Bennelongia Environmental Consultants

Tower Hill Subterranean Fauna Assessment

Prepared for:

Genesis Minerals Limited

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Final Report

Short-Range Endemics | Subterranean Fauna

Waterbirds | Wetlands

Tower Hill Subterranean Fauna Assessment

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EXECUTIVE SUMMARY

Genesis Minerals Limited (Genesis) is planning to dewater the Tower Hill pit lake (hereafter "the Project") and currently seeks to recommence operations with a projected mine life of seven years. The Tower Hill pit was historically used to store hypersaline discharge from other mine sites. Currently, the base of the Tower Hill pit extends to 190 mBGL, with a final expansion proposed to deepen the pit by 130 m, resulting in a total depth of 320 mBGL; therefore, substantial dewatering (4.5 GL) is required as part of development. Genesis wishes to finalise the existing subterranean fauna report based on updated pit layout and drawdown contour.

Recognising the potential for Project development to affect subterranean communities, Genesis commissioned Bennelongia Environmental Consultants to assess subterranean biological values in the Project area.

Desktop assessment of an area 100 x 100 km centred on the Project recovered 69 records of 990 individuals attributable to at least 16 species of stygofauna, and 38 records of 40 individuals attributable to at least 14 species of troglofauna. Besides two stygofauna samples collected from Melita Calcrete, which partially overlaps with the Gwalia lease, none of the subterranean samples were collected within 25 km of the Project. This probably reflects a historical absence of sampling, as the geology at the Project is highly prospective for stygofauna: colluvium, alluvium, and calcrete all occur, and while in general the groundwater salinity is high, there are areas where it is suitable for stygofauna.

Subsequent field survey sampled stygofauna from 10 boreholes. Stygofauna were collected from 5 of the 10 boreholes (4/5 boreholes overly the Melita Calcrete), in salinity ranging from 10,800-120,100 µS/cm (seawater is approximately 50,000 µS/cm). In total, 364 specimens attributable to at least 21 species were collected; 13 of the species are new, including two potentially new genera. The majority of species were crustaceans, particularly copepods, but there were some oligochaete annelids, beetles, and miscellaneous roundworms.

The survey indicates a rich assemblage of stygofauna occurs at least in the Melita Calcrete, which partially overlaps the Project area, and possibly beyond it, despite relatively high salinity levels in and around the Project area. The small size (2.5 km^2, the smallest of any calcrete known in the Yilgarn) and isolation of the Melita Calcrete probably contributed to generating a rich styogofaunal community. Groundwater drawdown occurred during the original establishment of the Gwalia mine pit and the Tower Hill drawdown likely intersects it. It is evident the stygofaunal community has acclimated to any changes in groundwater regimen as a result of mining at Gwalia, which has been ongoing for over a century.

Of the specimens collected during the survey, only one new species (*Nitocrella* \`BHA368\`) was found outside the Melita Calcrete. Although collected just outside the margin of the mine pit, *Nitocrella* \`BHA368\` was found in a habitat type that is extensive; accordingly, it is unlikely that this species will be negatively affected by Project development. Thus, despite the unexpectedly high diversity of stygofauna collected in the survey, the Project is not expected to affect stygofauna conservation values.

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1. INTRODUCTION

Genesis Minerals Limited (Genesis) manages several gold operations in the Leonora region of Western Australia, including Gwalia and Tower Hill mines, both located near Leonora and approximately 235 km north of Kalgoorlie in Western Australia (Figure 1). Gwalia was established in 1896 and has since become the deepest underground trucking mine in Australia. In 2023, Genesis acquired St Barbara Ltd (St Barbara), along with the Leonora Gold Operation (LGO) and surrounding development opportunities such as Gwalia, Harbour Lights, Tower Hill and Green Banana pits. Genesis is seeking to recommence developments at the Tower Hill Project (hereafter "the Project") which includes dewatering of the Tower Hill pit lake to recommence mining operations with a projected mine life of seven years. The Tower Hill pit was historically used to store hypersaline discharge from other mine sites; substantial dewatering (4.5 GL) is required as part of development.

Recognising the potential for Project development to affect subterranean communities, Genesis commissioned Bennelongia Environmental Consultants to finalise the existing subterranean fauna report (BEC #600) in the Project area, inclusive of updated site layout and drawdown contours. This report presents the findings of a desktop assessment as well as a subsequent field survey as reported in Bennelongia (2024), and updates relevant data as per pit layout and drawdown contours. In accordance with established guidelines (EPA 2016a, 2021), the objectives of this report are:

- To collate records of subterranean animals from the proposal area and surrounds to determine the types of subterranean fauna present;
- To identify and collate all records of subterranean animals collected during survey;
- To determine the conservation status of the subterranean species recorded and the known distribution of any conservation-significant species; and
- To estimate the likely impact of mining activities on subterranean fauna based on groundwater flow, direction, connectivity, and drawdown.

1.1. Regional Geology

The Project lies in the Eastern Murchison subregion of the Murchison bioregion in Western Australia's Goldfields. The Eastern Murchison is primarily used for grazing on native pastures (85.47% of the area; Cowan 2001). Calcrete aquifers in the subregion's north are known to host significant subterranean communities (Humphreys 2001).

The climate in Leonora is arid. The highest daily mean maximum and minimum temperatures fall in January (37.0 °C and 21.8 °C respectively), and the lowest in July (18.4 °C and 6.1 °C). Monthly mean rainfall is highest in February (30.9 mm) and lowest in September (8.9 mm), but the month with highest mean number of days with rain is June (3.5 days).

The Project lies in the Gwalia Domain, which comprises Archaean mafic to ultramafic greenstone units. The Gwalia Domain is bounded by the Mount George Shear Zone to the east, the Sons of Gwalia Shear Zone to the west and south, and the Clifford Fault to the north. Mafic volcanic extrusives up to 400 m wide make up much of the Gwalia Domain, interspersed with minor thin cherty or pelitic interflow sediments. Dolerite sills and dykes also occur.

Much of the Project area is categorised as anthropogenically disturbed, in this case cleared for mining. Beyond the immediate impact zones of existing and historic mining operations, regolith comprises predominantly colluvium and alluvium, with small lacustrine areas or areas of exposed rock (Figure 2).

1.2. Hydrogeology

Available data suggest groundwater near the Project is saline to hypersaline (8,000-220,000 µS/cm), but salinity may be locally diluted by the introduction of water drawn up elsewhere (Subterranean Ecology 2008). The Raeside Palaeovalley, which partially overlaps the Project area (Figure 2) is known to host a distinct stygofauna community (Humphreys 2001). Lake Raeside palaeovalley is partly filled by Palaeogene to Quaternary age sedimentary deposits present west of Tower Hill (Pennington Scott 2024).

Clay is the dominant lithology below and adjacent to playas over the lower portion of the palaeovalley associated with internal drainage and deposition of alluvial and lacustrine deposits into slat lakes occupying the central palaeodrainage areas. Mixture of sand, gravel, clay and slit is present through the middle and upper portions of the valley slope. Calcrete has developed associated with present or past drainages through the replacement or cementation of pre-existing material with carbonate in or close to the present or past phreatic zone (Pennington Scott 2024).

Calcrete has been interested extensively in the Upper Deposits by exploratory drill-holes about the eastern margin of the palaeovalley deposits near Tower Hill, although there are no obvious outcrops of calcrete. Drill logs record calcrete extending to depths of over 50 m in some areas. However, it is uncertain what form the calcrete takes, and whether it is solid calcrete deposit or alluvium with carbonate cementation, and it is also unknown whether karstic features are develop in the calcrete (Pennington Scott 2024).

