HASTINGS
Technology Metals Limited

APPENDIX 2-4

Subterranean Fauna Assessment

Bennelongia Environmental Consultants

Yangibana Rare Earths Project: Subterranean Fauna Assessment

Prepared for:

Hastings Technology Metals Limited

June 2018

Final Report

Short-Range Endemics I Subterranean Fauna

Waterbirds I Wetlands

Yangibana Rare Earths Project: Subterranean Fauna Assessment

Bennelongia Pty Ltd
5 Bishop Street
Jolimont WA 6014

P: (08) 9285 8722
F: (08) 9285 8811
E: info@bennelongia.com.au

ABN: 55 124 110 167

Report Number: 293

Report Version	Prepared by	Reviewed by	Submitted to Client	
			Method	Date
Draft	Huon Clark Anton Mittra	Stuart Halse Michael Curran	email	25 June 2018
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EXECUTIVE SUMMARY

Hastings Technology Metals Limited (Hastings) plans to develop the Yangibana Rare Earths Project (the Project) in the Gascoyne region of Western Australia. Proposed operations include excavation and dewatering of the Bald Hill, Frasers and Yangibana North/West deposits, and water extraction at the SipHon Borefield for mineral processing purposes. Based on recognised subterranean fauna values in the vicinity of the Project, Hastings determined that there was a risk that Project activities had the potential to degrade or remove prospective subterranean fauna habitat, in turn threatening conservation values of subterranean species and communities. Bennelongia Environmental Consultants were therefore commissioned to assess the potential impact of mine operations on subterranean fauna in the Project area.

Building on a previous study of subterranean fauna in 2016 by Ecoscape, Bennelongia conducted extensive field surveys of stygofauna and troglofauna in the Project and surrounding areas, which coincide with some of the Priority 1 Priority Ecological Community (PEC) '*Gifford Creek, Mangaroon, Wanna calcrete groundwater assemblage type one Lyons palaeodrainage on Gifford Creek, Lyons and Wanna Stations*'. Stygofauna sampling included 136 samples from 104 reference and 32 impact bores and drill holes. Stygofauna site type was determined by occurrence outside (reference) or inside (impact) predicted 2 m drawdown contours. Troglofauna sampling included 20 samples (comprising both trap and scrape sub-samples) from 15 reference and five impact drill holes.

Stygofauna sampling by Bennelongia yielded 1,654 specimens belonging to 78 species. Reference sites yielded 1,554 specimens, including all 78 species, while impact areas yielded 99 specimens of six species. The total number of stygofauna species known from the study area is at least 80 (the two additional species were collected by Ecowise), nearly half of which are undescribed and likely to be restricted to the calcrete PEC. Recorded taxa include flatworms (Turbellaria), annelids (Oligochaeta), rotifers (Rotifera), roundworms (Nematoda), ostracods (Ostracoda), copepods (Cyclopoida and Harpacticoida), amphipods (Amphipoda), slaters (Isopoda), aquatic mites (Acari) and beetles (Coleoptera). On the basis that all stygofauna species known to occur in the study area have been recorded from reference areas, it is concluded that the conservation values of the stygofauna community and its constituent species are unlikely to be threatened by mining or water abstraction associated with the Project.

Troglofauna sampling by Bennelongia yielded 17 specimens belonging to 13 species. A total of 15 troglofauna species have been recorded from the study area and at least six of these are considered likely to be endemic to the study area. Yields of troglofauna were low in terms of both abundance and species per sample, and it would appear that the Project area hosts a low-to-moderately diverse troglofaunal assemblage. However, four species are known only from proposed mine pits. These are the two centipedes Chilenophilidae sp. B09, and Schendylidae sp., the dipluran Parajapygidae sp. B41 and the isopod *Troglarmadillo* sp. B60.

It is considered likely (although not certain because of identification issues) that both Chilenophilidae sp. and Schendylidae sp. occur in reference areas and, therefore, are not of conservation concern. The dipluran Parajapygidae sp. B41 was collected from two holes at the Yangibana North deposit and has a known linear range of approximately 0.25 km. However, based on existing information the median linear range troglofaunal dipluran species in the Pilbara is at least 4.5 km and such a range would mean the species occurs outside the proposed mine pit at Yangibana North. The isopod *Troglarmadillo* sp. B60 is known from a single hole in the Frasers deposit. Existing data suggest the median linear ranges of troglofaunal Pilbara isopods is at least 1.8 km and such a range would mean the species occurs outside the proposed mine pit at Frasers. Thus, while there is no direct evidence that Parajapygidae sp. B41 and *Troglarmadillo* sp. B60 occur in reference areas, this is considered likely because of the probable ranges of the species and the fact the geological units from which both taxa were collected are continuous across reference and impact areas. The likely reason for not collecting the species in references areas is that sampling intensity was too low to collect more specimens of each species and demonstrate this wider occurrence. Low capture rates for troglofauna species and, consequently, a stochastic distribution of records within the species' actual envelope of occurrence is a common phenomenon.

Considering sampling results and the inferred distributions of the species recorded only in impact areas, it is considered that the threat to the conservation values of troglofauna communities and species from mining operations at the Project is likely to be low.

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1. INTRODUCTION

Hastings Technology Metals Limited (Hastings) plans to develop the Yangibana Rare Earths Project (the Project) in the Gascoyne region of Western Australia (Figure 1). The site represents a significant Australian rare earth elements project. Exploration drilling programmes in the 1980s, and more recently in 2014–2016, have revealed extensive deposits of ferrocarbonate and ironstone veins that could produce substantial volumes of total rare earth oxides, of which neodymium, praseodymium and dysprosium are amongst the most valuable.

Accessing mineral ore at the Project will involve open-cut mining. It is possible that the excavations and associated abstraction of surrounding groundwater to enable dry mining, as well as the abstraction of process water from a nearby borefield, may potentially degrade or remove prospective habitat of subterranean fauna species, which could in turn threatening the conservation values of subterranean species and communities.

Although inconspicuous, subterranean fauna contribute markedly to the overall biodiversity of Australia and, additionally, play important roles in ecosystem function (Humphreys 2006). While studies of subterranean fauna in the Gascoyne remain uncommon, the neighbouring Pilbara and Yilgarn regions of Western Australia are recognised as subterranean faunal biodiversity hotspots. Guzik et al. (2010) suggested that over 4,000 species of subterranean fauna are likely to occur in the western half of Australia, with over 80 % of these species not yet discovered. The Gascoyne region is geologically similar to the Pilbara region and supports rich stygofauna communities (Humphreys 1999; Halse et al. 2014), including the Priority 1 Priority Ecological Community (PEC) '*Gifford Creek, Mangaroon, Wanna calcrete groundwater assemblage type one Lyons palaeodrainage on Gifford Creek, Lyons and Wanna Stations*' covers the area of the Project and its surrounds (Figure 2).

Most subterranean fauna satisfy Harvey's (2002) criteria for short-range endemism (SRE), namely ranges of less than 10,000 km^2, confinement to discontinuous habitats, slow growth and low fecundity. In fact, ranges of troglofauna are frequently only a few square kilometres in extent (Halse and Pearson 2014) and Eberhard et al. (2009) pointed out that threshold of 1,000 km^2 (or a linear range of 18 km) was more appropriate than Harvey's 10,000 km^2 for recognizing stygofauna with small ranges. Given that locally-restricted species are more vulnerable to extinction following habitat degradation than wider-ranging species (Ponder & Colgan 2002), it follows that the very small ranges of many subterranean species make them are highly susceptible to anthropogenic threats, such as habitat degradation and groundwater abstraction.

A previous desktop assessment, with a reconnaissance stygofauna survey and more detailed troglofauna survey in the Project area recorded 10 species of stygofauna and at least five species of troglofauna (Ecoscape 2016). Three stygofauna and all five troglofaunal species were recorded exclusively at locations tentatively designated as impact areas and were therefore deemed to be of potential conservation concern, although the footprints of proposed developments were not fully defined at the time of the Ecoscape survey. The additional surveys by Bennelongia reported here were undertaken to determine the distribution of subterranean fauna species belonging to the *Gifford Creek, Mangaroon, Wanna calcrete groundwater assemblage type one Lyons palaeodrainage on Gifford Creek, Lyons and Wanna Stations* Pec relative to the Project area, as well as to provide specific information about whether any species may possibly be impacted by Project development.

The program consisted of five components:

(i) Review of previous subterranean fauna surveys in the Project area, including the Ecoscape (2016) study and an updated search of relevant databases and literature;

(ii) Undertake a Level 2 field survey of stygofauna and troglofauna in the Project area and surrounding PEC to clarify the diversity and distribution of species relative to the impact area;

(iii) Level 2 field survey of stygofauna in the SipHon Well Borefield to assess potential impacts from drawdown associated with borefield water usage;

(iv) Increase the number of reference samples throughout the Project area; and

(v) Evaluate the possible threats posed by the Project activities to the conservation values of subterranean fauna.

2. FRAMEWORK

2.1. Project Description

The Project and relevant survey areas are situated approximately 290 km northeast of Carnarvon and occupy parts of the Wanna, Gifford Creek and Edmund pastoral stations in the northern Gascoyne region (Figure 1). Tenement areas cover approximately 550 km^2 including four major deposits – Yangibana West, Yangibana North, Bald Hill South and Fraser's (Figure 2), as well as several smaller deposits (Gossan, Kanes Gossan, Hook, Lion's Ear). The proposed works includes the SipHon Well borefield, which will supply process water for the Project (Figure 2). Excavation and the dewatering associated with the major deposits and the borefield proposed for development are considered to be the main potential threats to subterranean fauna.

2.2. Regional Setting

The Project occurs in the Gascoyne bioregion of Western Australia, which is characterised by low, rugged ranges and broad, flat valleys. Vegetation is dominated by open mulga woodlands and extensive sheep and cattle grazing are the major regional land uses. The Gascoyne has an arid climate with predominantly winter rainfall in the west shifting to summer-dominated rainfall further inland. Median annual rainfall is approximately 200 mm.

Three subregions are specified within the Gascoyne – Ashburton (GAS1), Carnegie (GAS2) and Augustus (GAS3). The current study area falls within both the Ashburton and Augustus subregions. The Ashburton subregion is characterised by mountainous ranges interspersed by broad flat valleys within the Ashburton River catchment comprising the Ashburton (shales, sandstones and conglomerates) and Bangemall (sandstone, shale and carbonates) basins (Kendrick 2002). Vegetation is typified by mulga and snakewood low woodlands on earthy loams over hardpan on plains and mulga scrub and *Eremophila* shrublands on shallow loams of ranges. Kendrick (2002) and Humphreys (2001) predicted that significant subterranean fauna communities would occur in calcretes associated with the Lyons River, which falls within the study area.

The Augustus subregion is characterised by rugged low Proterozoic sedimentary and granite ranges divided by low flat valleys. Major regional drainage is supplied by the Gascoyne River System as a well as the Ashburton and Fortescue Rivers (Desmond et al. 2001).

According to geological descriptions in the previous ecological survey (Ecoscape 2016), the most common geological unit in the study area is the Pimbyana Granite (PLgpi) covering 22.5 % of the study area (12,037 ha), followed by sand and gravel with ferruginous cement; deeply dissected by present-day drainage (A3ti, 14.9 %); calcrete, developed in and adjacent to alluvial channels (Rk, 11.6 %); unconsolidated silt, sand and gravel in active drainage channels and floodplains (A1, 7.4 %); evenly-textured to weakly porphyritic medium-grained biotite-muscovite(-tourmaline) monzogranite with metasedimentary rock or porphyritic granodiorite (PLgynx, 7.1 %); and Porphyritic, medium- to coarsegrained biotite-muscovite granodiorite to syenogranite with metasedimentary and metamafic rocks (PLgpix, 6.1%).

Several calcrete aquifers in the study area comprise the PEC *Gifford Creek, Mangaroon, Wanna calcrete groundwater assemblage type on Lyons palaeodrainage on Gifford Creek, Lyons and Wanna Stations* (Figure 2), which was considered likely to harbour significant and unique assemblages of subterranean fauna.

Figure 1. Location of the Yangibana Rare Earths Project.

