Bennelongia
Environmental Consultants

North Star Subterranean Fauna Desktop and Survey Report

Prepared for:

Fortescue Metals Group

July 2022
Draft Report

Short-Range Endemics I Subterranean Fauna

Waterbirds I Wetlands

North Star Subterranean Fauna Desktop and Survey Report

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EXECUTIVE SUMMARY

Fortescue Metals Group (FMG) Ltd was granted approval for mining the North Star magnetite project in 2013. North Star is located approximately 110 km south east of Port Hedland in the Pilbara region of WA. As a part of the original investigations for the project, a subterranean fauna survey and impact assessment was conducted that resulted in the collection of a number of subterranean fauna species. Fortescue is now proposing an expanded Stage 2 of the North Star magnetite project to include the southern extent of the magnetite resource at Glacier Valley. As such, Bennelongia was engaged to further examine the subterranean fauna community and assess the likely impacts associated with the proposed expansion of the Project.

Subterranean fauna includes two distinct animal communities: aquatic stygofauna and air-breathing troglofauna. Due to their evolutionary history in underground habitats, subterranean species typically exhibit many convergent morphological and physiological characteristics; for example, reduced or absent eyes, deficient pigmentation, vermiform bodies, elongate sensory structures, loss of wings, increased lifespan, a shift towards K-selection breeding strategy and decreased metabolism

It is well established that the diversity of subterranean fauna is closely linked to geology, because these animals are restricted to colonising areas with appropriate spaces to provide habitat. Geologies supporting rich troglofauna communities include mineralised or weathered iron formations, calcrete, alluvium, and, sometimes, mafic volcanic rocks. Stygofauna communities are usually richest in alluvial and calcrete aquifers, especially within palaeochannels, although they may also be found in iron formations, especially detrital and channel iron. There are five major geological units at the project including the Pincunah Banded-Iron Member, Cradinal Formation, Kangaroo Caves Formation, Corboy Formation and Ferriginous duricrust regolith, some of which are known to harbour spaces suitable for subterranean fauna.

Habitat information is reflected in the desktop search, which identified a rich subterranean fauna community in the broader landscape including subterranean fauna species from a survey conducted on site in 2011. As such, a field survey was conducted during 2020-21 to determine if there may be any impacts to subterranean fauna through the proposed expansion.

The 2020-21 field survey collected a total of 332 stygofauna specimens from at least 11 species, including copepods (four species), oligochaete worms (three species), syncarids (two species), ostracods (one species) and nematode worms (not assessed as a part of the EIA process). Three stygofauna species are currently only known from areas of significant (≥2 m) groundwater drawdown at the Project. These are the worm Tubificidae \`BOL066\` and the syncarids *Atopobathynella* \`BSY214\` and Parabathynellidae sp.

A total of 102 troglofauna specimens from at least 16 species were collected during the survey including beetles (three species), spiders (two species), isopods (two species), cockroaches (two species), centipedes (two species), palpigrads (one species), pseudoscorpions (one species), diplurans (one species), silverfish (one species) and millipedes (one species). Seven species of troglofauna are currently known only from impact areas associated with pit voids at the Project. These include the spider *Prethopalpus* \`BAR135\`, the palpigrade *Eukoenenia* \`BPAL048\`, the pseudoscorpion *Tyrannochthonius* \`BPS439\`, the isopods Armadillidae \`BIS416\` and Armadillidae \`BIS438\`, Japygidae \`BDP187\` and the silverfish Atelurinae sp.

Habitat modelling was conducted to demonstrate habitat connectivity extending beyond the proposed impact areas of the mine and the stygofauna model demonstrated that stygofauna is unlikely to be found in the area of significant groundwater drawdown due to the water table being deep and the limited presence of porous geology that could harbour stygofauna. Therefore, it is believed that the proposal will have a minimal impact on stygofauna.

Troglofauna habitat was demonstrated to extend over much of the modelled area and well beyond the boundaries of the proposed pits. The model suggests that troglofauna habitat extends into the low lying areas both to the east and west of the Project and is considered extensive over the strike of the orebody. While there will be habitat loss due to the removal of the pit void, it is believed that there appears to be sufficient suitable habitat extending beyond the pit boundaries to support the troglofauna community identified at the Project.

CONTENTS

LIST OF FIGURES

LIST OF TABLES

1. INTRODUCTION

Fortescue Metals Group (FMG) Ltd was granted approval for the North Star magnetite project in 2013 under Ministerial Statement 933. The project is located approximately 110 km south east of Port Hedland in the Pilbara region of WA (Figure 1). The project consists of a mining area, slurry pipeline, infrastructure corridor, Canning Basin borefield and water supply pipeline. Construction of the mining area has commenced, and the mine access road and mine accommodation village are operational.

Fortescue is now seeking to expand the North Star mine approval in the Stage 2 North Star magnetite project that will include the southern extent of the magnetite resource at Glacier Valley. Additional development will involve more mine pits, waste rock dumps and supporting infrastructure. As a part of the original investigations for the Project, a subterranean fauna survey and impact assessment was conducted (Subterranean Ecology 2012). This identified a significant troglofauna community at the project.

Bennelongia has been engaged to further examine the subterranean fauna community and assess the likely impacts associated with the planned expansion of the Project.

1.1. Subterranean Fauna

Subterranean fauna includes two distinct animal communities: aquatic stygofauna and air-breathing troglofauna. Due to their evolutionary history in underground habitats, subterranean species typically exhibit many convergent morphological and physiological characteristics; for example, reduced or absent eyes, deficient pigmentation, vermiform bodies, elongate sensory structures, loss of wings, increased lifespan, a shift towards K-selection breeding strategy and decreased metabolism (Gibert and Deharveng 2002). The overwhelming majority of subterranean species in Western Australia are invertebrates, apart from a few species of fish and snakes. Troglofauna includes a wide variety of invertebrate groups such as isopods, palpigrades, spiders, schizomids, pseudoscorpions, harvestmen, millipedes, centipedes, pauropods, symphylans, bristletails, silverfish, cockroaches, true bugs, beetles and fungus-gnats. On the other hand, stygofauna comprises mostly crustaceans, and some species of earthworms, beetles, snails and some other groups that have poorly defined taxonomy, such as nematodes and rotifers (Halse 2018b).

Although inconspicuous, subterranean fauna contributes markedly to the overall biodiversity of Australia. Most subterranean species satisfy Harvey's (2002) criterion for short-range endemism (SRE), having total geographic ranges of less than 10,000 km^2 and occupying patchy or discontinuous habitats within those ranges. Given that species with small ranges are more vulnerable to extinction following habitat degradation than wider ranging species (Ponder and Colgan 2002), it follows that subterranean taxa are highly susceptible to anthropogenic threats, particularly large-scale excavation and groundwater abstraction.

Categorisations of subterranean species according to their dependence of subterranean habitats are based on cave habitats (Howarth and Modovan 2018) and their translation to species in the wider subterranean landscape is only approximate. The species dependent on subterranean habitats for their persistence are referred to as troglobites / stygobites if their entire life cycles is completed below ground and as troglophiles / stygophiles if they move to the surface during a life stage (or, in the case of some cyclopoid copepods, have surface populations). Troglophiles and stygophiles usually have larger distributions than troglobites and stygobites, given that there are greater dispersal opportunities at the surface. Species that use subterranean spaces only opportunistically are referred to as trogloxenes and stygoxenes, and are generally much more widespread than the obligate subterranean species.

Understanding of the subterranean fauna in the Pilbara has progressed immensely since the late 1990s (Humphreys 1999; Eberhard *et al.* 2005), in large part due to extensive sampling for the assessments of potential mining impacts on these communities. The diversity of the region is now recognised as globally

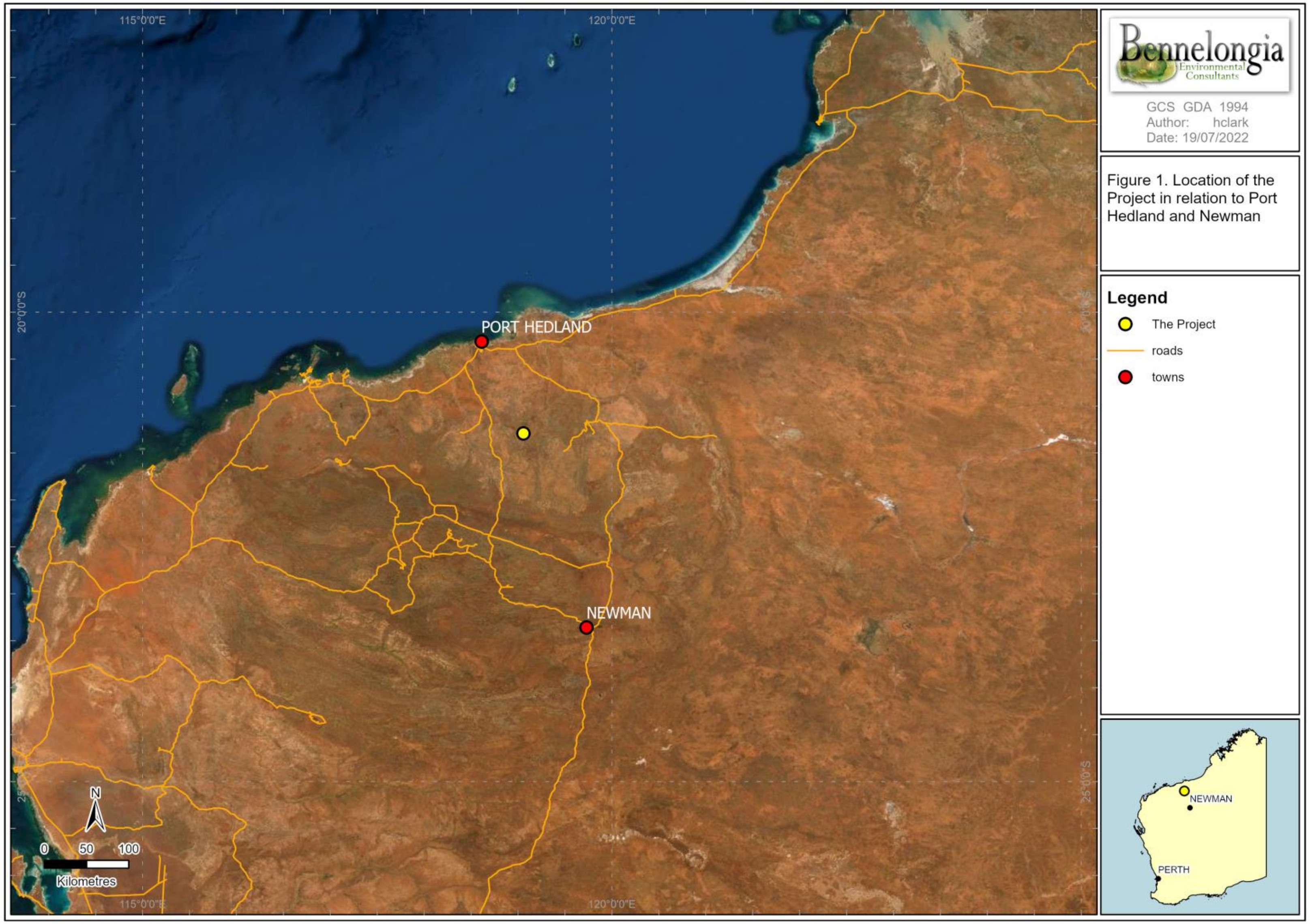

Figure 1: Location of the Project in relation to Port Hedland and Newman

significant, with at least 1,500 species of troglofauna and around 1,300 species of stygofauna occurring (Halse 2018a, Halse 2018b), although reliable estimates are hindered by a developing and sometimes non-existent taxonomic framework for some of the animal groups. It is, however, well established that the diversity of subterranean fauna is closely linked to geology because these animals can only colonise areas with appropriate spaces to provide habitat. Geologies supporting rich troglofauna communities include mineralised or weathered iron formations, calcrete, alluvium, and, sometimes, mafic volcanic rocks. Stygofauna communities are usually richest in alluvial and calcrete aquifers, especially within palaeochannels, although they may also be found in iron formations, especially detrital and channel iron (Halse 2018a). As a result of their dependence on the distribution of underground spaces, the composition and richness of both stygofauna and troglofauna communities often varies significantly over short distances. Therefore, knowledge of local geology and cannot provide information about the composition of the subterranean fauna of an area and provides only unreliable estimates of likely species richness. Biological surveys are needed to provide reliable information..

1.2. Framework

Native flora and fauna in Western Australia are protected at both State and Commonwealth levels. At the national level, the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) provides a legal framework to protect and manage nationally and internationally important flora, fauna and ecological communities. However, the threatened fauna lists of the EPBC Act currently place little emphasis on subterranean fauna. The legal framework for protection of flora and fauna at the state level in Western Australia is the *Biodiversity Conservation Act 2016* (BC Act). Most protection is provided for species listed under the BC Act as 'threatened' and this list includes some subterranean species. In addition to the list of threatened species under the BC Act, the Department of Biodiversity, Conservation and Attractions (DBCA) maintains a list of priority species that are of conservation importance but, for various reasons, do not meet the criteria for listing as threatened.

Both the EPBC and BC Acts provide frameworks for the protection of threatened ecological communities (TECs). Within Western Australia, DBCA also informally recognises communities of potential conservation concern, but for which there is not enough information to support listing, as priority ecological communities (PECs). The list of TECs and PECs recognised under the BC Act and by DBCA is larger than the EPBC Act TEC list and has much greater focus on subterranean communities.

2. DESKTOP

2.1. Methods

A comprehensive review of previous subterranean fauna records was conducted for an area approximately 100 x 100 km around the Study Area (Figure 2 and Figure 3; final decimal degrees search area, top left: -20.8405°S:118.5717°E, bottom right -21.744°S:119.5425°E). This area serves to provide a list of the stygofauna and troglofauna that could possibly occur in the Study Area. The desktop review included a search of the Western Australian Museum (WAM) database, Bennelongia's own database, and previous surveys within the search area including that conducted by Subterranean Ecology (2012). Additionally, lists of conservation-significant communities and species (BC Act and EPBC Act) and records in the Atlas of Living Australia were consulted for the desktop assessment.

2.2. Geology and Hydrogeology

There are five major geological units at the project including the Pincunah Banded-Iron Member, Cradinal Formation, Kangaroo Caves Formation, Corboy Formation and Ferriginous duricrust regolith (Figure 4 and Table 1). Of particular interest are the Pincunah Banded-Iron Member and the Cardinal Formation as both of these consist of weathered geologies that provide the voids and spaces required as habitat by subterranean fauna. Both of these geological units extend in a north/south direction through the Project Area (Figure 4).