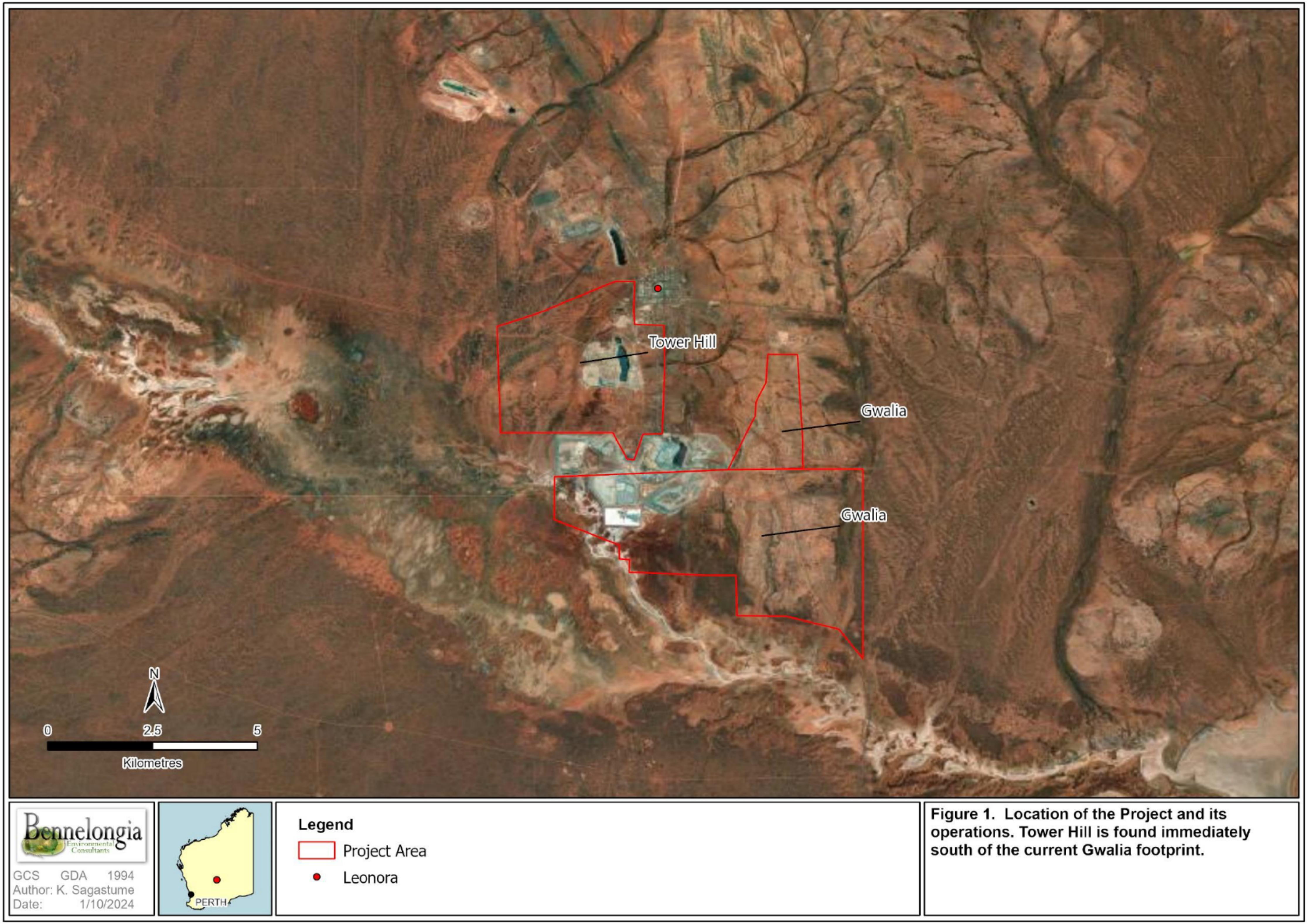


Figure 1. Location of the Project and its operations. Tower Hill is found immediately south of the current Gwalia footprint.

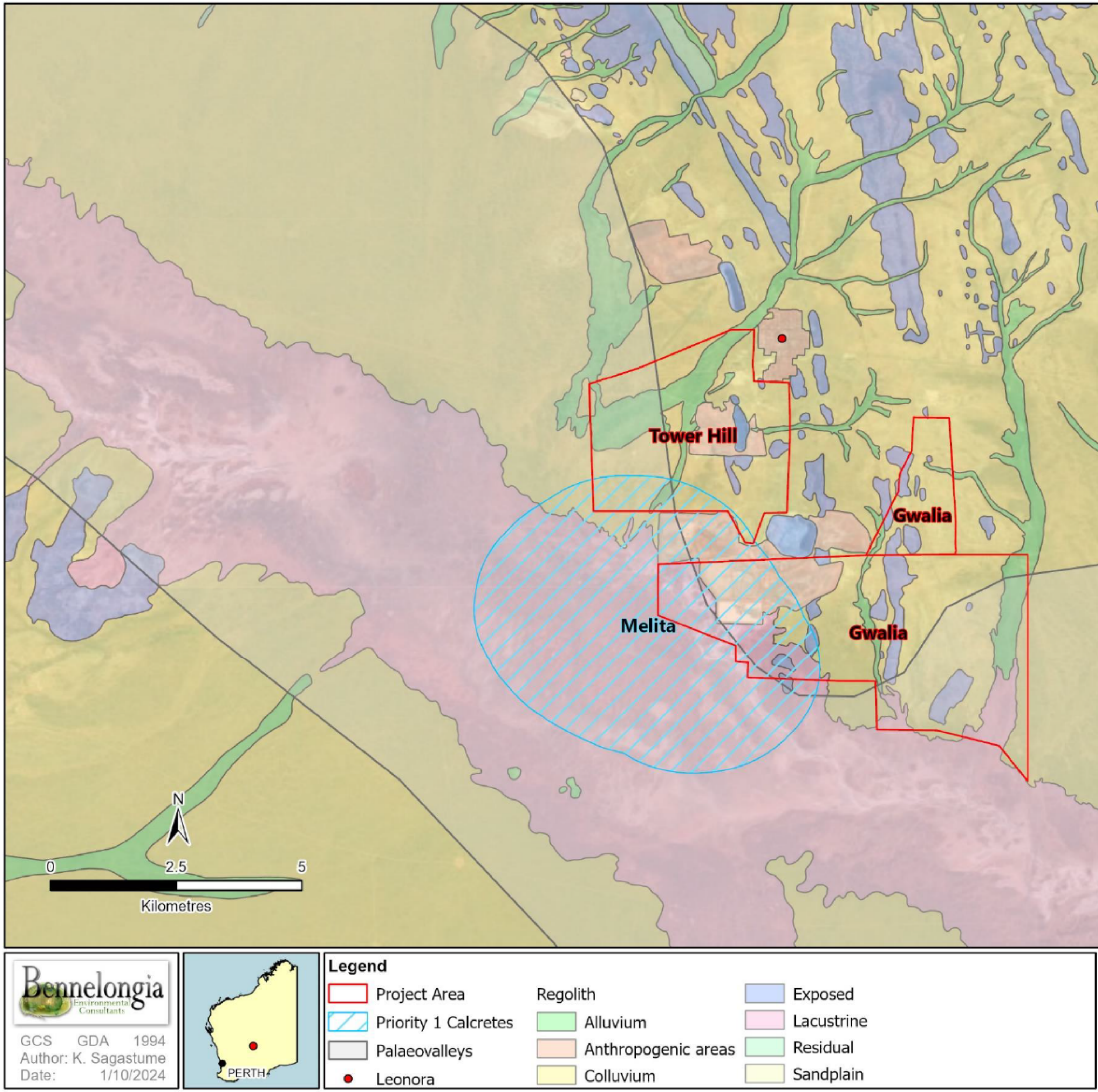


Figure 2. Surface geology at the Project.

1.3. Regional Subterranean Fauna Framework

The term subterranean fauna refers to animals living essentially full-time underground. Subterranean animals are divided into two types: stygofauna are aquatic animals that live below ground in water, while troglofauna are air-breathing animals that live underground and require very high humidity (Gibson *et al.* 2019). Stygofauna inhabit vugs, fissures, and interstitial spaces in groundwater aquifers, especially those in alluvium and calcretes. Troglofauna inhabit similar spaces above the water table but with more emphasis on vugs, fissures, and relatively large interstitial spaces.

Subterranean species share several convergent adaptations to life underground where it is dark and resources are limited. These include worm-shaped bodies, elongated chemosensory apparatus, loss of wings, transition towards K-selected breeding strategies, and the loss of skin colouration and eyes (Gibert and Deharveng 2002). Western Australia supports a particularly rich subterranean fauna outside caves (Humphreys 2000; UNESCO World Heritage Centre 2022), with estimates of over 4,000 species, 90% of which remain to be described (Guzik *et al.* 2011; Halse 2018a). Almost all subterranean animals in Western Australia are invertebrates, but fishes (Whitely 1945) and one snake (Aplin 1998) have also been recorded. Most subterranean species are inconspicuous, but contribute substantially to biodiversity and other values, for example by moderating groundwater quality (Hose and Stumpp 2019).

