, 5515	• Marra Mamba - Chert, ferruginous chert and banded iron-formation • Calcrete-sheet carbonate • Alluvium – unconsolidated silt, sand and gravel.	1518	6	13.7	12.0	12.6	13.7	8.7
			Total	19					

Of the four schizomid species collected in two or more drillholes, two were also collected in more than one surface geological unit. Species *Draculoides* sp. BHD4 was collected from Brockman Iron Formation in the south of the study area and also from two drillholes in Colluvium units, within the proposed pit outline. *Draculoides* sp. CI1 has been collected over a greater range (1,518 ha) from three locations in three geological units (Marra Mamba, Colluvium and Alluvium) (Figure 4.2).

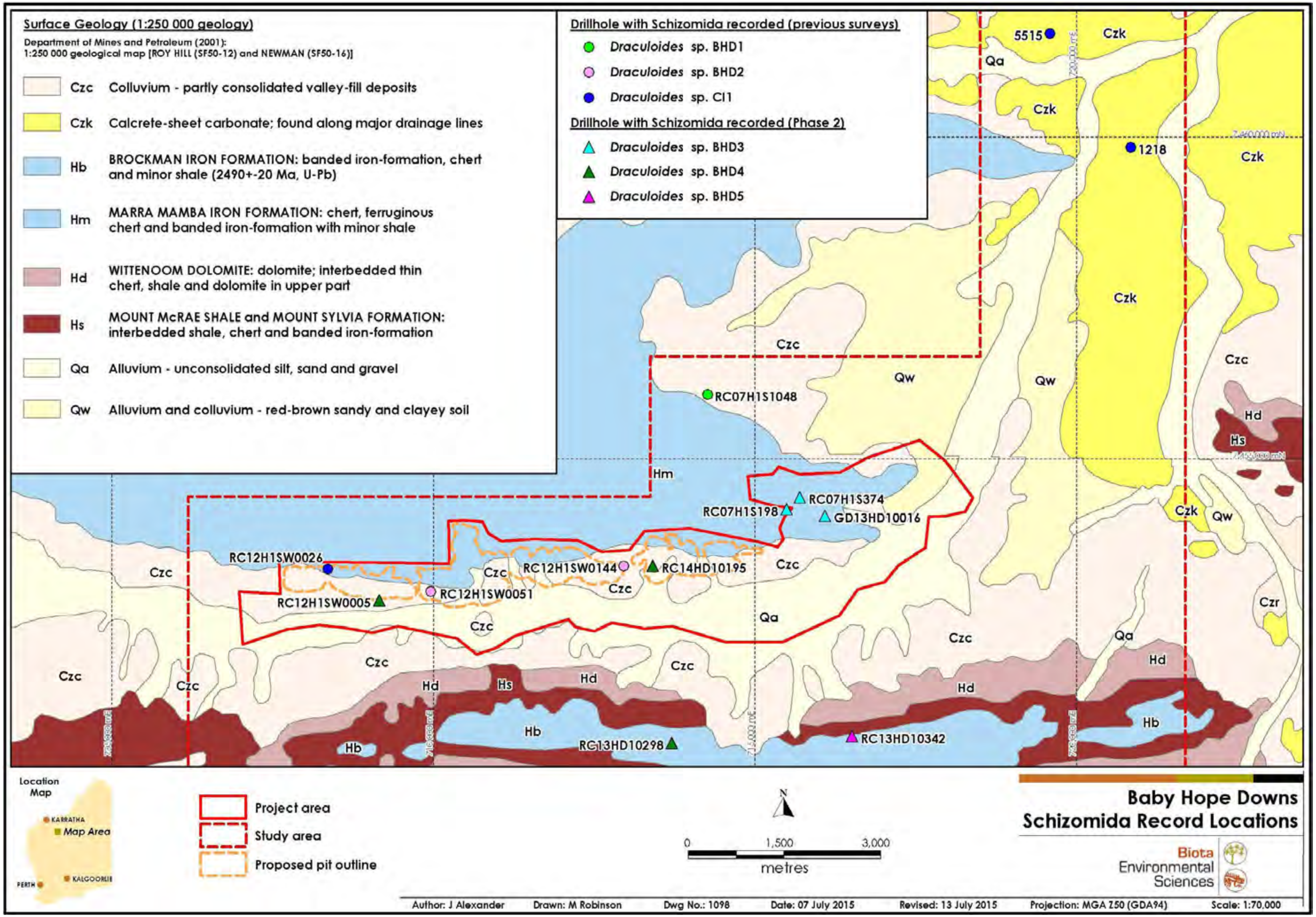


Figure 4.2: Locations and surface geology of all collected species of Schizomida from the Baby Hope Downs study area.

5.0 Troglofauna Habitat

5.1.1 Geological Setting

The Hope Downs 1 deposits, of which the Baby Hope Downs project area forms part, are associated with the Marra Mamba Iron Formation at the eastern end of the Weeli Wolli Anticline, a large-scale event fold, with the existing Hope Downs 1 operations north and south deposits located on the northern flanks of the anticlinal structures.

Mineralisation lies primarily within the Mount Newman Member of the Marra Mamba Iron Formation, with lesser amounts of mineralisation occurring in the Macleod Member and the West Angelas Member of the overlying Wittenoom Formation. The West Angelas Member of the Wittenoom Formation overlies the Marra Mamba Iron Formation, and consists predominantly of laminated pink, grey and khaki shales interbedded with lesser chert and minor Banded Iron Formation (BIF) bands.

In addition to the bedded mineralisation, deposits of secondary surficial ironstone have accumulated as cover over the bedded Marra Mamba mineralisation, and to the north of the outcropping Marra Mamba Iron Formations. These include canga, limonite or bedded goethite, pisolite, red ochre detritals and detrital material types.

The formation and position of the Hope Downs deposits are structurally and stratigraphically controlled, with substantial faulting and folding in the more complex areas of the deposits.

5.1.2 Surface Geology and Stratigraphy

The detailed surface geology mapping provided by Rio Tinto was intersected with the locations where troglobitic schizomids were recorded (drillholes RC12H1SW0026, RC12H1SW0051 and RC12H1SW0144). The geological units mapped at this local scale were generally consistent with the regional geology mapping, with records coming from Czc (colluvium) and Hm (Marra Mamba; goethite mineralisation over Mount Newman Member) as mapped at 1:4,000 scale.

Rio Tinto geologists compiled preliminary cross-sections of the stratigraphic arrangement of geological units at depth. In some parts of the study area, the mapped surface geology is representative of subterranean habitats at depth (e.g. where Marra Mamba has surface expression), but in other areas the surface units overlie other rock types at depth that represent the habitats being used by the fauna. Past work at multiple Pilbara sites (e.g. (Biota 2006b, 2012a, 2012b, 2014) has demonstrated that hydrated zones, both mineralised and non-mineralised, are likely to constitute habitat for troglofauna due to the presence of vugs, cavities and other habitat space. The preliminary cross-sections showed evidence of intersecting hydrated material at all three drillholes where schizomids were recorded in Phase 1 of sampling (Figure 5.1 to Figure 5.3).

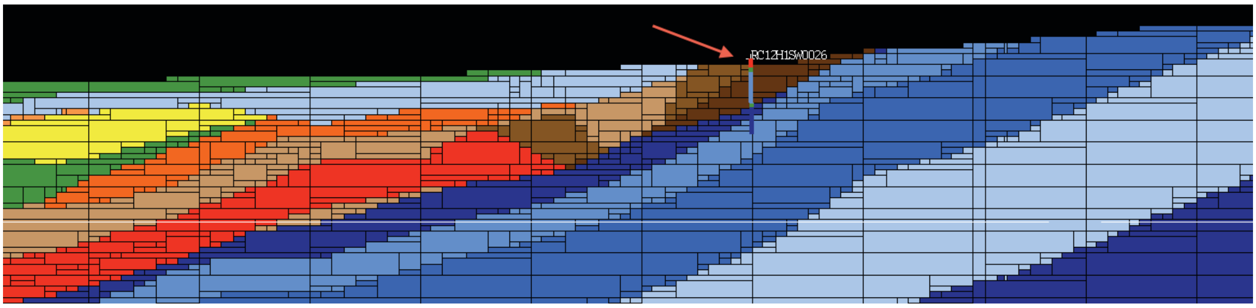


Figure 5.1: Preliminary cross-section showing location of drillhole RC12H1SW0026 (non-mineralised hydrated material shown in brown; mineralised hydrated material shown in red; arrow=drillhole location).

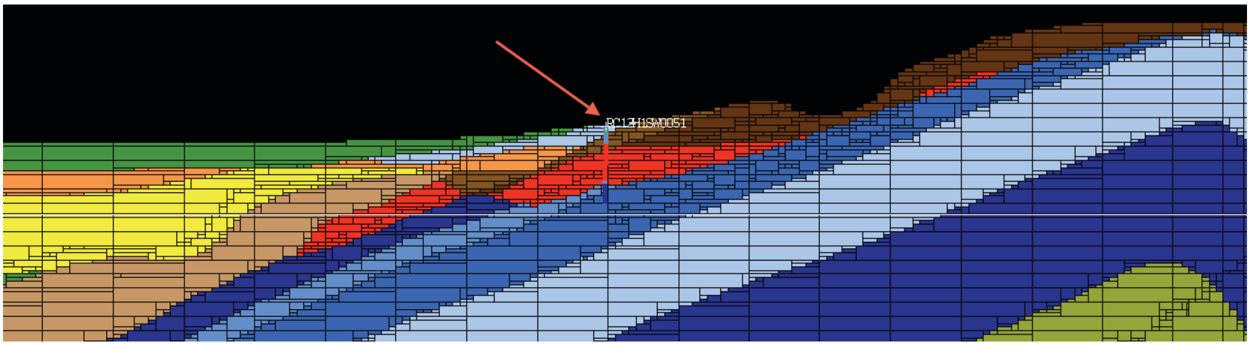


Figure 5.2: Preliminary cross-section showing location of drillhole RC12H1SW0051 (non-mineralised hydrated material shown in brown; mineralised hydrated material shown in red; arrow=drillhole location).

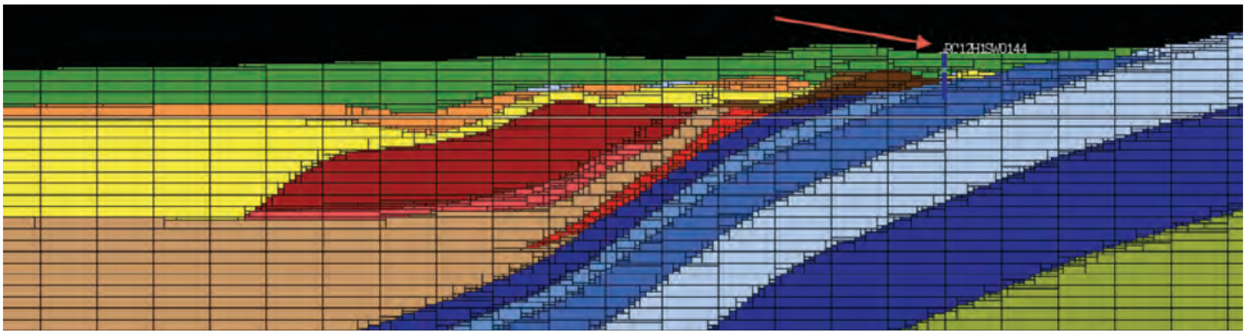
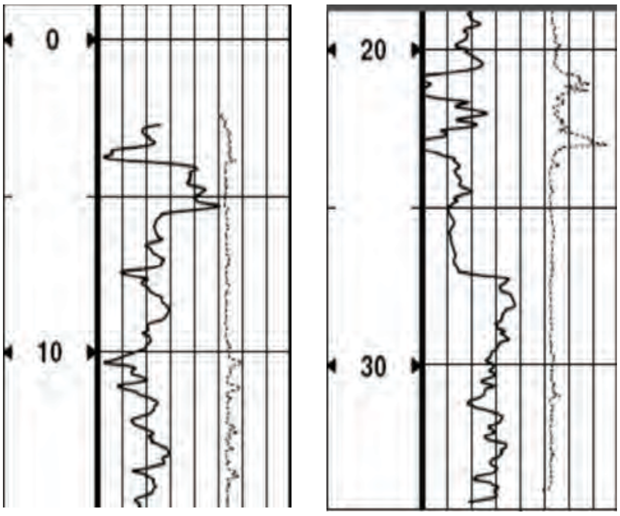


Figure 5.3: Preliminary cross-section showing location of drillhole RC12H1SW0144 (non-mineralised hydrated material shown in brown; mineralised hydrated material shown in red; arrow=drillhole location).