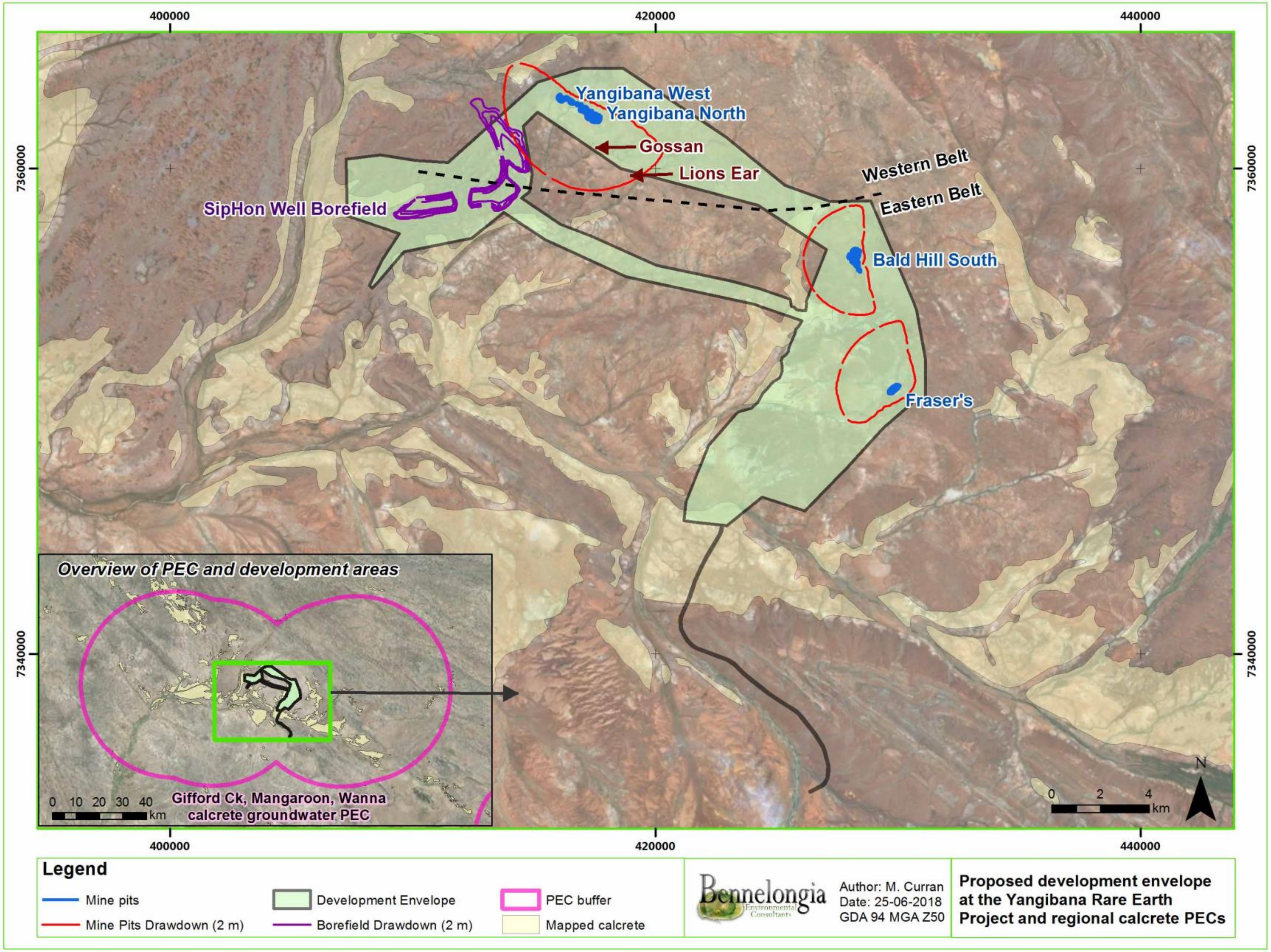

Figure 2. Proposed development envelope at the Yangibana Rare Earths Project and regional calcrete PECs.

2.3. Conservation Framework

Consideration of impacts on subterranean fauna is a requirement of environmental impact assessment in Western Australia under the Environmental Protection (1986). The Environmental Protection Authority's (EPA) approach to protection is laid out in EPA (2016). Subterranean fauna are also afforded protection by state and federal legislation for the protection of native flora, fauna and ecosystems. At the federal level, the Environmental Protection and Biodiversity Conservation Act (1999) provides a legal framework for the protection of threatened species and threatened or endangered ecological communities (TECs).

At the state level, the Wildlife Conservation (WC) Act (1950) states that, "all fauna is wholly protected throughout the whole of the State at all times", excepting circumstances where alternative declarations are made by the Minister for Environment. In addition, special protection is provided to those species listed as endangered, threatened or otherwise in need of special protection under the Wildlife Conservation (Specially Protected Fauna) Notice 2015. This state list of threatened species contains several subterranean fauna species, including crustaceans, arachnids and myriapods. Additionally, the Department of Biodiversity, Conservation and Attractions (DBCA) maintains a list of priority fauna species that are of conservation importance, but for various reasons do not meet the criteria for listing as threatened.

Currently, the state has no provision for formal listing of TECs but the Minister annually endorses a List of TECs for protection. In addition, and of particular relevance to the Project area, DBCA maintains a less formal list of Priority Ecological Communities (PECs) for protection. Several subterranean ecological communities in Western Australia are listed as TECs and more than 80 subterranean communities in calcretes, predominantly recognised for their stygofauna element, are listed as PECs, including. the *Gifford Creek, Mangaroon, Wanna calcrete groundwater assemblage type on Lyons palaeodrainage on Gifford Creek, Lyons and Wanna Stations* PEC.

2.4. Subterranean Fauna

With the exception of two known species of cave-dwelling fish, Western Australian subterranean fauna are invertebrates and are divided into aquatic stygofauna and air-breathing troglofauna. Both groups typically lack eyes and are poorly pigmented due to lack of light. Other characteristic morphological and physiological adaptations such as vermiform bodies, elongate sensory structures, loss of wings, increased lifespan, a shift towards a K-selection breeding strategy and decreased metabolism reflect low inputs of carbon and nutrients in subterranean habitats and the requirement to navigate enclosed spaces (Gibert & Deharveng 2002).

Geology influences the presence, richness and distribution of subterranean fauna by providing different types of habitat (Eberhard et al. 2005; Hose et al. 2015). Highly transmissive geologies support greater assemblages of subterranean fauna, both in terms of abundance and diversity, than consolidated ones. Alluvial deposits may host subterranean fauna in interstitial spaces between constituent sand and gravel, and coarser sediments tend to host greater assemblages than silty or clay-rich substrates (Korbel and Hose 2011). Physical and chemical weathering of consolidated strata can also provide prospective niches such as fissures, vugs and caves.

Fluctuating groundwater levels and resulting precipitation of carbonates along the internal palaeochannel river system of Western Australia has resulted in the formation of many calcrete aquifers. Although classical karst formations are absent from the Western Australian landscape, calcretes display karstic characteristics and provide excellent habitat for stygofauna, as well as for troglofauna above the water table (Humphreys 2001).

Geological, topographical and hydrological features influence subterranean faunal assemblages by allowing, or restricting, dispersal between populations. The relative importance of dispersal and vicariance (i.e. geographical range is disconnected resulting in physical or biotic barriers) in explaining spatial patterns of stygofauna community structure is likely to vary between regions according to historical and present-day hydrogeology (Finston et al. 2007; Culver et al. 2009). For instance, vertical shifts in the water table may act to unite previously isolated aquifers, thus allowing gene flow between populations (Finston et al. 2007). By the same token, subterranean geology and surface features such as drainage patterns and tributary boundaries may barricade dispersal, causing vicariance between populations and subsequent speciation over relatively fine geographical scales. For instance, populations of some troglofaunal pseudoscorpions in the Pilbara are known to be genetically isolated between adjacent mesas (i.e. ranges of a few square kilometres), as a result of being restricted to specific geological structures (Harvey et al. 2008).

2.4.1. Stygofauna

Hydraulic conductivity is an important factor dictating the movement of oxygen and carbon into and throughout ecosystems. Therefore, transmissive aquifers with large pore spaces allowing movement of oxygen and carbon tend to accommodate the most abundant and diverse stygofauna communities (Hose et al. 2015). In the Pilbara and Yilgarn, surveys of calcrete aquifers have revealed rich and endemic stygofaunal assemblages.

Earthworms (Oligochaeta), beetles (Coleoptera) and crustaceans (amphipods, isopods, copepods, ostracods and syncarids) comprise typical stygal communities in calcretes and many species are restricted to single aquifers (Humphreys 2001; Cooper et al. 2002; Guzik et al. 2008; Watts and Humphreys 2006; Leys et al. 2008; Javidkar 2014). The listing of a large number of Yilgarn calcretes as PECs reflects their physical, biological and genetic isolation and high prevalence of locally endemic species. Less transmissive geologies, such as banded iron formations (BIF) and saprolite, rarely support rich stygofaunal communities, although low numbers of species may occur in these geologies too (Bennelongia 2009; Ecologia 2009; Ecoscape 2016; GHD 2009).

Although the physiochemical tolerances of stygofauna have not been well-defined, assumptions about tolerance of specific taxa can be made based on related surface water surrogates. Stygofauna occur in aquifers of varying salinities, but are mostly found in fresh to brackish waters with conductivities of less than 5,000 µS cm^{-1} (approximately 640 mg L^{-1} TDS), and are seldom found in hypoxic groundwater (<0.3 mg O_2 L^{-1}) (Hose et al. 2015). Whilst stygofauna sometimes occur in hyporheic zones and groundwater springs, this review assesses the presence of stygofauna in groundwater aquifers.

2.4.2. Troglofauna

While the earliest troglofauna surveys in Western Australia focussed on cave habitats, subsequent records from pisolitic mesas in the Robe River Valley in the Pilbara (Biota 2006) demonstrated the occurrence of troglofauna in non-karstic formations. Troglofauna have since been recorded throughout the Western Australian landscape, with the greatest diversity and abundance occurring in the Pilbara. Troglofauna are represented by a wide variety of invertebrate groups, including isopods, palpigrads, spiders, schizomids, pseudoscorpions, harvestmen, millipedes, centipedes, pauropods, symphylans, bristletails, silverfish, cockroaches, bugs, beetles and fungus-gnats.

Regional patterns of troglofauna occurrence and community composition in various habitats are not well understood because the majority of surveys have focussed on areas of mining development, particularly mineralised iron formations. Consequently, troglofauna have been found to occur widely in mineralised iron formations (e.g. Biota 2006; Bennelongia 2008a, b) but there is little basis for assessing the extent of their occurrence in other habitats. Nonetheless, it is known that troglofauna occur in calcrete and alluvial-detrital deposits in the Pilbara (Edward and Harvey 2008).

Troglofauna surveys in the Yilgarn have been limited, and in most cases have recorded modest abundances and diversities of troglofauna in calcretes above the water table. Bennelongia (2015) notably recorded 45 species of troglofauna from the Yeelirrie calcrete, while Outback Ecology (2012) recorded 20 species at Lake Way. These relatively rich assemblages illustrate the suitability of calcrete as a subterranean fauna habitat. Surveys in BIF in the Yilgarn at Koolyanobbing, Mt Jackson, Mt Dimmer and Yendilberin Hills have yielded depauperate to moderately rich troglofauna communities (Bennelongia 2008a, b, c).

3. IMPACTS OF MINING

The effects of developing mining infrastructure and subsequent mining operations on subterranean fauna communities can be broadly divided into two categories:

1. Primary impacts – the direct removal of habitat, through activities such as pit excavation and groundwater abstraction that may lead to threats to the persistence of local populations or even the possible extinction of species of subterranean fauna; and
2. Secondary impacts – reductions in quality of habitat, as a result of factors such as pollution, changed nutrient inputs and increased turbidity, that may reduce densities of subterranean fauna populations (Appendix 1).

3.1. Impacts on Stygofauna

Open cut and underground mining sometimes requires groundwater abstraction to access mineral ore and prevent flooding of mine pits. Abstracted groundwater is typically also used in ore processing. Drawdown of the water table may have a primary impact on the stygofauna species that occur within the dewatering footprint. In particular, species restricted to within the impact footprint may face possible extinction. The excavation of the pit itself removes habitat of stygofauna but, because this lies within the area of dewatering, it is not considered separately. The construction of other infrastructure, such as tailings storage facilities, may have secondary impacts on stygofauna.

3.2. Impacts on Troglofauna

Mine pit excavation is likely to have a primary impact on troglofauna occurring within the pit footprint. However, the extent of habitat loss for a species will depend on the area and depth of mine pits and other excavations, as well as the occurrence and connectivity of suitable habitat outside the impact zone. Animals utilising small isolated pockets of habitat are more vulnerable to significant primary impacts than those inhabiting more extensive geologies. Secondary impacts are not considered here in detail.

4. PREVIOUS SURVEY

4.1. Ecoscape Survey

Ecoscape conducted a desktop assessment identifying physical and biological aspects of the Project area followed by a two-season field survey of subterranean fauna in 2015. The survey comprised two sampling rounds: post wet season in May 2015; and during the dry season in September 2015. Sampling methods were consistent with current practice and the methods used by Bennelongia in the present study (Section 5).