The distribution of subterranean animals is largely determined by prevailing lithology. In Western Australia, subterranean animals probably mostly occupy spaces only a few millimetres in width (Halse 2018a, b; Halse *et al.* 2018) but the key characteristics of their habitat(s) is that it is rich in such spaces (e.g. interstices in alluvium, screen, and voids; vugs, cavities, and fissures in consolidated geologies) and that the spaces are well connected laterally and vertically. Lateral connectivity facilitates dispersal of animals, while vertical connectivity ultimately to the surface is crucial for delivering carbon and other nutrients to subterranean ecosystems (Korbel and Hose 2011). Connectivity may be disrupted by a range of factors, including dykes, major landscape features, and chemical barriers.

Subterranean animals tend to have limited distributions. Most stygofauna species exhibit short range endemism (SRE), having substantially smaller ranges than Harvey's (2002) SRE criterion of 10,000 km^2 (Cooper *et al.* 2007; Cooper *et al.* 2002; Eberhard *et al.* 2009). The ranges of troglofauna have yet to be investigated in detail but are mostly even more restricted than those of stygofauna, with many species having linear ranges less than 10 km (Halse and Pearson 2014; Lamoreux 2004). Given that species with small ranges are more vulnerable to extinction following habitat degradation than wider ranging species, it follows that subterranean taxa are highly susceptible to anthropogenic threats, particularly large-scale excavation and groundwater abstraction (Halse 2018a; Ponder and Colgan 2002).

Stygofauna

Most stygofauna species in Western Australia are crustaceans, particularly ostracods and copepods, although other groups such as worms and beetles are sometimes abundant (DEC 2009; DPAW 2022; Matthews *et al.* 2019). The most productive known stygofauna habitats are saturated alluvial and calcrete aquifers associated with palaeochannel deposits, but stygofauna also inhabit karstic limestones, hyporheic zones, groundwater-fed springs, and aquifers in some iron formations, especially channel iron (Halse 2018b; Hyde *et al.* 2018). Stygofauna are rarely abundant where depth to the water table is more than 30 m below ground level (Halse 2018a; Halse and Pearson 2014). Aquifers with higher transmissivity are more likely to host stygofauna than aquifers with lower transmissivity (Maurice and Bloomfield 2012). Stygofauna mostly occur in fresh to hyposaline water (Halse *et al.* 2014; Humphreys *et al.* 2009), but can occur in higher salinities (Bennelongia 2016; Reeves *et al.* 2007; Watts and Humphreys 2006).

Troglofauna

Western Australia appears to be almost unique for its diverse and widespread troglofauna inhabiting small spaces in the vadose zone (Halse and Pearson 2014). The Western Australian troglofauna comprises mostly arthropods, with a variety of isopods, insects, spiders, pseudoscorpions, and millipedes, centipedes, and their allies represented. Troglofauna are particularly likely to occur in weathered or mineralised iron formations, alluvium or colluvium in valley-fill areas (including areas of karstic calcrete), and fractured sandstone (Halse 2018a). Troglofauna typically require relative humidity close to 100% (Howarth 1983).

1.3.1. Conservation legislation

Native flora and fauna in Western Australia are protected at both State and Commonwealth levels. At the state level, the *Biodiversity Conservation Act 2016* (BC Act) provides a legal framework for protection of species, particularly for species listed by the Minister for the Environment as threatened. In addition to the formal list of threatened species under the BC Act, the Department of Biodiversity, Conservation and Attractions (DBCA) also 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. 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.

Both the EPBC and BC Acts provide frameworks for the protection of threatened ecological communities (TECs), where an ecological community is defined as a naturally occurring group of plants, animals, and other organisms interacting in unique habitat (with the unique habitat created by the combination of the species and their landscape setting; DEC 2013). Communities occupying a small or threatened habitat are classified as threatened ecological communities (TECs) under the BC Act and the EPBC Act. Within Western Australia, DBCA also informally recognises communities of potential conservation concern, but for which there is little information, as priority ecological communities (PECs). The list of TECs recognised under the BC Act is larger than the EPBC Act list and has much greater focus on subterranean communities.

1.3.2. Previous survey

Subterranean Ecology (2008) carried out a pilot survey for stygofauna in January 2008. In total, 38 bores and wells were sampled using net hauling; 220 specimens were collected, of which only 14 proved to be stygofaunal, all specimens of the copepod *Mesocyclops brooksi* (Subterranean Ecology 2008). Because *M. brooksi* is widespread, its collection was not considered of conservation significance. No other stygofauna were collected.

Troglofauna have not been sampled in the Project area before.

2. DESKTOP ASSESSMENT

2.1.1. Methods

The desktop assessment combined three sources of information using GIS mapping:

- Boundary information and description of Project activity was supplied by Genesis.
- Records of subterranean animal occurrence in the vicinity of the project were derived from searching the Western Australia Museum and Bennelongia databases, as well as relevant consulting reports. For each identifiable taxon, the number of records (i.e. the number of times the taxon was found) and the number of individuals collected (i.e. how many were found in each record) from any or all of these sources was collated. Distribution patterns of identifiable taxa were cross-referenced with the Atlas of Living Australia.

- Boundaries of the calcrete PECs were provided by DBCA and the Department of Mines, Industry Regulation, and Safety.

These sources were combined in order to assess the presence or likely presence of subterranean fauna, based on prior records and habitat information. Database searches covered an area of 10,000 km^2 centred on the Project (vertices at -28.4322, 120.8207 and -29.3341, 121.8410). Analysis and mapping were undertaken using ArcGIS Pro v2.9.

2.1.2. Results

In total, 69 records of 990 individuals attributable to at least 16 species of stygofauna were recovered in the desktop search (Table 1; Figure 3). The majority (57 records of 923 specimens) were crustaceans, with strong representation from cyclopoids, harpacticoids, and isopods. The majority of specimens came from one of two surveys, one carried out by Bennelongia in March 2023 south-east of the Project and another carried out much earlier (early 2000s) in association with the Western Australian Museum north-west of the Project in the Sturt Meadows calcrete. Both surveys are more than 20 km from the Project boundaries. The closest samples comprised unidentified amphipods in the Melita Calcrete immediately west of the Gwalia lease.

Troglofauna results were similarly distributed. There were 38 records of 40 specimens in the collection records, attributable to at least 14 species (Table 2; Figure 4). All specimens were found at least 40 km from the Project boundaries, clustered in two survey areas as with stygofauna. Isopod crustaceans dominated the troglofauna samples.

Two Priority 1 calcrete PECs fall within the search area, both flagged for the unique assemblages of invertebrates found in the groundwater. The Sturt Meadows calcrete lies 36 km north-west of the Project area. The Melita Calcrete partially overlaps with the Tower Hill and Gwalia leases of the Project area. Both calcretes are associated with the Raeside Palaeovalley. The Melita Calcrete is the smallest known from the Yilgarn at 2.5 km^2 (Austin *et al.* 2023), whereas the mean calcrete area is 90.8 km^2 (Harvey *et al.* 2011).

Table 1. Stygofauna identified in the desktop search area.
No. records refers to the number of times the taxon was recorded. No. individuals refers to the number of individuals recorded across all records. Bolded values indicate higher taxonomic ranks. Grey highlighting indicates higher order identifications of specimens that may be representatives of species listed. Blue highlighting indicates higher order identifications of specimens that are not represented elsewhere in the list; these entries are considered discrete species.