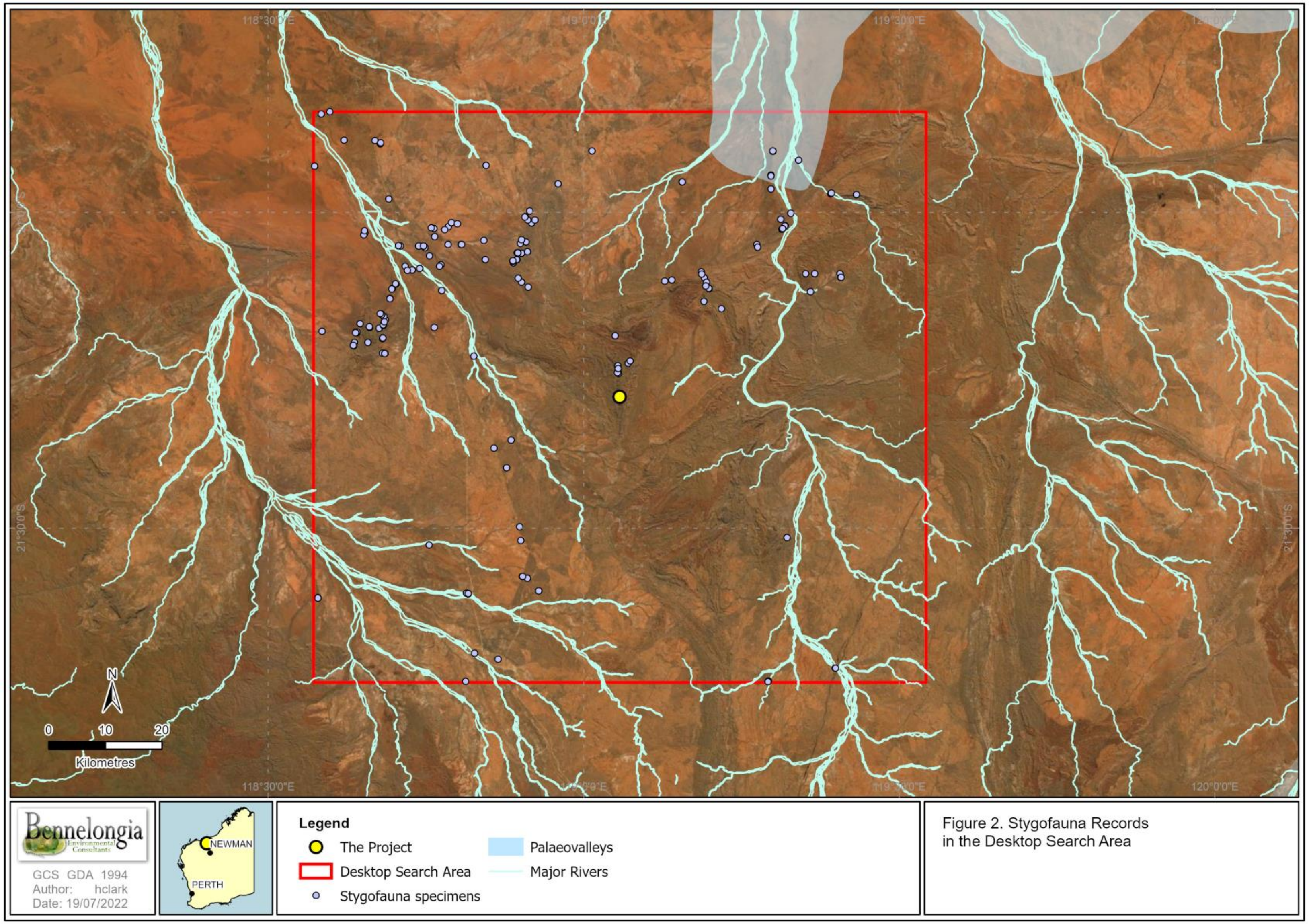

Figure 2: Stygofauna Records in the Desktop Search Area

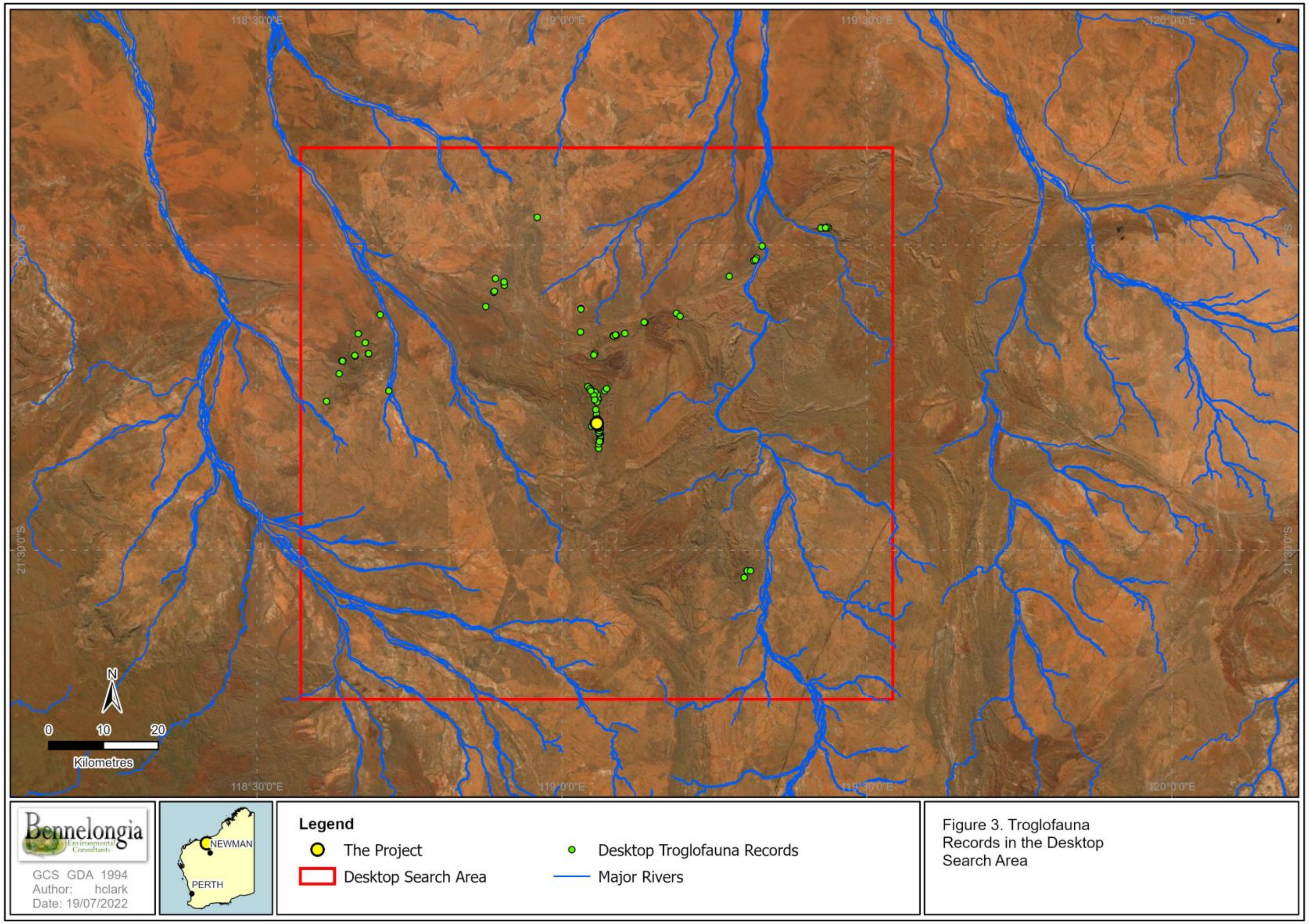

Figure 3: Troglofauna Records in the Desktop Search Area

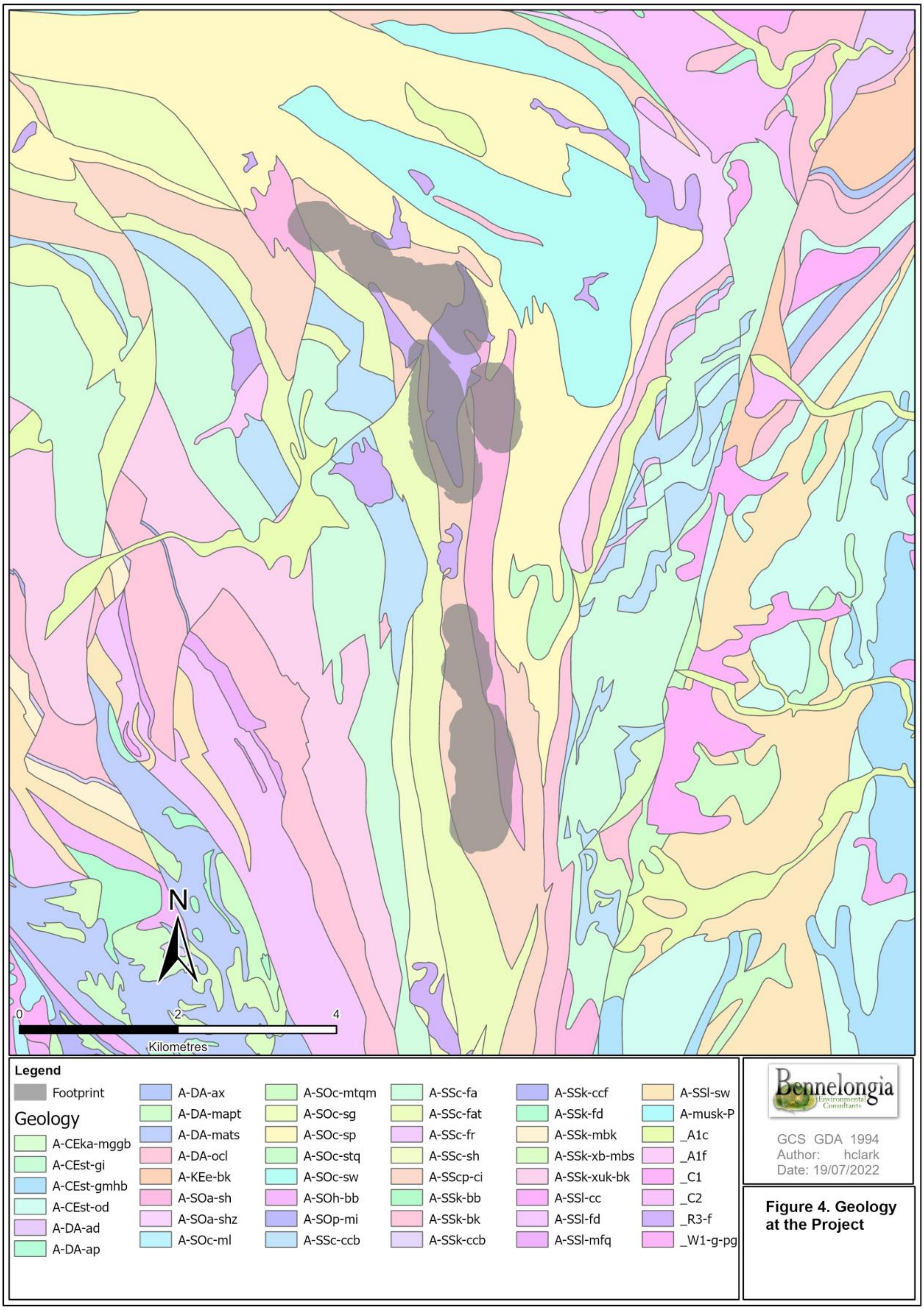

Figure 4: Geology at the project

Table 1: Geological codes to go with figure 4

CODE	BRIEF DESCRIPTION
A-CEka-mggb	Meta biotite granodiorite and minor pegmatitic granite; fine to medium grained; foliated
A-CEst-gi	Microdiorite and diorite; metamorphosed
A-CEst-gmhb	Equigranular hornblende--biotite monzogranite; outer phase; rapakivi textures; metamorphosed
A-CEst-od	Dolerite and gabbro; metamorphosed
A-DA-ad	Dunite; partly serpentinized; metamorphosed
A-DA-ap	Peridotite; partly serpentinized; metamorphosed
A-DA-ax	Pyroxenite; includes olivine pyroxenite and orthopyroxenite; metamorphosed
A-DA-mapt	Metaperidotite and serpentine--chlorite schist
A-DA-mats	Serpentinite, schistose
A-DA-ocl	Pyroxene leucogabbro; metamorphosed
A-KEe-bk	Komatiitic basalt; massive and pillowed lavas and subvolcanic intrusions; local pyroxene spinifex texture; metamorphosed
A-SOa-shz	Silicified shale; variegated, layered secondary chert; metamorphosed
A-SOa-sh	Red-weathered, ferruginized black shale, with minor siltstone; local banded iron-formation, chert, sandstone, and conglomerate; metamorphosed
A-SOc-ml	Pelite; metamorphosed siltstone, mudstone, and shale
A-SOc-mtqm	Muscovite-bearing quartzite; minor pelite
A-SOc-sg	Pebble and cobble conglomerate and minor coarse-grained arkosic sandstone; metamorphosed
A-SOc-sp	Sandstone and minor interbedded conglomerate; local siltstone and shale; metamorphosed
A-SOc-stq	Quartz sandstone and quartzite; locally fuchsitic; minor conglomerate and chert; metamorphosed
A-SOc-sw	Wacke and lithic arenite; local sandstone, conglomerate, and shale; metamorphosed
A-SOh-bb	Basalt; metamorphosed
A-SOp-mi	Meta-iron formation
A-SSc-ccb	White, grey, and black layered chert; includes felsic volcaniclastic sandstone and shale; metamorphosed
A-SSc-fa	Andesite and minor basalt; pillowed or massive; local dolerite sills; locally overlain by tuffaceous dacitic to rhyolitic volcaniclastic rocks; metamorphosed
A-SSc-fat	Andesitic volcanic sandstone; tuffaceous; local shale, and chert; metamorphosed
A-SSc-fr	Rhyolite lava and pumice breccia; metamorphosed
A-SSc-sh	Shale; metamorphosed
A-SScp-ci	Banded iron-formation; jaspilitic; minor layered chert and shale; metamorphosed
A-SSk-bb	Basalt; metamorphosed
A-SSk-bk	Komatiitic basalt; massive and pillowed flows; metamorphosed
A-SSk-ccb	White-, blueish black-, and grey-layered chert; metamorphosed
A-SSk-ccf	Bright green, fuchsitic chert; includes local silicified komatiitic basalt flow tops; metamorphosed
A-SSk-fd	Dacite
A-SSk-mbk	Carbonate-altered metamafic volcanic rocks; locally includes chlorite--sericite rock and mafic schist
A-SSk-xb-mbs	Interlayered mafic volcanic rock and mafic schist

CODE	BRIEF DESCRIPTION
A-SSk-xuk-bk	Komatiite and basaltic komatiite; local pyroxene spinifex texture; locally pillowed; metamorphosed
A-SSl-cc	Chert
A-SSl-fd	Dacite; includes local minor felsic schist; metamorphosed
A-SSl-mfq	Silicified fine-grained felsic volcaniclastic rocks; layered grey, white, and cream chert
A-SSl-sw	Wacke; local volcaniclastic sandstone, shale, and quartzite; metamorphosed
A-musk-P	Talc--carbonate and talc--carbonate--chlorite(--magnetite) schist
_A1c	Sand, silt, and gravel in active drainage channels; includes clay, silt, and sand in poorly defined drainage courses on floodplains; unconsolidated
_A1f	Floodplain deposits; sand, silt, clay, and gravel adjacent to main drainage channels; unconsolidated
_C1	Colluvial sand, silt, and gravel in outwash fans; scree and talus; proximal mass-wasting deposits; unconsolidated
_C2	Partly consolidated colluvial sand, silt, and gravel in proximal outwash fans; scree and talus; dissected by present-day drainage
_R3-f	Ferruginous duricrust and ferruginous colluvium; locally includes ferruginous alluvium; consolidated to partly consolidated; related to Hamersley Surface; dissected by present-day drainage
_W1-g-pg	Quartzofeldspathic sand and quartz pebbles in sheetwash fans; derived from mass-wasting of granitic rocks; unconsolidated

There are no paleovalleys in the vicinity of the project with the closest being the De Grey Palaeovalley approximately 40 km north-east of the project (Figure 2). Palaeovalleys are synonymous with the collection of stygofauna as they often harbour transmissive geologies containing appropriate habitat. The project lies on a ridgeline almost exactly halfway between two major rivers, the Turner and the Shaw Rivers. There are many tributaries to these rivers throughout the landscape that may act as pathways and or habitat for stygofauna. However, depth to groundwater at the project can be as deep as 80 m, which is too deep to be prospective for major stygofauna communities (Halse *et al*. 2014).