4.1.1. Stygofauna

Thirteen and 18 boreholes were sampled during wet and dry season components of the stygofauna survey, respectively (Ecoscape 2016). Sampled boreholes occurred in Rk, C1f, PLgpi and PLgpix geological units with most samples taken from PLgpi geology. Broadly, these units comprise calcrete (Rk), unconsolidated ferruginous rubble and scree (C1f) and granites (Plgpi and PLgpix). Stygofauna samples were taken largely from inside proposed pit areas and therefore correspond to the likely impact area pit exaction and associated dewatering.

Stygofauna were collected from eight boreholes in five of the areas sampled (Lion's Ear, Yangibana North, Hook and Kane's Gossan deposits and the reference area Andy's Bore). Deposit sites occurred largely in PLgpi geology (granite), while Andy's Bore occurred in Rk geology (calcrete).

Stygofauna recorded by Ecoscape are shown in Table 1, alongside records from current database and literature searches. Ecoscape collected 236 stygofauna specimens from four families representing 10 species. Copepods, ostracods, amphipods, oligochaetes and nematodes were all recorded. Three stygofauna species were deemed to be of conservation significance in the context of the Project: the copepod Ameiridae gen. nov. sp. B04; the candonid ostracod *Areacandona* sp. BOS550; and the amphipod Paramelitidae sp. B49.

Table 1. Historical records of stygofauna at the Project and surrounding area.
10,000 km^2 WAM search area defined by 23°28'S, 115°57'E and 24°24'S, 116°55'E. Grey shading indicates taxa recorded in studies other than the Ecoscape (2016) survey. * Previously called Enchytraeus sp. 1 PSS. ^ Previously called Phreodrilidae with dissimilar ventral chaetae.

Higher classification	Lowest identification	Locations	Comments on Distribution
ANNELIDA **Oligochaeta** Enchytraeidae	* Enchytraeidae sp. 21	Hook, Yangibana North	Potential SRE[1,5]
Phreodrilidae	*Phreodrilus peniculus*	Hook	Also recorded in the Pilbara[4]
	^ Phreodrilidae sp. AP DVC B12	Yangibana North, Lion's Ear	Potential SRE[1,5]
NEMATODA	Nematoda sp.	Gossan, Lion's Ear, Yangibana North	Not assessed in EIA
CRUSTACEA **Copepoda** Ameiridae	Ameiridae gen. nov. sp. B04	Andy's Bore	Only record of this genus; potential SRE; potentially conservation-significant[1]
Cyclopidae	*Diacyclops cockingi*	Lion's Ear, Yangibana North, Hook	Pilbara-wide[2]
	Diacyclops humphreysi humphreysi	Kane's Gossan	Pilbara-wide[2]
	Orbuscyclops westaustraliensis	Andy's Bore	Pilbara-wide[2]
Ostracoda Candonidae	*Areacandona* sp. BOS550	Andy's Bore	Presently known only from this record; potential SRE; potentially conservation-significant[1]
Amphipoda Paramelitidae	Parametlitidae sp. B49	Lion's Ear	Only record of species; potential SRE; potentially conservation-significant[1]
ISOPODA			
Tainisopidae	*Pygolabis gascoyne*	1 record from Stonetank Well (Gifford Creek PEC)	Likely restricted to Gifford Creek PEC[3]

[1]Ecoscape (2016); [2]Karanovic (2006); [3]Keable and Wilson 2002; [4]ABRS 2009; [5]Bennelongia unpublished data and expertise.

4.1.2. Troglofauna

Ecoscape collected 18 samples wet and 25 during the dry season survey, respectively. Additionally, troglofauna scraping was undertaken at 32 drill holes.

Troglofauna were collected from five drill holes across three deposits (Frasers, Kanes Gossan and Bald Hill) in granite geology (Table 2). Eleven troglofauna specimens from five orders representing five separate species were recorded, including the isopod *Troglarmadillo* sp. B60, the dipluran Projapygidae sp. B19, the thysanuran *Trinemura* sp. B29, the centipede Geophilidae sp. and the symphylan *Scutigerella* sp. B09. All recorded species of troglofauna were deemed to be of potential or unknown conservation concern.

Table 2. Historical records of troglofauna at the Project and surrounding area.
10,000 km^2 WAM search area defined by 23°28'S, 115°57'E and 24°24'S, 116°55'E. All records of troglofauna in the Project area were recorded by Ecoscape (2016).

Higher classification	Lowest identification	Locations	Comments on Distribution
CRUSTACEA **Isopoda** Armadillidae	*Troglarmadillo* sp. B60	Frasers	Only record of this genus in vicinity; likely SRE; potentially conservation-significant
HEXAPODA **Diplura** Projapygidae	Projapygidae sp. B19	Kane's Gossan	Only known from this record; potential SRE; potentially conservation-significant[1]
Insecta			
Nicoletiidae	*Trinemura* sp. B29	Bald Hill, Fraser's, Kane's Gossan	Only known from study area; potential SRE; potentially conservation-significant[1]
MYRIAPODA			
Chilopoda			
Geophilidae	Geophilidae sp.	Kane's Gossan	Damaged specimen; conservation status unknown
Symphyla Scutigerellidae	*Scutigerella* sp. B09	Bald Hill	Only known from this record; potentially conservation-significant[1]

[1]Ecoscape (2016)

4.2. Database and Literature Searches

Previous records of subterranean fauna in the vicinity of the Project were collated by searching available databases (Bennelongia, WAM) and relevant literature for records of subterranean fauna within an area of 10,000 km^2 defined by 23°28'S, 115°57'E and 24°24'S, 116°55'E (Figure 2). Distributions were estimated for species-level taxa. Where a taxon had not been identified to species-level a suitable congeneric or confamiliar surrogate species was used to approximate likely distribution. To avoid artificial inflation of species lists, higher level identifications were excluded unless no other species had been recorded in that taxonomic unit. Records of stygofauna and troglofauna in the Project area are shown in Table 1 and Table 2, respectively.

5. CURRENT SURVEY

5.1. Sampling effort

A total of 136 stygofauna samples were collected across four main sampling events from 2016-2018. Of these, 104 were reference samples and 32 were impact samples (Table 3). Sample locations are shown in Figure 3. Reference and impact sites were delineated according to their occurrence inside (impact) or outside (reference) predicted 2 m drawdown contours determined by modelling (GRM 2017, 2018; Figure 3). The appropriateness of the 2 m drawdown contour as a separator of reference and impact sites is discussed further in Section 7.1. The regional stygofauna reference site Judy's Bore was opportunistically sampled a second time December 2016, resulting in two samples for that site. A complete list of sampling sites for stygofauna are given in Appendix 2

Table 3. Sampling effort for stygofauna at the Project between September 2016 and May 2018.

Orebody	Sample Type	2016			2017		2018	Total
		Oct*		Dec^	Oct#	Dec#	May#	
Eastern Belt	Impact	10						**10**
Western Belt	Impact	5				1		**6**
SipHon Well borefield	Impact					6	10	**16**
	Reference					5	9	**14**
Regional	Reference	19	19	1	51			**90**
Total	**Impact**	**15**				**7**	**10**	**32**
	Reference	**19**	**19**	**1**	**51**	**5**	**9**	**104**
	Overall	**34**	**19**	**1**	**51**	**12**	**19**	**136**

NB: * denotes combined net and pump sample, ^ denotes pump sample only, and # denotes net sample only.

Twenty troglofauna samples, consisting of both a scrape and trap, were collected from 5-10 October 2016 (Table 4). One scrape sample (totalling 0.5 of a standard troglofauna sample) was opportunistically collected in October 2017 but did not yield any further troglofauna species. Sampling sites for troglofauna are shown in Figure 4. Altogether 15.5 reference and five impact troglofaunal samples were collected. Traps remained underground for approximately two months. A complete list of sampling sites for troglofauna are given in Appendix 3.

Table 4. Sampling effort for troglofauna at the Project from October 5 to 10, 2016 plus a single regional sample.

* Scrape and trap samples are combined to form one complete troglofauna sample. Trap S, single trap; Trap D, double trap (set every fourth hole).

Area	Site Type	Scrape	Trap S	Trap D	* No. of Samples
Eastern Belt					
Bald Hill	Impact	2	1	1	**2**
	Reference	4	3	1	**4**
Frasers	Impact	1		1	**1**
	Reference	5	5		**5**
Western Belt					
Yangibana North	Impact	2	1	1	**2**
Yangibana West	Reference	3	3		**3**
Gossan	Reference	2	2		**2**
Lions Ear	Reference	1		1	**1**
Regional					
Cobra Station	Reference	1			**0.5**
Total	**Impact**	**5**	**2**	**3**	**5**
	Reference	**16**	**13**	**2**	**15.5**
	Overall	**21**	**15**	**5**	**20.5**

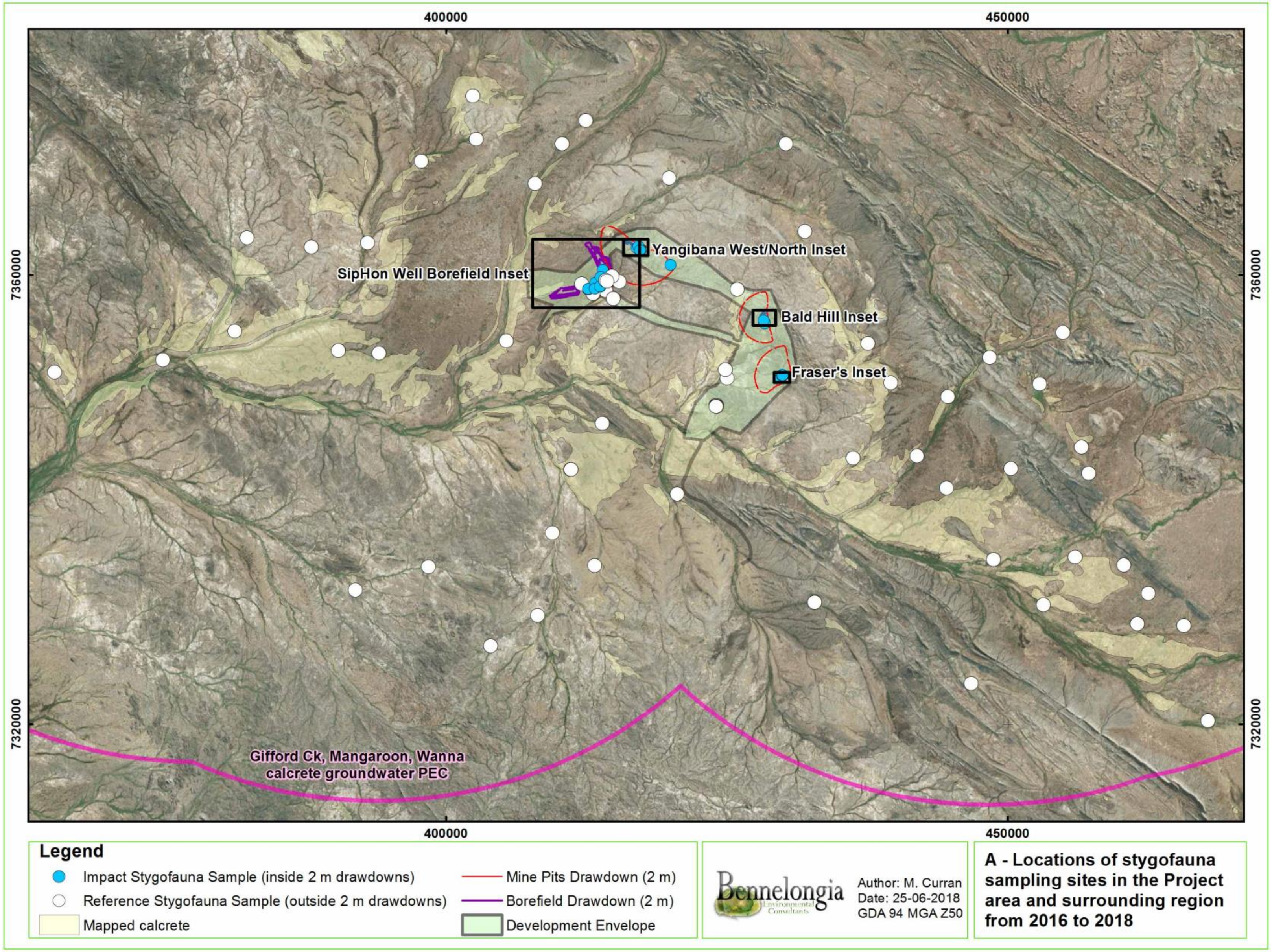

Figure 3A (above) & 3B (below). Locations of stygofauna sampling sites in the Project area and surrounding region from 2016 to 2018, with insets shown below in Figure 3B. 2 m drawdown contours were determined by hydrological modelling by GRM (2017, 2018).