Lowest identification	No. records	No. individuals	Comments
Annelida	**6**	**57**	
Clitellata	**6**	**57**	
Oligochaeta	**6**	**57**	
Tubificata	**6**	**57**	
Tubificida	**6**	**57**	
Enchytraeidae	**5**	**31**	
Enchytraeidae `2 bundle` s.l. (short sclero 4 per seg)	1	2	Probably amphibious. Least environmental significance.
Enchytraeidae `3 bundle` s.l. (short sclero)	2	25	Probably amphibious. Least environmental significance.
Enchytraeidae sp.	2	4	Probably amphibious. Least environmental significance.
Tubificidae	**1**	**26**	
Tubificidae `BOL086`	1	26	Nearest collection is 25 km south-east of Gwalia lease.
Arthropoda	**57**	**923**	
Crustacea	**57**	**923**	
Malacostraca	**37**	**138**	
Eumalacostraca	**37**	**138**	
Amphipoda	**37**	**138**	
Amphipoda sp.	3	23	Collected immediately west of Gwalia lease.
Talitrida	**34**	**115**	
Chiltoniidae	**34**	**115**	
Scutachiltonia axfordi	17	25	Nearest collection is ~45 km north-west of Tower Hill.
Stygochiltonia bradfordae	5	13	Nearest collection is ~45 km north-west of Tower Hill.
Yilgarniella sturtensis	12	77	Nearest collection is ~45 km north-west of Tower Hill.
Maxillopoda	**11**	**661**	
Copepoda	**11**	**661**	
Cyclopoida	**3**	**284**	

Lowest identification	No. records	No. individuals	Comments
Cyclopoida sp.			
Cyclopidae	**3**	**284**	
Mesocyclops brooksi	3	284	Widespread.
Harpacticoida sp.			
Harpacticoida	**8**	**377**	
Ameiridae	**1**	**2**	
Hirtaleptomesochra `BHA358`	1	2	Nearest collection is 38 km south-east of Gwalia lease.
Canthocamptidae	**6**	**374**	
Australocamptus similis	5	314	Nearest collection is ~45 km north-west of Tower Hill. Presumably widespread.
Australocamptus similis s.l.	1	60	Nearest collection is ~45 km north-west of Tower Hill. Possible species complex.
Miraciidae	**1**	**1**	
Schizopera `BHA357`	1	1	Nearest collection is 35 km south-east of Gwalia lease.
Ostracoda	**9**	**124**	
Ostracoda sp.	8	122	
Podocopa	**1**	**2**	
Podocopida	**1**	**2**	
Ilyocyprididae	**1**	**2**	
Ilyocypris australiensis	1	2	Widespread.
Nematoda	**3**	**7**	
Nematoda spp.	3	7	No conservation significance.
Platyhelminthes	**1**	**1**	
Turbellaria sp.	1	1	No conservation significance.
Rotifera	**2**	**2**	
Bdelloidea	**2**	**2**	
Bdelloidea sp. 2:2	2	2	No conservation significance.
Grand Total	**69**	**990**	

Table 2. Troglofauna identified in the desktop search area.
No. records refers to the number of times the taxon was recorded. No. individuals refers to the number of individuals recorded across all records. Bolded values indicate higher taxonomic ranks. Grey highlighting indicates higher order identifications of specimens that may be representatives of species listed. Blue highlighting indicates higher order identifications of specimens that are not represented elsewhere in the list; these entries are considered discrete species.

Lowest identification	No. records	No. individuals	Comments
Arthropoda	**38**	**40**	
Chelicerata	**17**	**17**	
Arachnida	**17**	**17**	
Araneae	**7**	**7**	
Araneomorphae	**7**	**7**	
Gallieniellidae	**1**	**1**	
Gallieniellidae sp.	1	1	Nearest collection is ~45 km north-west of Tower Hill.
Gnaphosidae	**2**	**2**	
nr *Encoptarthria* sp.	2	2	Nearest collection is ~45 km north-west of Tower Hill.
Oonopidae	**4**	**4**	
Prethopalpus humphreysi	4	4	Nearest collection is ~45 km north-west of Tower Hill.
Palpigradi	**1**	**1**	
Eukoeneniidae	**1**	**1**	
Eukoenenia guzikae	1	1	Nearest collection is ~45 km north-west of Tower Hill.
Pseudoscorpiones	**9**	**9**	
Panctenata	**3**	**3**	
Olpiidae	**3**	**3**	
Olpiidae `blind troglobite`	1	1	Nearest collection is ~45 km north-west of Tower Hill.
Olpiidae sp.	2	2	
Chthoniidae	**6**	**6**	
Lagynochthonius polydentatus	1	1	Nearest collection is ~45 km north-west of Tower Hill.
Tyrannochthonius `Helens Bore`	1	1	Nearest collection is ~45 km north-west of Tower Hill.
Tyrannochthonius billhumphreysi	4	4	Nearest collection is ~45 km north-west of Tower Hill.
Crustacea	**16**	**18**	
Malacostraca	**16**	**18**	

Lowest identification	No. records	No. individuals	Comments
Eumalacostraca	**16**	**18**	
Isopoda	**16**	**18**	
Isopoda sp.	1	1	
Ligiamorpha	**14**	**14**	
Platyarthridae	**14**	**14**	
Paraplatyarthrus `BIS514`	1	1	Nearest collection is 35 km south-east of Gwalia tenement.
Paraplatyarthrus occidentoniscus	13	13	Nearest collection is ~45 km north-west of Tower Hill.
Stenoniscidae	**1**	**3**	
Stenoniscidae gen. nov. `BIS515`	1	3	Nearest collection is ~45 km north-west of Tower Hill.
Myriapoda	**5**	**5**	
Chilopoda	**1**	**1**	
Scolopendrida	**1**	**1**	
Cryptopidae	**1**	**1**	
Cryptopidae sp.	1	1	Nearest collection is ~45 km north-west of Tower Hill.
Diplopoda	**1**	**1**	
Polyxenida	**1**	**1**	
Polyxenida sp.	1	1	Nearest collection is ~45 km north-west of Tower Hill.
Symphyla	**3**	**3**	
Symphyla sp.	3	3	Nearest collection is ~45 km north-west of Tower Hill.
Grand Total	**38**	**40**	

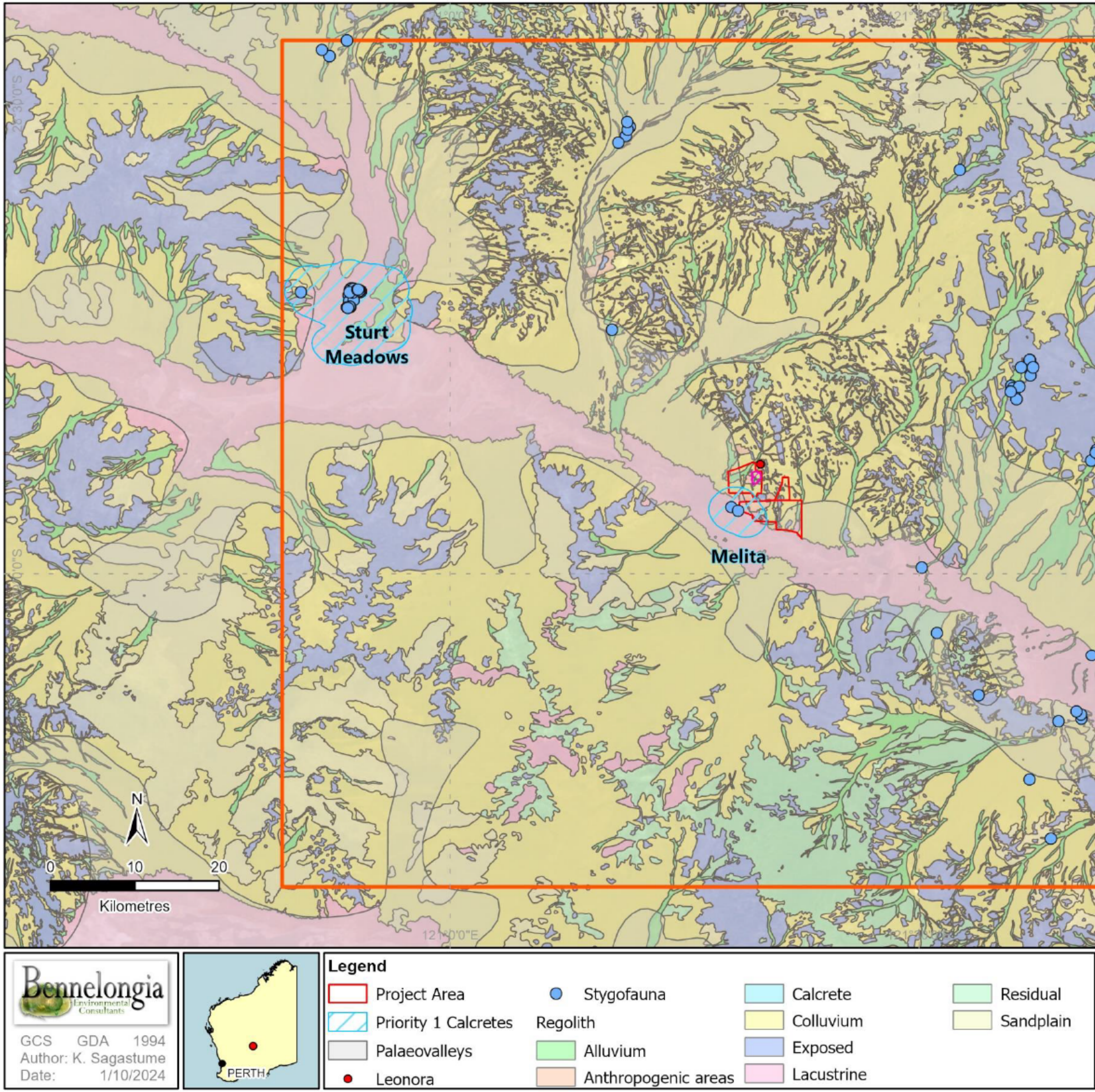


Figure 3. Stygofauna records recovered in the desktop search area.