2.3. Listed species and TECs and PECs

The desktop assessment did not identify any listed or threatened species as occurring in the search area. There are also no TECs or PECs that are likely to be impacted by the proposed development.

2.4. Results

The desktop review identified a total of 157 species of stygofauna previously collected from within the desktop search area. Groups represented are the annelid worms, mites, amphipods, isopods, syncarids, copepods, ostracods, beetles, nematodes, flatworms, and rotifers. This is a significant stygofauna community indicating that stygofauna are consistently found in the vicinity of the project. For a full list of species, please refer to Appendix 1. The vast majority of the stygofauna previously collected appears to be in the north of the search area and closely associated with the Turner and Shaw Rivers (and tributaries). There are a few records to the south-west; these appear to be more associated with the headwaters of the Yule River (Figure 2).

A total of 50 troglofauna species have been previously collected from within the desktop search area. Groups represented include, spiders, pseudoscorpions, schizomids, isopods, diplurans, cockroaches, beetles, flies, bugs, silverfish, millipedes, pauropods, and symphylans. This is a significant troglofauna community and indicates that there is a high chance of encountering troglofauna at the project. For a full list of species, please refer to Appendix 2. The historically collected troglofauna are scattered through the north of the desktop search area, however the highest concentration of animals is from the survey conducted by Subterranean Ecology in 2011 (Figure 3).

2.5. Previous Surveys at the Project

Subterranean Ecology (2012) surveyed the project area and surrounds in 2011 for initial environmental approval. This survey resulted in the collection of at least 17 species of stygofauna. Samples were collected outside of the proposed pits, where the water table is shallower and even as far east as the Yule River where a large proportion of these species were collected (Figure 5). Groups collected included amphipods, syncarids, copepods and oligochaete worms. At the time, no great drawdown was anticipated and, as a result, it was deemed that the potential impacts were minimal with Paramelitidae sp. NS and Melitidae sp. NS1 the only two species mentioned as having minor conservation risk.

A total of 70 troglofauna specimens from at least 11 species were collected during the survey (Subterranean Ecology 2012). This included pseudoscorpions, symphylids, diplurans, cockroaches, beetles, planthoppers and isopods. Troglofauna species were primarily collected in the ridge associated with mining; however a couple of specimens were collected up to 14 km to the north (Figure 6). Subterranean Ecology (2012) concluded that only one of these species, Curculionidae sp. NS, was at risk from mining activities.

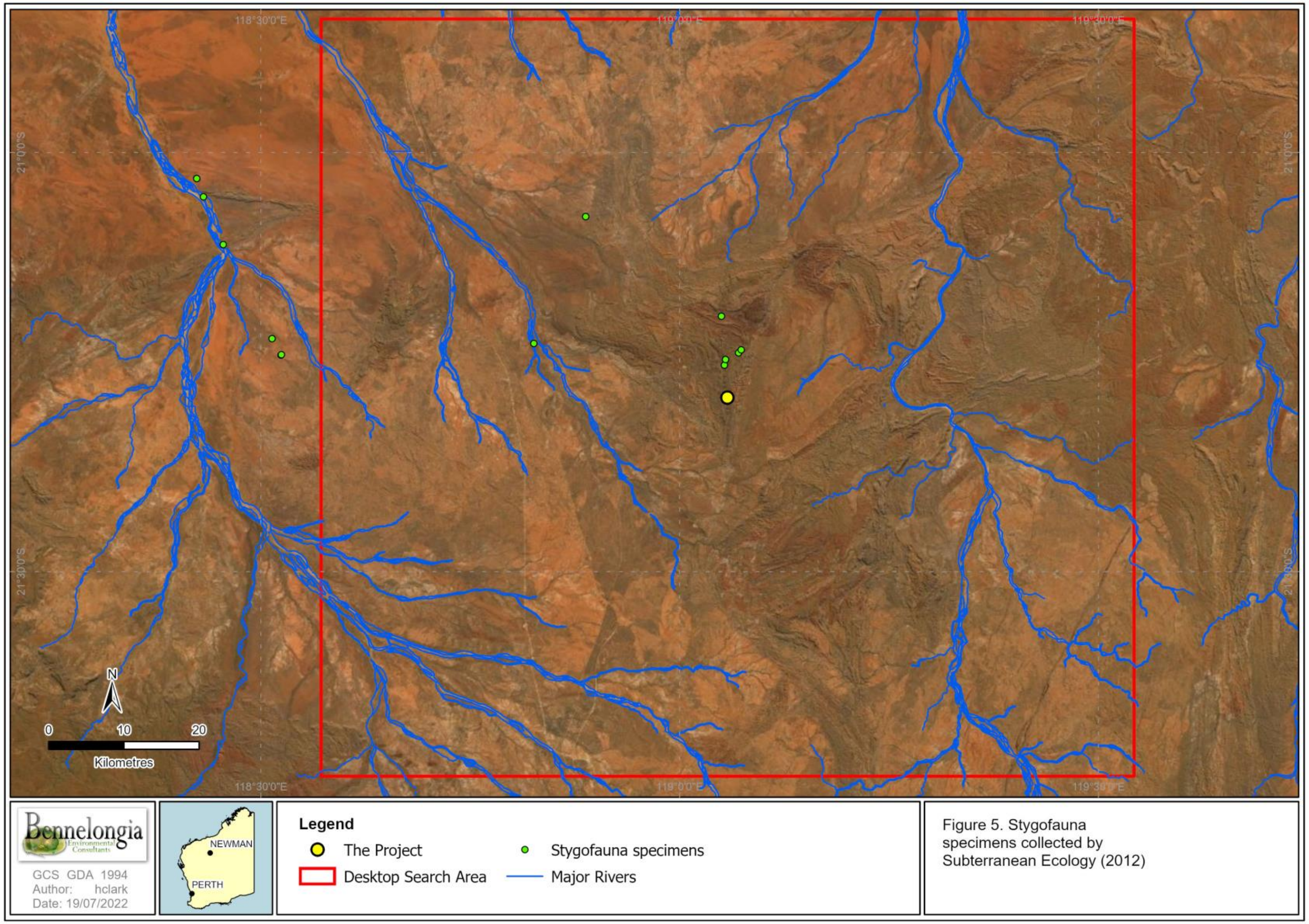

Figure 5: Stygofauna specimens collected by Subterranean Ecology (2012)

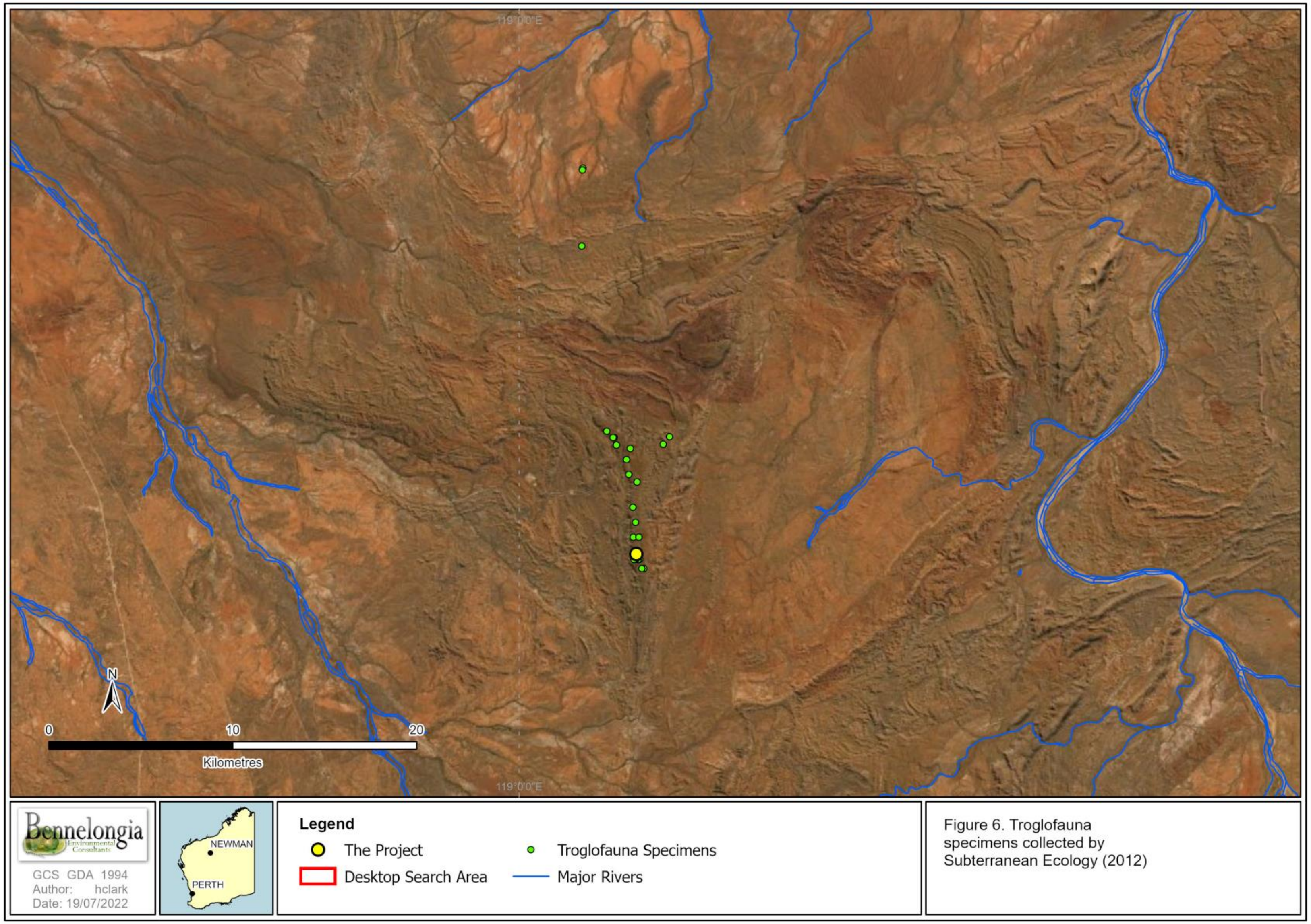

Figure 6: Troglofauna specimens collected by Subterranean Ecology (2012)

3. FIELD SURVEY

3.1. Methods

The subterranean fauna surveys reported here were conducted according to the general principles laid out for subterranean fauna sampling by the Environmental Protection Authority (EPA) at the time of sampling. The principles are described in *Technical Guidance – subterranean fauna survey* (EPA 2016c), *Technical Guidance – sampling methods for subterranean fauna* (EPA 2016b), and the *Environmental Factor Guideline – subterranean fauna* (EPA 2016a). The surveys conform with the recommendations in *Technical Guidance - subterranean fauna surveys for environmental impact assessment* (EPA 2021) if the sampling effort by Subterranean Ecology (2012) is taken into account.

3.1.1. Stygofauna

Stygofauna was collected by an active sampling technique. At each hole, a small weighted plankton net was lowered to the bottom of the hole and then agitated vigorously to stir benthic and epibenthic fauna into the water column, where animals were then captured as the net was slowly retrieved. Six separate net hauls were made (three with 50 µm mesh net and three with 150 µm mesh net). The contents of the net were transferred to 100% ethanol for preservation after each haul (EPA 2016b). Contamination between sites was avoided by washing the nets between the sampling of different drill holes.

3.1.2. Troglofauna

As far as possible, each troglofauna sample represented the combined results of two different, complementary sampling techniques: scraping and trapping.

Scraping is an active sampling technique that is used prior to setting traps. In each scraping event, a troglofauna net is prepared with a weighted ring net of 150 µm mesh, and a diameter closely matched to 60% of the bore diameter. This net is lowered to the bottom of a bore or to the water table, and subsequently scraped back to the surface at least four times. In each of these *scrapes* a different section of the wall of the hole is targeted (e.g., north, south) to maximize the organisms retrieved. The contents of each scrape are immediately transferred to 100% ethanol for preservation of the sample and its DNA.

Trapping is a passive sampling technique used after the drill hole is scraped. Traps of cylindrical PVC (270 x 70 mm) with holes drilled on the side and top to function as entrances were baited with microwaved leaf litter. Traps were lowered on nylon cord to the end of the bore, or to a few metres above the water table. An additional second trap was set (at half the depth of the first trap) in approximately every fourth hole (where possible), according to Halse *et al*. (2018). Traps were then left inside bores for nine weeks. During that period, the bores were sealed to minimise movement of surface animals into the troglofauna traps. When traps were retrieved, their contents were transferred to a zip-lock bag and transported alive to the laboratory in Perth.

3.1.3. Survey Effort

While calculating sample effort for stygofauna is relatively straightforward, sample effort for troglofauna is slightly more complicated. Sampling effort for troglofauna was calculated on the basis that standard sampling comprised both scraping and trapping. Thus, the combined results scraping and setting one or two traps in a bore on the same date were treated as one sample. If only one trap or a single scrape was collected from the hole the sampling effort was deemed to be 0.5 of a sample.

Two rounds of sampling were conducted in 2020 and 2021. The first round was conducted from 27-31 July 2020 (scrapes and net samples taken, traps set) with trap retrieval occurring on 22-23 July. The second round was undertaken from 10– 12 May (scrapes and net samples taken, traps set) and traps were retrieved on 8-9 July. Totals of 19 stygofauna samples and 80 troglofauna samples were collected across the two rounds (Table 2, Figure 7 and Figure 8). For a complete list of sampled holes, please refer to Appendix 3.

Table 2: Subterranean fauna survey effort conducted throughout 2020 and 2021

Sampling Round	Stygo Net Haul	Trog Scrape	Trog Trap 1	Trog Trap 2
2020	**17**	**40**	**40**	**11**
2021	**2**	**40**	**40**	**11**
Total	**19**	**80**		

3.1.4. Laboratory Methods

All samples were sorted in the laboratory. Leaf litter retrieved from traps was processed in Tullgren funnels under halogen lamps for 72 hours, during which time the light and heat drives animals downwards and towards a vial containing 100% ethanol as a preservative. Litter was checked after removal from the funnels to ensure no invertebrates remained.

Samples in ethanol from the Tullgren funnels were carefully screened under a dissecting microscope. Troglofauna scape samples and stygofauna net samples were elutriated to separate animals from sediment and put through sieves to fractionate the contents according to size (53, 90 and 250 µm) to improve searching efficiency before screening under a dissection microscope. All potential subterranean animals were removed from these samples for species or morpho-species level identification.