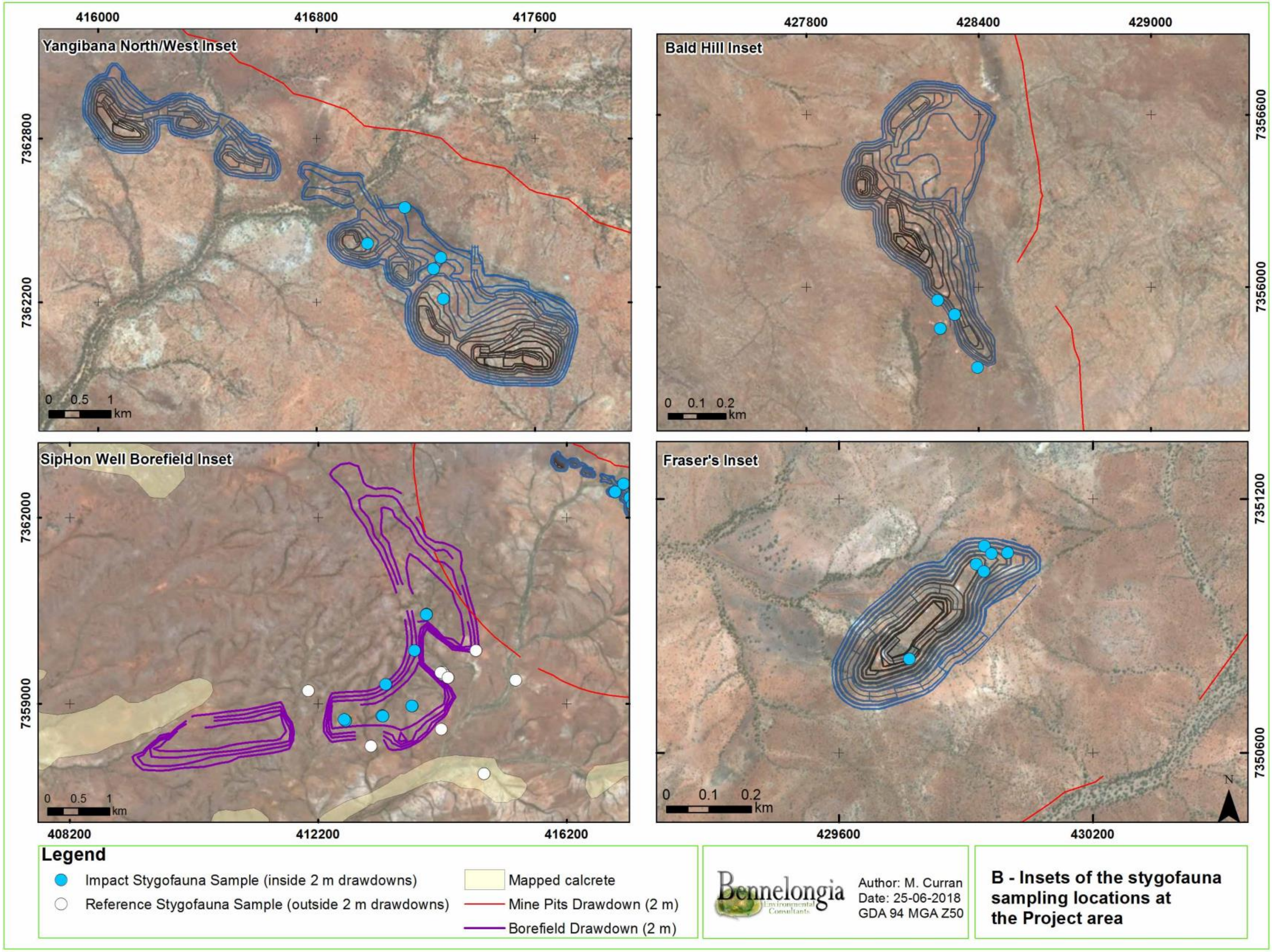

Figure 3B. Insets pertaining to Figure 3A showing stygofauna sampling at SipHon Well Borefield and deposits Yangibana North/West, Bald Hill and Fraser's.

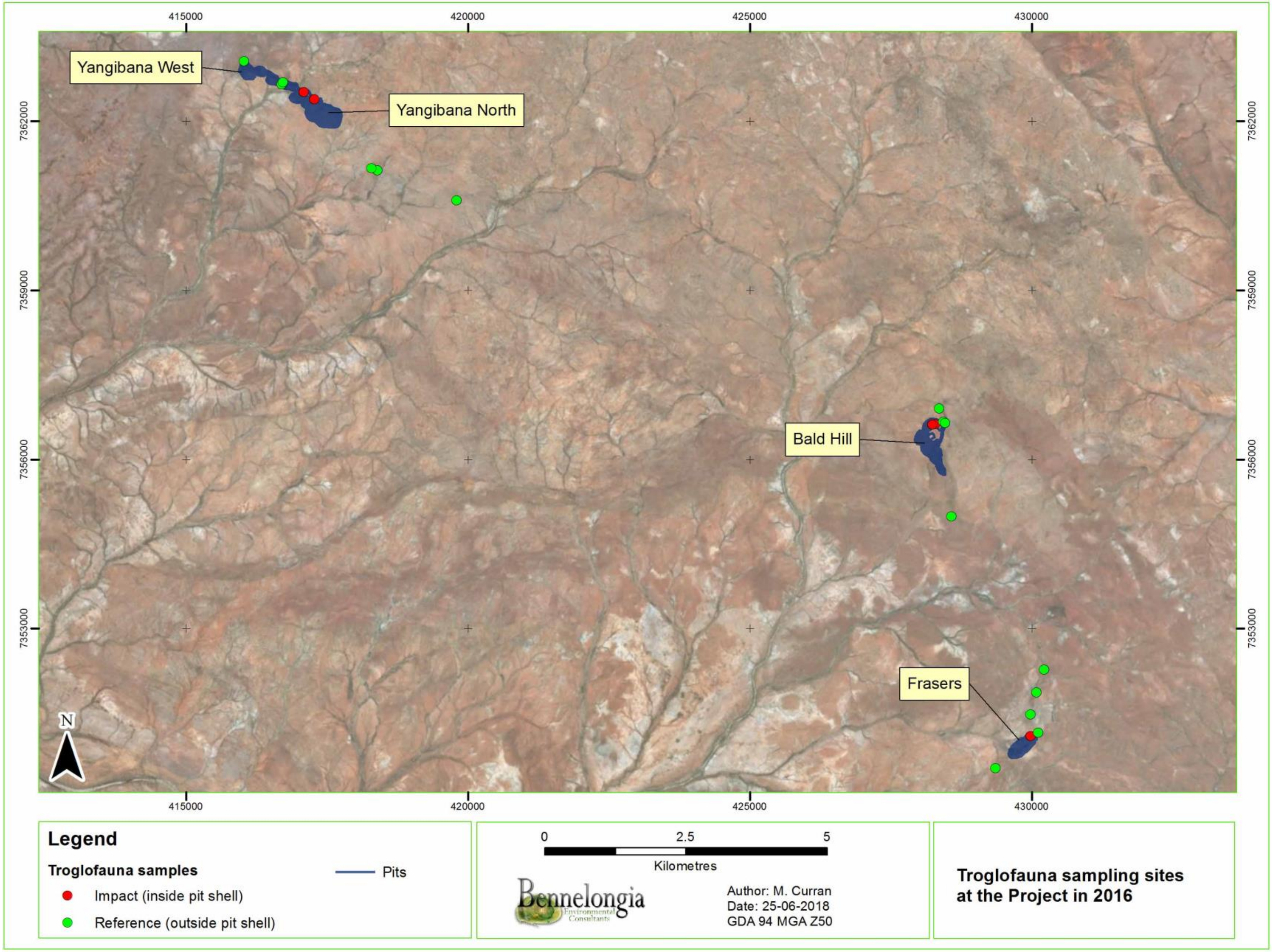

Figure 4. Troglofauna sampling sites at the Project in 2016.

5.2. Field and Laboratory Methods

5.2.1. Stygofauna

Sampling for stygofauna adhered to methods recommended in EPA (2016), whereby stygofauna were sampled at each bore using weighted plankton nets. Six hauls were taken at each site, three using a 50 µm mesh net and three with a 150 µm mesh net. The net was lowered to the bottom of the hole and jerked up and down briefly to agitate benthos (increasing the likelihood of collecting benthic species) and then slowly retrieved. This method was not possible at some regional sites, which rather than drill holes comprised windmill-driven pastoral bores. At these sites, pump outflow was filtered for approximately 20 minutes through a 150 µm mesh net. Contents of the net were transferred to a 125 ml polycarbonate vial after each haul, flushed with bore water to reduce fine sediment content, preserved in 100% ethanol and refrigerated at a constant 4 °C. Nets were washed between holes to minimise site-to-site contamination.

In situ water quality parameters – temperature, electrical conductance (EC) and pH – were measured at each site using a WP 81 field meter. Standing water level and total depth of hole were also measured using a Solinst water level meter.

In the laboratory, samples were elutriated to separate out heavy sediment particles and sieved into size fractions using 250, 90 and 53 µm screens. All samples were sorted under a dissecting microscope and specimens identified to species where possible using available keys and species descriptions. When necessary for identification, animals were dissected and examined under a compound microscope. If stygofauna did not represent a described species, they were identified to species/morphospecies using characters from species keys.

5.2.2. Troglofauna

Each troglofauna sample from a drill hole consisted of results of two separate collecting techniques, trapping and scraping:

1. *Trapping*. Custom made cylindrical PVC traps (270 x 70 mm, entrance holes side and top) were used for trapping. Traps were baited with moist leaf litter (sterilised by microwaving) and lowered on nylon cord to the most suitable habitat within the hole (this ranged from areas where there was a root constriction, to areas where vuginess was detected during scraping or to areas within a few metres of the water table). In every fourth hole a second trap was set mid-way down the bore. Holes were sealed while traps were set to minimise the ingress of surface invertebrates. Traps were retrieved 12 weeks after being set.

2. *Scraping*. Scrapes were collected immediately prior to setting traps. A troglofauna net (weighted ring net, 150 µm screen, various apertures according to diameter of the hole) was lowered to the bottom of the hole, or to the watertable, and scraped back to the surface along the walls of the hole. Each scrape comprised four sequences of lowering and retrieving the net. After each scrape, the contents of the net were transferred to a 125 ml vial and preserved in 100% ethanol. Scrapes were taken on the same dates as traps were set.

After returning to the laboratory, troglofauna were extracted from the leaf litter bait used in traps using Tullgren® funnels under incandescent lamps. The light and heat drives the troglofauna and other invertebrates out of the litter into the base of the funnel containing 100% ethanol, which acts as a preservative. After about 72 hours, the ethanol and its contents were removed and sorted under a dissecting microscope. Litter from each funnel was also examined under a microscope for any remaining live or dead animals. Preserved scrapes were elutriated in the laboratory to separate animals from heavier sediment and screened into size fractions (250 and 90 µm) to remove debris and improve searching efficiency. Samples were then sorted under a dissecting microscope.

All fauna picked from scrapes or extracted from bait were examined for troglomorphic characteristics (lack of eyes and pigmentation, well developed sensory organs, slender appendages, vermiform body). Surface and soil-dwelling animals were identified only to Order level. Troglofauna were, as far as possible, identified to species/morphospecies level, unless damaged, juvenile or the wrong sex for identification. Identifications were based on morphology and made under dissecting and/or compound microscopes, with specimens dissected as necessary to aid their identification.

5.3. Personnel

Field survey was undertaken by Michael Curran and Anton Mittra. Species identifications were completed by Jane McRae and Stuart Halse. Maps were produced by Mike Scanlon. Reporting was completed by Anton Mittra and Huon Clark.

6. RESULTS

6.1. Stygofauna

A total of 1400 specimens belonging to 78 species of stygofauna were recorded from the Project and surrounding region during surveys conducted in 2016-2018 (Table 5). Reference sites yielded 1301 specimens of 79 species, while impact areas yielded 99 specimens of 6 species. Combining results from current and previous studies (Table 1), the total number of stygofauna species known from the broader Gifford Creek PEC study area is at least 80 species.