Reviews of wireline logging of the same three drillholes that intersect this core troglofauna habitat show evidence of cavities throughout much of the profile intersected (Figure 5.4 to Figure 5.6).



(A) (B)

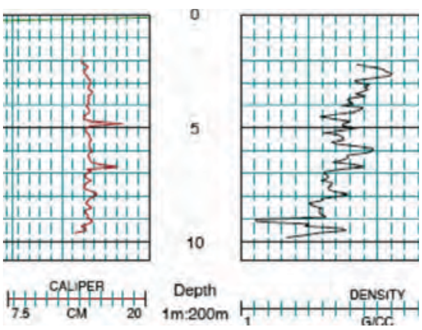


Figure 5.4: Caliper and density logs of RC12H1SW0051.

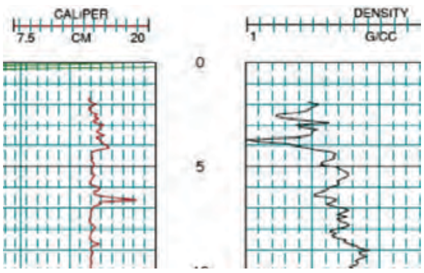


Figure 5.5: Caliper and density logs of RC12H1SW0026 (A: 0-18 m; B: 18-35 m).

Figure 5.6: Caliper and density logs of RC12H1SW0144.

Density and caliper logs indicated the presence of both relatively superficial cavities in the approximate top 10 m of the profile, in addition to cavities deeper in the profile (e.g. Figure 5.4 (B)).

This is also consistent with Optical Tele-viewer (OTV) imagery of nearby drillholes (OTV was not available for the holes yielding schizomids), which allow for more direct visual assessment of the physical characteristics of subterranean habitats. Plate 5.1 shows representative examples of subterranean habitat in the hydrated portion of the profile, with vugs and cavities evident both in the shallower parts of the profile and some deeper zones (e.g. GD14HD10014 in Plate 5.1).

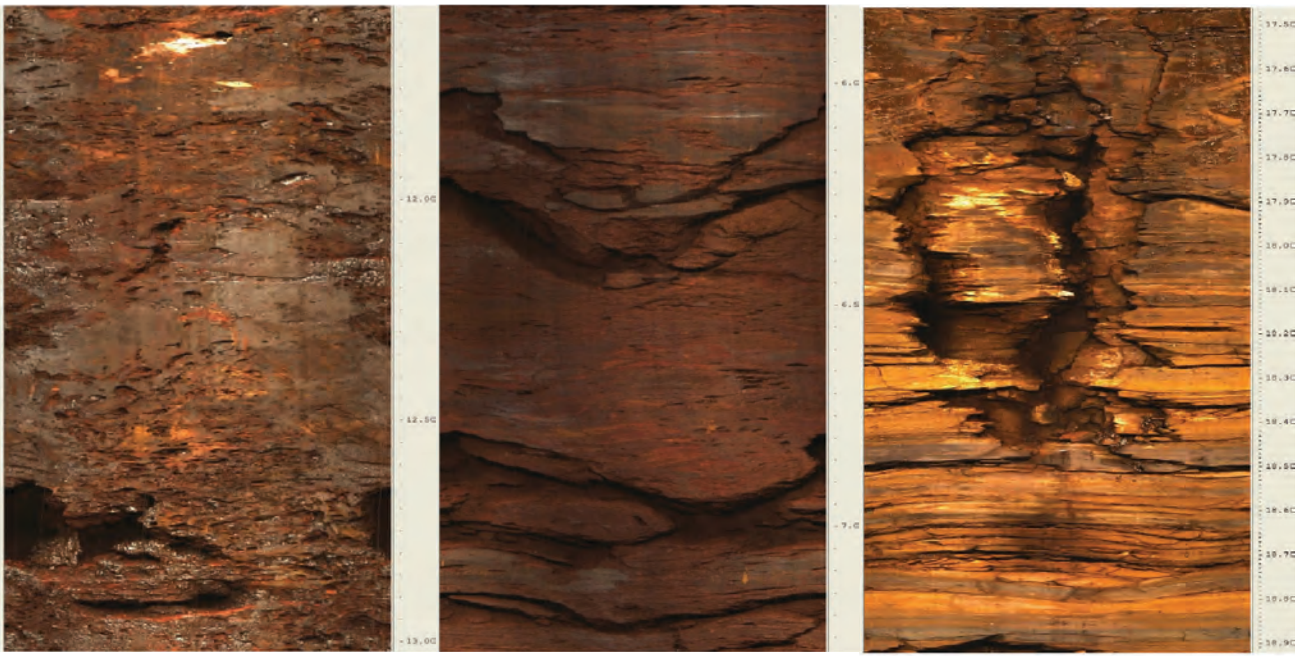


Plate 5.1: OTV imagery by depth from drillholes DD14HD10002, DD14HD10005 and GD14HD10014 (from left to right), showing cavities at varying depths in the profile (scale bars indicate depth below ground level).

5.1.3 Consolidation of Troglofauna Data and Subterranean Habitats

The currently available geological information suggests that potential troglofauna habitat in the project area is represented stratigraphically by hydrated zones in the profile, which spatially occur within surface geology units mapped locally as the valley fill unit Czc (Colluvium) and the Marra Mamba unit Hm (goethite mineralisation over Mount Newman Member). In order to provide a spatial analysis, these two units were merged to map potential troglofauna habitat within the study area.

Figure 5.7 consolidates findings from Section 4.0 and 5.1.1: it displays all locations where troglomorphic fauna (both Schizomida, Pseudoscorpiones and other troglomorphic taxa which utilise similar subterranean habitats) have been recorded in the project area and wider Hope Downs locality, overlain on mapping of the potential troglofauna habitat. This was also then spatially intersected with the1:250,000 regional geology unit mapping to allow extrapolation beyond the extent of the detailed Rio Tinto mapping (Figure 5.7).

This spatial analysis revealed good alignment between the distribution of the potential troglofauna habitat and the locations where troglofauna have been confirmed to occur, with all records coming from within the potential habitat polygon (Figure 5.7). The wider distribution of troglofauna habitat, and its connectivity with the study area, was also more broadly mapped as the combined Czc (colluvium – valley fill) and Hm (Marra Mamba) regional geology units. This is shown in a plan view in Figure 5.7, but more informatively in the isometric views presented in Figure 5.8 and Figure 5.9.

Both the local-scale habitat mapping and the regional scale geology units strongly suggest suitable habitat extends beyond the project area boundary to the northwest (Figure 5.7). The occurrence of hydrated zones in the locality also appears to be structurally controlled and a fault runs from the project area to the northwest, consistent with this likely habitat continuity (Rio Tinto, unpublished data). The landform perspective provide by Figure 5.8 and Figure 5.9 suggests that troglofauna habitat in the area sits relatively high in the landscape, extending upward in elevation from the sloping valley fill overlying hydrated material, to Marra Mamba units higher in the profile.

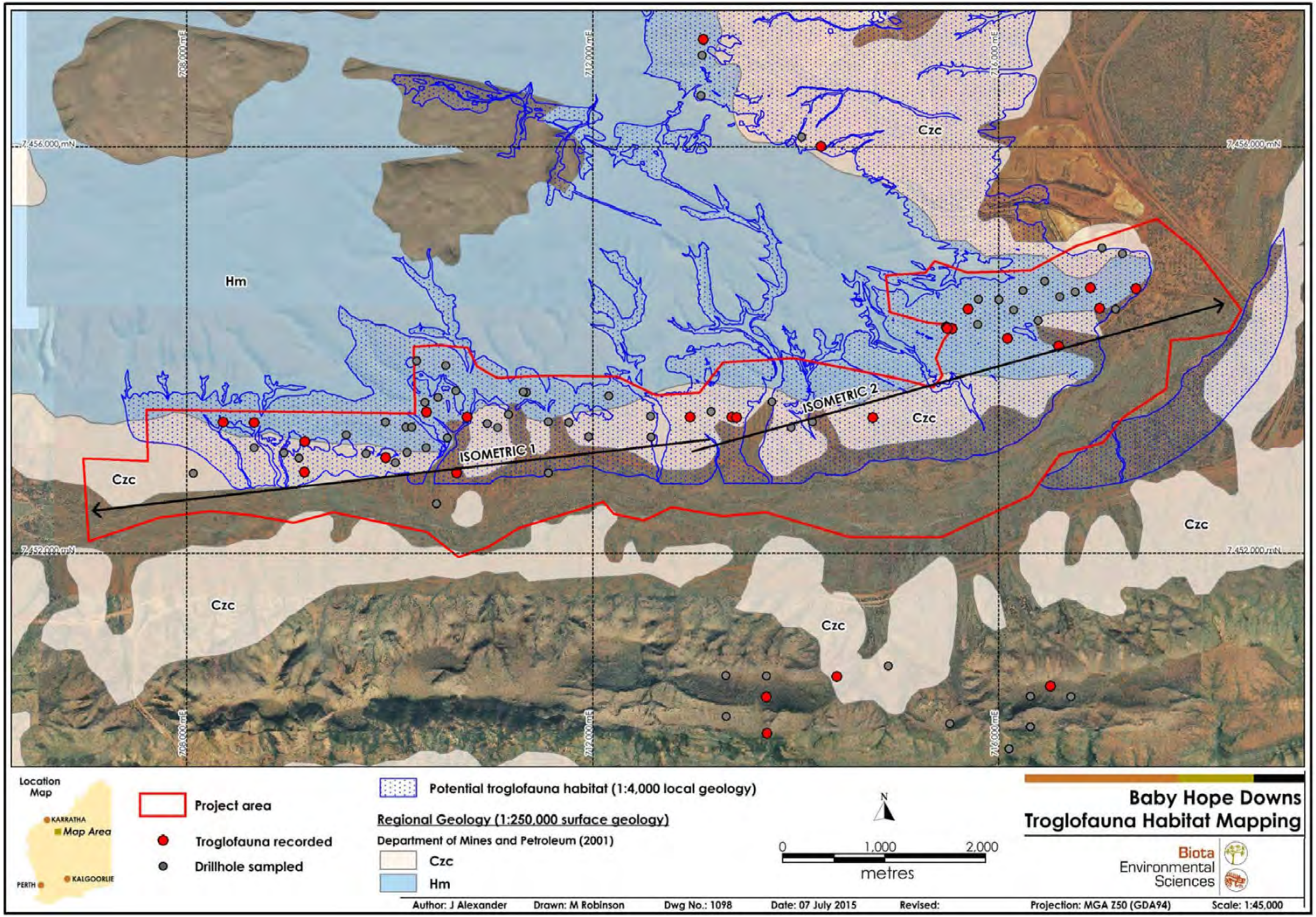


Figure 5.7: Plan view of troglofauna habitat mapping in relation to troglofauna records and sampling sites that yielded no records (Phase 1 and 2).