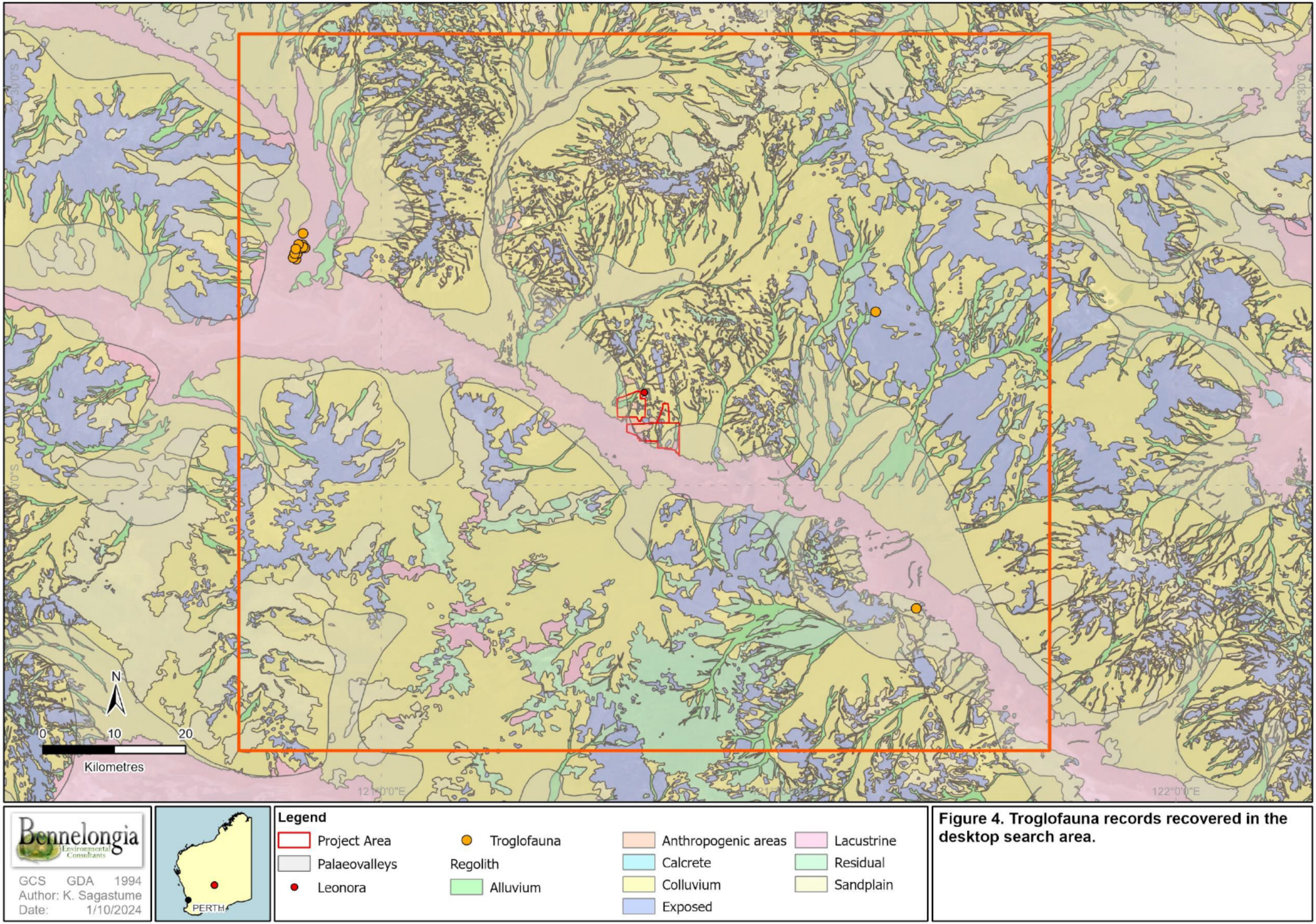


Figure 4. Troglofauna records recovered in the desktop search area.

2.1.3. Discussion

The records recovered in the desktop search indicate that a moderately rich stygofauna community exists in the Raeside Palaeovalley, and that a more modest troglofauna community probably occupies the vadose zone above the palaeovalley. However, little is known about the presence or absence of such communities within the Project area specifically, due to the lack of historical sampling.

On balance, troglofauna are probably not present in the Project area. Any pre-existing troglofauna in the Project area have probably been extirpated as a result of mining operations conducted for over a century. The Project is not expected to affect troglofauna.

By contrast, it is highly likely that stygofauna occur in the Project area. The presence of a Priority 1 calcrete partially overlapping with the Project area indicates that significant stygofauna are present in the Project area. Moreover, apart from the anthropogenically disturbed areas of the Project, the regolith in the area is generally conducive to hosting stygofauna: calcrete, alluvium, and colluvium tend to be prospective for subterranean fauna, especially when overlying a palaeovalley as in this case.

Groundwater salinity varies substantially in the region of the Project (8,000-220,000 µS/cm), but in the lower reaches of the range is certainly conducive to hosting stygofauna. The suitability of the regolith and salinity combined with the proximity of the Priority 1 calcrete and palaeovalley to the Project area suggest that stygofauna occur close to or within the Project area but have not been surveyed. Basic survey is recommended to investigate whether stygofauna are present in the Project area, and to provide a preliminary characterisation of any assemblage detected.

3. SURVEY

3.1. Methods

3.1.1. Stygofauna Sampling

A basic stygofauna sampling program was undertaken at 10 bores in the Project area (Table 3; Figures 5 and 6). Salinity among these bores was generally high and stable over time (Figure 5). Sampling was successfully completed at all bores, generating a sample effort of 10. Sampling occurred on 30-31 March 2023 and was carried out according to the methods specified by the EPA (2016a, 2016b, 2021). Six hauls using weighted plankton nets were taken at each bore, three using a 50-µm mesh net and three using a 150-µm mesh net. During each haul, the net was lowered to the bottom of the hole and oscillated vertically to agitate the benthos, increasing the likelihood of collecting benthic species, and then slowly retrieved. 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 conductivity, and pH) were measured in each bore using a WP 81 field meter. Standing water level and total depth of hole were also measured using a Solinst water level meter. Contents of the net hauls were preserved in cold ethanol and returned to the laboratory in Perth for processing.

Troglofauna were not sampled.

Table 3. Drill holes sampled for stygofauna during the field survey.
SWL: standing water level (m). EOH: end of hole (m). Temp: temperature (° C). EC: electrical conductivity (µS/cm; 1 µS/cm = 0.64 mg/L TDS).