Troglofauna and stygofauna identifications were made using published, unpublished and informal taxonomic keys, as well as species descriptions in the scientific literature. Morphospecies identifications based on the characters of existing species keys were used for undescribed species, and the lowest level of identification possible was reached given the constraints of sex, maturity of the specimens (juveniles and females are often impossible to identity to species level) and possible damage to body parts. During the final phase of identification, dissecting and compound microscopes were used, with the process often requiring dissection of specimens. After the taxonomic assessment was completed, representative animals were lodged with the WAM.

DNA sequencing of 19 animals from the Study Area (along with four reference animals from the surrounding area) were used to confirm morphological identifications or provide names for juvenile or damaged animals. Depending on the size of the specimens, legs or whole animals were used for DNA extractions using a Qiagen DNeasy Blood & Tissue kit (Qiagen 2006). Elute volumes varied from 30 µL to 80 µL depending on age, condition and quantity of material. Primers combinations used for PCR amplifications were: LCO1490:HCO2198, C1J1718:HCO2198, and LCO1490:HCOoutout for the MT-CO1 gene (Folmer *et al.* 1994; Schwendinger and Giribet 2005); and SRJ14197:SRN1474S for the 12S gene (Kambhampati and Smith 1995; Simon *et al.* 1994). Next, dual-direction sanger sequencing was undertaken for PCR products by the Australian Genome Research Facility (AGRF). The sequences returned were edited and aligned in Geneious (Kearse *et al.* 2012), where neighbour-joining phylogenetic trees were then calculated using 1000 bootstraps. Genetic distances (using the Tamura-Nei method) between unique sequences were measured as uncorrected p-distances (total percentage of nucleotide differences between sequences). Sequences on GenBank and in grey literature were included in phylogenetic analysis to provide a framework for assessing intra and interspecific variation, as well as to examine levels of differentiation among individuals within described species across their geographic ranges.

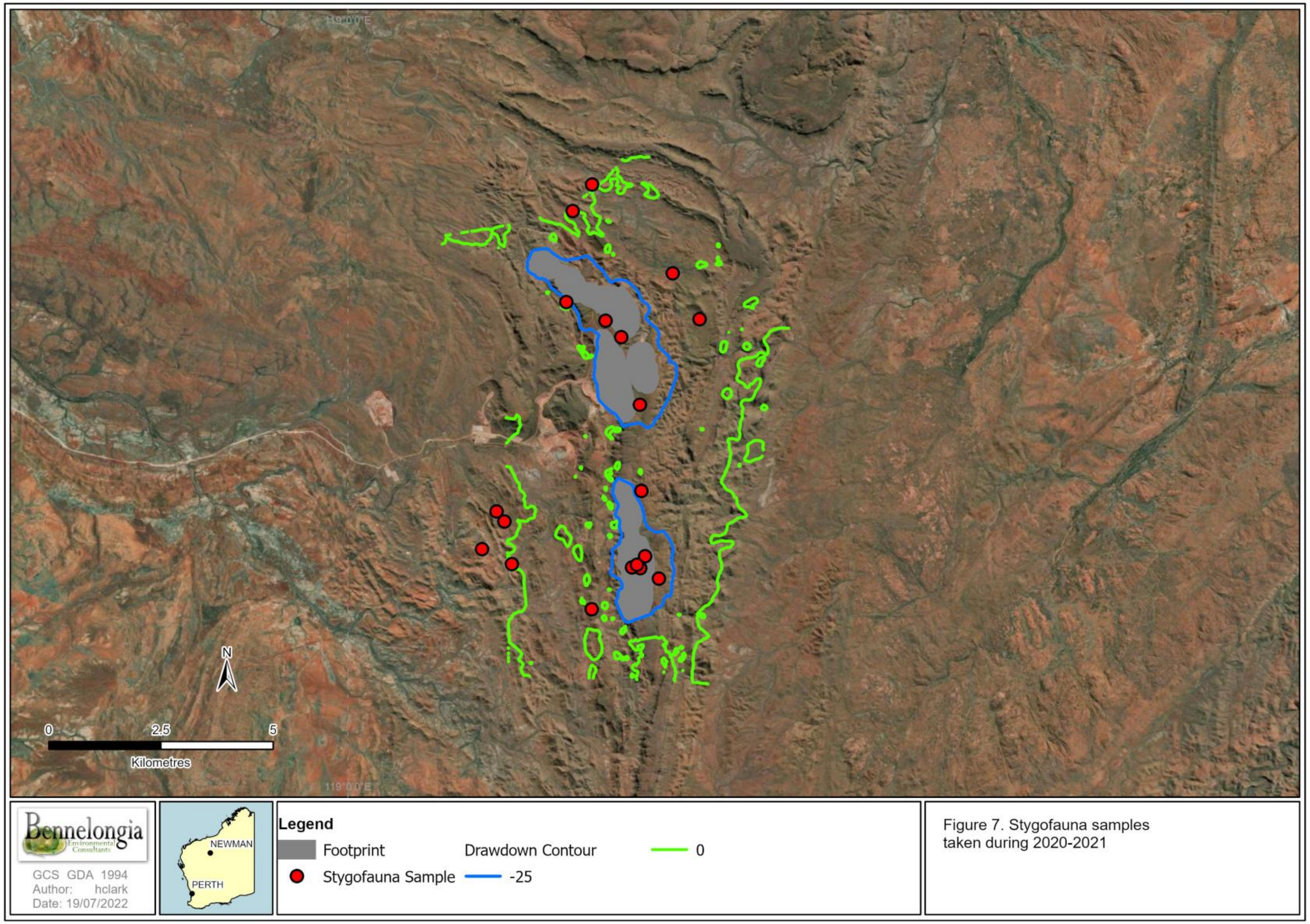

Figure 7: Stygofauna sampled taken during 2020-2021

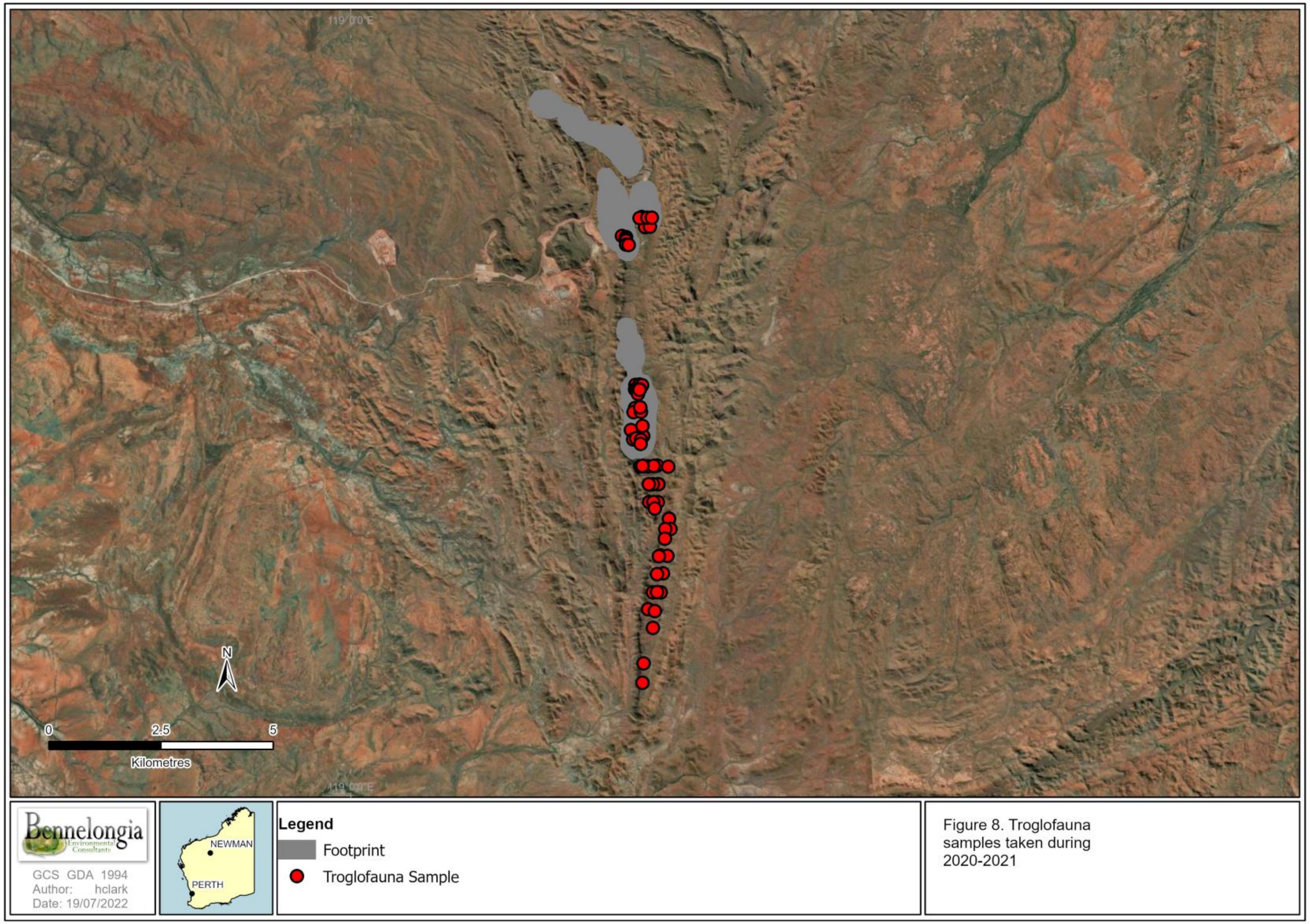

Figure 8: Troglofauna sampled taken during 2020-2021

3.2. Results

3.2.1. Genetic Analysis Results

Stygofauna

Four stygofauna specimens were sequenced for genetic analysis. These included three syncarid specimens (two *Atopobathynella* `BSY214` and Parabathynellidae sp.) and the oligochaete Tubificidae `BOL066`. Unfortunately, sequencing for all three syncarid specimens failed and as a result, no comparisons to sequences held at Bennelongia or in the public domain could be made. The identification of these animals remains the morphological identification made by the taxonomists.

Tubificidae `BOL066` returned a successful sequence and as such could be compared to other known sequences. No match could be found, however, with the nearest species being 15.9% divergent in the Mt-COI gene. As a result, the Tubificidae `BOL006` remains a singleton currently only known from within the drawdown impact area.

Troglofauna

Sixteen specimens of troglofauna collected at the Project were sequenced. Results are outlined in Table 3. Sequencing for five animals failed to return adequate data for comparison and only morphological identifications are available. Seven individuals did not match any available sequences while two matched sequences either from the Bennelongia database or from the public domain (Table 3). All results obtained from genetic analysis are incorporated in the species lists in Table 4 and Table 5. Further discussion of results for individual groups is provided below.

Table 3: Genetic sequencing undertaking and results for troglofauna at the Project.

Identification	Sequence result	Match found
Armadillidae gen. indet.`BIS438`	Failed	NA
Atelurinae sp.	Failed	NA
Atopobathynella `BSY214`	Failed	NA
Carabidae sp.	Failed	NA
Gracilanillus `BCO217`	Successful	No match
Curculionidae Genus 1 `BCO218`	Successful	Match
Cryptops sp. B06	Successful	Match
Cryptops `BSCOL076`	Successful	No match
Dalodesmidae `BDI073`	Successful	No match
Eukoenenia `BPAL048`	Failed	NA
Japygidae `BDP187`	Successful	No match
Nocticola `BLA006`	Successful	No match
Blattidae sp. B06	Successful	Match
Oonopidae `BAR134`	Successful	No match
Prethopalpus `BAR135`	Successful	No Match
Tyrannochthonius `BPS439`	Successful	No Match

Isopods

Unfortunately, the Armidillidae gen. indet. `BIS438` failed to return a successful sequence. As a result, the morphological identification stands. While the genus of this individual could not be determined, it is very close to *Troglarmadillo*. As a result, we can confidently say this is not the species collected by Subterranean Ecology (2012) and listed in their report as *Troglarmadillo* sp. NS. Distinctive anatomical features separate the two Armidillidae species (`BIS438` and `BIS416`) collected during the current survey. For example, Armidillidae gen. indet. `BIS438` has a very distinctive head and telson shape while Armidillidae gen. indet. `BIS416` has very wide schisma, a feature allowing isopods to roll into a ball.

Silverfish

A single damaged specimen of silverfish (Atelurinae sp.) was collected. Only the head and thorax were present resulting in the morphological identification only reaching subfamily level. Unfortunately, genetic sequencing was unsuccessful, so no further information could be derived from this individual. The desktop search identified a single other Atelurinae specimen (genus *Dodecastyla*) from 52 km to the northeast of the project. Unfortunately, there is no way to ascertain if these individuals are conspecific or not.

Beetles

A total of 16 carabid beetles were collected during the 2020-21 survey. Seven adults were identified morphologically as *Gracilanillus* `BCO217`. DNA analysis was conducted on one specimen in an attempt to align it with other species in the area. This individual was sequenced for the Mt-COI gene and was found to be 12.8% divergent from the nearest match, *Gracilanillus* sp. B04 (Figure 9). This level of divergence in Mt-COI is more consistent with interspecific, rather than intraspecific, divergence (Guzik *et al.* 2009) and as such maintains its status as a new species.

The remaining nine specimens collected during the current survey were larvae and most likely are members of the aforementioned morpho-species. Unfortunately, genetic sequencing was unsuccessful on the larvae and as a result no further information could be provided on these specimens. Subterranean Ecology (2012) collected three individuals identified at subtribe level as Anillini sp. NS. It is possible these are *Gracilanillus* `BCO217`.

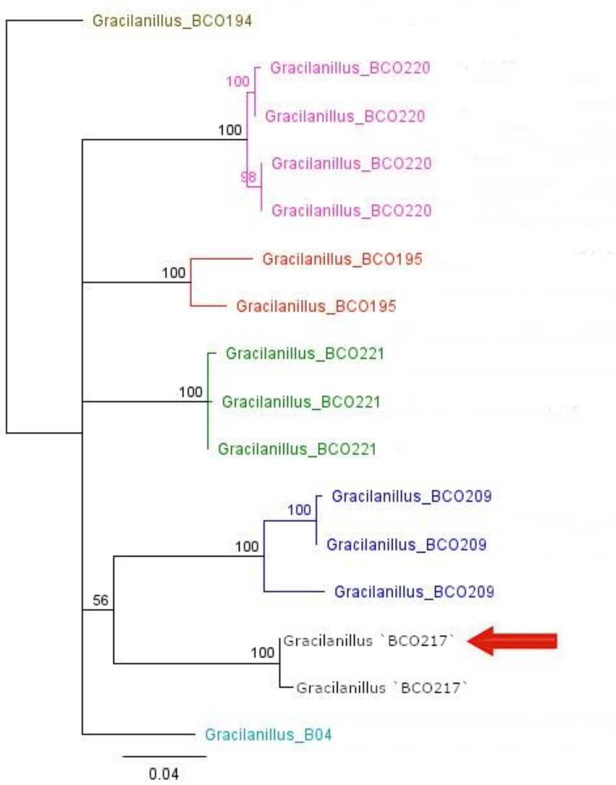

Figure 9: Maximum likelihood tree from the genus *Gracilanillus*.
The species from the current survey is highlighted with a red arrow.