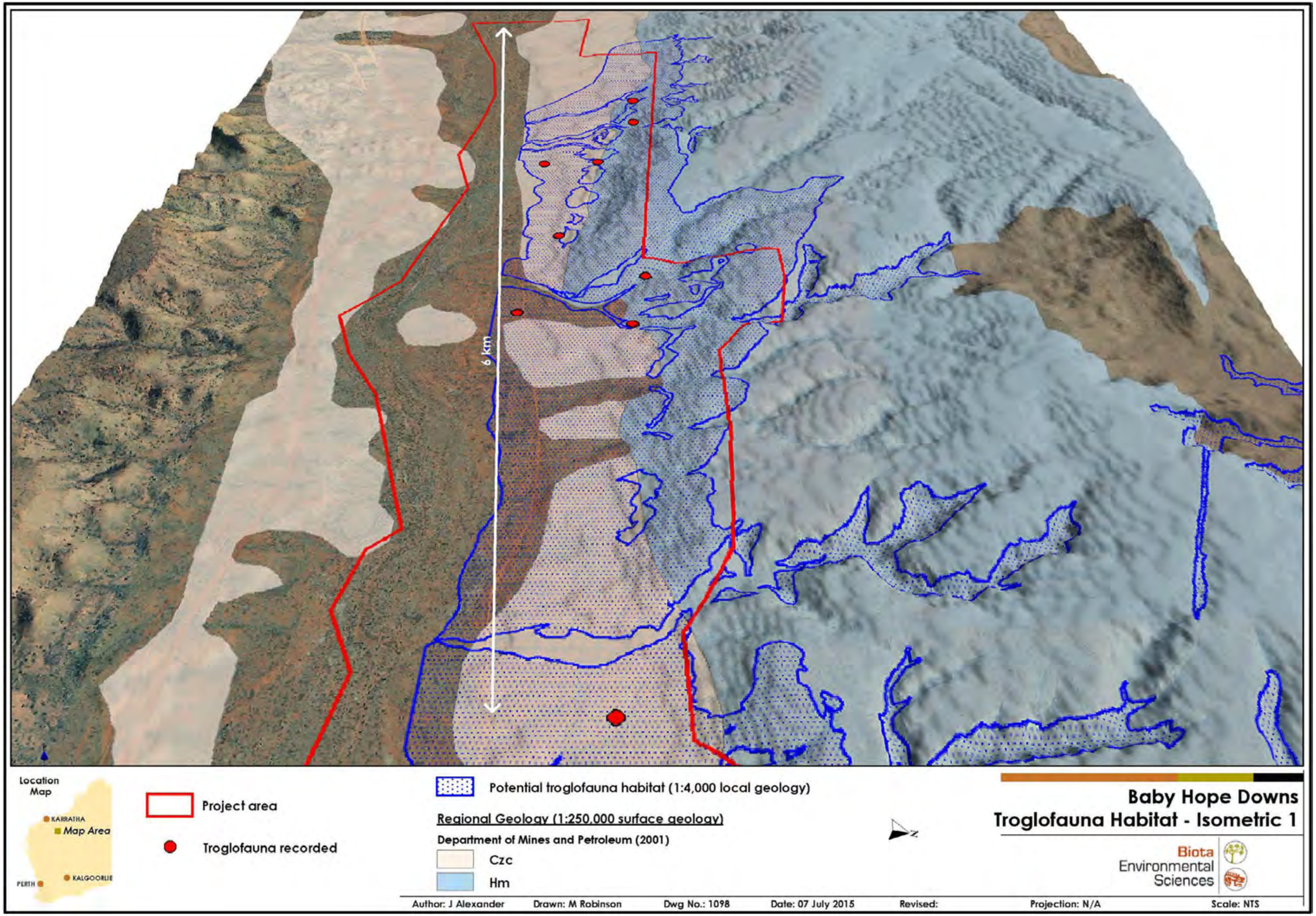


Figure 5.8: Isometric landscape view of troglofauna habitat mapping in relation to troglofauna records, looking west along the project area.

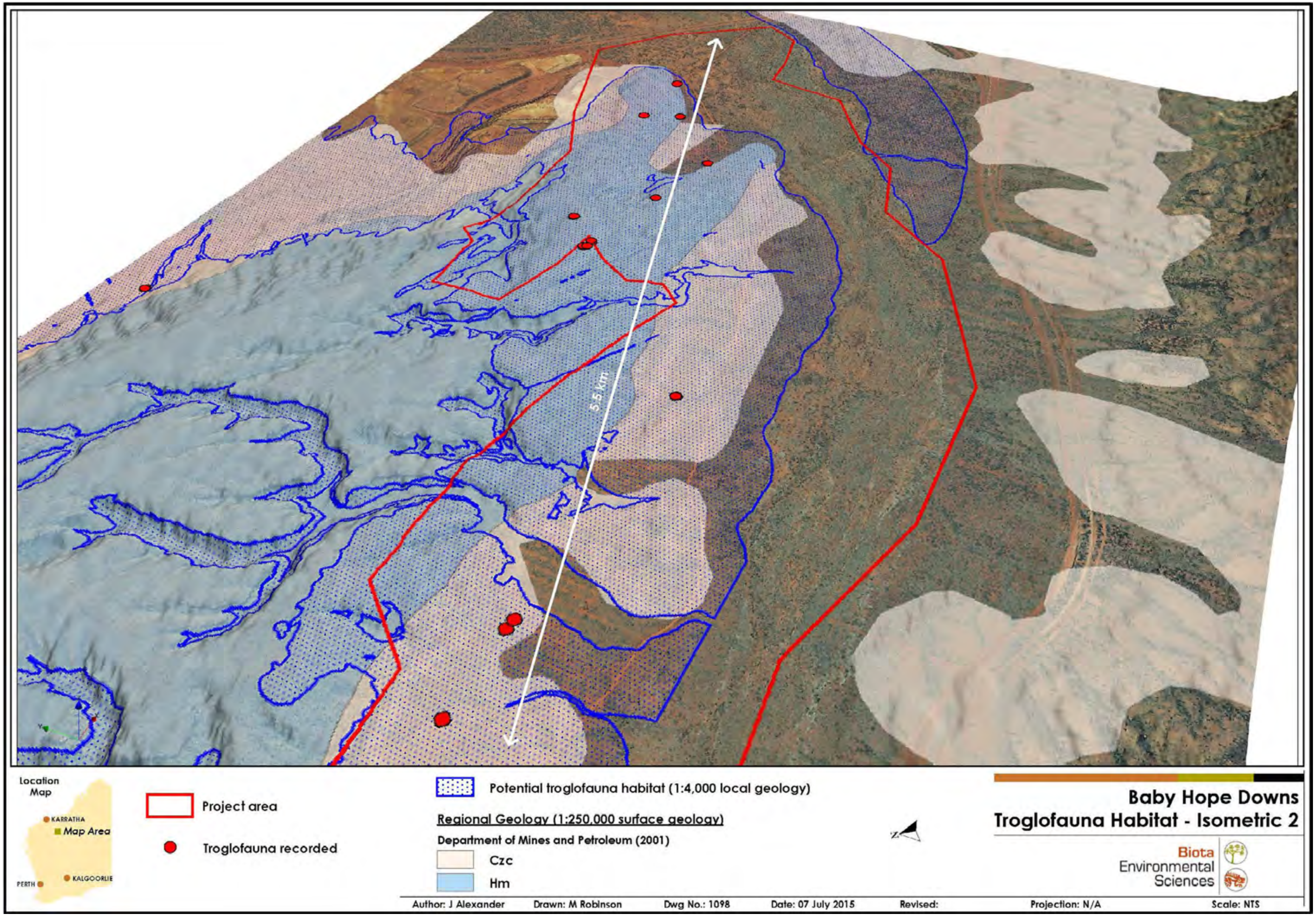


Figure 5.9: Isometric landscape view of troglofauna habitat mapping in relation to troglofauna records, looking east along the project area.

6.0 Conservation Significance

Nineteen potentially troglobitic fauna specimens were recorded from Phase 1 and 2 of sampling at Baby Hope Downs, representing nine species from four orders; Palpigradi, Pseudoscorpiones, Diplura and Schizomida. The majority of the specimens collected belong to the order Schizomida (n=13). While these orders have the potential to include troglobitic and SRE taxa, and therefore be of conservation significance, species from the orders Diplura and Palpigradi require wider taxonomic or molecular reviews to be completed before their status can be more fully confirmed at species level.

Seven of the nine recorded taxa (from the orders Pseudoscorpiones and Schizomida) are considered true troglobites, but only two of the taxa recorded are currently known only from the project area within the proposed pit outlines (Table 6.1). *Draculoides* sp. BHD2 and Palpigradi sp. have to date only been recorded from sites within proposed pit outlines (Figure 6.1).

Table 6.1: Summary of conservation significant species collected only from within the Baby Hope Downs proposed pit outlines.

Species	Subterranean Habitat	Conservation Significance
Draculoides sp. BHD2	Three specimens collected from colluvium only within the proposed pit outlines.	Confirmed troglobite and SRE species.
Palpigradi sp.	Singleton record collected from colluvium within the proposed pit outlines.	Potentially troglobitic and SRE species.

Detailed mapping of prospective troglofauna habitat based on areas where local-scale geology was available shows a strong correlation with the distribution of troglofauna records (Section 5.1.3), suggesting it is valid at local scale. Reviews of this habitat mapping suggest that suitable subterranean habitat extends northwest of the project area boundary. Given that the record of *Draculoides* sp. BHD2 came from close to the northern margin of the project area, and that the same habitat is mapped contiguously to the north (Figure 6.1), the species would also appear likely to occur further to the north in the locality, outside of the proposed pit outlines.