Bore ID	**Locality**	**Latitude**	**Longitude**	**Date Visited**	**SWL**	**EOH**	**Temp**	**EC**	**pH**
Bens Bore	Gwalia	-28.927	121.35	30/03/2023	27.57	50	22.1	13,900	6.56
TSF2/04	Gwalia	-28.927	121.309	31/03/2023	1.68	17.56	21.8	120,100	5.25
TSF2/06	Gwalia	-28.92	121.305	31/03/2023	1.8	11	20.4	54,300	6.74
TSF2/08	Gwalia	-28.91	121.312	31/03/2023	4.43	14.6	23.1	11,500	7.53
UNK01	Gwalia	-28.933	121.308	30/03/2023	2.5	30	23.4	49,800	6.73
HLWB01	Harbour Lights	-28.875	121.328	30/03/2023	12.87	30	19.6	4,260	6.51
THWB005	Tower Hill	-28.897	121.329	30/03/2023	13.25	50	22.3	10,800	6.48
THWB007	Tower Hill	-28.898	121.322	30/03/2023	9.4	120	21.4	140,100	5.74
THWB012	Tower Hill	-28.897	121.327	30/03/2023	12.02	48	20	12,700	6.4
GRANT1	TSF5	-28.941	121.351	30/03/2023	19.95	57	22.1	62,800	6.48

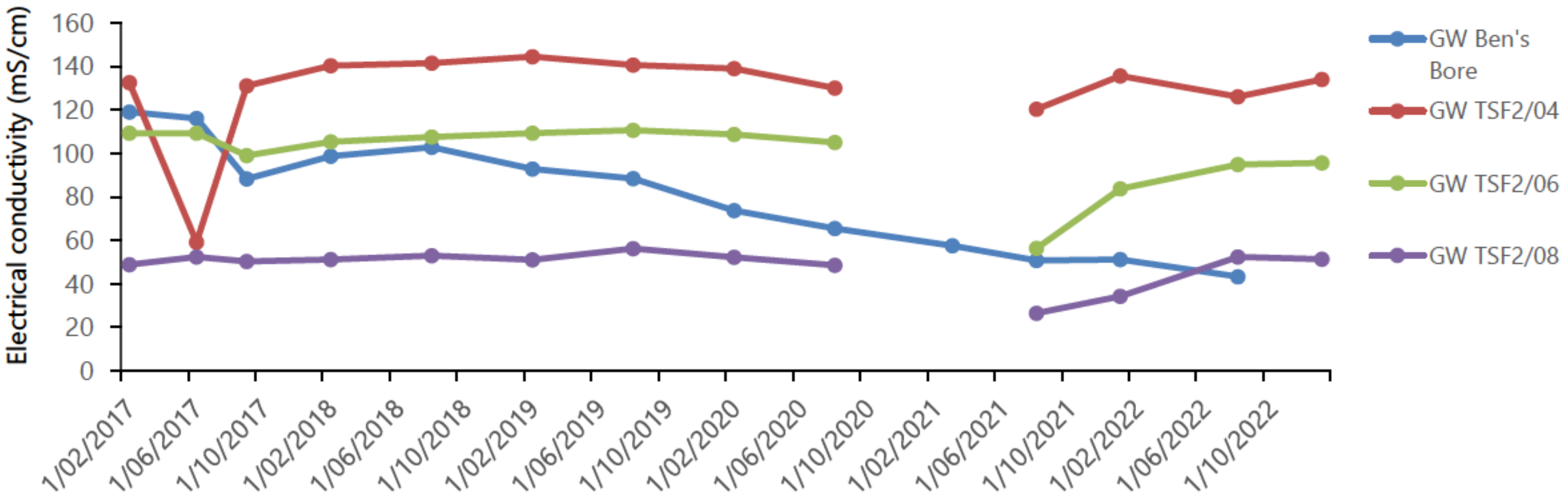
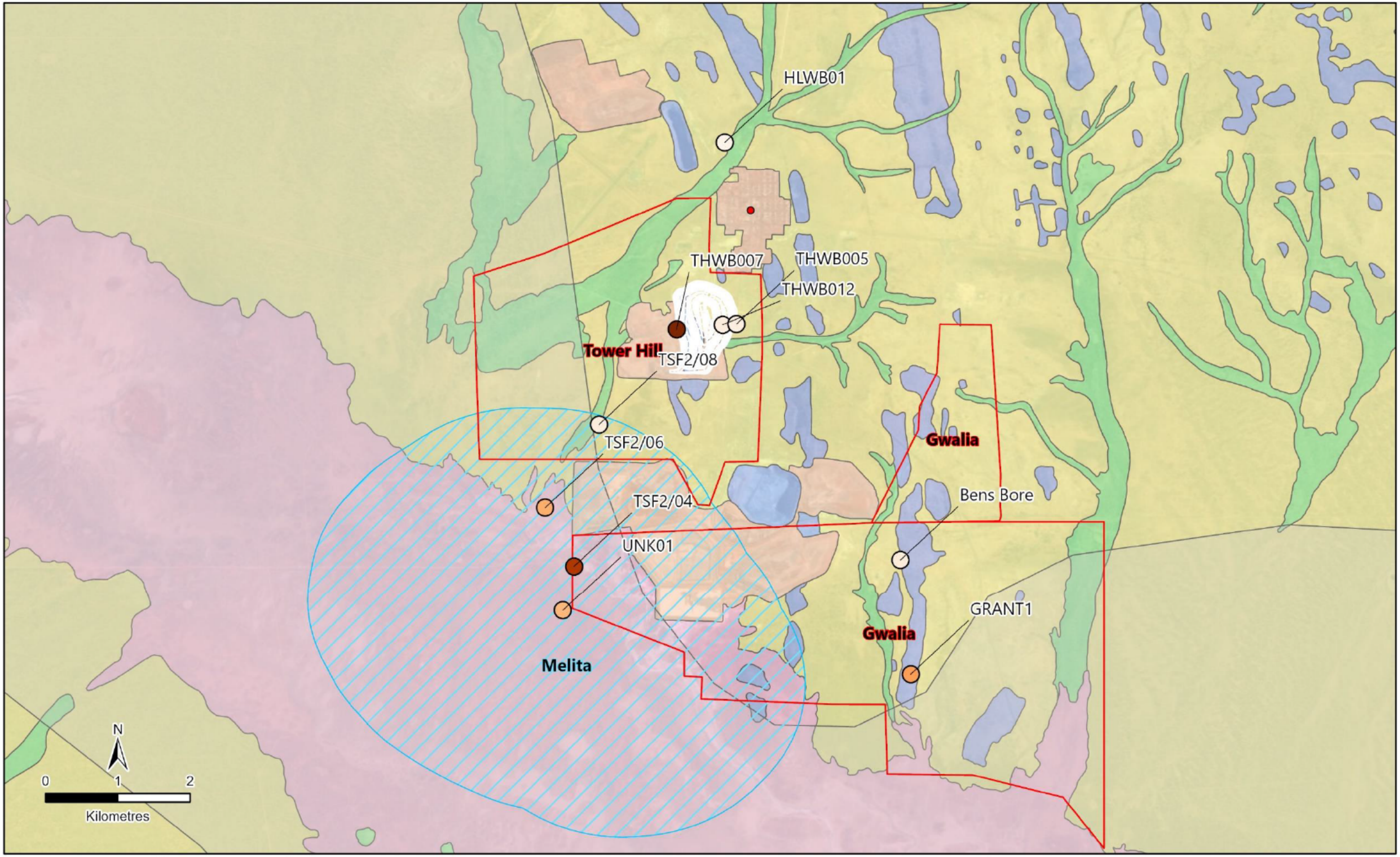


Figure 5. Salinity of select boreholes over time.



Bennelongia Environmental Consultants

GCS GDA 1994
Author: K. Sagastume
Date: 1/10/2024

PERTH

Legend

Project Area
Tower Hill LOM Impact area
Priority 1 Calcretes
Palaeovalleys
Leonora
Bores sampled
0
150000

Regolith
Alluvium
Anthropogenic areas
Colluvium
Exposed
Lacustrine
Residual

Figure 6. Boreholes sampled for stygofauna in March 2023. Degree of colouration corresponds with electrical conductivity (µS/cm).

3.1.2. Laboratory Processing

In the laboratory, samples were elutriated to separate out heavy sediment particles and sieved into size fractions using 250-, 90-, and 53-µm screens. Samples were sorted under a dissecting microscope and, where necessary, dissected and examined under a differential interference contrast compound microscope. Specimens were identified to described species where possible using available keys and species descriptions. In many cases among subterranean fauna, species descriptions and taxonomic frameworks are lacking. In these cases, specimens may be identified morphologically and/or genomically as belonging to new species that await formal description; such species are usually assigned placeholder codes (e.g. 'B01'). In other cases, when the taxonomic framework is exceptionally poor and/or the specimen in question is damaged, juvenile, or of the nondiagnostic sex, the specimen is classified to the lowest level possible, but this level is usually higher than species. These specimens often carry the miscellaneous designation "sp."