Eleven specimens of Curculionidae Genus 1 `BCO218` were collected during the survey and are currently only known from the Project Area. Genetic sequencing was conducted to ascertain if conspecifics had been collected previously. A successful sequence for the Mt-COI gene was returned and resulted in a blast match with an individual, Curculionidae sp. 5 JAH-2016 (accession code KU519731) from outside the Project (Figure 10). We have retained the assigned morpho-species code here but acknowledge the match with a previously identified conspecific individual from outside the project.

Centipedes

Two centipede specimens assigned to two morphospecies were collected during the survey. These individuals were sequenced for the Mt-COI gene to confirm the morphological separation of these morpho-species and to identify any conspecific individuals from the Bennelongia database or the public domain.

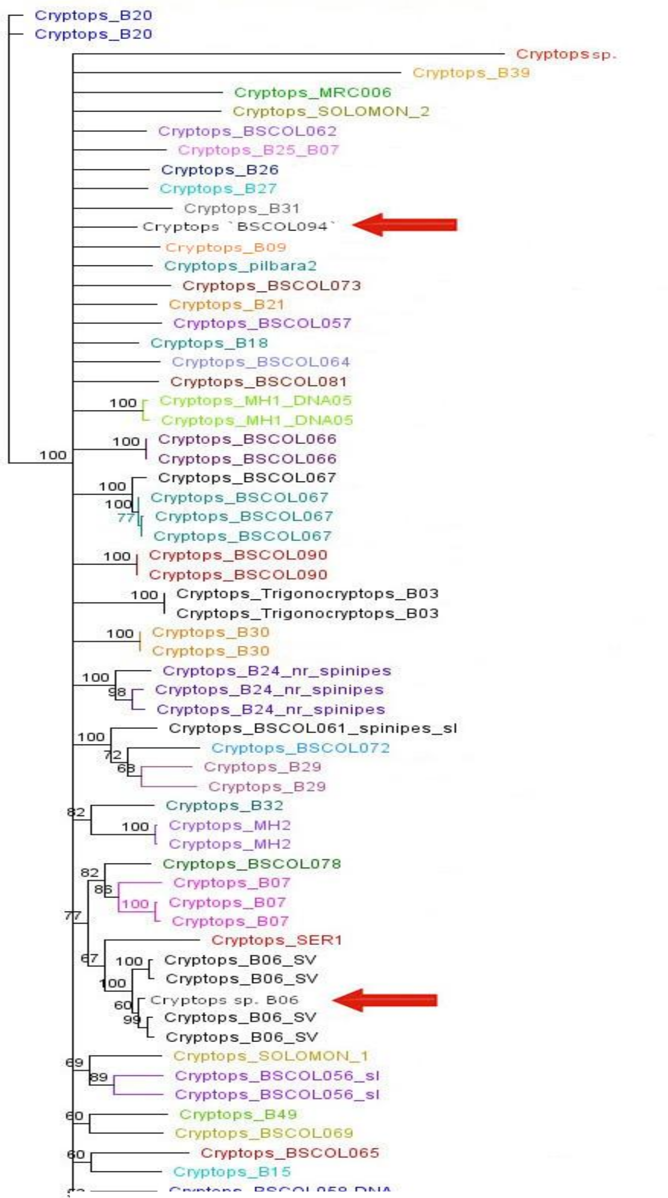

Figure 11: Maximum likelihood tree from the genus *Cryptops*.
The species from the current survey is highlighted with a red arrow.

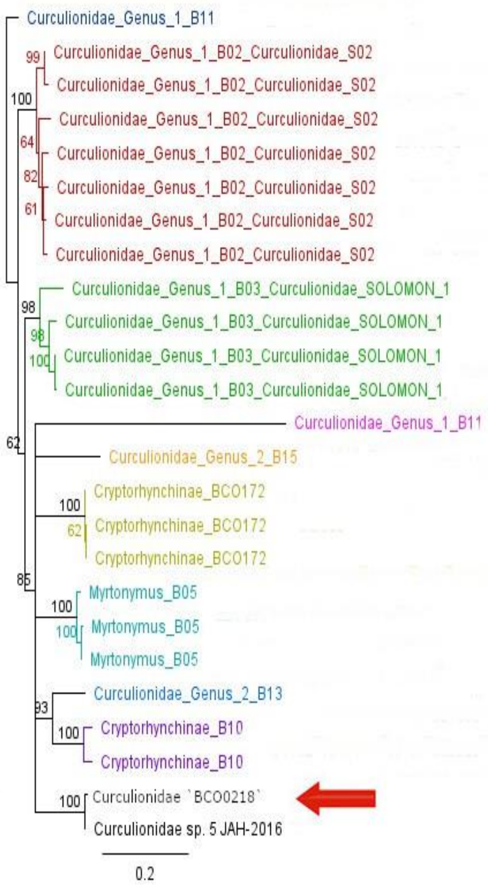

Figure 10: Maximum likelihood tree from the family Curculionidae.
The species from the current survey is highlighted with a red arrow.

One individual was found to match *Cryptops* sp. B06 with an interspecific divergence between 4.3 and 7.2% (Figure 11). As a result, these species have been synonymised and attributed to *Cryptops* sp. B06 in Table 5. This species has a distribution throughout the Hamersley ranges.

The closest match to *Cryptops* `BSCOL076` is *Cryptops* sp. B09 which was 22.3% divergent for the 12S gene. As a result, Cryptops `BSCOL076` is considered a new species that has not been previously collected and is known only from reference sites at the Project area.

Millipedes

A single specimen of dalodesmid millipede was collected during the 2020-21 survey. Morphologically, this species did not match any known specimen and was therefore identified as Dalodesmidae `BDI073`. Sequencing for the Mt-COI gene was conducted on this specimen in an attempt to find a conspecific in the surrounding region, however no match was found. The closest match was an individual from the Hamersley Ranges which was 17.5% divergent (Figure 12). These two specimens are considered to be two different species.

The desktop did not identify any other specimens from the Dalodesmidae family in the search area. The specimen collected at the Project retains the name Dalodesmidae `BDI073` and is considered a new species known only from reference sites at the Project.

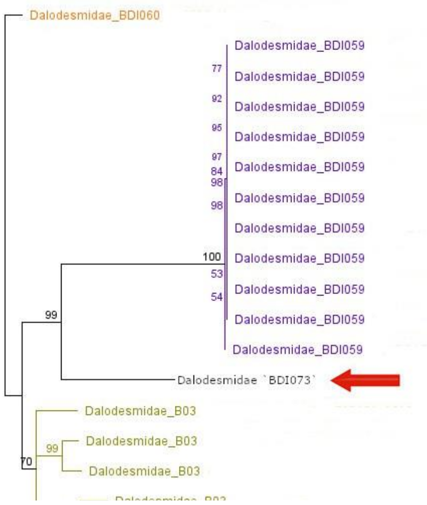

Figure 12: Maximum likelihood tree from the family Dalodesmidae.
The species from the current survey is highlighted with a red arrow.

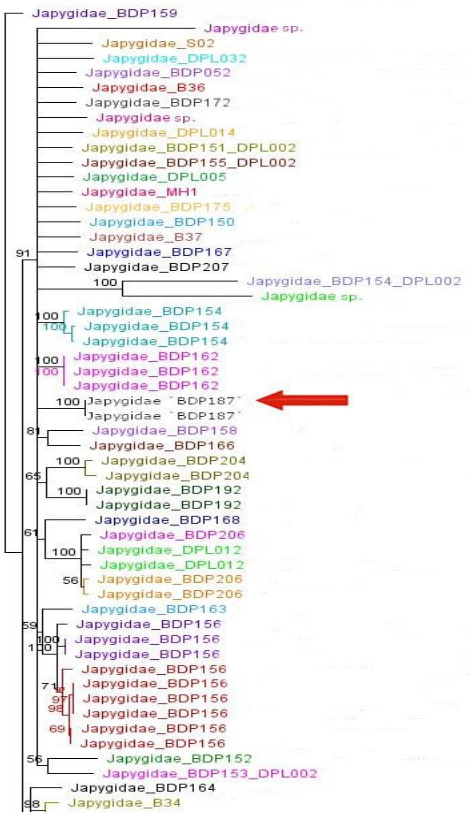

Figure 13: Maximum likelihood tree from the family Japigidae.
The species from the current survey is highlighted with a red arrow.

Palpigrads

A single palpigrad specimen was collected within impact areas at the project. It was placed in the genus *Eukoenenia*. This specimen did not match any known species, and the desktop search failed to identify any other palpigrad specimens from within the search area. Genetic analysis was undertaken to locate a conspecific individual outside of impact. Unfortunately, sequencing failed and due to the lack of other palpigrads in the desktop search area, this species is considered new and has been assigned the name *Eukoenenia* `BPAL048`. It is currently only known from within impact areas at the Project.

Diplurans

Two dipluran specimens were collected, both within impact areas at the Project. They were an adult and nymph. The adult was identified as Japygidae `BDP187` and it is likely that the juvenile will belong to the same species. The Mt-COI gene was sequenced to identify any conspecifics outside of the Project area. The closest match was Japygidae `BDP172` from the western end of the Hamersley Range. These individuals were 13.7% divergent and are therefore considered to be separate species (Figure 13).

Cockroaches

The cockroaches were represented by 47 individuals from two families. The 42 Nocticolidae included 12 adults which aligned morphologically closest to *Nocticola currani*. Genetic analysis of the Mt-COI gene was conducted to compare the specimens from the Project with *N. currani* and other *Nocticola* species. The individuals at the project did not match any other known species and were 17.5% divergent from *Nocticola* sp. B33, which was the closest match (Figure 14). As a result, the animals collected at the project are considered to be a new species and have been assigned to the morpho-species *Nocticola* \`BLA006\`. These animals were collected in both impact and reference sites.

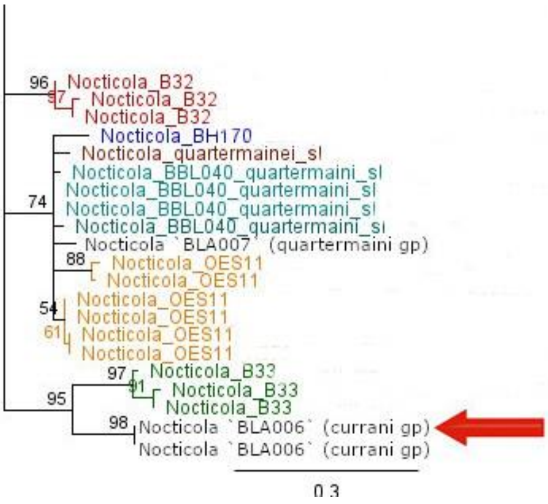

Figure 14: Maximum likelihood tree from the genus *Nocticola*.
The species from the current survey is highlighted with a red arrow.

The desktop search identified both *Nocticola currani* and *Nocticola quartermainei* as having been collected in the area before and it is likely that at least some of these *N. currani* individuals are representatives of *Nocticola* \`BLA006\`. In addition, Subterranean Ecology (2012) collected 53 specimens of *Nocticola* representing two morpho-species, *Nocticola* sp. NS1 and *N*. Sp. NS2. It is likely one of these morphospecies are members of the *Nocticola* \`BLA006\` species.

Five specimens from the Blattidae family were collected, one adult and four juveniles. Morphologically, the adult matched Blattidae sp. B06 and as such has been assigned to this morpho-species. Genetic analysis was conducted to confirm this morphological ID as this would be a range extension for this species. The induvial from the Project matched Blattidae sp. B06 for the Mt-COI gene with an intraspecific divergence of between 4.2 and 5% (Figure 15).

Figure 15: Maximum likelihood tree from the family Blattidae
The species from the current survey is highlighted with a red arrow.

Spiders

Two troglofaunal spiders were collected during the survey. Both of these species are members of the family Oonopidae. No members of this family were identified during the desktop search. Oonopidae \`BAR134\` was represented by a single specimen from a reference site. This species did not match any other animals based on morphology and as such, genetic analysis for the Mt-COI gene was conducted. The closest match was *Prethopalpus* sp. B29 with a divergence of 21.5% and as a result, Oonopidae \`BAR134\` remains a singleton known from a reference site.

One Juvenile from the genus *Prethopalpus* was collected from within project impact. No similar individuals have been noted from within the desktop search area and this genus is known to have restricted distributions. Genetic sequencing was undertaken to identify any conspecifics, however no genetic match was found. *Prethopalpus* `BAR117 was 14.3% divergent from the animal collected at the project, which is consistent with interspecific divergence. As a result it is currently considered to be a new species *Prethopalpus* `BAR135`.

Pseudoscorpions

A single specimen of *Tyrannochthonius* `BPS439` was collected from within impact at the project. Seven other *Tyrannochthonius* species were identified during the desktop assessment and an eighth species, Chthoniidae sp. NS has been collected at the project by Subterranean Ecology (2012). *Tyrannochthonius* `BPS439` was sequenced for Mt-COI but no match was detected. The nearest match was from a BLAST and was 15.3% divergent (Figure 16). However, only one of the species reported in the desktop had sequences available for comparisons, and *Tyrannochthonius* `BPS439` is possibly one of these species.

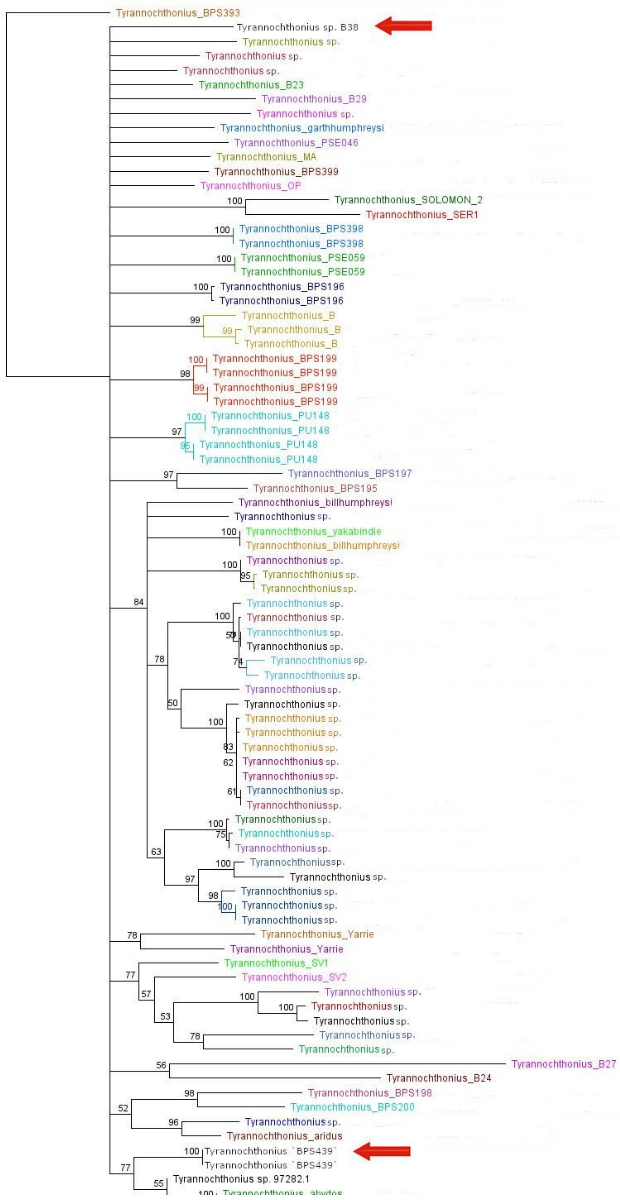

Figure 16: Maximum likelihood tree from the genus *Tyrannochthonius*.
The species from the current survey is highlighted with a red arrow.