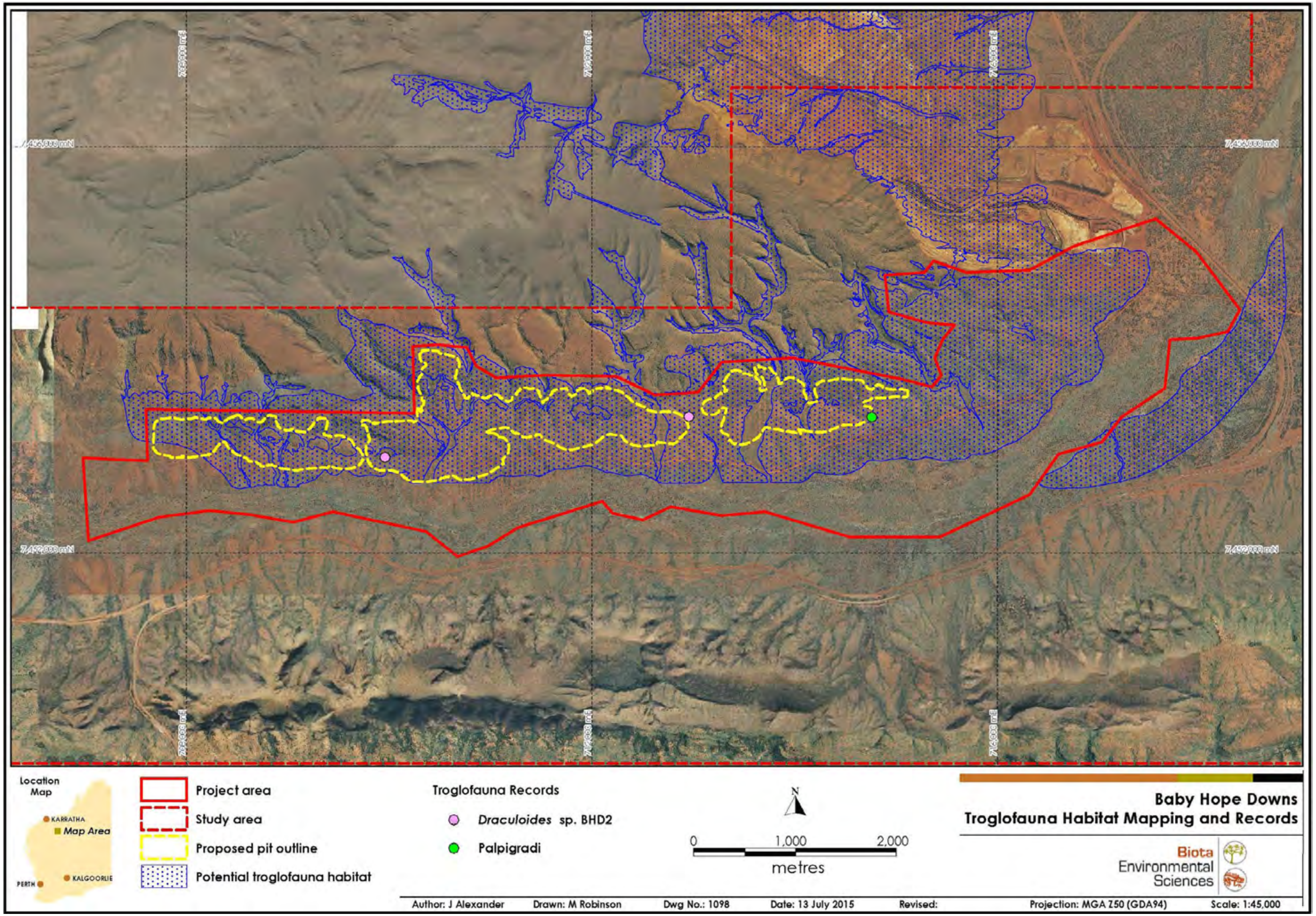


Figure 6.1: Location of troglofauna species currently restricted to the project area

7.0 Glossary

Edaphobitic / Edaphobite	Soil dwelling fauna that can often display troglomorphic characteristics. Edaphobites are unlikely to have limited distributions and therefore unlikely to be classified as short-range endemics.
EPA	Environmental Protection Authority.
Interstices	An opening or space, especially a small or narrow one between mineral grains in a rock or within sediments or soil.
Karst	Soluble-rock landscape; terrain with distinctive hydrology and landforms arising from a combination of high rock solubility and well-developed secondary porosity (Goodall et al. 2000).
Short-Range Endemic (SRE)	A species that has a naturally small distribution and is often characterised by having poor dispersal capabilities, confinement to disjunct habitats and low fecundity.
Taxonomy	Theory and practice of biological classification.
Troglomorphic	Pertaining to morphological, behavioural and physiological characters that are convergent in subterranean populations (Christiansen 1962).
Troglophilic / Troglophile	Species able to live and reproduce underground as well as in the epigean environment (Goodall et al. 2000).
Troglobite / Troglofauna	Species living obligatory in caves; also blind, depigmented and often having an elongate body morphology.
Trogloxene	Organisms that can come and go from a cave environment but use it during certain periods of their life cycles, such as nesting and hibernation.
Stygobite / Stygofauna	Obligate groundwater fauna.
WAM	West Australia Museum

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Appendix 1

Department of Parks and Wildlife Licence to Take Fauna for Scientific Purposes (SF010266)

DEPARTMENT OF PARKS AND WILDLIFE

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Facsimile: 08 9334 0242

Correspondence: **Locked Bag 30**
Bentley Delivery Centre WA 6983

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JESSICA CAIRNES
PENNY BROOSHOOFT
DAVID KEIRLE
VICKIE CARTLEDGE
CHRIS COLE
NICOLA WATSON
SYLVIE SCHMIDT
STEWART FORD
JACINTA KING
MICHAEL DELANEY
ANDREW SHEPPARD
SCOTT WERNER

DATE OF ISSUE 24/03/2015
VALID FROM 14/04/2015
DATE OF EXPIRY 30/12/2015

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WILDLIFE CONSERVATION ACT 1950
REGULATION 17

LICENCE TO TAKE FAUNA FOR SCIENTIFIC PURPOSES

THE UNDERMENTIONED PERSON MAY TAKE FAUNA FOR RESEARCH OR OTHER SCIENTIFIC PURPOSES AND WHERE AUTHORISED, KEEP IT IN CAPTIVITY, SUBJECT TO THE FOLLOWING AND ATTACHED CONDITIONS, WHICH MAY BE ADDED TO, SUSPENDED OR OTHERWISE VARIED AS CONSIDERED FIT.

DIRECTOR GENERAL

CONDITIONS

1 THE LICENSEE SHALL COMPLY WITH THE PROVISIONS OF THE WILDLIFE CONSERVATION ACT AND REGULATIONS AND ANY NOTICES IN FORCE UNDER THIS ACT AND REGULATIONS.

2 UNLESS SPECIFICALLY AUTHORISED IN THE CONDITIONS OF THIS LICENCE OR OTHERWISE IN WRITING BY THE DIRECTOR GENERAL, SPECIES OF FAUNA DECLARED AS LIKELY TO BECOME EXTINCT, RARE OR OTHERWISE IN NEED OF SPECIAL PROTECTION SHALL NOT BE CAPTURED OR OTHERWISE TAKEN.

3 NO FAUNA SHALL BE TAKEN FROM ANY NATURE RESERVE, WILDLIFE SANCTUARY, NATIONAL PARK, MARINE PARK, TIMBER RESERVE OR STATE FOREST WITHOUT PRIOR WRITTEN APPROVAL OF THE DIRECTOR GENERAL. NO FAUNA SHALL BE TAKEN FROM ANY OTHER PUBLIC LAND WITHOUT THE WRITTEN APPROVAL OF THE GOVERNMENT AUTHORITY MANAGING THAT LAND.

4 NO ENTRY OR COLLECTION OF FAUNA TO BE UNDERTAKEN ON ANY PRIVATE PROPERTY OR PASTORAL LEASE WITHOUT THE CONSENT IN WRITING OF THE OWNER OR OCCUPIER, OR FROM ANY ABORIGINAL RESERVE WITHOUT THE WRITTEN APPROVAL OF THE DEPARTMENT OF INDIGENOUS AFFAIRS.

5 NO FAUNA OR THEIR PROGENY SHALL BE RELEASED IN ANY AREA WHERE IT DOES NOT NATURALLY OCCUR, NOR BE HANDED OVER TO ANY OTHER PERSON OR AUTHORITY UNLESS APPROVED BY THE DIRECTOR GENERAL, NOR SHALL THE REMAINS OF SUCH FAUNA BE DISPOSED OF IN SUCH MANNER AS TO CONFUSE THE NATURAL OR PRESENT DAY DISTRIBUTION OF THE SPECIES.

6 THIS LICENCE AND THE WRITTEN PERMISSION REFERRED TO AT CONDITIONS 3 & 4 MUST BE CARRIED BY THE LICENSEE OR AUTHORISED AGENT AT ALL TIMES FOR THE PURPOSE OF PROVING THEIR AUTHORITY TO TAKE FAUNA WHEN QUESTIONED AS TO THEIR RIGHT TO DO SO BY A WILDLIFE OFFICER, ANY OTHER STATE OR LOCAL GOVERNMENT EMPLOYEE OR ANY MEMBER OF THE PUBLIC.

7 **********ANY INTERACTION INVOLVING GAZETTED THREATENED FAUNA THAT MAY BE HARMFUL AND/OR INVASIVE MAY REQUIRE APPROVAL FROM THE DEPT OF SUSTAINABILITY, ENVIRONMENT, WATER, POPULATION & COMMUNITIES PH 02 6274 1111. INTERACTION WITH SUCH SPECIES IS CONTROLLED BY THE COMMONWEALTH GOVERNMENT'S "ENVIRONMENT PROTECTION AND BIODIVERSITY CONSERVATION ACT 1999" & "ENVIRONMENT PROTECTION AND BIODIVERSITY CONSERVATION REGULATIONS 2000" AS WELL AS DPaW'S WILDLIFE CONSERVATION ACT & REGULATIONS.**********

8 NO BIOPROSPECTING INVOLVING THE REMOVAL OF SAMPLE AQUATIC AND TERRESTRIAL ORGANISMS (BOTH FLORA AND FAUNA) FOR CHEMICAL EXTRACTION AND BIOACTIVITY SCREENING IS PERMITTED TO BE CONDUCTED WITHOUT SPECIFIC WRITTEN APPROVAL BY THE DIRECTOR GENERAL OF DPaW.

9 FURTHER CONDITIONS (NUMBERED 1 TO 9) ARE ATTACHED.

PURPOSE SUBTERRANEAN FAUNA SURVEY SAMPLING OF TROGLOFAUNA WILL BE VIA CUSTOM-BUILT LEAF-LITTER COLONISATION TRAPS AND STYGOFAUNA HAUL NETS WITHIN DRILL HOLES AT BABY HOPE DOWNS DEPOSIT 76KM WEST NORTH-WEST OF NEWMAN.

WILDLIFE CONSERVATION REGULATIONS 1970

Regulation 17:- Licence to Take Fauna for Scientific Purposes

FURTHER CONDITIONS (OF LICENCE NUMBER SF010266)

1. The licensee shall take fauna only in the manner stated on the endorsed Regulation 17 licence application form and endorsed related correspondence.

2. Except in the case of approved lethal traps, the licensee shall ensure that measures are taken in the capture and handling of fauna to prevent injury or mortality resulting from that capture or handling. Where traps or other mechanical means or devices are used to capture fauna these shall be deployed so as to prevent exposure of trapped animals to ants and debilitating weather conditions and inspected at regular intervals throughout each day of their use. At the conclusion of research all markers etc and signs erected by the licensee and all traps shall be removed, all pitfalls shall be refilled or capped and the study area returned to the condition it was in prior to the research/capture program. During any break in research, cage traps should be removed and pitfalls either removed, capped or filled with sand.

3. No collecting is to be undertaken in areas where it would impinge on pre-existing scientific research programs.

4. Any form of colour marking of birds or bats shall only be undertaken in accordance with the requirements of the Australian Bird and Bat Banding Scheme.

5. Any inadvertently captured specimen of fauna which is declared as likely to become extinct, rare or otherwise in need of special protection is to be released immediately at the point of capture. Where such a specimen is injured or deceased, the licensee shall contact Department of Parks and Wildlife licensing staff at Kensington (08 9219 9831) for advice on disposal. Records are to be kept of any fauna so captured and details included in the report required under further condition 6 below.

6. Within one month of the expiration of this licence, the holder shall submit an electronic return detailing the locality, site, geocode, date and number of each species captured, sighted or vouchered during the currency of the licence, into the Department of Parks and Wildlife Fauna Survey Database (FSD). A copy of any paper, report or thesis resulting from the research shall on completion be lodged with the Director General. If a renewal of this licence is required, the licensee shall submit a written progress report for activities undertaken during this licence period prior to the expiry of this licence.