3.1.3. Molecular Methods

Ten specimens from the survey were sent for sequencing to improve taxonomic resolution. For all samples, DNA was extracted using a Qiagen DNeasy Blood & Tissue kit (Qiagen 2006). For smaller animals, legs and other body parts (e.g. sections of the abdomen) were used for DNA extraction. For larger animals, and where possible, muscle tissue was collected from the legs. Elute volumes varied from 50 µL to 100 µL, and were dependent on the age, condition, and quantity of material available.

Primer combinations used for PCR amplifications were LCO1490:HCO2198, C1J1718:HCO2198, and LCO1490:HCOoutout, targeting the COI region of the mitochondrial genome; and 16SAR-L:16SBR-H targeting the 16S gene (Folmer *et al.* 1994; Schwendinger and Giribet 2005). PCR products were sequenced using dual-direction Sanger sequencing carried out by the Australian Genome Research Facility (AGRF). The returned sequences were edited and aligned manually in Geneious (version 2022.2.2; Kearse *et al.* 2012). Geneious was also used to calculate neighbour-joining phylogenetic trees with 1,000 bootstrap permutations.

Tamura-Nei genetic distances were measured as uncorrected *p*-distances (total percentage of nucleotide differences between squares). Sequences on GenBank and in grey literature were included in the phylogenetic analysis to provide a framework for assessing intra- and interspecific variation.

3.1.4. Personnel

Field work was carried out by [redacted] Samples were sorted in the laboratory by [redacted] Stygofauna dentifications were carried out by [redacted] Molecular extraction was carried out by [redacted] and analysis by [redacted]

3.2. Results

Sequencing was successful in 5 of 10 specimens sent for sequencing (Table 4); in the remainder, small body size and/or degradation of tissue probably caused the sequencing failure. Among the successfully sequenced specimens, the original morphological identification was supported in four of five cases. For the final specimen, the morphological identification of *Australocamptus similis* s.l. was updated to *Australocamptus hamondi* as a result of molecular analysis. All subsequent results and discussion consider only these final, post-molecular identifications.

In total, 364 specimens attributable to at least 21 species were collected (Table 5; Figures 7 & 8). The majority of species were crustaceans, particularly copepods, but there were some oligochaete annelids, beetles, and miscellaneous roundworms. Of the 21 species, 13 are new; 12 of the new species were found in the Melita Calcrete. The remaining species, the harpacticoid amphipod *Nitocrella* \`BHA368\`, was found approximately 4.5 m outside of the margin of the updated proposed Tower Hill pit boundary (inset Figure 7).

Stygofauna were collected from five of the ten bores. The most saline and the least saline bores (THWB007 and HLWB01, respectively) did not yield any stygofauna samples. Of the five bores that did yield samples, salinity ranged from 10,800-120,100 µS/cm.

The most diverse borehole was UNK01 with 50 specimens of 11 species (49,800 µS/cm, approximately the concentration of seawater), in the centre of Melita Calcrete (Figure 8). Two more bores in the calcrete showed high diversity: TSF2/04 with 112 specimens of at least 10 species (120,100 µS/cm) and TSF2/06 with 115 specimens of 3 species (54,300 µS/cm). Outside the calcrete, THWB005 yielded 86 specimens of 2 species (10,800 µS/cm); and just inside the calcrete's buffer area TSF2/08 yielded 1 specimen of 1 unidentifiable copepod (11,500 µS/cm).

3.3. Discussion

The survey indicates a rich assemblage of stygofauna occurs at least in the Melita Calcrete, which partially overlaps the Project area, despite relatively high salinity levels in and around the Project area. Almost two thirds (13/21) of the species collected are new; all but one of the new species (*Nitocrella* \`BHA368\`) were collected from the Priority 1 Melita Calcrete.

The harpacticoid amphipod *Nitocrella* \`BHA368\` was collected from a bore with relatively low salinity (10,800 µS/cm), and outside both Melita Calcrete and Raeside Palaeovalley. It was, however, collected from an area mapped as colluvium. Calcrete, alluvium, and colluvium provide habitat highly conducive to stygofauna when at least partially inundated. Although the single specimen of *N.* \`BHA368\` was collected just outside the margin of the mine pit, its habitat and therefore probably distribution extend beyond the mine pit and into the Raeside Palaeovalley. It is therefore, not expected to be negatively affected by Project development.

Several factors probably interact to generate the high diversity found. Despite generally being high, the salinity varied across the calcrete's extent, suggesting subdivisions or salinity gradients occur within the calcrete, which can drive diversity (Humphreys *et al.* 2009). For example, the stygal diving beetles *Limbodessus melitaensis* and *L. micromelitaensis* co-evolved in the Melita Calcrete, the type and only known locality of both species (Watts and Humphreys 2006; Watts and Humphreys 2009). Despite both being predators, the two species probably target different prey and/or occupy different salinities (Austin *et al.* 2023). Indeed, species of stygal beetles are almost always restricted to a single calcrete, but often share that calcrete with one, sometimes two, and rarely three other species (Austin *et al.* 2023; Bradford *et al.* 2013b).

Similar patterns of closely related species co-existing in shared habitats occur elsewhere in the Raeside Palaeovalley. In the Sturt Meadows calcrete 36 km north-west of the Project, the three chiltoniids listed in Table 1 (*Scutachiltonia axfordi*, *Stygochiltonia bradfordae*, and *Yilgarniella sturtensis*) are morphologically indistinguishable but are divergent at the genus level genetically (King *et al.* 2012). Considering that many subterranean species originate from epigean species that become permanently trapped belowground, these species probably began as relatively small populations isolated in separate areas within the host calcrete. Genomic evidence suggests that the populations subsequently expanded to occupy most of the calcrete and to overlap with one another, but remained genetically discrete (Bradford *et al.* 2013a; Saccò *et al.* 2020).

Table 4. Results of molecular analysis.
Orange highlighting indicates an identification that was changed using molecular evidence. Grey highlighting indicates a specimen for which sequencing was unsuccessful. Alphanumeric strings preceded by # are GenBank accession codes.

Morphological Identification	Drill Hole	Updated Identification	Comments
Yilgarniella \`BAM220\`	UNK01	*Yilgarniella* \`BAM220\`	At least 8% divergent from the closest known referent on GenBank (Chiltoniidae sp. SW2b isolate YBWA_CW410_1, #KT958044). New species code conservatively retained.
Halicyclops ambiguus	TSF2/06		
Halicyclops pescei	UNK01	*Halicyclops pescei*	92.5% similarity with a specimen (Harpacticoida sp. TB-2009 ABTC:104230, #FJ785772) from 78 km south-east that is almost certainly the same species.
Halicyclops pescei	TSF2/04		
Australocamptus similis s.l.	THWB005	*Australocamptus hamondi*	94.5% identity to *Australocamptus hamondi* isolate 11508 (#ON931468).
Nitokra \`BHA366\`	TSF2/04		
Nitokra \`BHA367\`	TSF2/04		
nr *Inermipes* \`BHA364\`	TSF2/04		
Pseudectinosoma \`BHA363\`	TSF2/04		
Haloniscus \`BIS516\`	UNK01	*Haloniscus* \`BIS516\`	At least 20% divergent from all referents in GenBank or in the Bennelongia database. New species code retained.

Table 5. Subterranean fauna recovered during the field survey carried out in March 2023.
No. records refers to the number of times the taxon was recorded. No. individuals refers to the number of individuals recorded across all records. EC: electrical conductivity (µS/cm; 1 µS/cm = 0.64 mg/L TDS). Bolded values indicate higher taxonomic ranks. Orange highlighting indicates a species with a known distribution restricted to the Project area, usually collected for the first time in this survey. Grey highlighting indicates higher order identifications of specimens that may be representatives of species listed.