3.2.2. Stygofauna Survey Results

The 2020-21 field survey collected 332 stygofauna specimens of at least 11 species (Table 4) including copepods (four species), oligochaete worms (three species), syncarids (two species), ostracods (one species) and nematode worms (not assessed as a part of the EIA process). Seven of these species have been collected outside of the project area. Three species are currently only known from a single bore and are therefore referred to as singletons. One of these species, *Parastenocaris* `BHA298`, was collected in a reference site and therefore will not be impacted by planned activities. Both the worm Tubificidae `BOL066 and the syncarid *Atopobathynella* `BSY214` have currently only been collected from within impact areas (defined as ≥2m of drawdown – Figure 17) and are therefore considered to be at higher risk of impacts associated with mining related drawdown. Another individual, Parabathynellidae sp., is listed in Table 4 as a higher order identification. This damaged individual could not be identified to species level because of damage but it was clear from morphology that it does not belong to the other syncarid species collected in the current survey. Parabathynellidae sp. was also collected from within impact and as such, this species is also considered to be at risk of impact from mining operations.

The stygofauna community is considered to be low to moderately diverse with only three low-abundance species considered to be at risk from development.

3.2.3. Troglofauna Survey Results

The 2020-21 survey collected 102 troglofauna specimens from at least 16 species (Table 5), including members of the beetles (three species), spiders (two species), isopods (two species), cockroaches (two species), centipedes (two species), palpigrads (one species), pseudoscorpions (one species), diplurans (one species), silverfish (one species) and millipedes (one species). Four of these animals have been collected outside of the Project area and are not considered to be at risk by the development. Five species, currently only known from the project were collected in reference areas and as a result will not be impacted by mining activities. Seven species, including the higher order identification, Atelurinae sp., are discussed in more detail as they are considered to be singletons that are at a greater risk of impacts associated with mining activities as they have all currently only known from within impact areas (Figure 18).

The troglofauna community collected during the survey is considered to be moderately rich with seven species known only from proposed impact areas.

Table 4: Stygofauna specimens and species collected during the 2020-21 subterranean fauna survey

Higher Order Identification	Lowest Identification	Number of specimens	Linear Distribution	Collection locations	Impact or Reference	Notes on taxonomy
Annelida						
Oligochaeta						
Enchytraeidae	Enchytraeidae `3 bundle` s.l. (short sclero)	33	Widespread	GV0207 GVD0009 SS0063 NS0305 1B-NST-M01 SS0036A	Both	Species complex known throughout Western Australia. Probably contains many undescribed species Could be Enchytraeidae sp. indet from 2011 survey
Phreodrilidae	Phreodrilidae sp. AP DVC s.l.	1	Widespread	NSEXS35	Reference	Species complex known throughout Western Australia. Probably contains many undescribed species Could be Phreodrillidae sp. indet from 2011 survey
Tubificidae	Tubificidae `BOL066`	8	Singleton	SS0003	Impact	Currently only known from a single location at the Project
Arthropoda						
Crustacea						
Syncarida						

Higher Order Identification	Lowest Identification	Number of specimens	Linear Distribution	Collection locations	Impact or Reference	Notes on taxonomy
Atopobathynella	Atopobathynella `BSY214`	57	Singleton	NS0664	Impact	Currently only known from a single location at the Project Could be Parabathynellidae sp. NS from 2011 survey
	Parabathynellidae sp.	1	Higher order	NS0664	Impact	Not the same as Atopobathynella `BSY214` as it is either a Brevisomabathynella or Billibathynella Could be Parabathynellidae sp. NS from 2011 survey
Copepoda						
Cyclopoida						
Diacyclops	Diacyclops humphreysi s.l.	18	Widespread	GV0224 NS0664	Reference	Species complex known throughout Western Australia. Probably contains many undescribed species Also collected in 2011
Pescecyclops	Pescecyclops pilbaricus	9	Widespread	SS0034A	Reference	Known from throughout the Pilbara

Higher Order Identification	Lowest Identification	Number of specimens	Linear Distribution	Collection locations	Impact or Reference	Notes on taxonomy
Harpacticoida						
Elaphoidella	Elaphoidella humphreysi	3	Widespread	GV0224	Reference	Known from throughout the Pilbara Also collected in 2011
Parastenocarididae						
Parastenocaris	Parastenocaris \`BHA298\`	3	Singleton	SS0034A	Reference	Currently only known from a single location at the Project
Ostracoda						
Areacandona	Areacandona yuleae	2	120 km	NSEXS35	Reference	also known from a location approx. 50 km south west of Port Hedland
Nematoda	Nematoda spp.	197	Widespread	GV0206 GV0208 GVD0009 NS0789 NS0794 SS0002 SS0002A SS0005 SS0016 SS0018 SS0026 SS0032 SS0034A	Both	Higher order identification. Nematodes not assessed through the EIA process

Higher Order Identification	Lowest Identification	Number of specimens	Linear Distribution	Collection locations	Impact or Reference	Notes on taxonomy
				SS0036 SS0036A SS0040 SS0042 SS0047 SS0048		

Table 5: Troglofauna specimens and species collected during the 2020-21 subterranean fauna survey

Higher Order Identification	Lowest Identification	Number of specimens	Linear Distribution	Collection Location	Impact or Reference	Notes on taxonomy
Arthropoda						
Araneae						
Oonopidae						
Oonopidae Genus 2	Oonopidae `BAR134`	1	Singleton	SS0028	Reference	Currently only known from a single location at the Project
Prethopalpus	Prethopalpus `BAR135`	1	Singleton	NS0306	Impact	Currently only known from a single location at the Project
Palpigradi						
Eukoenenia	Eukoenenia `BPAL048`	1	Singleton	NS0752	Impact	Currently only known from a single location at the Project
Pseudoscorpiones						
Chthoniidae						
Tyrannochthonius	Tyrannochthonius `BPS439`	1	Singleton	NS0795	Impact	Currently only known from a single location at the Project Could be Chthoniidae sp. NS from 2011.
Crustacea						
Isopoda						
Armadillidae	Armadillidae `BIS416`	1	Singleton	GV0207	Impact	Currently only known from a single location at the Project

Higher Order Identification	Lowest Identification	Number of specimens	Linear Distribution	Collection Location	Impact or Reference	Notes on taxonomy
	Armadillidae `BIS438`	1	Singleton	NS0788	Impact	Currently only known from a single location at the Project
Hexapoda						
Diplura						
Japygidae	Japygidae `BDP187`	1	Singleton	GV0213	Impact	Currently only known from a single location at the Project
	Japygidae sp.	1		GV0207	Impact	Higher order, maybe another member of Japygidae `BDP187`
Insecta						
Blattidae	Blattidae sp. B06	1	Widespread	GV0208	Impact	Also known from throughout the Hamersley Ranges Could be the same as Blattidae sp. indet from 2011
	Blattidae sp.	4		SS0007 SS0005	Reference	Higher order, maybe another member of Blattidae sp. B06
Nocticolidae						
Nocticola	Nocticola `BLA006`	12	54 km	GV0208 NS0305 NS0794 NS0790 NS0755 SS0042	Both	Also known 54 km north east of the Project Could be Nocticola sp. NS1 or NS2 from 2011 survey

Higher Order Identification	Lowest Identification	Number of specimens	Linear Distribution	Collection Location	Impact or Reference	Notes on taxonomy
				SS0016A SS0032A		
	Nocticola sp.	25		GV0208 GV0229 GV0254 NS0755 NS0759 NS0795 SS0005 SS0017 SS0028 SS0042	Both	Higher order, maybe another member of listed Nocticolid species above
	Nocticolidae sp.	5		GV0211	Impact	Higher order, maybe another member of listed Nocticolid species above
Coleoptera						
Carabidae						
Gracilanillus	Gracilanillus `BCO217`	7	10.5km	GVW06 SS0071 NS0752 SS0042	Both	Only known from the Project maybe other members of Anillini sp. NS from 2011 survey
	Carabidae sp.	9		GV0207 SS0048 SS0002 SS0040B	Both	Higher order maybe other members of Gracilanillus `BCO217` above or Anillini sp. NS from 2011 survey

Higher Order Identification	Lowest Identification	Number of specimens	Linear Distribution	Collection Location	Impact or Reference	Notes on taxonomy
Curculionidae						
Curculionidae Genus 1	Curculionidae Genus 1 `BCO218`	11	8.4 km	GV0207 NS0788 NS0790 SS0054 SS0003 SS0028 SS0034A	Both	Only known from the Project Could be Curculionidae sp. NS from 2011 survey
Coleoptera gen 1	Coleoptera gen 1 sp. B08	16	32 km	SS0007 NS0794 NS0759 SS0004A SS0026	Both	Also known from 32 km northwest of the Project
Zygentoma						
Nicoletiidae	Atelurinae sp.	1		GV0207	Impact	Higher Order Identification however no known members of this genus from nearby projects
Myriapoda						
Chilopoda						
Cryptopidae						
Cryptops	Cryptops `BSCOL076`	1	Singleton	SS0005	Reference	Currently only known from a single location at the Project
	Cryptops sp. B06 (=SV, B14)	1	240 km	SS0018	Reference	Also known throughout the Hamersley Ranges
Diplopoda						

Higher Order Identification	Lowest Identification	Number of specimens	Linear Distribution	Collection Location	Impact or Reference	Notes on taxonomy
Dalodesmidae	Dalodesmidae `BDI073`	1	Singleton	SS0005	Reference	Currently only known from a single location at the Project