7. Not more than ten specimens of any one protected species shall be taken and removed from any location less than 20km apart. Where exceptional circumstances make it necessary to take large series in order to obtain adequate statistical data the collector will 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 shall 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 shall be donated on request to the Western Australian Museum.

9. To prevent any unnecessary collecting in this State, all specimens and material collected under the authority of this license shall, on request, be loaned to the Western Australian Museum. Also, the unused portion or portions of any specimen collected under the authority of this license shall be offered for donation to the Western Australian Museum or made available to other scientific workers if so required.

Appendix 2

Report on the molecular systematics of Schizomida from Baby Hope Downs; Phase 2

Helix
Molecular
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30 June 2015

Jason Alexander
Biota Environmental Sciences
Level 1, 228 Carr Place
Leederville, WA 6007

Via email

Re. Report on the molecular systematics of Schizomida from Baby Hope Downs II

Dear Jason,

Following is a summary of the results of the schizomid study we have completed from a second round of collections from Baby Hope Downs. The eight specimens of schizomids likely belong to three species. The three species are closely related to one another and to the species detected previously at Baby Hope Downs, as genetic distances between them are only moderate. However, we conclude that the level of divergence is sufficient to suggest that the three species represent new species, because the observed levels of genetic divergence between them and the reference lineages exceeds that which is typical among members of the same population at a single site.

Thanks once again for collaborating on this project with Helix. We hope we can continue to provide you with useful information, and feel free to contact us if you have any questions or would like to discuss the results in detail.

Sincerely,

Dr. Terrie Finston, Yvette Hitchen and Dr. Oliver Berry
Helix Molecular Solutions

Background and Objective

Extensive molecular work has been conducted on the schizomid fauna of Western Australia (Helix, unpublished). The resulting dataset provides a molecular framework that can be used to provide a regional context for localised sampling. In a recent survey at Baby Hope Downs, three schizomid species were detected, one of which had been detected previously at a site in the Hamersley Range (species CI1), and two of which were new (BHD1 and BHD2; Helix, 2015).

The present study involved the collection and sequencing of eight additional schizomid specimens from the Baby Hope Downs site in order to assess their relationships to the existing sequencing records for more than 300 specimens from the Pilbara.

The new Baby Hope Downs schizomid sequences were added to the existing sequence dataset to assign specimens to existing lineages and species or to identify new lineages/species.

Executive summary

- Eight additional schizomid specimens from Baby Hope Downs were sequenced for variation at the COXI gene.
- The eight specimens yielded a 259 - 664 base-pair fragment of the COXI gene.
- Phylogenetic analysis and genetic distance measures were employed to estimate the number of species present.
- The eight schizomid specimens were placed in three distinct genetic lineages, which likely correspond to three distinct species.
- The three lineages are likely to represent three new species, although they are closely related to one another and to the species detected previously at Baby Hope Downs, as genetic distances between them are only moderate.

Methods

Eight specimens of Schizomida collected from the Baby Hope Downs area (Table 1) were sequenced for variation at the mitochondrial cytochrome oxidase subunit I gene (COXI) using primers LCOI/CIN2341.

Sequences were edited using GENEIOUS software (Drummond *et al.* 2011). Alignment was performed with CLUSTAL W (Thompson *et al*. 1994) using default parameters. Genetic distances between unique genetic sequences (haplotypes) were measured using uncorrected p-distances (total percentage of nucleotide differences between sequences).

MODELTEST software (Posada and Crandall, 1998) was used to determine the model of sequence evolution that best fitted the data. Bayesian analysis was used to construct the phylogenetic tree, incorporating the model as identified in MODELTEST. The phylogeny, branch lengths and posterior probabilities were obtained by running two trees simultaneously, each running four simultaneous MCMC chains. The number of cycles needed was determined by the standard deviation of the split frequencies of the two trees. The analysis was paused after every 1×10^6 generations and when the standard deviation fell below 0.01, the analysis was stopped. A majority rule consensus tree was constructed after discarding the "burn-in" trees. The burn-in value was determined by plotting the posterior probabilities obtained after every generation and identifying the point at which the values reach stationarity (= the asymptote). Trees produced prior to stationarity were discarded.

Results

The eight specimens yielded a 259 - 664 base-pair fragment of the COXI gene (Table 1).

<u>Preliminary analysis</u>

In order to reduce analysis time and to simplify the presentation of results, a preliminary neighbour-joining (NJ) tree was constructed from the eight new sequences in order to identify the number of unique lineages present. Representatives from each lineage were then used in a model-based phylogenetic analysis along with a sub-set of reference specimens of schizomids that were selected based on the criteria that they showed ≤ 15% sequence divergence from at least one of the new lineages. Four hundred and one reference sequences were tested, and of those, 42 were detected that differed by ≤ 15% sequence divergence from the new Baby Hope

Downs specimens. The 42 individuals represented 41 distinct lineages (haplotypes or groups of closely related haplotypes that differ from other such groups by >3% sequence divergence). Representatives of the nine described species of *Draculoides* and *Paradraculoides* were also included in the preliminary analysis and those that fit the above criteria were included in the analysis as reference sequences.

The NJ tree revealed the presence of three distinct lineages of schizomids from Baby Hope Downs (Figure 1). The number of specimens in each lineage ranged from one to four (Table 2).

Lineage 3 contained a single individual (Figure 1). Individuals within lineages 1 and 2 differed from one another by a mean of 0.2% and 2.9% sequence divergence, respectively (Table 2). The three NJ lineages differed from one another by between 6.9 and 9.0% mean sequence divergence (Table 3).

<u>Phylogenetic analysis</u>
The phylogenetic analysis, which included representatives of the three Baby Hope Downs lineages detected in the NJ analysis, in addition to 42 reference specimens of schizomids, revealed the presence of 44 lineages (Figure 2). All of the Baby Hope Downs specimens (highlighted in yellow; Figure 2) formed a well-supported clade with reference specimens from previous surveys at Baby Hope Downs and the Hamersley Range area (Figure 2). However, each of the three new Baby Hope Downs lineages formed new, distinct genetic lineages (Figure 2).

<u>Differentiation within and between lineages</u>
The 45 specimens included in the phylogenetic analysis shown in Figure 2 differed from one another by between 2.3 and 20.8% sequence divergence (Table 4). The three lineages from the present study differed from the reference lineages by between 5.5 and 19.1% sequence divergence (Table 4).

Conclusions
COXI is widely considered to show suitable variation to distinguish species (Hebert et al., 2003a). In a comparison of COXI sequences for over 13,000 pairs of taxa, Hebert et al (2003b) found a mean of 11.1% sequence divergence between distinct species. Nearly 80% of the comparisons showed that species pairs differed from one another by greater than 8% sequence divergence. More specifically, previous analyses of genetic variation between morphologically distinct species of Schizomida can be used as a genetic 'yardstick' to interpret the current data set. The five species of *Paradraculoides* differ from one another by between 8.4 to 12.1% sequence divergence (uncorrected p-distances; calculated from Harvey et al., 2008). Similarly, the four species of *Draculoides* differ from one another by between 4.5 to 13.7% sequence divergence (uncorrected p-distances from Harvey et al., 2008).

In a recent survey at Baby Hope Downs, three schizomid species were detected, one of which had been detected previously at a site in the Hamersley Range (species CI1), and two of which were new (BHD1 and BHD2; Helix, 2015). Three additional lineages of schizomids from Baby Hope Downs were detected in the present study, differing from one another by between 6.2 and 9.0% mean sequence divergence. Based on the observed distances between the three lineages, each likely represents a distinct species. Further, it is likely that these three lineages represent new species, assigned to BHD3 – BHD5. While the level of sequence divergence among the three lineages and the reference lineages is only moderate, the variation exceeds what might be normally expected among individuals from a population at the same site. However, all lineages detected so far from Baby Hope Downs share a recent common ancestor, and included in that group are reference specimens from a previous survey at Hamersley Range. These species are closely related and morphological differences between them would support the hypothesis of separate species.

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Table 1. Specimens of Schizomida from Baby Hope Downs used in the present study and the lineage and species to which they were assigned, based on variation at the COXI gene.

Helix ID	Site	Sample ID	Tube ID	Lineage/ Species
IC1	GD13HD10016	GD13HD10016-20150520-T1-02	98	1/BHD3
IC2	RC07H1S198	RC07H1S198-20150520-T1-01	187	1/ BHD3
IC3	RC07H1S198	RC07H1S198-20150520-T2-01	189	1/ BHD3
IC4	RC12H1SW0005	RC12H1SW0005-20150520-T3-01	109	2/ BHD4
IC5	RC13HD10298	RC13HD10298-20150521-T2-01	118	2/ BHD4
IC6	RC13HD10342	RC13HD10342-20150521-T1-05	79	3/ BHD5
IC7	RC14HD10195	RC14HD10195-20150520-T3-02	6	2/ BHD4
IC8	RC07H15374	RC07H15374-20150410-sc-01	scrape	1/ BHD3

Table 2. Mean distance (D) and standard error (s.e.) within lineages of schizomids and the number (N) of individuals assigned to that lineage, detected in the preliminary NJ analysis as shown in Figure 1. rep= haplotype(s) chosen to represent the lineage in the model-based phylogenetic analysis. n/c = not calculated, for groups where n=1.

Lineage	D	s.e.	N	rep
1	0.002	0.002	4	IC1
2	0.029	0.009	3	IC5
3	n/c	n/c	1	IC6

Table 3. Mean distance (below diagonal) and standard error (above diagonal, in blue) between lineages of schizomids detected at Baby Hope Downs in the preliminary NJ analysis as shown in Figure 1.

Lineage	1	2	3
1		0.013	0.017
2	0.085		0.015
3	0.090	0.069	

Table 4 (attached). Pairwise COXI distances (below diagonal) between lineages of schizomids included in the model-based phylogenetic analysis as shown in Figure 2. Above diagonal= standard error. Distances between the lineages from Baby Hope Downs and the reference lineages are highlighted in yellow.

Figure 1. Neighbour-joining analysis of the eight specimens of schizomids from Baby Hope Downs. Numbers on nodes correspond to bootstrap support over 2000 iterations; values < 50% not shown. Scale bar= genetic distance. The three specimens selected to represent the three genetic lineages are highlighted in yellow.