Major groups collected include flatworms (Turbellaria), annelids (Oligochaeta), rotifers (Rotifera), roundworms (Nematoda), ostracods (Ostracoda), copepods (Cyclopoida and Harpacticoida), amphipods (Amphipoda), slaters (Isopoda), aquatic mites (Acari) and beetles Coleoptera). Nine of the 10 stygofauna species recorded in the Ecoscape (2016) survey were recorded in the current survey (Ameiridae gen. nov. sp. B04, *Diacyclops cockingi*, *Diacyclops humphreysi humphreysi*, Orbuscyclops westaustraliensis, Areacandona sp. BOS550, Paramelitidae sp. B49, Phreodrilidae sp. AP DVC B12, Enchytraeidae sp. 21 and Nematoda sp.), and only one species (*Phreodrilus peniculus*) were not re-collected. Higher-order identifications were removed from the final species list to avoid artificial inflation of richness; these taxa are given in Appendix 4.

Results clearly demonstrate that the Gifford Creek Calcrete PEC hosts a highly diverse stygofaunal assemblage. Furthermore, at least 50 species recorded in the Ecoscape (2016) and current surveys (~48 % of species) are not known from elsewhere and are probably restricted to the PEC. Considering other extensively surveyed calcrete aquifers in Western Australia, the Gifford Creek Calcrete PEC is among the most diverse in terms of known species richness. In comparison, at least 70 species are known to occur in the Yeelirrie Calcrete PEC (Bennelongia 2015) and at least 58 species in calcretes associated with Lake Way and the PECs associated with it (Outback Ecology 2012).

The most diverse group in the area appears to be harpacticoid copepods, with 13 species. Twelve of these species are undescribed. Other notably diverse groups are ostracods (10 species), cyclopoid copepods (9) and amphipods (8).

6.1.1. Sampling Efficiency

Of the 136 stygofauna samples taken, 60 yielded stygofauna. Three troglofauna scrape samples yielded stygofauna. The collection of stygofauna in troglofauna samples is not unusual and may reflect fluctuations in the water table or scrape samples being taken from very close to the water table.

Targeted stygofauna samples in reference areas yielded an average of 12.23 specimens and 2.28 species per sample, while those in impact areas averaged 11.11 specimens and 1.66 species per sample.

Table 5. Stygofauna recorded at the Yangibana Project and surrounding areas in 2016 to 2018.
Values are absolute abundance. Higher order identifications not included in final list of species are given in Appendix 4.

Higher Taxonomy	Lowest Identification	Abundance			Comments on Distribution
		Impact	Reference	Total	
Nematoda	Nematoda sp.	4	96	100	Not assessed in EIA.
Platyhelminthes					
Turbellaria	Microturbellaria sp.		3	3	Not assessed in EIA.
Rotifera					
Bdelloidea	Bdelloidea sp. 2:2		45	45	Not assessed in EIA.
	Bdelloidea sp. 3:3		5	5	Not assessed in EIA.
Monogononta					
Flosculariidae	Flosculariidae sp.		2	2	Not assessed in EIA.
Lecanidae	Lecane bulla		2	2	Not assessed in EIA.
Annelida					
Aphanoneura					
Aeolosomatidae	Aeolosoma sp.		8	8	Likely to be widespread
Clitellata					
Enchytraeidae	Enchytraeidae sp. B20		2	2	PEC endemic?
	Enchytraeidae sp. B21	10	4	14	PEC endemic?
Naididae	*Dero (Aulophorus) furcatus*		5	5	Widespread
	Pristina aequiseta		7	7	Common throughout WA
	Pristina longiseta		92	92	Cosmopolitan (ABRS 2009).
Phreodrilidae	Phreodrilidae sp. AP DVC B12	6	35	41	PEC endemic?
	Phreodrilidae sp. AP SVC B13		14	14	PEC endemic?
Tubificidae	Tubificidae sp. B04		3	3	PEC endemic?
Arthropoda					
Arachnida					
Piersigiidae	nr *Stygolimnochares* sp. B02		1	1	PEC endemic?
Insecta					
Dytiscidae	*Paroster* sp. B02		4	4	PEC endemic?
	Paroster sp. B03		1	1	PEC endemic?
	Paroster sp. B04		1	1	PEC endemic?
Malacostraca					
Bathynellidae	*Bathynella* sp. B31		3	3	PEC endemic?.
Bogidiellidae	*Bogidiella* sp. B06		1	1	PEC endemic?
Eriopisidae	*Nedsia* sp. B06 (*hurlberti* group)		50	50	PEC endemic?.
Melitidae	Melitidae sp. 1 group (PSS)		1	1	Higher order identification
Microcerberidae	Microcerberidae sp.		1	1	Higher order identification from a juvenile specimen
Parabathynellidae	*Atopobathynella* sp. B30		3	3	PEC endemic?
	Brevisomabathynella sp. B09		1	1	PEC endemic?
	nr *Atopobathynella* sp. B21		5	5	PEC endemic?
	nr *Atopobathynella* sp. B22		3	3	PEC endemic?
Paramelitidae	*Maarrka* sp. B02		1	1	PEC endemic?
	Paramelitidae sp. B49	10	18	28	PEC endemic?
	Paramelitidae sp. B51		48	48	PEC endemic?
	Paramelitidae sp. B52		4	4	PEC endemic?
	Paramelitidae sp. B53		2	2	PEC endemic?
	Paramelitidae sp. B54		1	1	PEC endemic?
	Paramelitidae sp. B55		18	18	PEC endemic?
Tainisopidae	*Pygolabis* sp. B11		6	6	PEC endemic?.
Maxillopoda					
Ameiridae	Ameiridae gen. nov. sp. B04		15	15	PEC endemic?
	Nitokra lacustris pacifica		6	6	Very widespread
Canthocamptidae	*Australocamptus* sp. B16		5	5	PEC endemic?
	Australocamptus sp. B17		4	4	PEC endemic?
Cyclopidae	*Australoeucyclops karaytugi*		2	2	Australia-wide distribution (ABRS

Higher Taxonomy	Lowest Identification	Abundance			Comments on Distribution
					2009).
	Diacyclops cockingi		72	72	Widespread throughout Pilbara and Yilgarn (Karanovic 2006).
	Diacyclops humphreysi humphreysi	62	50	112	Widespread throughout Pilbara and Yilgarn (Karanovic 2006).
	Diacyclops humphreysi unispinosus		1	1	Not restricted to the Project area
	Fierscyclops (Fierscyclops) fiersi		5	5	Widespread throughout Pilbara and Yilgarn (Karanovic 2004).
	Mesocyclops brooksi		24	24	Australia-wide distribution (ABRS 2009).
	Mesocyclops notius		85	85	Australia-wide distribution (ABRS 2009).
	Metacyclops sp. B06		56	56	PEC endemic?
	Microcyclops varicans	7	128	135	Australia-wide distribution (ABRS 2009).
	nr *Eucyclops* (ngen?) sp. B01		8	8	PEC endemic?
	Orbuscyclops westaustraliensis		1	1	Widespread species
Ectinosomatidae	*Pseudectinosoma* sp. B02		8	8	PEC endemic?
Miraciidae	*Schizopera* sp. B25		4	4	PEC endemic?
	Schizopera sp. B26		3	3	PEC endemic?
	Schizopera sp. B27		2	2	PEC endemic?
	Schizopera sp. B28		5	5	PEC endemic?
	Schizopera sp. B29		2	2	PEC endemic?
	Schizopera sp. B30		3	3	PEC endemic?
Parastenocarididae	*Parastenocaris* sp. B37		25	25	PEC endemic?
	Parastenocaris sp. B38		4	4	PEC endemic?
Ostracoda					
Candonidae	*Areacandona* sp. BOS550		5	5	PEC endemic?
	Areacandona sp. BOS675		8	8	PEC endemic?
	Candonidae sp. BOS1108		9	9	PEC endemic?
	Candonidae sp. BOS1110		12	12	PEC endemic?
	Candonidae sp. BOS1113		13	13	PEC endemic?
	Candonidae sp. BOS1116		8	8	PEC endemic?
	Candonidae sp. BOS1121		2	2	PEC endemic?
	Candonopsis sp. BOS1118		3	3	PEC endemic?
	Candonopsis tenuis		70	70	Widespread outside study area (ABRS 2009).
	Deminutiocandona murrayi		3	3	Also known from Pilbara (Karanovic 2007).
	Humphreyscandona sp. BOS1124		2	2	PEC endemic?
Cyprididae	*Candonocypris novaezelandiae*		5	5	Widespread
	Cypricercus sp. BOS908		3	3	PEC endemic?
	Cyprinopsinae sp. BOS1112		4	4	PEC endemic?
	Riocypris fitzroyi		78	78	Pilbara/Kimberley
	Sarscypridopsis aff. *aculeata*		23	23	Widespread
	Strandesia sp. 466.		6	6	Widespread
Limnocytheridae	*Limnocythere dorsosicula*		33	33	Widespread outside the study area (ABRS 2009).
Total		**99**	**1301**	**1400**	

*Total abundance was calculated to include higher-order identifications that were not included in final count of species.
#Does not include results from previous surveys and literature, which augment number of known species to 80.

6.1.2. Distribution of Stygofauna Species

All species of stygofauna recorded in the current survey were present in reference areas, while eight species also occurred inside 2 m drawdown contours associated with dewatering at proposed development sites (i.e. impact areas). Records of stygofauna in impact areas included 11 specimens from two species at Bald Hill, 132 specimens from six species at Yangibana North and two specimens from one species at Yangibana West. No stygofauna species were found at Frasers pit nor at the

SipHon Well Borefield. Of the eight species recorded in impact areas, seven species (*Phreodrilus peniculus Diacyclops cockingi, Diacyclops humphreysi humphreysi*, *Microcyclops varicans*, Phreodrilidae sp. AP DVC B12, *Enchytraeus* sp. 21 and Nematoda sp.) are common species that are widespread outside the study area. The remaining species, Paramelitidae sp. B49, is probably endemic to the local calcrete PEC but it was recorded in moderate abundance throughout the study area, including reference areas, and has a known range of approximately 1,000km^2.

Ecoscape (2016) noted three species of stygofauna as being of potential conservation concern: the harpacticoid *Ameiridae* gen. nov. sp. B04; the ostracod *Areacandona* sp. BOS550; and the amphipod Paramelitidae sp. B49. Based on drawdown modelling (GRM 2017, 2018), collection locations for all three of these species are now considered to occur in reference areas as they occur outside the 2 m drawdown contour (Figure 5). Two of these species were also collected in the current survey at reference locations: Ameiridae gen. nov. sp. B04 was recorded from three additional regional reference sites (Figure 5); and Paramelitidae sp. B49 was recorded from eight additional reference sites (Figure 5).

The fact that all stygofauna species collected from impact areas were also found in reference areas provides evidence that groundwater drawdown associated with mine dewatering at the Bald Hill, Frasers and Yangibana West/North deposits is not likely to threaten the persistence of stygofauna species.

6.2. Troglofauna

Seventeen specimens representing 12 distinct species of troglofauna were recorded from 20 drill holes in the study area in 2016 and 2017 (Table 6). Five troglofauna specimens of four species were collected in traps, eleven troglofaunal animals of seven species were collected in stygofauna samples and one troglofauna specimen was collected in a scrape sample. One specimen of the millipede family Lophoproctidae was damaged and could not be identified further (i.e. Lophoproctidae sp.). It probably belongs to the widespread species *Lophoturus madecassus*, which was also collected, and so is not treated as a separate species. All species were collected in very low abundances as either one or two individuals (Table 6).

After appropriately aligning Ecoscape (2016) and current results, there are at least 15 species of troglofauna known from the study area, including a palpigrade, three isopods, three centipedes, a millipede, a symphylan, two diplurans, a sciarid fly, a meenoplid bug and a silverfish. At least six of these species are considered likely to be restricted to the study area, although assessments of endemism are limited by unresolved taxonomy in many groups. Two taxa recorded in the current survey may be species collected and more fully identified by Ecoscape (2016) and they treated as the same species when calculating species richness: the specimen of *Scutigerella* sp. is considered to be *Scutigerella* sp. B09; and *Trinemura* sp. is treated as belonging to *Trinemura* sp. B29. Overall, the Project area appears to harbour a troglofauna community of low-to-moderate diversity. Additional sampling is likely to increase known ranges of some species and would probably also augment the number of known species.