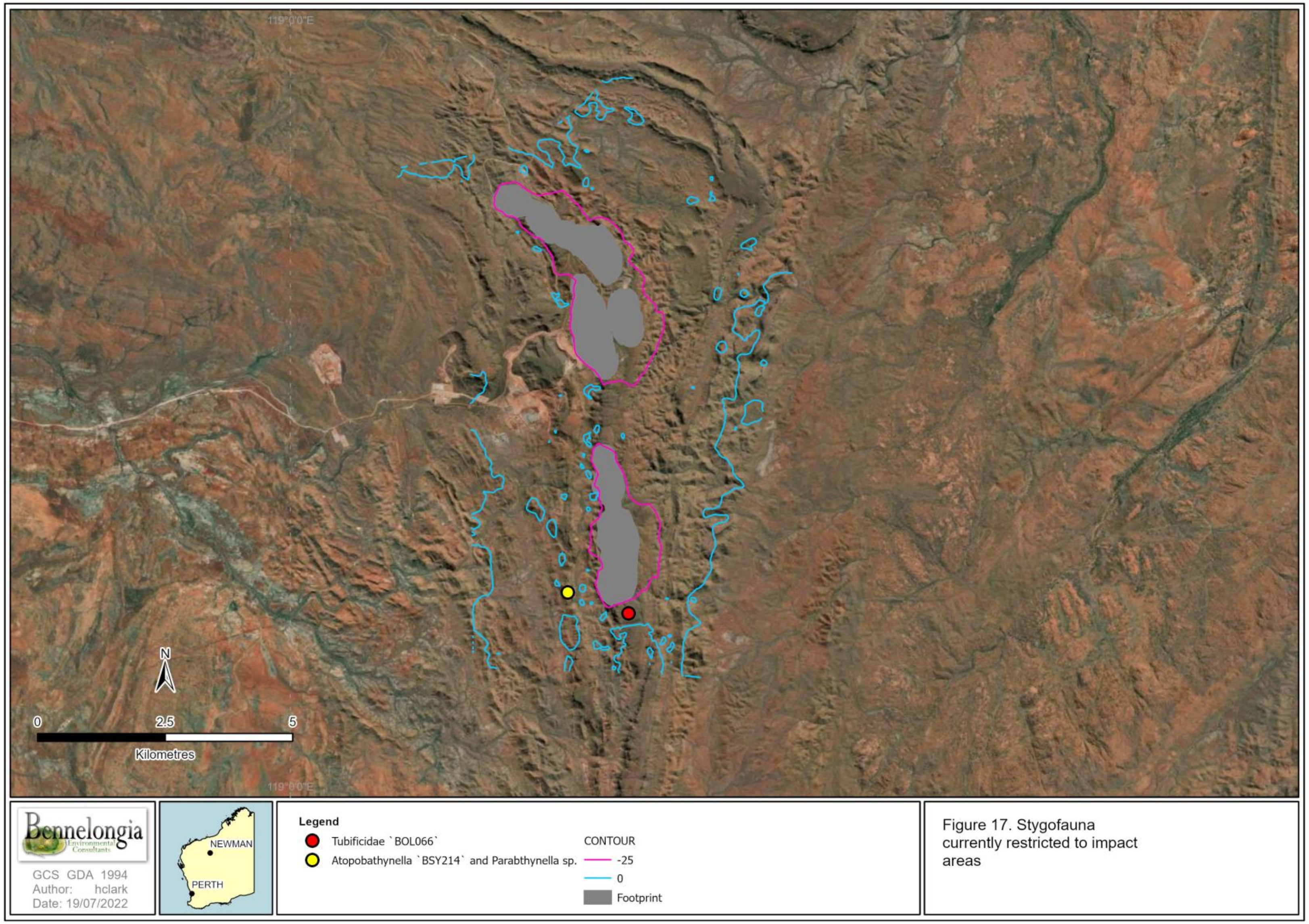

Figure 17: Stygofauna currently restricted to impact areas

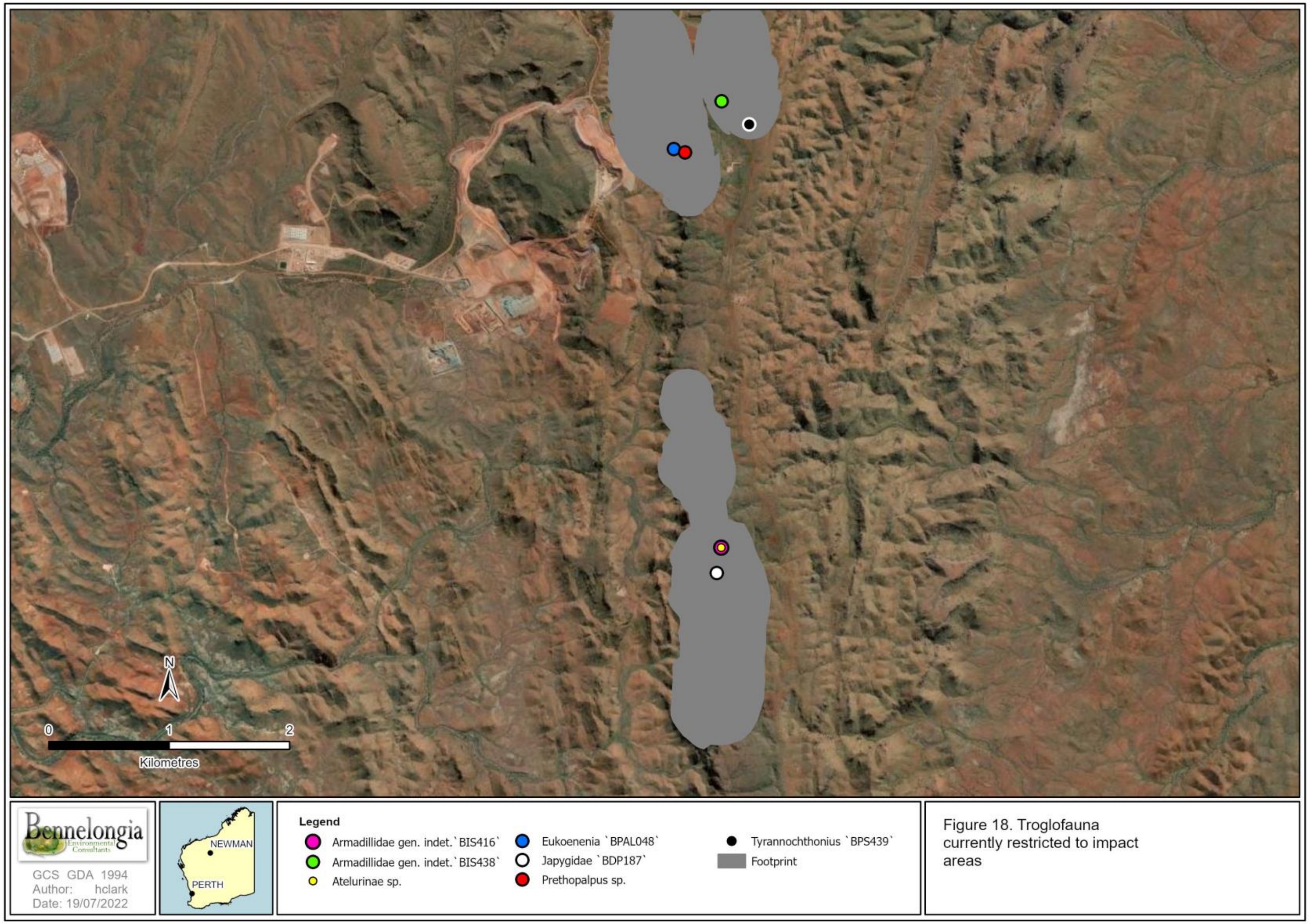

Figure 18: Troglofauna currently restricted to impact areas

4. GEOLOGICAL MODELLING

Habitat modelling was conducted by AQ2 to infer the presence of habitat extending outside of the proposed pits. The AQ2 full report can be found in Appendix 4 but the results are summarised below.

AQ2 identified that the most likely location for subterranean fauna is within the oxidised zone at depths of between 60 and 70 mbgl. Oxidation zones are defined as weathered and transition zones and fractured bedrock. The models for both stygofauna and troglofauna demonstrated that available habitat extends well beyond the boundaries of the pits and into the surrounding floodplain.

The stygofauna model demonstrated that stygofauna are unlikely to be found in the pit area due to deep water table and relatively little porous below water-table geology that could harbour stygofauna. Areas where stygofauna were found during the 2020-21 survey, often coincided with drainage lines where groundwater was shallower and also a higher incidence of saturated weathered material. In lower lying areas, weathered bedrock more commonly intersects groundwater, providing more appropriate habitat for stygofauna.

Troglofauna habitat was demonstrated to extend over much of the modelled area and well beyond the boundaries of the proposed pits. This is supported by the assessment that all drill holes intersect possible troglofauna habitat. The model suggests that troglofauna habitat extends into the low lying areas both to the east and west of the Project and is considered extensive over the strike of the orebody.

5. DISCUSSION

5.1. Stygofauna

Three stygofauna species are currently only known from within proposed impact (2 m drawdown) at the Project. These are the worm Tubificidae `BOL066`, and the syncarids Atopobathynella `BSY214` and Parabathynellidae sp. (Figure 17).

Tubificid Worms

Eight specimens of Tubificidae `BOL066` were collected from a single bore south of the southern extension, situated at the top of the ridge (Figure 17). Depth to water at this location was 35 m while the end of the hole was 270 mbgl, providing significant amount of water column from which these individuals could be collected. Information is largely lacking on subterranean Tubificidae outside of a handful of descriptions from the various parts of Australia (Pinder and Brinkhurst 2000; Pinder *et al.* 2006). Despite this, it is not uncommon to collect Tubificidae worms in subterranean fauna surveys.

Other subterranean worms in the area have been collected either from only one hole or as species with wider distributions, such as Enchytraeidae `3 bundle` s.l. (short sclero) collected during the current survey across the length of the strike and Enchytraeidae sp. indet. (they could be the same species) which was collected in 2011 and has a distribution of approximately 67 km.

Syncarids

Syncarids are small crustaceans that are almost exclusively groundwater inhabitants. The Western Australian syncarid fauna is significantly diverse (Guzik *et al.* 2008; Perina *et al.* 2018). The ranges of many syncarid species (such as Bathynellidae and Parabathynellidae) are typically small with many species endemic to single aquifers or sections of regional aquifers (Guzik *et al.* 2008).

Syncarids are common in alluvium but as a group appear to occur in many geologies (Guzik *et al.* 2008; Halse *et al*. 2014). Syncarid species are well adapted to life in interstitial spaces through life history traits such as multiple non-resting larval stages (Cho *et al.* 2006).

Interestingly, both syncarid species were collected from the same bore located within a minor drainage line at the southern end of the southern extension (Figure 17), suggesting that these animals were collected from the interstitial spaces associated with the feature (Cho *et al.* 2006). Depth to water at this site was 3.18 mbgl and the end of hole was 120 mbgl providing ample water column from which these animals could have been collected.

It is also possible that one of these species (Parabathynellidae sp.) is a conspecific with Parabathynellidae sp. NS collected in 2011. This species was collected east of the North Star project area but was also collected approximately 58 km west in the floodplains of the Yule River. This demonstrates that these animals can be quite widespread when connective habitat is available such bas the interstitial spaces in drainage and creek lines.

5.2. Troglofauna

Seven species of troglofauna are currently only known from impact areas associated with pit voids at the Project (Figure 18). These include the spider *Prethopalpus* `BAR135`, the palpigrade *Eukoenenia* `BPAL048`, the pseudoscorpion *Tyrannochthonius* `BPS439`, the isopods Armadillidae `BIS416` and Armadillidae `BIS438`, Japygidae `BDP187` and the silverfish Atelurinae sp.

Prethopalpus

Prethopalpus sp. was collected from a trap within the North Star deposits. The standing water level was 55 mbgl and the trap depth was 10 mbgl. This individual is located 200 m from the closest pit wall (Figure 18). The median range for spiders in the Pilbara is 3.7 km (Halse and Pearson 2014). This juvenile individual could not be taken to species however given that no other *Prethopalpus* specimens have been recorded from within the desktop search area, it is likely that this will represent a new species.

Palpigrads

The palpigrad *Eukoenenia* `BPAL048` was collected only 89 m from the spider mentioned above. This individual was collected from a bore that had a standing water level of 90 mbgl from a trap set 20 mbgl. Approximately 300 m from the edge of the pit at its closest point and no other palpigrads were identified in the desktop search area. However, subterranean palpigrads have a median range of 345 km (Halse and Pearson 2014) making it less likely this species will be restricted to the project area.

Pseudoscorpions

Collected at the southern end of the northern deposits, *Tyrannochthonius* `BPS439` was collected from a bore that had no water and was only 22 m deep. This individual was collected in a trap which was set 20 mbgl. Subterranean pseudoscorpions have a median range of 22 km (Halse and Pearson 2014) and this individual was collected 120 m from the edge of the pit. While this species was not matched through genetics, six of the eight species identified as potential conspecifics in the desktop assessment did not have sequences available for comparison.

Isopods

Two isopod specimens representing two species were collected during the 2020-21 survey. Both of these individuals were collected within impact (Figure 18). Armadillidae `BIS416` was dead when collected and as a result was not suitable for sequencing. This individual was collected from the middle of the southern extension approximately 240 M from the edge of the pit. Armadillidae `BIS416` was collected from a scrape in a bore that had a standing water level of 52 m and contained a lot of root material, which provides habitat and energy for subterranean animals.

Armadillidae `BIS438` was collected at the southern end of the north star deposits. Approximately 125 m from the nearest edge of the pit this species was collected from a bore with a standing water depth of 49 m. Unfortunately, the sequence of this failed and has a result could not be compared genetically with other specimens from the region.

Isopods have a median distribution of 2.5 km making them one of the more restricted of the troglofauna groups (Halse and Pearson 2014).

Japygids
The taxonomic framework for subterranean diplurans in Australia is underdeveloped at this stage and there is little basis for assessing species ranges besides local collection and habitat data. Having said that, Halse and Pearson (2014) predicted a median range of 16 km for diplurans based on assessing 15 known species. Two individuals of the family Japygidae were collected during the current survey, and adult and a juvenile. Both of these individuals were collected in impact. The adult was assigned the morpho-species Japygidae `BDP187` based on there being no morphological or genetic match.

Japygidae `BDP187` was collected from a bore in the middle of the southern extension (Figure 18). This bore had a standing water depth of 68 mbgl and Japygidae `BDP187` was collected in a trap at a depth of 40 mbgl. This individual was collected approximately 345 m from the edge of the planned pit.

Silverfish
The silverfish Atelurinae sp. was collected from the same bore as Armadillidae `BIS416` which contained root material and had a standing water depth of 52 m. Approximately 240 m from the edge of the pit, Halse and Pearson (2014) determined that silverfish have a median range of 11 km.

6. CONCLUSION

Historical work conducted at the Project indicated that subterranean fauna exists within the weathered geologies at the Project. The desktop assessment revealed a significant subterranean fauna community throughout the surrounding landscape, with 157 species of stygofauna and 50 species of troglofauna having been previously collected in a 100 X 100 km square surrounding the project. A survey conducted in 2011 collected 17 stygofauna species and 11 troglofauna species (Subterranean Ecology 2012). This survey concluded that there would be very little impact to stygofauna and only one restricted troglofauna species, Curculionidae sp. NS, was at risk from the planned project.

Fortescue is exploring the option of extending the project to the south and as a result, another subterranean survey was required. Bennelongia conducted a two season survey across 2020-21, which resulted in collection of 332 stygofauna specimens from at least 11 species and 102 troglofauna specimens from at least 16 species.

Stygofauna groups represented include the copepods (four species), oligochaete worms (three species), syncarids (two species), ostracods (one species) and nematode worms. Three of these species are currently only known from within predicted drawdown areas at the project, and as such, are at risk due to mining processes. These species are the worm Tubificidae `BOL066`, and the syncarids Atopobathynella `BSY214` and Parabathynellidae sp.

The syncarids were collected within drainage lines, where groundwater is shallow and there is a higher incidence of submerged weathered interstitial spaces. These species are well adapted to life in interstitial spaces (Cho *et al.* 2006) as is evidenced by a similar species (which may be a conspecific to one of the two restricted syncarids) Parabathynellidae sp. NS, which has a range of 58 km and extends to the flood plains of the Yule River. As a result, it is likely the two syncarid species also utilise interstitial spaces within drainage lines and have distributions that extend beyond the impacts associated with drawdown.

Eight specimens of Tubificidae `BOL066` were collected from a single bore south of the southern extension (Figure 17). The bore from which this species was collected contained 235 m of water column, providing ample habitat below the anticipated drawdown at this location. AQ2 (Appendix 4), through geological modelling, anticipated that the majority of subterranean fauna would be collected between 60 and 70 mbgl. Additionally, similar species such as Enchytraeidae `3 bundle` s.l. (short sclero) and as

Enchytraeidae sp. indet, which could in fact be conspecifics have ranges extending well beyond the planned impact associated with drawdown. As such, it is likely that Tubificidae `BOL066` also has a range extending beyond planned impact.

Troglofauna groups collected include beetles (three species), spiders (two species), isopods (two species), cockroaches (two species), centipedes (two species), palpigrads (one species), pseudoscorpions (one species), diplurans (one species), silverfish (one species) and millipedes (one species). Seven of the species have known distributions restricted to impact areas. These are the spider *Prethopalpus* `BAR135`, the palpigrade *Eukoenenia* `BPAL048`, the pseudoscorpion *Tyrannochthonius* `BPS439`, the isopods Armadillidae `BIS416` and Armadillidae `BIS438`, Japygidae `BDP187` and the silverfish Atelurinae sp. All of these individuals were collected at the top of the ridge where modelling by AQ2 has indicated that troglofauna habitat extends extensively along strike and broadly throughout the landscape through low lying areas to the east and west (Appendix 4).

Each of these species were collected withing 400 m of the edge of impact which is smaller than the median ranges for all groups outlined by Halse and Pearson (2014). While impacts on troglofauna will be experienced, the relative amount of habitat removed compared to that modelled throughout the landscape indicates that troglofauna species will have ranges extending beyond the edges of the pit boundaries.

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Appendix 1 – Stygofauna Species Identified During the Desktop Search

Higher Order Identifications	Lowest Identification
Annelida	
Aeolosomatidae	
Aeolosoma	Aeolosoma sp. 1 (PSS)
Clitellata	
Enchytraeida	
Enchytraeidae	
Enchytraeus	Enchytraeus sp. AP PSS1 s.l.
	Enchytraeidae `3 bundle` s.l. (short sclero)
	Enchytraeidae sp.
	Enchytraeidae sp. B23
	Enchytraeidae sp. B24
Haplotaxida	
Naididae	
Dero	Dero (Aulophorus) furcatus
	Dero furcata
Pristina	Pristina longiseta
	Naididae sp. indet
	Naididae sp. NS
Phreodrilidae	
	Phreodrilidae sp. AP DVC B14
	Phreodrilidae sp. AP DVC B15
	Phreodrilidae sp. AP DVC s.l.
	Phreodrilidae sp. AP SVC s.l.
	Phreodrilidae sp. indet
Tubificidae	
Monopylephorus	Monopylephorus sp. nov. WA29 (ex Pristina WA3) (PSS)
	Tubificidae `BOL049`
	Tubificidae `BOL050`
	Tubificidae `BOL075`
	Tubificidae `stygo type 1` (imm Ainudrilus ?WA25/26) (PSS)
	Tubificidae `stygo type 4`
	Oligochaeta sp.
	Oligochaeta sp. S01
Arthropoda	
Arachnida	
Trombidiformes	
Halacaridae	
`Genus indet.`	`Genus indet.` `sp. 1`
	Halacaridae sp.
Hydryphantidae	
Wandesia	Wandesia sp.