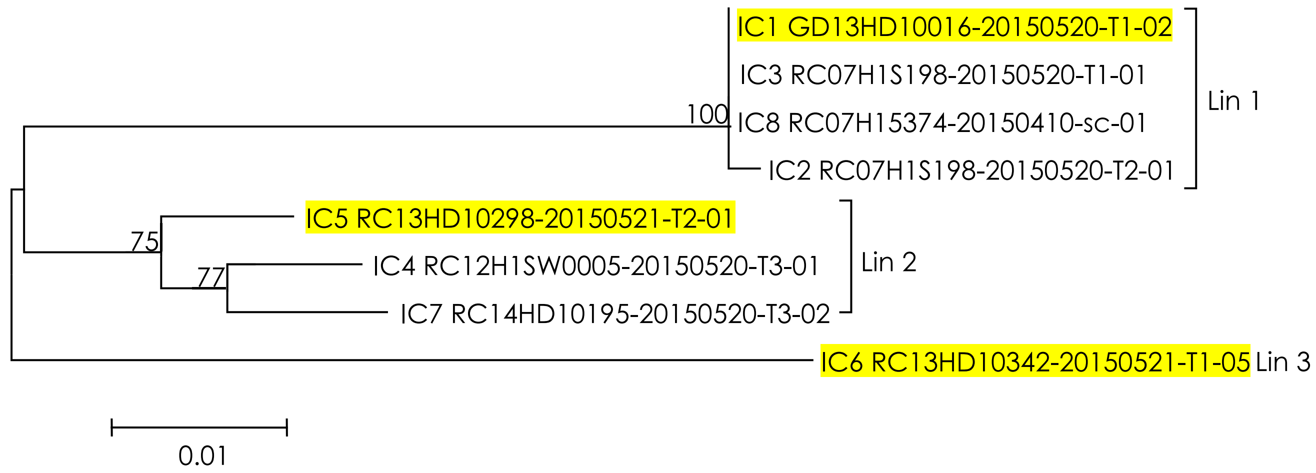
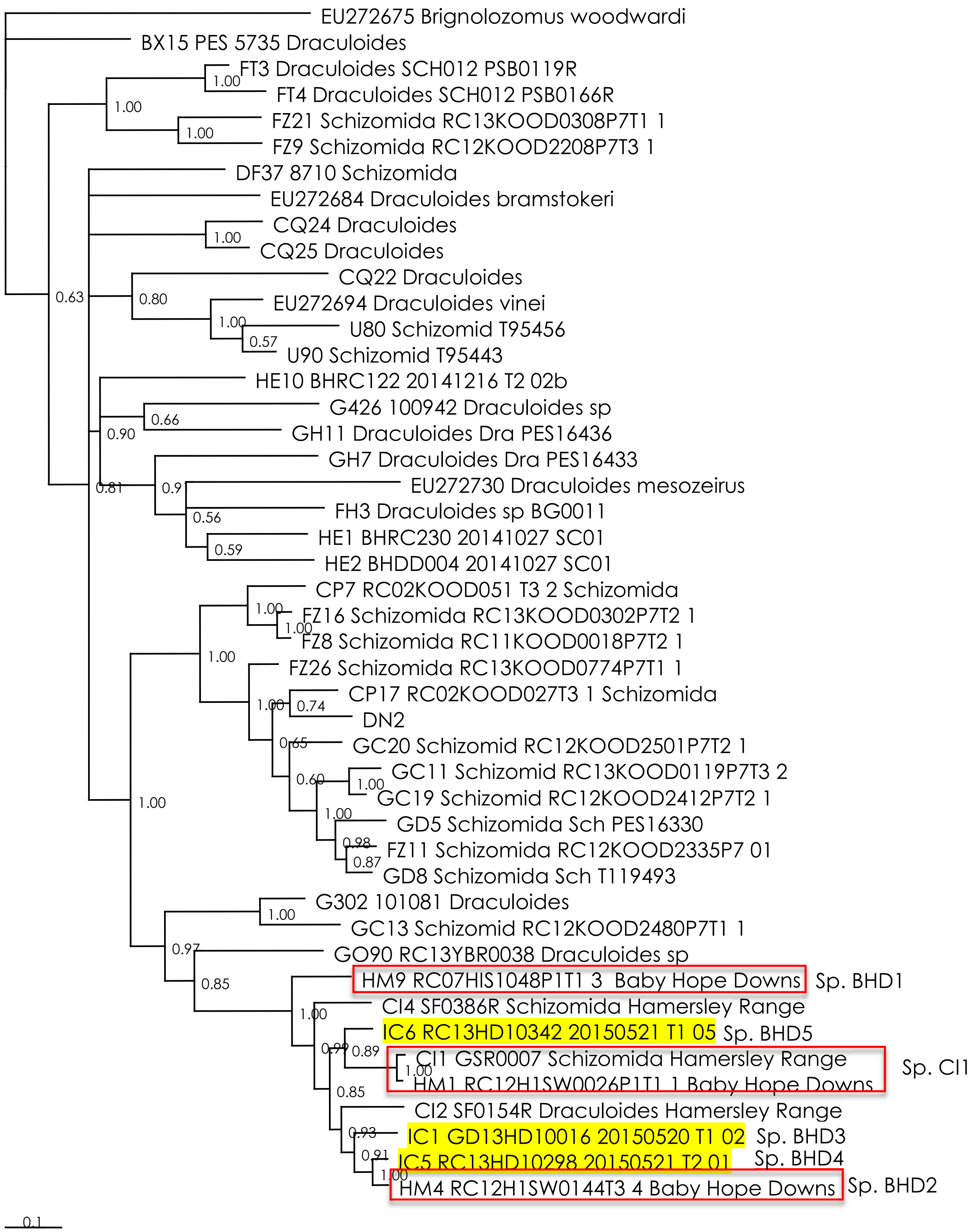


Figure 2. Bayesian analysis of COXI haplotypes of Schizomida from the present study. Numbers on major nodes correspond to posterior probabilities; values <50% are not shown. Specimens from the present study are highlighted in yellow. Scale bar= number of substitutions per site. The three species detected in the first survey at Baby Hope Downs are enclosed by red boxes.



Appendix 3

Phase 2; Raw collection data

Site Name	Easting (m E)	Northing (m N)	Taxonomy				Method of Identification	Number Collected	Method of Collection
			Order	Family	Species	Lineage			
GD13HD10016	716087	7454116	Acarina	-	-	-	-	14	Troglofauna trap
GD13HD10016	716087	7454116	Acarina	-	-	-	-	6	Troglofauna trap
GD13HD10016	716087	7454116	Diptera	-	-	-	-	1	Troglofauna trap
GD13HD10016	716087	7454116	Schizomida	Hubbardiidae	*Draculoides* sp. BHD3	BHD3	Genetic Analysis	1	Troglofauna trap
RC07H1S198	715491	7454213	Collembola	-	-	-	-	2	Troglofauna trap
RC07H1S198	715491	7454213	Hymenoptera	-	-	-	-	15	Scrape
RC07H1S198	715491	7454213	Schizomida	Hubbardiidae	*Draculoides* sp. BHD3	BHD3	Genetic Analysis	1	Troglofauna trap
RC07H1S198	715491	7454213	Schizomida	Hubbardiidae	*Draculoides* sp. BHD3	BHD3	Genetic Analysis	1	Troglofauna trap
RC07H1S356	715543	7454208	Acarina	-	-	-	-	30	Troglofauna trap
RC07H1S356	715543	7454208	Acarina	-	-	-	-	16	Troglofauna trap
RC07H1S356	715543	7454208	Acarina	-	-	-	-	7	Troglofauna trap
RC07H1S356	715543	7454208	Coleoptera	-	-	-	-	18	Troglofauna trap
RC07H1S356	715543	7454208	Collembola	-	-	-	-	3	Troglofauna trap
RC07H1S356	715543	7454208	Collembola	-	-	-	-	14	Troglofauna trap
RC07H1S356	715543	7454208	Collembola	-	-	-	-	9	Troglofauna trap
RC07H1S356	715543	7454208	Diplura	-	-	-	-	1	Troglofauna trap
RC07H1S356	715543	7454208	Diptera	-	-	-	-	20	Troglofauna trap
RC07H1S356	715543	7454208	Diptera	-	-	-	-	6	Troglofauna trap
RC07H1S356	715543	7454208	Diptera	-	-	-	-	1	Troglofauna trap
RC07H1S374	715699	7454403	Acarina	-	-	-	-	6	Troglofauna trap
RC07H1S374	715699	7454403	Collembola	-	-	-	-	7	Troglofauna trap
RC07H1S374	715699	7454403	Psocoptera	-	-	-	-	1	Scrape
RC07H1S374	715699	7454403	Schizomida	Hubbardiidae	*Draculoides* sp. BHD3	BHD3	Genetic Analysis	1	Scrape
RC07H1S390	715795	7454250	Acarina	-	-	-	-	6	Troglofauna trap
RC07H1S390	715795	7454250	Acarina	-	-	-	-	2	Troglofauna trap
RC07H1S395	715803	7454501	Acarina	-	-	-	-	1	Troglofauna trap
RC07H1S395	715803	7454501	Acarina	-	-	-	-	1	Troglofauna trap
RC07H1S395	715803	7454501	Aranea	-	-	-	-	1	Troglofauna trap
RC07H1S422	716241	7454589	Acarina	-	-	-	-	1	Troglofauna trap
RC07H1S422	716241	7454589	Blattodea	-	-	-	-	1	Scrape
RC07H1S422	716241	7454589	Blattodea	-	-	-	-	1	Troglofauna trap
RC07H1S422	716241	7454589	Coleoptera	-	-	-	-	1	Troglofauna trap
RC07H1S422	716241	7454589	Collembola	-	-	-	-	30	Troglofauna trap
RC07H1S422	716241	7454589	Collembola	-	-	-	-	30	Troglofauna trap

Site Name	Easting (m E)	Northing (m N)	Taxonomy				Method of Identification	Number Collected	Method of Collection
			Order	Family	Species	Lineage			
RC07H1S422	716241	7454589	Hemiptera	-	-	-	-	1	Troglofauna trap
RC07H1S422	716241	7454589	Polyxenida	-	-	-	-	1	Troglofauna trap
RC07H1S439	716004	7454497	Collembola	-	-	-	-	20	Troglofauna trap
RC07H1S5554	716148	7454397	Acarina	-	-	-	-	11	Troglofauna trap
RC07H1S5554	716148	7454397	Acarina	-	-	-	-	3	Troglofauna trap
RC07H1S5554	716148	7454397	Collembola	-	-	-	-	10	Troglofauna trap
RC07H1S559	716389	7454288	Acarina	-	-	-	-	8	Troglofauna trap
RC07H1S559	716389	7454288	Coleoptera	-	-	-	-	1	Troglofauna trap
RC07H1S613	715485	7454223	Acarina	-	-	-	-	30	Troglofauna trap
RC07H1S613	715485	7454223	Acarina	-	-	-	-	15	Troglofauna trap
RC07H1S613	715485	7454223	Blattodea	-	-	-	-	2	Scrape
RC07H1S613	715485	7454223	Blattodea	-	-	-	-	1	Troglofauna trap
RC07H1S613	715485	7454223	Blattodea	-	-	-	-	1	Troglofauna trap
RC07H1S613	715485	7454223	Collembola	-	-	-	-	5	Troglofauna trap
RC07H1S613	715485	7454223	Collembola	-	-	-	-	2	Troglofauna trap
RC07H1S613	715485	7454223	Diplura	-	-	-	-	1	Troglofauna trap
RC07H1S613	715485	7454223	Diptera	-	-	-	-	3	Troglofauna trap
RC07H1S613	715485	7454223	Diptera	-	-	-	-	4	Troglofauna trap
RC07H1S613	715485	7454223	Hemiptera	-	-	-	-	1	Troglofauna trap
RC07H1S613	715485	7454223	Hymenoptera	-	-	-	-	2	Scrape
RC07H1S613	715485	7454223	Hymenoptera	-	-	-	-	1	Troglofauna trap
RC10H1SW039	708665	7453041	Acarina	-	-	-	-	10	Troglofauna trap
RC10H1SW039	708665	7453041	Acarina	-	-	-	-	4	Troglofauna trap
RC10H1SW039	708665	7453041	Acarina	-	-	-	-	10	Troglofauna trap
RC10H1SW039	708665	7453041	Collembola	-	-	-	-	4	Troglofauna trap
RC10H1SW039	708665	7453041	Collembola	-	-	-	-	1	Troglofauna trap
RC11H1SW0008	708064	7452787	Acarina	-	-	-	-	3	Troglofauna trap
RC11H1SW0008	708064	7452787	Acarina	-	-	-	-	2	Troglofauna trap
RC11H1SW0008	708064	7452787	Collembola	-	-	-	-	10	Troglofauna trap
RC11H1SW0008	708064	7452787	Collembola	-	-	-	-	10	Troglofauna trap
RC11H1SW0008	708064	7452787	Collembola	-	-	-	-	10	Troglofauna trap
RC12H1SW0005	709160	7452800	Acarina	-	-	-	-	20	Troglofauna trap
RC12H1SW0005	709160	7452800	Collembola	-	-	-	-	1	Troglofauna trap
RC12H1SW0005	709160	7452800	Collembola	-	-	-	-	2	Troglofauna trap