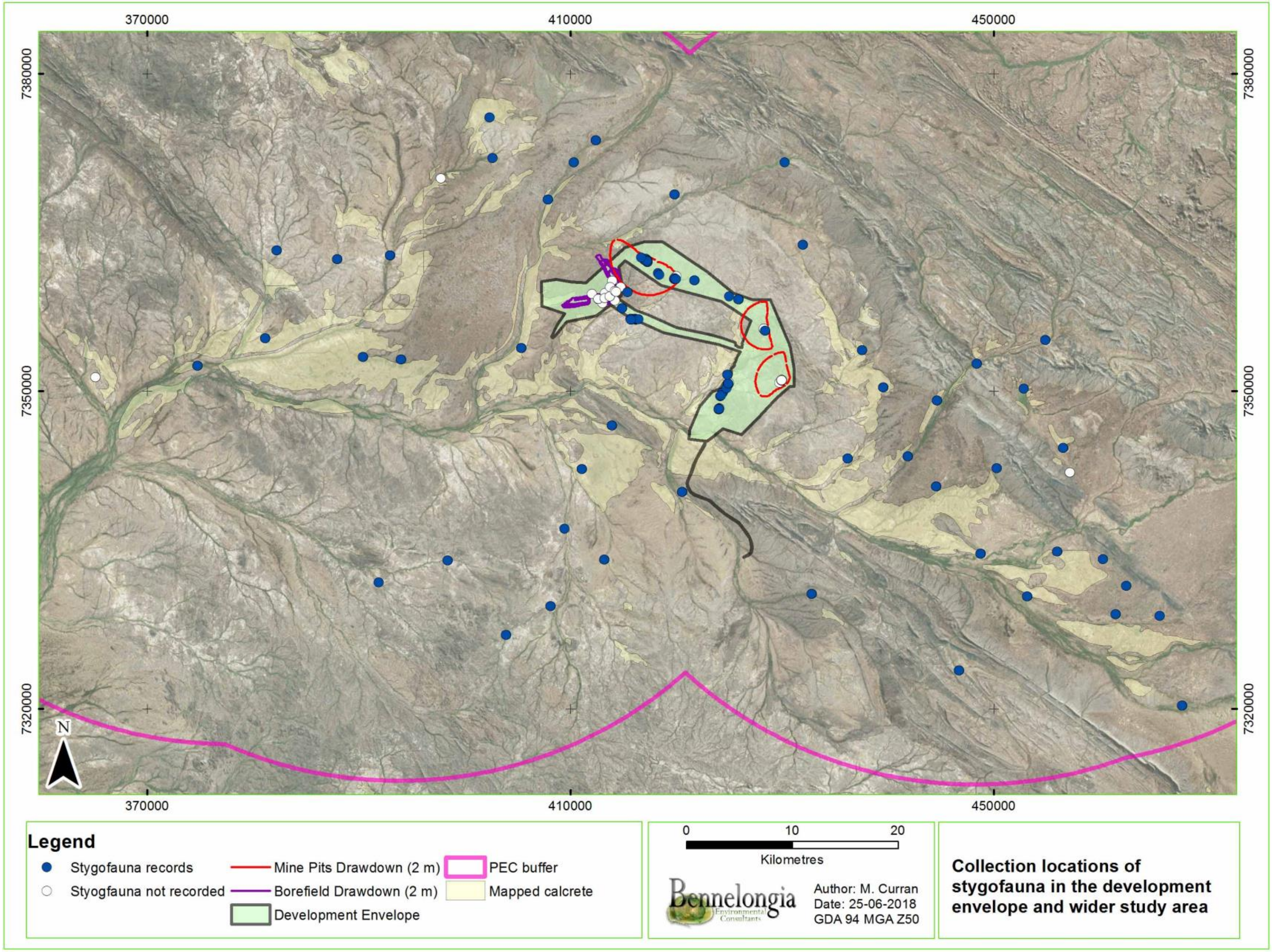

Figure 5. Collection locations for stygofauna within the development envelope and wider study area.

Table 6. Troglofauna recorded in the Project area in 2016 and 2017.
Values are the number of specimens. Higher order taxa likely to belong to recorded species are denoted by '*' and were not included in final counts of species. Species shaded in grey are only known from impact areas.

Higher Taxonomy	Lowest Identification	Number of Specimens			Comments on Distribution
		Impact	Reference	Total	
Arthropoda					
Chelicerata					
Arachnida					
Palpigradi	Palpigradi sp. B21		1	1	Median range for troglofaunal palpigrades in Pilbara is 345 km^2, although group poorly studied[2]
Crustacea					
Malacostraca					
Isopoda					
Platyarthridae	*Trichorhina* sp. B29		1	1	Likely to have small range[3]
Stenoniscidae	Stenoniscidae gen. nov. sp. B07		1	1	PEC endemic?
Hexapoda					
Entognatha					
Diplura					
Parajapygidae	Parajapygidae sp. B41	2		2	Known linear range of 0.25 km; possibly endemic
Insecta					
Diptera					
Sciaridae	Sciaridae sp. B01		1	1	Widespread[6]
Hemiptera					
Meenoplidae	*Phaconeura* sp.		2	2	Likely to be widespread[8]
Thysanura					
Nicoletiidae	*Trinemura* sp.		1	1	May be *Trinemura* sp. B29 [7]
Myriapoda					
Chilopoda					
Geophilida					
Chilenophilidae	Chilenophilidae sp.	1		1	Partial specimen, may be Chilenophilidae sp. B09
	Chilenophilidae sp. B09	1		1	PEC endemic?
Schendylidae	Schendylidae sp.	2		2	Both specimens probably same species
Diplopoda					
Polyxenida					
Lophoproctidae	Lophoproctidae sp.	1		1	Likely to be *Lophoturus madecassus*
	Lophoturus madecassus		2	2	Widespread[4,5]
Symphyla					
Cephalostigmata					
Scutigerellidae	*Scutigerella* sp.	1		1	May be *Scutigerella* sp. B09[7]
Total		**8**	**9**	**17**	

[1]Halse and Pearson 2014; [2]Barranco and Harvey 2008; [3]Javidkar 2014; [4]Bennelongia 2012; [5]Bennelongia 2008c; [6]Bennelongia 2014; [7]Ecoscape 2016; Bennelongia unpublished data.

6.2.1. Sampling Efficiency

Of the 20 troglofauna samples collected, only four yielded troglofaunal (three by trapping and one by scraping). Seven stygofauna net samples yielded troglofauna. The collection of troglofauna in stygofauna samples is not unusual and may reflect the capture of animals on the sidewalls of drill holes, as per scrape sampling. Analysis of the efficiency of troglofauna sampling is somewhat confounded by the poor success rate of targeted sampling types (traps and scrapes) combined with incidental collections of troglofauna in stygofauna samples.

Targeted troglofauna samples (combined traps and scrapes in each hole) in reference areas yielded an average of 0.4 specimens and 0.33 species per sample, while those in impact areas did not yield any troglofauna. Stygofauna net samples taken from holes inside deposit boundaries (including reference and impact samples across Bald Hill, Frasers and Yangibana North; Figure 3) yielded, on average, 0.67 specimens and 0.4 species per sample.

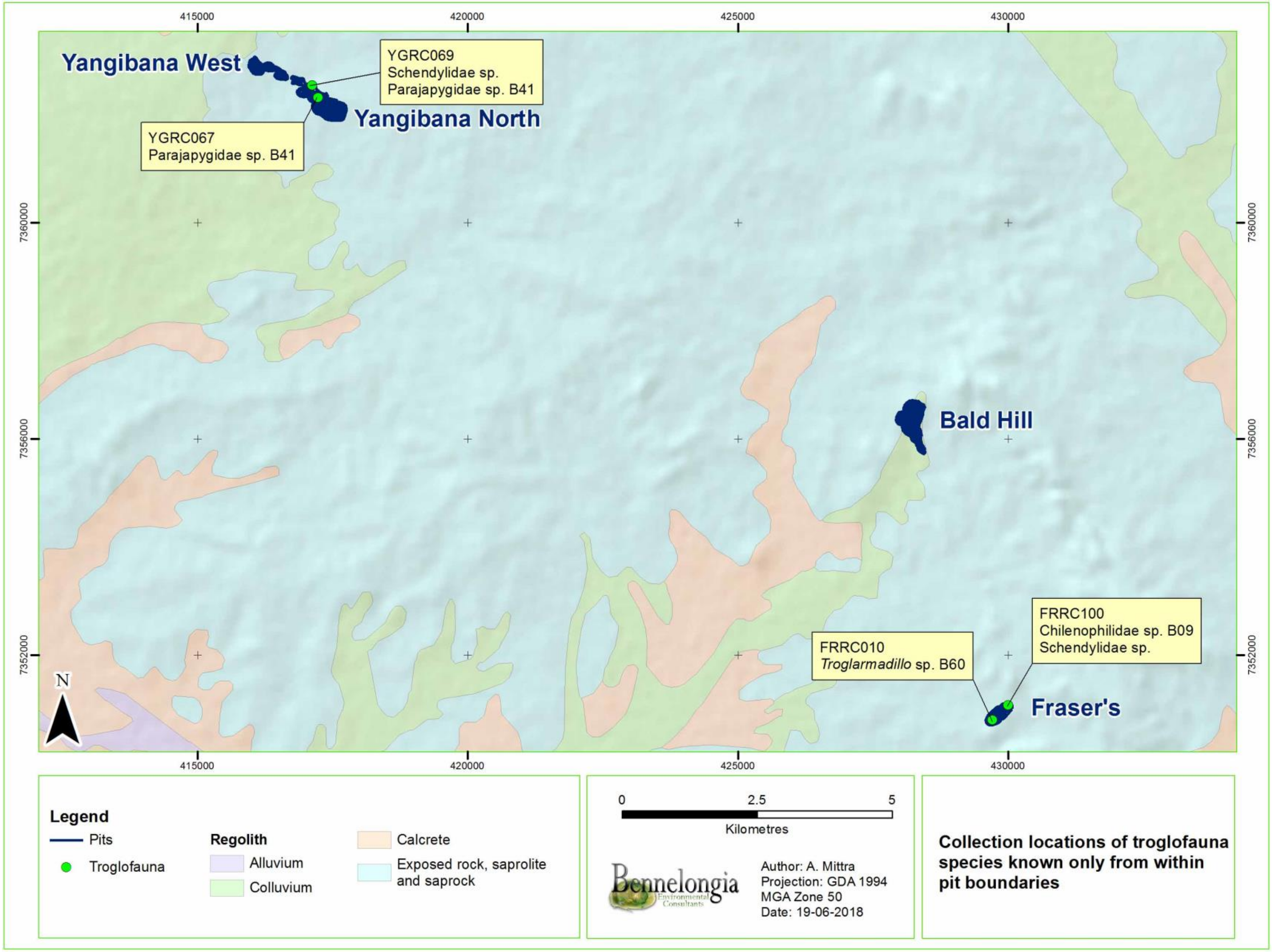

Figure 6. Collection locations for troglofauna, including species known only from proposed mine pits.

6.2.2. Distributions of Troglofauna Species

Holes in three deposit areas planned for development yielded troglofauna – Frasers, Yangibana North and Yangibana West. Underlying geology of these deposits is largely granite and granitoid rock (PLgpi), with some unconsolidated ferruginous rubble and scree (C1f) present at Frasers (Ecoscape 2016). Troglofauna were also collected from the Bald Hill and Kanes Gossan deposits by Ecoscape (2016) but were not recorded there in the current survey. Bald Hill geology comprises granites (PLgpi and PLgpix) and unconsolidated units (C1f), while geology at Kanes Gossan largely comprises granite (PLgpi) (Ecoscape 2016). Additionally, the troglofaunal hemipteran *Phaconeura* sp. was collected from calcrete in a stygofauna sample in the regional reference site No. 1 Bore. Granite and granitoid units occur widely throughout the study area and may provide suitable habitat for troglofauna in areas that are not proposed for development. The presence of troglofauna at Gossan and Kanes Gossan, which are not currently proposed for development, provides evidence that prospective troglofauna habitat occurs outside proposed development areas. Three specimens from three species were collected in the current survey at Gossan (Palpigradi sp. B21, Sciaridae sp. B01 and *Trichorhina* sp. B29), while four specimens of three species were collected by Ecoscape (2016) at Kanes Gossan (Geophilidae sp., Projapygidae sp. B19 and *Trinemura* sp. B29).

Eight of the 10 troglofauna species in the current survey were recorded at single sites, and the centipede Schendylidae sp. and the dipluran Parajapygidae sp. B41 were each collected at two sites. Schendylidae sp has a known linear range of approximately 17 km, while collection sites for Parajapygidae sp. B41 were separated by just 0.25 km (Figure 5). The centipede Chilenophilidae sp. B09 was also located from one impacted site but an additional specimen that could only be identified to family level (Chilenophilidae sp.) was also identified 17 km away.

Six species were recorded in reference areas and, therefore, are not of conservation concern (Table 4). An additional higher-order identification, Lophoproctidae sp., was only recorded at a single impact site, but as this taxon is considered likely to belong to the widespread species *Lophoturus madecassus*, it is currently not of conservation significance. The symphylan *Scutigerella* sp. was recorded as a singleton at the impact site YGWB001, but as it possibly belongs to *Scutigerella* sp. B09 that was recorded previously at a reference site (Ecoscape 2016), it is not currently considered to be of conservation concern.