Higher Order Identifications	Lowest Identification
Mideopsidae	
Tillia	Tillia `sp.`
Crustacea	
Malacostraca	
Amphipoda	
Bogidiellidae	Bogidiellidae sp.
	Bogidiellidae sp. NS
Eriopisidae	
Nedsia	Nedsia `hurlberti group` sp. 1 spine
	Nedsia hurlberti s.l.
	Nedsia sp.
Melitidae	Melitidae `BAM147` (sp. 1 group)
	Melitidae `BAM149` (sp. 1 group)
	Melitidae `BAM160` (sp. 1 group)
	Melitidae sp. 1 group (PSS) s.l.
	Melitidae sp. B08 (sp. 1 group)
	Melitidae sp. NS
Paramelitidae	
Molina	Molina sp.
Paramelitidae Genus 2	Paramelitidae Genus 2 `BAM148`
	Paramelitidae Genus 2 `BAM163`
	Paramelitidae Genus 2 `BAM164`
	Paramelitidae Genus 2 sp.
	Paramelitidae Genus 2 sp. B15
Pilbarus	Pilbarus `BAM145`
	Pilbarus sp. S02 (PSS)
	Paramelitidae `BAM144`
	Paramelitidae `BAM161`
	Paramelitidae sp.
	Paramelitidae sp. 2 s.l. (PSS)
	Paramelitidae sp. 6 s.l. (PSS)
	Paramelitidae sp. 7 s.l. (PSS)
	Paramelitidae sp. NS
	Amphipoda sp.
Isopoda	
Microcerberidae	Microcerberidae `BIS346-DNA`
	Microcerberidae `BIS356` (B01 gp)
	Microcerberidae `BIS357`
	Microcerberidae sp.
	Microcerberidae sp. B11
	Microcerberidae sp. B12
	Microcerberidae sp. B18
Syncarida	
Bathynellidae	Bathynella sp. B25

Higher Order Identifications	Lowest Identification
Bathynella	Bathynellidae `BSY200`
	Bathynellidae sp.
	Bathynellidae sp. NS
Parabathynellidae	Atopobathynella `A`
Atopobathynella	Atopobathynella `BSY201`
	Atopobathynella sp. B36
	Atopobathynella sp. B37
	Billibathynella `BSY199`
Billibathynella	Billibathynella `sp. MW`
	Billibathynella sp. B17
	Brevisomabathynella sp. B11
Brevisomabathynella	Chilibathynella sp.
Chilibathynella	Hexabathynella sp.
Hexabathynella	Hexabathynella sp. B10
	Hexabathynella sp. B13
Notobathynella	Notobathynella sp.
nr Brevisomabathynella	nr Brevisomabathynella sp. B12
Parabathynellidae gen. nov. 1	Parabathynellidae gen. nov. 1 sp. B10
	Parabathynellidae gen. nov. 1 sp. B12
	Parabathynellidae sp. NS
	Syncarida sp.
Maxillopoda	
Cyclopoida	
Cyclopidae	
Diacyclops	Diacyclops `BCY062` (humphreysi s.l.)
	Diacyclops `BCY087`
	Diacyclops cockingi
	Diacyclops einslei
	Diacyclops humphreysi s.l.
	Diacyclops humphreysi unispinosus
	Diacyclops scanloni
	Diacyclops sobeprolatus
	Diacyclops sp.
	Diacyclops sp. B01 = Diacyclops sp. 4 (PSS)
Dussartcyclops	Dussartcyclops (Dussartcyclops) mortoni
Meridiecyclops	Meridiecyclops baylyi
Mesocyclops	Mesocyclops brooksi
	Mesocyclops notius
	Mesocyclops sp.
Metacyclops	Metacyclops sp.
Microcyclops	Microcyclops varicans
nr Goniocyclops (1222)	nr Goniocyclops (1222) `BCY061`
Orbuscyclops	Orbuscyclops westaustraliensis
Pescecyclops	Pescecyclops `BCY065`

Higher Order Identifications	Lowest Identification
	Pescecyclops `BCY066`
	Cyclopoida sp.
Harpacticoida	
Ameiridae	
Gordanitocrella	Gordanitocrella trajani
Megastygonitocrella	Megastygonitocrella bispinosa
	Megastygonitocrella dec
	Megastygonitocrella sp. B05
	Megastygonitocrella trispinosa
	Megastygonitocrella unispinosa s.l.
Megastygonitocrella	Megastygonitocrella dec
Stygonitocrella	Stygonitocrella sp.
Canthocamptidae	
Australocamptus	Australocamptus `BHA258`
Elaphoidella	Elaphoidella humphreysi s.l.
	Elaphoidella sp.
	Elaphoidella sp. B09
	Canthocamptidae `BHA267`
	Canthocamptidae sp.
Ectinosomatidae	
Pseudectinosoma	Pseudectinosoma galassiae
Parastenocarididae	
Parastenocarididae n. gen.	Parastenocarididae n. gen. `BHA259`
	Parastenocarididae n. gen. `BHA265`
	Parastenocarididae n. gen. sp. B01
Parastenocaris	Parastenocaris `BHA268`
	Parastenocaris jane
	Parastenocaris sp.
	Parastenocaris sp. nov. B03 (PIL)
	Parastenocarididae sp.
	Harpacticoida sp.
	Copepoda sp.
Ostracoda	
Podocopida	
Candonidae	
?Candoninae	?Candoninae sp.
Areacandona	Areacandona ?incogitata
	Areacandona `BOS579`
	Areacandona `calmi` (PSS)
	Areacandona akatallele
	Areacandona dec
	Areacandona jessicae
	Areacandona nr korallion
Candonopsis	Candonopsis `1` (PSS)

Higher Order Identifications	Lowest Identification
	Candonopsis nr tenuis
	Candonopsis pilbarae
	Candonopsis tenuis
Leicacandona	Leicacandona `BOS1343`
	Leicacandona `BOS1354`
	Leicacandona `BOS1356`
	Leicacandona `BOS1357`
	Leicacandona lite
Meridiescandona	Meridiescandona lucerna
	Candonidae `BOS1292`
	Candonidae `BOS1332`
	Candonidae `BOS1333`
	Candoninae sp.
Cypridiae	Cypridiae sp. indet
Cyprididae	
?Ampullacypris	?Ampullacypris `BOS1341`
?Cypretta	?Cypretta sp.
Cypretta	Cypretta `BOS1353`
	Cypretta seurati
	Cypretta sp.
Cypridopsis	Cypridopsis `BOS1337`
	Cypridopsis sp.
Cyprinotus	Cyprinotus kimberleyensis s.l.
Heterocypris	Heterocypris sp.
Ilyodromus	Ilyodromus sp.
Riocypris	Riocypris fitzroyi
Stenocypris	Stenocypris major
Strandesia	Strandesia sp.
	Cyprididae sp.
Darwinulidae	
Penthesilenula	Penthesilenula brasiliensis
Vestalenula	Vestalenula matildae
(blank)	Darwinulidae sp.
Ilyocyprididae	
Ilyocypris	Ilyocypris sp.
Limnocytheridae	
Gomphodella	Gomphodella `6` (PSS)
	Gomphodella aura
	Gomphodella pilbarensis
	Gomphodella sp.
Limnocythere	Limnocythere dorsosicula
	Ostracoda `BOS1293`
	Ostracoda `BOS645`
	Ostracoda sp. NS1

Higher Order Identifications	Lowest Identification
	Ostracoda sp. NS2
	Ostracoda sp. NS3
	Ostracoda sp. unident.
Hexapoda	
Insecta	
Coleoptera	Coleoptera `sp.`
Nematoda	Nematoda sp. 17 (PSS)
	Nematoda sp. 20 (PSS)
	Nematoda spp.
Platyhelminthes	
Turbellaria	Turbellaria sp.
Rotifera	
Eurotatoria	
Bdelloidea	Bdelloidea sp. 2:2

Appendix 2 – Troglofauna Species Identified During the Desktop Search

Higher Order Identification	**Lowest Identification**
Arthropoda	
Arachnida	
Anapistula	Anapistula `sp. MW`
	Anapistula sp.
Pseudoscorpiones	
Chthoniidae	
Tyrannochthonius	Tyrannochthonius `abydos`
	Tyrannochthonius `BPS228`
	Tyrannochthonius `sp. AB A`
	Tyrannochthonius `sp. AB B`
	Tyrannochthonius `sp. AB`
	Tyrannochthonius aridus
	Tyrannochthonius sp. B38
	Chthoniidae sp. NS
Hyidae	
Indohya	Indohya `BPS201`
	Indohya `BPS202`
	Indohya `sp. MW`
Schizomida	
Draculoides	Draculoides `sp. MW`
Crustacea	
Isopoda	
Armadillidae	
?Troglarmadillo	?Troglarmadillo `sp.`
Troglarmadillo	Troglarmadillo sp.
	Troglarmadillo sp. NS
	Armadillidae sp. B13
Hexapoda	
Diplura	
Anajapygidae	Anajapygidae sp. NS
Japygidae	Japygidae sp.
Parajapygidae	Parajapygidae `BDP181`
	Parajapygidae sp. B40
Insecta	
Blattodea	Blattodea `sp. AB_NS`
Blattidae	Blattidae sp. indet
Nocticolidae	
Nocticola	Nocticola currani
	Nocticola quartermainei.
	Nocticola sp.
	Nocticola sp. S5_NS1
	Nocticola sp. NS2

Higher Order Identification	**Lowest Identification**
Coleoptera	
Carabidae	Anillini `sp.`
	Anillini sp. NS
Curculionidae	Curculionidae `sp.`
	Cryptorhynchinae `BCO192`
	Curculionidae sp. NS
Ptiliidae	
Ptinella	Ptinella sp.
Coleoptera gen 1	Coleoptera gen 1 sp. B08
Diptera	
Allopnyxia	Allopnyxia sp. B01
Hemiptera	
Meenoplidae	Meenoplidae `sp.`
	Meenoplidae sp. NS
Phaconeura	Phaconeura sp.
Zygentoma	
Nicoletiidae	
Dodecastyla	Dodecastyla sp.
Hemitrinemura	Hemitrinemura sp.
Subtrinemura	Subtrinemura sp.
	Subtrinemura sp. B03
Trinemura	Trinemura `BZY088`
	Trinemura sp.
Trinemurodes	Trinemurodes sp.
Myriapoda	
Diplopoda	
Prosopodesmus	Prosopodesmus nr `OES8`
Polyxenida	Polyxenida sp. indet
Spirobolida	
Trigoniulidae	Trigoniulidae sp.
Pauropoda	
Tetramerocerata	
Pauropodidae	Pauropodidae `BPU083`
	Pauropodidae `BPU084`
	Pauropodidae `BPU085`
	Pauropodidae `BPU086`
	Pauropodidae sp. B01 s.l.
	Pauropodidae sp. B38 (B04 group)
Symphyla	
Symphylella	Symphylella sp.
	Symphylella sp. B22
Scutigerellidae	
Scutigerella	Scutigerella sp.
	Symphyla sp.

Appendix 3 – Sampled holes for 2020-2021 subterranean fauna survey

Field code	Latitude	Longitude	Sample Type
1B-NST-M01	-21.256	119.0585	Stygofauna
GV0206	-21.2842	119.057	Troglofauna
GV0207	-21.2842	119.0578	Troglofauna
GV0208	-21.2844	119.0583	Troglofauna
GV0209	-21.2852	119.0569	Troglofauna
GV0210	-21.2851	119.0574	Troglofauna
GV0211	-21.2852	119.0579	Troglofauna
GV0213	-21.2861	119.0575	Troglofauna
GV0224	-21.2879	119.0328	Stygofauna
GV0226	-21.2889	119.0569	Troglofauna
GV0227	-21.2863	119.0595	Stygofauna
GV0228	-21.2887	119.0585	Stygofauna
GV0229	-21.2897	119.0566	Troglofauna
GV0232	-21.2908	119.0623	Stygofauna
GV0232	-21.2896	119.0581	Troglofauna
GV0241	-21.2946	119.0577	Troglofauna
GV0243	-21.2945	119.0585	Troglofauna
GV0250	-21.2925	119.0584	Troglofauna
GV0254	-21.2933	119.0561	Troglofauna
GV0263	-21.2952	119.0565	Troglofauna
GV0264	-21.295	119.0572	Troglofauna
GV0266	-21.2952	119.0581	Troglofauna
GVD0009	-21.2961	119.058	Troglofauna
GVD0011	-21.2886	119.0569	Stygofauna
GVD0012	-21.288	119.0578	Stygofauna
GVRD0289	-21.2888	119.058	Troglofauna
GVW06	-21.2389	119.0704	Stygofauna
IBM01	-21.2732	119.0588	Stygofauna
NS0079	-21.2392	119.0516	Stygofauna
NS0305	-21.2549	119.0551	Troglofauna
NS0306	-21.2547	119.0551	Troglofauna
NS0624	-21.2297	119.065	Stygofauna
NS0663	-21.2119	119.0489	Stygofauna
NS0664	-21.2969	119.0489	Stygofauna
NS0752	-21.2545	119.0543	Troglofauna
NS0755	-21.2554	119.0551	Troglofauna
NS0759	-21.2563	119.0556	Troglofauna
NS0760	-21.2562	119.0551	Troglofauna
NS0788	-21.2509	119.0578	Troglofauna
NS0789	-21.2507	119.0583	Troglofauna
NS0790	-21.2508	119.0593	Troglofauna
NS0791	-21.2508	119.0603	Troglofauna

Field code	Latitude	Longitude	Sample Type
NS0794	-21.2527	119.0589	Troglofauna
NS0795	-21.2526	119.0599	Troglofauna
NSEXS35	-21.2774	119.0298	Stygofauna
NSEXS36	-21.2794	119.0314	Stygofauna
NSOBS024	-21.2172	119.045	Stygofauna
NSOBS029	-21.2355	119.0437	Stygofauna
NSOBSS19	-21.2849	119.0269	Stygofauna
NSPB01	-21.2425	119.0547	Stygofauna
SS0001	-21.3005	119.058	Troglofauna
SS0002	-21.3006	119.0596	Troglofauna
SS0002A	-21.3005	119.0584	Troglofauna
SS0003	-21.3006	119.0595	Troglofauna
SS0004	-21.3005	119.0607	Troglofauna
SS0004A	-21.3005	119.0606	Troglofauna
SS0005	-21.3004	119.0613	Troglofauna
SS0006	-21.3005	119.0585	Troglofauna
SS0007	-21.3006	119.0636	Troglofauna
SS0016	-21.3042	119.0598	Troglofauna
SS0016A	-21.3042	119.0597	Troglofauna
SS0017	-21.3041	119.0605	Troglofauna
SS0018	-21.3041	119.0617	Troglofauna
SS0018A	-21.3041	119.0616	Troglofauna
SS0025B	-21.3078	119.0597	Troglofauna
SS0026	-21.3077	119.0606	Troglofauna
SS0027	-21.3077	119.0615	Troglofauna
SS0028	-21.309	119.0609	Troglofauna
SS0032	-21.311	119.0637	Troglofauna
SS0032A	-21.3111	119.0637	Troglofauna
SS0034A	-21.3131	119.063	Troglofauna
SS0035	-21.3131	119.064	Troglofauna
SS0036	-21.315	119.0629	Troglofauna
SS0036A	-21.3151	119.0629	Troglofauna
SS0040	-21.3184	119.0621	Troglofauna
SS0040B	-21.3185	119.0617	Troglofauna
SS0042	-21.3185	119.0634	Troglofauna
SS0047	-21.3222	119.0613	Troglofauna
SS0048	-21.322	119.0625	Troglofauna
SS0054	-21.3258	119.0605	Troglofauna
SS0055	-21.3257	119.0613	Troglofauna
SS0056	-21.3258	119.0621	Troglofauna
SS0061	-21.3292	119.0595	Troglofauna
SS0063	-21.3296	119.0609	Troglofauna
SS0071	-21.3329	119.0605	Troglofauna
SS0082	-21.34	119.0587	Troglofauna

Field code	Latitude	Longitude	Sample Type
SS0083	-21.2852	119.0578	Troglofauna
SS0086	-21.3439	119.0584	Troglofauna

Appendix 4 – AQ2 habitat modelling report