Site Name	Easting (m E)	Northing (m N)	Taxonomy				Method of Identification	Number Collected	Method of Collection
			Order	Family	Species	Lineage			
RC12H1SW0005	709160	7452800	Collembola	-	-	-	-	3	Troglofauna trap
RC12H1SW0005	709160	7452800	Schizomida	Hubbardiidae	*Draculoides* sp. BHD4	BHD4	Genetic Analysis	1	Troglofauna trap
RC12H1SW0120	711561	7452791	Acarina	-	-	-	-	30	Troglofauna trap
RC12H1SW0120	711561	7452791	Acarina	-	-	-	-	8	Troglofauna trap
RC12H1SW0120	711561	7452791	Collembola	-	-	-	-	3	Troglofauna trap
RC12H1SW0120	711561	7452791	Collembola	-	-	-	-	1	Troglofauna trap
RC12H1SW0137	712155	7453550	Blattodea	-	-	-	-	1	Scrape
RC12H1SW0137	712155	7453550	Collembola	-	-	-	-	20	Troglofauna trap
RC12H1SW0137	712155	7453550	Collembola	-	-	-	-	20	Troglofauna trap
RC12H1SW0137	712155	7453550	Diptera	-	-	-	-	1	Troglofauna trap
RC12H1SW0137	712155	7453550	Hymenoptera	-	-	-	-	5	Scrape
RC12H1SW0137	712155	7453550	Isopoda	-	-	-	-	1	Troglofauna trap
RC12H1SW0203	714913	7450889	Acarina	-	-	-	-	4	Troglofauna trap
RC12H1SW0203	714913	7450889	Acarina	-	-	-	-	4	Troglofauna trap
RC12H1SW0203	714913	7450889	Acarina	-	-	-	-	1	Troglofauna trap
RC12H1SW0203	714913	7450889	Coleoptera	-	-	-	-	1	Troglofauna trap
RC12H1SW0203	714913	7450889	Collembola	-	-	-	-	1	Troglofauna trap
RC12H1SW0203	714913	7450889	Collembola	-	-	-	-	1	Troglofauna trap
RC13HD10011	710056	7452890	Acarina	-	-	-	-	4	Troglofauna trap
RC13HD10011	710056	7452890	Acarina	-	-	-	-	2	Troglofauna trap
RC13HD10011	710056	7452890	Acarina	-	-	-	-	1	Troglofauna trap
RC13HD10011	710056	7452890	Collembola	-	-	-	-	15	Troglofauna trap
RC13HD10011	710056	7452890	Collembola	-	-	-	-	9	Troglofauna trap
RC13HD10011	710056	7452890	Collembola	-	-	-	-	1	Troglofauna trap
RC13HD10011	710056	7452890	Diptera	-	-	-	-	1	Troglofauna trap
RC13HD10055	710658	7452791	Acarina	-	-	-	-	12	Troglofauna trap
RC13HD10055	710658	7452791	Acarina	-	-	-	-	7	Troglofauna trap
RC13HD10055	710658	7452791	Acarina	-	-	-	-	16	Troglofauna trap
RC13HD10055	710658	7452791	Collembola	-	-	-	-	1	Troglofauna trap
RC13HD10055	710658	7452791	Collembola	-	-	-	-	2	Troglofauna trap
RC13HD10055	710658	7452791	Collembola	-	-	-	-	1	Troglofauna trap
RC13HD10055	710658	7452791	Diplura	-	-	-	-	1	Troglofauna trap
RC13HD10066	710650	7453601	Collembola	-	-	-	-	30	Troglofauna trap
RC13HD10066	710650	7453601	Collembola	-	-	-	-	20	Troglofauna trap

Site Name	Easting (m E)	Northing (m N)	Taxonomy				Method of Identification	Number Collected	Method of Collection
			Order	Family	Species	Lineage			
RC13HD10066	710650	7453601	Collembola	-	-	-	-	20	Troglofauna trap
RC13HD10066	710650	7453601	Diptera	-	-	-	-	4	Troglofauna trap
RC13HD10151	711061	7453239	Coleoptera	-	-	-	-	4	Troglofauna trap
RC13HD10151	711061	7453239	Collembola	-	-	-	-	1	Troglofauna trap
RC13HD10151	711061	7453239	Diptera	-	-	-	-	3	Troglofauna trap
RC13HD10151	711061	7453239	Diptera	-	-	-	-	2	Troglofauna trap
RC13HD10151	711061	7453239	Hemiptera	-	-	-	-	1	Troglofauna trap
RC13HD10169	711959	7453145	Acarina	-	-	-	-	2	Troglofauna trap
RC13HD10169	711959	7453145	Coleoptera	-	-	-	-	1	Troglofauna trap
RC13HD10169	711959	7453145	Coleoptera	-	-	-	-	1	Troglofauna trap
RC13HD10169	711959	7453145	Collembola	-	-	-	-	1	Troglofauna trap
RC13HD10230	713957	7453242	Acarina	-	-	-	-	3	Troglofauna trap
RC13HD10230	713957	7453242	Collembola	-	-	-	-	20	Troglofauna trap
RC13HD10230	713957	7453242	Collembola	-	-	-	-	20	Troglofauna trap
RC13HD10277	710459	7452485	Acarina	-	-	-	-	12	Troglofauna trap
RC13HD10277	710459	7452485	Acarina	-	-	-	-	60	Troglofauna trap
RC13HD10277	710459	7452485	Acarina	-	-	-	-	24	Troglofauna trap
RC13HD10277	710459	7452485	Coleoptera	-	-	-	-	1	Troglofauna trap
RC13HD10277	710459	7452485	Coleoptera	-	-	-	-	3	Troglofauna trap
RC13HD10277	710459	7452485	Coleoptera	-	-	-	-	14	Troglofauna trap
RC13HD10277	710459	7452485	Collembola	-	-	-	-	4	Troglofauna trap
RC13HD10298	713708	7450585	Collembola	-	-	-	-	3	Troglofauna trap
RC13HD10298	713708	7450585	Schizomida	Hubbardiidae	*Draculoides* sp. BHD4	BHD4	Genetic Analysis	1	Troglofauna trap
RC13HD10299	713708	7450791	Acarina	-	-	-	-	20	Troglofauna trap
RC13HD10299	713708	7450791	Acarina	-	-	-	-	17	Troglofauna trap
RC13HD10299	713708	7450791	Collembola	-	-	-	-	7	Troglofauna trap
RC13HD10299	713708	7450791	Collembola	-	-	-	-	4	Troglofauna trap
RC13HD10299	713708	7450791	Diptera	-	-	-	-	1	Troglofauna trap
RC13HD10319	713162	7453392	Collembola	-	-	-	-	4	Troglofauna trap
RC13HD10319	713162	7453392	Collembola	-	-	-	-	3	Troglofauna trap
RC13HD10327	713309	7450792	Acarina	-	-	-	-	7	Troglofauna trap
RC13HD10327	713309	7450792	Acarina	-	-	-	-	15	Troglofauna trap
RC13HD10327	713309	7450792	Collembola	-	-	-	-	3	Troglofauna trap
RC13HD10327	713309	7450792	Diptera	-	-	-	-	1	Troglofauna trap

Site Name	Easting (m E)	Northing (m N)	Taxonomy				Method of Identification	Number Collected	Method of Collection
			Order	Family	Species	Lineage			
RC13HD10331	713310	7450392	Acarina	-	-	-	-	8	Troglofauna trap
RC13HD10331	713310	7450392	Acarina	-	-	-	-	20	Troglofauna trap
RC13HD10331	713310	7450392	Blattodea	-	-	-	-	4	Scrape
RC13HD10331	713310	7450392	Collembola	-	-	-	-	1	Troglofauna trap
RC13HD10336	713716	7450225	Acarina	-	-	-	-	10	Troglofauna trap
RC13HD10336	713716	7450225	Acarina	-	-	-	-	10	Troglofauna trap
RC13HD10336	713716	7450225	Blattodea	-	-	-	-	5	Troglofauna trap
RC13HD10336	713716	7450225	Coleoptera	-	-	-	-	20	Troglofauna trap
RC13HD10336	713716	7450225	Pseudoscorpiones	Chthoniidae	*Lagynochthonius* sp'PSE096'	-	Morphological (T137072)	1	Troglofauna trap
RC13HD10339	716312	7450593	Acarina	-	-	-	-	15	Troglofauna trap
RC13HD10339	716312	7450593	Acarina	-	-	-	-	8	Troglofauna trap
RC13HD10339	716312	7450593	Blattodea	-	-	-	-	1	Troglofauna trap
RC13HD10339	716312	7450593	Collembola	-	-	-	-	1	Troglofauna trap
RC13HD10339	716312	7450593	Collembola	-	-	-	-	1	Troglofauna trap
RC13HD10339	716312	7450593	Diptera	-	-	-	-	7	Troglofauna trap
RC13HD10339	716312	7450593	Diptera	-	-	-	-	4	Troglofauna trap
RC13HD10342	716510	7450691	Acarina	-	-	-	-	30	Troglofauna trap
RC13HD10342	716510	7450691	Acarina	-	-	-	-	30	Troglofauna trap
RC13HD10342	716510	7450691	Aranea	-	-	-	-	1	Troglofauna trap
RC13HD10342	716510	7450691	Coleoptera	-	-	-	-	30	Troglofauna trap
RC13HD10342	716510	7450691	Coleoptera	-	-	-	-	15	Troglofauna trap
RC13HD10342	716510	7450691	Coleoptera	-	-	-	-	2	Troglofauna trap
RC13HD10342	716510	7450691	Collembola	-	-	-	-	5	Troglofauna trap
RC13HD10342	716510	7450691	Collembola	-	-	-	-	13	Troglofauna trap
RC13HD10342	716510	7450691	Collembola	-	-	-	-	3	Troglofauna trap
RC13HD10342	716510	7450691	Diptera	-	-	-	-	5	Troglofauna trap
RC13HD10342	716510	7450691	Schizomida	Hubbardiidae	*Draculoides* sp. BHD5	BHD5	Genetic Analysis	1	Troglofauna trap
RC13HD10344	716713	7450589	Coleoptera	-	-	-	-	10	Troglofauna trap
RC13HD10344	716713	7450589	Coleoptera	-	-	-	-	12	Troglofauna trap
RC13HD10344	716713	7450589	Hemiptera	-	-	-	-	14	Troglofauna trap
RC13HD10356	716313	7450290	Acarina	-	-	-	-	12	Troglofauna trap
RC13HD10356	716313	7450290	Acarina	-	-	-	-	24	Troglofauna trap
RC13HD10356	716313	7450290	Coleoptera	-	-	-	-	2	Troglofauna trap