The troglofaunal isopod *Troglarmadillo* sp. B60, collected by Ecoscape (2016) and three troglofauna species recorded in the current survey are known only from impact areas (Figure 3) and are of potential conservation concern. They are discussed in further detail below.

<u>Centipedes</u>

Single individuals of the centipede Schendylidae sp. were collected from two impact holes. The distance between the two locations is approximately 17 km (Figure 6) and the individuals are considered to probably represent the same species.

One Chilenophilidae sp. B09 was identified from within the impact zone at the Frasers deposit and another damaged individual that could only be identified to family level (Chilenophilidae sp.) was located 17 km away at a Yangibana North impact site. This is considered likely to be another Chilenophilidae sp. B09 individual, partly because a species of Geophilidae was also recorded in the survey area (Ecoscape 2016) at reference site KGRC011 and three species of centipede is an unusually high number of centipedes. Occurrence of another Chilenophilidae is unlikely.

Halse and Pearson (2014) estimated a median range for troglofaunal centipede species in the Pilbara of 30 km^2. This is a far greater area than the proposed mine operations area and suggests that it is reasonably likely that both Chilenophilidae sp. and Schendylidae sp. also occur in reference areas. Furthermore, areas not proposed for excavation or developments occur between collection locations, with the two species recorded from both Yangibana North and Frasers pits (Figure 6). Intermediate areas consisting mainly of PLgpi geological units, which is found in collection locations, and thus may provide similar habitat. This suggests that both species occur in reference areas interspersed between proposed pits, if not further afield.

Parajapygidae sp. B41

Subterranean diplurans, and indeed all members of the hexapod order Dilpura, are poorly studied in Western Australia, and much of their lower systematics remains unchartered. Koch (2009) suggested that diplurans were diverse in arid and semi-arid regions of WA.

Parajapygidae sp. B41 is one of two dipluran species that have been recorded from the Project area and each represents a separate family. Projapygidae sp. B19 was recorded from a hole at the Kanes Gossan deposit that is now considered to be a reference location (Ecoscape 2016). Parajapygidae sp. B41 was recorded from two holes separated by approximately 0.25 km in the Yangibana North impact area (Figure 5). Troglofaunal species of Diplura in the Pilbara have estimated median ranges of 16 km^2 (Halse and Pearson 2014), suggesting that Parajapygidae sp. B41 is reasonably likely to occur outside the proposed operations area. The notion that it occurs in reference areas is further supported by the continuation of deposit geology (PLgpi) outside impact areas (Figure 5). However, without actual field collections, estimates of range size for this likely SRE species remain conjectural. This species is therefore considered to be of potential conservation concern.

***Troglarmadillo* sp. B60**

Two males and one female belonging to the troglofaunal isopod species *Troglarmadillo* sp. B60 were collected from a single hole in the impact area at the Frasers deposit by Ecoscape (2016). The species was not recollected in the current survey. Based on previous biogeographic studies of subterranean isopods in the Yilgarn, it is highly likely that *Troglarmadillo* sp. B60 is a short range endemic that is restricted to the prevailing calcrete PEC. In a study of 12 calcrete aquifers along three palaeodrainages in the Yilgarn, Javidkar (2014) identified 28 discrete lineages of subterranean isopods, each of which probably represents a new species. Furthermore, only three lineages were recorded from more than one calcrete, invariably from neighbouring calcretes within a single palaeodrainage, while the remaining species were restricted to individual aquifers. This exemplifies the high incidence of short range endemism among subterranean isopods in Western Australia (see also Cooper *et al*. 2008).

Given that *Troglarmadillo* sp. B60 is a new SRE species that has not been recorded in reference areas, it is considered to be of potential conservation concern. However, the notion that it occurs in reference areas is supported by the continuation of deposit geology (PLgpi) outside impact areas (Figure 6).

7. POTENTIAL IMPACTS ON SUBTERRANEAN FAUNA

7.1. Stygofauna

All stygofauna species known from the Project area have been recorded in areas outside the 2 m drawdown contour inferred from hydrological modelling by GRM (2017, 2018). Two-metre drawdown contours associated with proposed developments (Figure 3) were considered appropriate delineators between reference and impact areas because (a) the occurrence of calcrete in the immediate vicinity of proposed development areas is low, meaning that drawdown affecting calcrete aquifers will be relatively insignificant in the regional context; and (b) the likely depth and volume of calcrete aquifers in the vicinity of proposed development areas means that substantial stygofauna habitat would remain intact outside the 2 m drawdown contour.

Geologies of the proposed excavation areas at the Bald Hill, Frasers, Yangibana North and Yangibana West largely comprise consolidated granite and granitoid units (PLgpi) that are generally unconducive to stygofauna. Sampling in impact areas yielded significantly fewer animals and species per sample than in reference areas (that for the most part coincided within calcrete aquifers). Furthermore, stygofauna species recorded in impact areas were also collected in reference areas, and are common species that are known to be widespread outside the study area.

It is considered unlikely that dewatering, excavation and other mine-related activities at the Project will have any substantial impacts on the conservation values of stygofauna communities or the persistence of any individual species.

7.2. Troglofauna

The primary mine-related factor contributing to the loss of troglofauna habitat is mine pit excavation. In the case of proposed mining operations at the Project, pit excavations are the only proposed operations that will result in significant loss of troglofauna habitat.

As discussed in Section 6, four troglofauna species were only recorded from inside proposed pit boundaries, however it is considered highly likely that two of these, the centipedes Chilenophilidae sp. and Schendylidae sp., occur outside the impact areas. Although there is some identification uncertainty, it is considered likely that both species were recorded from two pits and have known linear ranges of approximately 17 km, with collection locations interspersed by reference areas with similar granite geologies to collection locations. Thus, these centipede species are not currently considered to be of conservation concern.

The dipluran Parajapygidae sp. B41 and the isopod *Troglarmadillo* sp. B60 remain known only from inside proposed pit boundaries and their occurrence outside these areas remains speculative. Parajapygidae sp. B41 was collected from two holes (YGRC069 and YGRC067) in the Yangibana North deposit and has a known linear range of approximately 0.25 km. A total of 6 impact holes have been surveyed for troglofauna in the Yangibana North deposit, but no reference holes; 3 reference holes have been surveyed in the adjoining Yangibana West deposit. *Troglarmadillo* sp. B60 was recorded as three individuals from a single hole in the Frasers deposit, where a total of 5 reference and 7 impact holes have been surveyed for troglofauna.

Two pieces of evidence provide some support to the notion that both Parajapygidae sp. B41 and *Troglarmadillo* sp. B60 are likely to occur in reference areas. Firstly, granite and granitoid (PLgpi) geologies similar to those at collection locations occur extensively in reference areas outside proposed development areas. This suggests that habitat suitable for both species probably occurs in reference areas. The presence of troglofauna at the Gossan and Kanes Gossan deposits, which are not currently proposed for development, shows that prospective troglofauna habitat occurs in granite units outside proposed development areas.

Secondly, yield rates for troglofauna sampling, including yields of troglofauna in stygofauna samples, were very low, suggesting either low troglofauna population densities, a high degree of sampling difficulty, or a combination of both these limiting factors. It is inferred that sampling effort was insufficient to collect further specimens of Parajapygidae sp. B41 or *Troglarmadillo* sp. B60.

8. CONCLUSION

This report summarised the results of previous and current field surveys of subterranean fauna at the Yangibana Project and surrounding area, including the Priority 1 PEC, '*Gifford Creek, Mangaroon, Wanna calcrete groundwater assemblage type on Lyons palaeodrainage on Gifford Creek, Lyons and Wanna Stations*'. It subsequently evaluated the risks posed by proposed mining operations, including excavations and dewatering, to the conservation values of subterranean fauna communities and species.

Combining results of previous and current studies, at least 80 species of stygofauna have been recorded in the study area, making it one of the most speciose assemblages of stygofauna known from WA. Recorded taxa include flatworms (Turbellaria), earthworms (Oligochaeta), rotifers (Rotifera), nematode roundworms (Nematoda), ostracods (Ostracoda), copepods (Cyclopoida and Harpacticoida), amphipods (Amphipoda), isopods (Isopoda), aquatic mites (Arachnida: Acari) and beetles (Insecta: Coleoptera). Notably diverse groups include harpacticoid copepods (13 species), ostracods (11 species), cyclopoid copepods (9) and amphipods (8). Just under half of the species recorded are undescribed and are likely to be restricted (endemic) to the study area, particularly the calcrete aquifers of the PEC. The suitability of calcrete geologies as stygofauna habitat was demonstrated by significantly higher yield rates in terms of both abundance and species in calcrete samples than in those taken from granite geologies.

All stygofauna species that have been recorded in the study area, including those previously thought to be of conservation concern, are known from reference areas outside predicted 2 m drawdown contours associated with proposed developments. This provides evidence that the conservation values of stygal species and communities will not be threatened by mine-related activities at the Project.

Combining historic and current studies, a total of 13 species of troglofauna have been recorded from the study area in subterranean spaces above the water table. At least six of these are considered likely to be endemic to the study area, although range assessments are hampered by unresolved taxonomy in many troglofauna groups, and the rate of endemism may indeed be higher. Targeted troglofauna sampling was largely confined to deposit areas in granite and granitoid geologies and yield rates were low in terms of both abundance and species per sample. It would appear that the Project area hosts a low-to-moderately diverse troglofaunal assemblage, although additional sampling would probably augment the number of known species.

Many troglofauna species previously considered to be of potential conservation concern were, in the light of updated pit boundaries, actually collected from reference locations. Considering all records of troglofauna at the Project, four species are of possible concern – the centipedes Chilenophilidae sp. and Schendylidae sp., the dipluran Parajapygidae sp. B41 and the isopod *Troglarmadillo* sp. B60. Both centipede species were recorded from two deposits and have linear ranges of approximately 17 km. Troglofaunal centipedes have estimated median ranges of 30 km^2. Furthermore, the geological unit from which both centipede species were collected is continuous throughout reference and impact areas, and probably provides suitable habitat away from proposed development sites. It is considered likely that both Chilenophilidae sp. and Schendylidae sp. occur in reference areas and are therefore not of great conservation concern.

The dipluran Parajapygidae sp. B41 was collected from two holes at the Yangibana North deposit and has a known linear range of approximately 0.25 km. However, the median linear range troglofaunal dipluran species in the Pilbara is estimated to be at least 4.5 km (Halse 2018) and such a range would mean the species occurs outside the proposed mine pit at Yangibana North. The isopod *Troglarmadillo* sp. B60 is known from a single hole in the Frasers deposit impact area. Existing data suggest the median linear ranges of troglofaunal Pilbara isopods is at least 1.8 km and such a range would mean the species occurs outside Frasers. Geology also suggests it is likely both species have wider ranges than the deposits in which they were collected. The geological units from which both taxa were collected are continuous across reference and impact areas..

Considering sampling results and the probable distributions of recorded troglofauna species, the risk to the conservation values of troglofauna communities and species from operations at the Project is considered to be low.

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Appendix 1. Secondary impacts of mining on subterranean fauna.

Mining activities that may result in secondary impacts to subterranean fauna include:

1. *De-watering below troglofauna habitat*. The impact of a lowered water table on subterranean humidity and, therefore, the quality of troglofauna habitat is poorly studied but it may represent risk to troglofauna species in some cases. The extent to which humidity of the vadose zone is affected by depth to the watertable is unclear. Given that pockets of residual water probably remain trapped throughout de-watered areas and keep the overlying substrate saturated with water vapour, de-watering may have minimal impact on the humidity in the unsaturated zone. In addition, troglofauna may be able to avoid undesirable effects of a habitat drying out by moving deeper into the substrate if suitable habitat exists at depth. Overall, de-watering outside the proposed mine pits is not considered to be a significant risk to troglofauna.
2. *Percussion from blasting*. Impacts on both stygofauna and troglofauna may occur through the physical effect of explosions. Blasting may also have indirect detrimental effects through altering underground structure (usually rock fragmentation and collapse of voids) and transient increases in groundwater turbidity. The effects of blasting are often referred to in grey literature but are poorly quantified and have not been related to ecological impacts. Any effects of blasting are likely to dissipate rapidly with distance from the pit and are not considered to be a significant risk to either stygofauna or troglofauna outside the proposed mine pits.
3. *Overburden stockpiles and waste dumps*. These artificial landforms may cause localised reduction in rainfall recharge and associated inflow of dissolved organic matter and nutrients because water runs off stockpiles rather than infiltrating through them and into the underlying ground. The effects of reduced carbon and nutrient input are likely to be expressed over many years and are likely to be greater for troglofauna than stygofauna (because lateral movement of groundwater should bring in carbon and nutrients). The extent of impacts on troglofauna will largely depend on the importance of chemoautotrophy in driving the subterranean system compared with infiltration-transported surface energy and nutrients. Stockpiles are unlikely to cause species extinctions, although population densities of species may decrease under them.
4. *Aquifer recharge with poor quality water*. It has been observed that the quality of recharge water declines during, and after mining operations as a result of rock break up and soil disturbance (i.e. Gajowiec 1993; McAuley and Kozar 2006). Impacts can be minimised through management of surface water and installing drainage channels, sumps and pump in the pit to prevent recharge though the pit floor.
5. *Contamination of groundwater by hydrocarbons*. Any contamination is likely to be localised and may be minimised by engineering and management practices to ensure the containment of hydrocarbon products.