Site Name	Easting (m E)	Northing (m N)	Taxonomy Order	Family	Species	Lineage	Method of Identification	Number Collected	Method of Collection
RC13HD10356	716313	7450290	Coleoptera	-	-	-	-	2	Troglofauna trap
RC13HD10356	716313	7450290	Collembola	-	-	-	-	6	Troglofauna trap
RC13HD10356	716313	7450290	Collembola	-	-	-	-	2	Troglofauna trap
RC13HD10356	716313	7450290	Diptera	-	-	-	-	1	Troglofauna trap
RC13HD10359	716101	7450071	Collembola	-	-	-	-	2	Troglofauna trap
RC13HD10359	716101	7450071	Diptera	-	-	-	-	10	Troglofauna trap
RC13HD10362	715520	7450320	Coleoptera	-	-	-	-	9	Troglofauna trap
RC13HD10362	715520	7450320	Coleoptera	-	-	-	-	8	Troglofauna trap
RC13HD10362	715520	7450320	Coleoptera	-	-	-	-	10	Troglofauna trap
RC13HD10362	715520	7450320	Coleoptera	-	-	-	-	20	Troglofauna trap
RC13HD10362	715520	7450320	Coleoptera	-	-	-	-	12	Troglofauna trap
RC14HD10022	714759	7453338	Acarina	-	-	-	-	10	Troglofauna trap
RC14HD10022	714759	7453338	Coleoptera	-	-	-	-	1	Troglofauna trap
RC14HD10022	714759	7453338	Collembola	-	-	-	-	10	Troglofauna trap
RC14HD10022	714759	7453338	Collembola	-	-	-	-	10	Troglofauna trap
RC14HD10022	714759	7453338	Palpigradi	-	-	-	-	1	Troglofauna trap
RC14HD10195	713414	7453337	Acarina	-	-	-	-	3	Troglofauna trap
RC14HD10195	713414	7453337	Acarina	-	-	-	-	3	Troglofauna trap
RC14HD10195	713414	7453337	Collembola	-	-	-	-	5	Troglofauna trap
RC14HD10195	713414	7453337	Collembola	-	-	-	-	4	Troglofauna trap
RC14HD10195	713414	7453337	Collembola	-	-	-	-	13	Troglofauna trap
RC14HD10195	713414	7453337	Schizomida	Hubbardiidae	*Draculoides* sp. BHD4	BHD4	Genetic Analysis	1	Troglofauna trap
RC14HD10674	711313	7453588	Acarina	-	-	-	-	20	Troglofauna trap
RC14HD10674	711313	7453588	Acarina	-	-	-	-	2	Troglofauna trap
RC14HD10674	711313	7453588	Acarina	-	-	-	-	13	Troglofauna trap
RC14HD10674	711313	7453588	Collembola	-	-	-	-	30	Troglofauna trap
RC14HD10674	711313	7453588	Collembola	-	-	-	-	20	Troglofauna trap
RC14HD10674	711313	7453588	Collembola	-	-	-	-	20	Troglofauna trap
RC14HD10933	710214	7453243	Acarina	-	-	-	-	37	Troglofauna trap
RC14HD10933	710214	7453243	Acarina	-	-	-	-	8	Troglofauna trap
RC14HD10933	710214	7453243	Coleoptera	-	-	-	-	2	Troglofauna trap
RC14HD10933	710214	7453243	Collembola	-	-	-	-	2	Troglofauna trap
RC14HD10933	710214	7453243	Collembola	-	-	-	-	1	Troglofauna trap
RC14HD10968	709107	7452938	Acarina	-	-	-	-	4	Troglofauna trap

Site Name	Easting (m E)	Northing (m N)	Taxonomy				Method of Identification	Number Collected	Method of Collection
			Order	Family	Species	Lineage			
RC14HD10968	709107	7452938	Acarina	-	-	-	-	7	Troglofauna trap
RC14HD10968	709107	7452938	Acarina	-	-	-	-	12	Troglofauna trap
RC14HD10968	709107	7452938	Diptera	-	-	-	-	1	Troglofauna trap
RC14HD11114	714405	7450784	Acarina	-	-	-	-	10	Troglofauna trap
RC14HD11114	714405	7450784	Acarina	-	-	-	-	8	Troglofauna trap
RC14HD11114	714405	7450784	Coleoptera	-	-	-	-	1	Troglofauna trap
RC14HD11114	714405	7450784	Collembola	-	-	-	-	20	Troglofauna trap
RC14HD11114	714405	7450784	Collembola	-	-	-	-	60	Troglofauna trap
RC14HD11114	714405	7450784	Collembola	-	-	-	-	30	Troglofauna trap
RC14HD11114	714405	7450784	Diplura	-	-	-	-	1	Troglofauna trap
RD13HD10020	712571	7453141	Acarina	-	-	-	-	3	Troglofauna trap
RD13HD10020	712571	7453141	Acarina	-	-	-	-	20	Troglofauna trap
RD13HD10020	712571	7453141	Diptera	-	-	-	-	7	Troglofauna trap
RD13HD10020	712571	7453141	Diptera	-	-	-	-	8	Troglofauna trap
RD13HD10020	712571	7453141	Hemiptera	-	-	-	-	22	Troglofauna trap
RD13HD10020	712571	7453141	Hemiptera	-	-	-	-	3	Troglofauna trap

Appendix 4

WA Museum Morphological Taxonomy Report (WAMTS384)

WAMTS384: Arachnology

Pseudoscorpions from 'Baby Hope Downs', Western Australia

(Biota Project *1098 Baby Hope Downs)*

Report to Biota

6 July 2015

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SUMMARY

WAMTS384 specimens were submitted to the Western Australian Museum on the 25 June 2015. The project contained: 1 pseudoscorpion from the family Chthoniidae and 1 palpigrade (palpigrades could not be identified morphologically as they are poorly known taxonomically). A summary of specimen identifications together with their SRE status may be found in Table 1. A full explanation of the SRE categories used by the Western Australian Museum may be found in Appendix 1.

Table 1. Summary of specimen identifications and SRE status.

ORDER	FAMILY	GENUS	SPECIES	# OF SPECIMENS	SRE STATUS	SRE SUB-CATEGORY
Pseudoscorpiones	Chthoniidae		*PSE096*	1	Confirmed SRE	B) Habitat C) Morphology E) Research
Palpigradi				1	Potential SRE	A) Data deficient

SHORT-RANGE ENDEMISM

The terrestrial invertebrate fauna of inland Australia contains a plethora of species, and just the arthropods were recently estimated to consist of more than 250,000 species (Yeates, Harvey et al. 2004; Chapman 2009). The vast majority of these are found within the Insecta and Arachnida, although significant numbers of millipedes are to be expected. For many years, the prospect of including invertebrates in assessments of biological systems subject to modification proved daunting because of the large numbers of unknown species. These animals were largely ignored, as they were too diverse and their taxonomy too little known for them to be considered in environmental surveys that require a rapid turn-around time.

In a recent publication, the issue of Short-Range Endemism in the Australian invertebrate fauna was examined (Harvey 2002). Species that could be defined as Short-Range Endemics (SRE) were those that had a naturally small range of less than 10,000 km^2. Harvey (2002) found that those species possessed a series of distinct ecological and life-history traits that contributed to their limited distributions, including:

- poor powers of dispersal;
- confinement to discontinuous habitats;
- usually highly seasonal, only active during cooler, wetter periods; and
- low levels of fecundity.

A number of major invertebrate groups have a high proportion of individual species that show these traits and can be considered SRE's. The Western Australian fauna contains a number of SRE taxa, including millipedes, land snails, trap-door spiders, some pseudoscorpions, slaters, and onychophorans and these represent focal groups in Environmental Impact Assessment studies in the state (EPA 2009). The south coast region is relatively well known compared with other regions of the state (Framenau, Moir et al. 2008), but there are many poorly known species and gaps in our understanding of the distributions of many species.

METHODS

Specimens collected by *Biota* were submitted to the Western Australian Museum on the 25 June 2015. The specimens were examined at the WA museum using Leica dissecting microscopes (MZ6, MZ16). The SRE status of each taxonomic group was given using the SRE categorisation system developed and implemented by the Western Australian Museum. A full explanation of the WAM SRE categories is available in Appendix 1.

SIGNIFICANT OUTCOMES

The significant findings of WAMTS384 are summarised below.

ARACHNIDA

ORDER Pseudoscorpiones

Family Chthoniidae

1. *Lagynochthonius sp. PSE096*:
    - **SRE Category: Confirmed SRE**
    - This study identified a previously unknown species of *Lagynochthonius* which has been given the species code `PSE096`. This specimen is the only known examples of this species at present.

      ` PSE096` has been categorized as a SRE due to the restricted geographic distribution, its troglomorphic form and based on prior research that has shown other blind *Lagynochthonius* species to be SREs.

APPENDIX 1. WAM SHORT-RANGE ENDEMIC CATEGORIES

<table>
<tr><th></th><th>Taxonomic Certainty</th><th>Taxonomic Uncertainty</th></tr>
<tr><td>Distribution < 10 000km^2</td><td>Confirmed SRE
• A known distribution of < 10 000km^2.
• The taxonomy is well known.
• The group is well represented in collections and/ or via comprehensive sampling.</td><td rowspan="2">Potential SRE
• Patchy sampling has resulted in incomplete knowledge of the geographic distribution of the group.
• We have incomplete taxonomic knowledge.
• The group is not well represented in collections.
• This category is most applicable to situations where there are gaps in our knowledge of the taxon.

Sub-categories for this SRE designation are outlined below</td></tr>
<tr><td>Distribution > 10 000km^2</td><td>Widespread (not an SRE)
• A known distribution of > 10 000km^2.
• The taxonomy is well known.
• The group is well represented in collections and/ or via comprehensive sampling.</td></tr>
</table>

SRE SUB-CATEGORIES

If a taxon is determined to be a "Potential SRE", the following sub-categories will further elucidate this status.

A. *Data Deficient:*
- There is insufficient data available to determine SRE status.
- Factors that fall under this category include:
  - New species.
  - Lack of geographic information.
  - Lack of taxonomic information.
  - The group may be poorly represented in collections.
  - The individuals sampled (e.g. juveniles) may prevent identification to species level.

B. *Habitat Indicators:*
- It is becoming increasingly clear that habitat data can elucidate SRE status.
- Where habitat is known to be associated with SRE taxa and vice versa, it will be noted here.

C. *Morphology Indicators:*
- A suite of morphological characters are characteristic of SRE taxa.
- Where morphological characters are known to be associated with SRE taxa and vice-versa, it will be noted here.

D. *Molecular Evidence:*
- If molecular work has been done on this taxon (or a close relative), it may reveal patterns congruent or incongruent with SRE status.

E. *Research & Expertise:*
- Previous research and/ or WAM expertise elucidates taxon SRE status.
- This category takes into account the expert knowledge held within the WAM.

APPENDIX 2. SPECIMEN DATA

REGNO	FLDNO	ORDER	INFRAORDER	FAMILY	GENUS	SPECIES	AUTHORITY	STATE	SITE	LATITUDE	LONGITUDE	M	F	JUV	TOT
137071	RC14HD10022-20150520-T2-01	Palpigradi						W.A.	Baby Hope Downs, 75.2km WNW of Newman	23°00`52.2"S	119°05`43.7"E				1
137072	RC13HD10336-20150520-T2-01	Pseudoscorpiones		Chthoniidae	*Lagynochthonius*	*PSE096*		W.A.	Baby Hope Downs, 74.5km WNW of Newman	23°02`33.9"S	119°05`08.7"E		1		1

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