Appendix 2. List of sampling sites for stygofauna in October 2016.

Site Identification	Orebody	Latitude	Longitude	Type	Date	Sample Method#	Groundwater Depth (m)	Depth of Hole (m)	Temperature (°C)	EC (µS cm^{-1})	pH
BHRC082	Bald Hill	-23.90855939	116.2965337	Reference	5/10/2016	Net	23.09	49	30	1759	7.44
BHRC158	Bald Hill	-23.90733035	116.295256	Reference	5/10/2016	Net	23.6	57	27.6	398	7.1
BHRC160	Bald Hill	-23.90688341	116.2957598	Impact	5/10/2016	Net	25.25	54	33.8	498	7.04
BHRC164	Bald Hill	-23.90643161	116.2951837	Impact	5/10/2016	Net	25.76	48	30.3	755	6.75
Minga Well	Edmund Station	-23.7954585	116.095883	Reference	9/10/2016	Net	4.21	5	22.2	17	7.25
No. 1 Bore	Edmund Station	-23.72481296	116.0421623	Reference	9/10/2016	Net	4.42	6.4	22.6	17	7.6
Old Shed Bore	Edmund Station	-23.75947274	116.0446259	Reference	9/10/2016	Net	7.94	12	23.8	16.1	7.27
FRRC074	Frasers	-23.950612	116.3116682	Impact	5/10/2016	Net	34.62	41.6	26.7	215	7.07
FRRC075	Frasers	-23.95045228	116.3114999	Impact	6/10/2016	Net	34.07	42	27.5	75.1	7.15
FRRC080	Frasers	-23.95099592	116.311481	Impact	5/10/2016	Net	35.9	43.4	28.2	276	7.1
FRRC082	Frasers	-23.95083989	116.3113088	Impact	5/10/2016	Net	34.08	50.58	30.5	310	6.88
FRRC098	Frasers	-23.95284862	116.3097478	Reference	5/10/2016	Net	32.13	41.5	34	316	6.9
FRRC100	Frasers	-23.95060093	116.3120397	Impact	6/10/2016	Net	35.73	44	26.9	2082	7.09
Buffer Well	Gifford Creek Station	-23.92865971	115.9229582	Reference	9/10/2016	Pump	-	-	26.5	61.7	6.81
Burts Bore	Gifford Creek Station	-24.02557693	116.1254482	Reference	10/10/2016	Pump	-	-	22.9	5480	7.55
Burts Well	Gifford Creek Station	-24.02554393	116.1256126	Reference	10/10/2016	Net	5	18.5	22.3	7650	7.7
Dixons Well	Gifford Creek Station	-24.13324093	116.3384921	Reference	8/10/2016	Pump	-	-	25.3	566	7.46
Edmund Well	Gifford Creek Station	-23.92192443	116.0700261	Reference	9/10/2016	Net	12.39	13	27.7	3540	7.37
Elliot Well	Gifford Creek Station	-24.01607222	116.4285924	Reference	8/10/2016	Pump	-	-	27.6	42.2	6.7
Foxys Bore	Gifford Creek Station	-23.83506353	116.3316856	Reference	7/10/2016	Pump	-	-	29.8	2156	7.09
Fraser Well	Gifford Creek Station	-23.94588443	116.2614996	Reference	10/10/2016	Net	10.79	34.5	23	2780	7.37
Hart Bore	Gifford Creek Station	-24.01769607	116.372702	Reference	8/10/2016	Pump	-	-	27.1	46.7	7.08
Hawkes Nest Bore	Gifford Creek Station	-23.93104944	115.958275	Reference	9/10/2016	Pump	-	-	28.7	2870	6.96
Henderson Bore	Gifford Creek Station	-23.92530284	116.38635	Reference	7/10/2016	Pump	-	-	26.6	6170	7.67
Judys Bore*	Gifford Creek Station	-24.09971308	116.4956005	Reference	8/10/2016	Pump	-	-	29.1	78.2	7.32
Minga Bore	Gifford Creek Station	-23.88136783	116.2719768	Reference	7/10/2016	Net	-	-	25.6	3050	7.44
Pimbyana Bore	Gifford Creek Station	-23.95731252	116.4059847	Reference	7/10/2016	Pump	-	-	28.1	2510	7.43
Range Bore	Gifford Creek Station	-24.0267352	116.5110249	Reference	8/10/2016	Pump	-	-	27	2279	7.37
Roadside Bore	Gifford Creek Station	-23.96855254	116.4559119	Reference	7/10/2016	Pump	-	-	26.5	3580	7.81
Stone Tank Bore	Gifford Creek Station	-23.93721025	116.4927801	Reference	7/10/2016	Net	6.67	16	30.1	3070	6.77
Swamp Bore	Gifford Creek Station	-23.95867834	116.5363186	Reference	7/10/2016	Pump	-	-	30.7	198.1	7.03
Terminus Bore	Gifford Creek Station	-24.00952379	116.5729493	Reference	7/10/2016	Pump	-	-	30	167.8	6.92
Woodsys Bore	Gifford Creek Station	-23.98868246	116.1535755	Reference	9/10/2016	Pump	-	-	26.6	2990	7.52
Yangibana Bore	Gifford Creek Station	-23.88842296	116.1637604	Reference	9/10/2016	Net	10.67	17	26.7	33.7	7.05
Alma Well	Mangaroon Station	-23.91219602	115.8323321	Reference	9/10/2016	Net	13.39	14	28.3	8340	7.23
No. 1 Bore	Mangaroon Station	-23.94401164	115.6746289	Reference	9/10/2016	Pump	-	-	26.8	6810	7.27
River Bore	Mangaroon Station	-23.93505681	115.7693148	Reference	9/10/2016	Pump	-	-	25.3	2960	7.43
Middle Well	Maroonah Station	-23.84224323	115.9490486	Reference	9/10/2016	Net	5.34	7	26.6	3590	6.96
Old Alma Well	Maroonah Station	-23.84515529	115.8999084	Reference	9/10/2016	Net	4.71	6.71	28.7	1576	7.25
Pooranoo Well	Maroonah Station	-23.83719788	115.8437093	Reference	9/10/2016	Net	8.51	9.51	28	3090	7.06
5-01	Mt Augustus Station	-24.1272314	116.6311185	Reference	8/10/2016	Net	10.57	14	28.3	82.8	7.43

Site Identification	Orebody	Latitude	Longitude	Type	Date	Sample Method#	Groundwater Depth (m)	Depth of Hole (m)	Temperature (°C)	EC ($\mu S\ cm^{-1}$)	pH
Borpheus	Mt Augustus Station	-24.03039338	116.5788653	Reference	7/10/2016	Net	5.5	11	30.7	148.7	7.19
Centipede Bore	Mt Augustus Station	-24.15306219	116.6621479	Reference	8/10/2016	Pump	-	-	28.6	3460	7.61
Clarke Well	Mt Augustus Station	-24.1045411	116.6094617	Reference	8/10/2016	Pump	-	-	27.1	81.6	7.04
Jamieson Well	Mt Augustus Station	-24.13615377	116.5390278	Reference	8/10/2016	Net	3.2	3.7	26.9	71.1	7.26
McEwen Well	Mt Augustus Station	-24.2296283	116.6829457	Reference	7/10/2016	Net	4.5	6	27.6	122.9	7.96
Ryans Bore	Mt Augustus Station	-24.09793257	116.56708	Reference	8/10/2016	Net	-	-	27.5	57.4	7.21
Uni Well	Mt Augustus Station	-24.15175889	116.6212478	Reference	8/10/2016	Net	7.15	7.65	29.7	2299	7.45
YGRC066	Yangibana North	-23.84800524	116.1874499	Impact	6/10/2016	Net	16.6	18.6	31.2	198	6.9
YGRC067	Yangibana North	-23.8483922	116.1871824	Impact	6/10/2016	Net	15.65	28.15	32.2	207.5	6.17
YGRC069	Yangibana North	-23.84635465	116.186164	Impact	6/10/2016	Net	10.72	15	33.9	237	7.24
YGRC073	Yangibana North	-23.84753068	116.1848114	Impact	6/10/2016	Net	7.2	34.2	31.8	147.7	6.63
YGWB001	Yangibana North	-23.84938753	116.1875297	Impact	6/10/2016	Net	17	39	29.8	1402	8.5

#Pump refers to samples taken by filtering bore pump outflow.

*Sampled opportunistically on 6/12/2016.

Appendix 3. List of sampling sites for troglofauna in October 2016.

Site Identification	Orebody	Date	Type	Depth to Groundwater (m)	Depth of Hole (m)	Method	Latitude	Longitude	Trap Depth
BHRC023	Bald Hill	5/10/2016	Reference	-	20	Trap	-23.89786363	116.2961102	30
BHRC135	Bald Hill	5/10/2016	Reference	-	18	Trap*	-23.90012646	116.2971687	10, 18
BHRC230	Bald Hill	5/10/2016	Impact	-	35	Trap	-23.90038013	116.2954222	34
BHRC231	Bald Hill	5/10/2016	Impact	-	42	Trap*	-23.90039619	116.2949274	10, ?
BHRC232	Bald Hill	5/10/2016	Reference	-	24	Trap	-23.89992565	116.2968648	23
BHRC250	Bald Hill	5/10/2016	Reference	20	-	Trap	-23.91511744	116.2981457	19
FRRC031	Frasers	6/10/2016	Reference	-	13	Trap	-23.95549445	116.3056256	12
FRRC035	Frasers	6/10/2016	Reference	-	16	Trap	-23.94695988	116.311774	15
FRRC040	Frasers	6/10/2016	Reference	-	28	Trap	-23.94338799	116.3128346	27
FRRC047	Frasers	6/10/2016	Reference	-	15.5	Trap	-23.93973599	116.3141609	15
FRRC103	Frasers	6/10/2016	Impact	35	-	Trap*	-23.95039214	116.311805	8, 31
FRRC106	Frasers	6/10/2016	Reference	20	-	Trap	-23.94985596	116.3130854	19
GSRC002	Gossan	6/10/2016	Reference	28	-	Trap	-23.85885087	116.1974777	
GSRC004	Gossan	6/10/2016	Reference	6	-	Trap	-23.85922669	116.198536	5
LERC012	Lions Ear	6/10/2016	Reference	14	-	Trap*	-23.86405747	116.2122947	6, 13
YGRC065	Yangibana North	6/10/2016	Impact	-	10	Trap	-23.84778043	116.1876379	9
YGRC070	Yangibana North	6/10/2016	Impact	12	-	Trap*	-23.8465875	116.1857894	6, 11
YWRC013	Yangibana West	6/10/2016	Reference	11	-	Trap	-23.84497866	116.1821565	10
YWRC014	Yangibana West	6/10/2016	Reference	6	-	Trap	-23.84536576	116.1819184	6
YWRC042	Yangibana West	6/10/2016	Reference	14	-	Trap	-23.84159174	116.1753829	13

*Two traps deployed.

Appendix 4. Higher-order stygofauna identifications that were removed from final list of species to avoid artificial inflation of richness.

Higher order identification		Site type		
		Reference	Impact	Total
Arthropoda				
Crustacea				
Malacostraca				
Amphipoda				
Bogidiellidae	Bogidiellidae sp.	1		1
Eriopisidae	Nedsia sp.	4		4
Paramelitidae	Paramelitidae sp.	7	1	8
Maxillopoda				
Cyclopoida				
Cyclopidae	Diacyclops sp.	4		4
	Mesocyclops sp.	1		1
	Cyclopoida sp.	7		7
Harpacticoida				
Ameiridae	Ameiridae sp.	7		7
Parastenocarididae	Parastenocaris sp.	4		4
Ostracoda				
Popocopida				
Candonidae	Candonopsis sp.	53		53
Cyprididae	Cypricercus sp.	36		36
	Cyprididae sp.	17		17
	Cyprinopsinae sp.	15		15
	Sarscypridopsis sp.	86		86
Limnocytheridae	Limnocythere sp.	1		1
	Ostracoda sp. unident.	9		9
Platyhelminthes				
Turbellaria	Turbellaria sp.	1		1
Grand Total		**253**	**1**	**254**