Classification	No. records	No. individuals	Bore ID(s)	EC	Notes
Annelida	**5**	**7**			
Clitellata	**5**	**7**			
Enchytraeida	**2**	**3**			
Enchytraeidae	**2**	**3**			
Enchytraeidae `2 bundle` s.l. (long thin 2 per seg)	1	1	UNK01	49,800	Probably amphibious; of no conservation significance.
Enchytraeidae `2 bundle` s.l. (short sclero 4 per seg)	1	2	UNK01	49,800	Probably amphibious; of no conservation significance.
Haplotaxida	**3**	**4**			
Tubificidae	**3**	**4**			
Tubificidae `BOL088`	1	1	UNK01	49,800	Morphologically distinct from `BOL089` and from another tubificid collected 42 km south-east. Collected from Melita Calcrete.
Tubificidae `BOL089`	2	3	TSF2/04	120,100	Morphologically distinct from `BOL088` and from another tubificid collected 42 km south-east. Collected from Melita Calcrete.
Arthropoda	**24**	**352**			
Crustacea	**20**	**288**			
Malacostraca	**4**	**16**			
Amphipoda	**2**	**10**			
Chiltoniidae	**2**	**10**			
Yilgarniella `BAM220`	1	9	UNK01	49,800	Morphologically and genomically distinct. Collected from Melita Calcrete.

Classification	No. records	No. individuals	Bore ID(s)	EC	Notes
Yilgarniella sp.	1	1	TSF2/04	120,100	Incomplete, degraded specimen.
Isopoda	**2**	**6**			
Scyphacidae	**2**	**6**			
Haloniscus \`BIS516\`	1	2	UNK01	49,800	Morphologically and genomically distinct. Collected from Melita Calcrete.
Haloniscus sp.	1	4	TSF2/04	120,100	Incomplete, degraded specimens.
Maxillopoda	**16**	**272**			
Cyclopoida	**4**	**128**			
Cyclopoida sp.	1	1	TSF2/08	11,500	Juvenile specimen. Collected from within the waste area and within the buffer zone for Melita Calcrete.
Cyclopidae	**3**	**127**			
Halicyclops ambiguus	1	110	TSF2/06	54,300	Widespread in the region. Associated with high salinity.
Halicyclops pescei	2	17	TSF2/04, UNK01	120,100, 49,800	Also known from 350 km north-west.
Harpacticoida	**12**	**144**			
Ameiridae	**6**	**44**			
Ameiridae gen. nov. \`BHA362\`	1	2	UNK01	49,800	Morphologically distinct from another ameirid collected 42 km south-east. Collected from Melita Calcrete.
Nitocrella \`BHA368\`	1	1	THWB005	10,800	Morphologically distinct. **Collected from the margin of the pit boundary.**
Nitokra \`BHA365\`	1	1	TSF2/06	54,300	Morphologically distinct. Collected from Melita Calcrete.
Nitokra \`BHA366\`	1	5	TSF2/04	120,100	Morphologically distinct. Collected from Melita Calcrete.
Nitokra \`BHA367\`	1	15	TSF2/04	120,100	Morphologically distinct. Collected from Melita Calcrete.

Classification	No. records	No. individuals	Bore ID(s)	EC	Notes
nr *Inermipes* \`BHA364\`	1	20	TSF2/04	120,100	Differs from *Inermipes* in several morphological characters. Specimens in poor condition.
Canthocamptidae	**2**	**86**			
Australocamptus hamondi	1	85	THWB005	10,800	Widespread in the region.
Australocamptus sp.	1	1	TSF2/04	120,100	Incomplete specimen.
Ectinosomatidae	**2**	**11**			
Pseudectinosoma \`BHA363\`	2	11	TSF2/04, TSF2/06	120,100, 54,300	Morphologically distinct. Collected from Melita Calcrete.
Miraciidae	**2**	**3**			
Schizopera \`BHA360\`	1	1	UNK01	49,800	Morphologically distinct from *Schizopera* \`BHA361\` and from a congener collected 42 km south-east. Collected from Melita Calcrete.
Schizopera \`BHA361\`	1	2	TSF2/04	120,100	Morphologically distinct from *Schizopera* \`BHA360\` and from a congener collected 42 km south-east. Collected from Melita Calcrete.
Hexapoda	**4**	**64**			
Insecta	**4**	**64**			
Coleoptera	**4**	**64**			
Dytiscidae	**4**	**64**			
Limbodessus melitaensis	2	56	TSF2/04, UNK01	120,100, 49,800	Adults and larvae collected; sites are approx. 200 m from type locality.
Limbodessus micromelitaensis	2	8	TSF2/04, UNK01	120,100, 49,800	Adult and larvae collected.
Nematoda	**1**	**5**			
Nematoda spp.	1	5	TSF2/04	120,100	No conservation significance.
Grand Total	**30**	**364**			

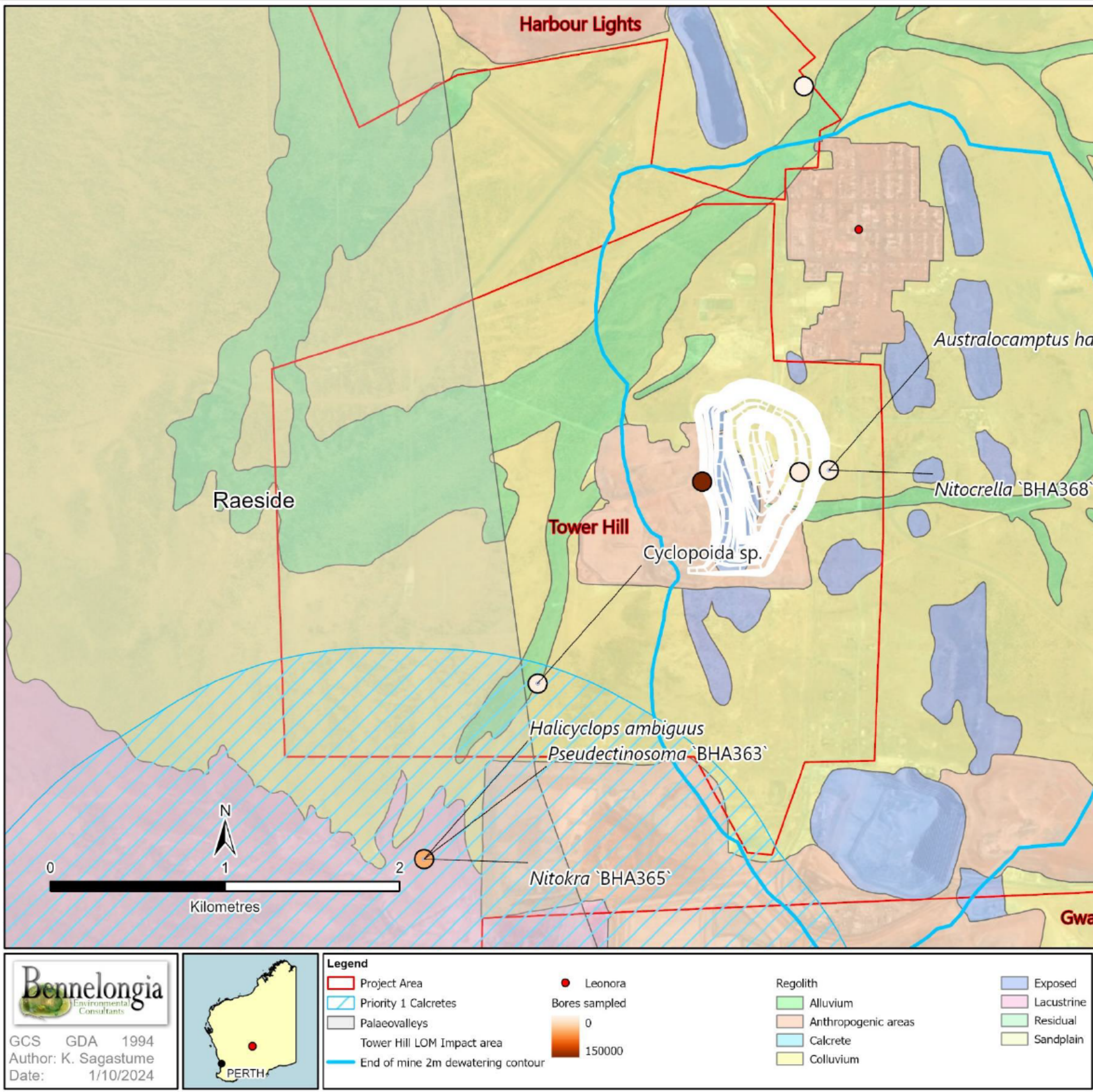


Figure 7. Stygofauna collected in March 2023. Degree of colouration corresponds with electrical conductivity (µS/cm). White outlines indicate mine pit. Inset shows close up of bore THWB005 and how it sits just outside of the pit outline.

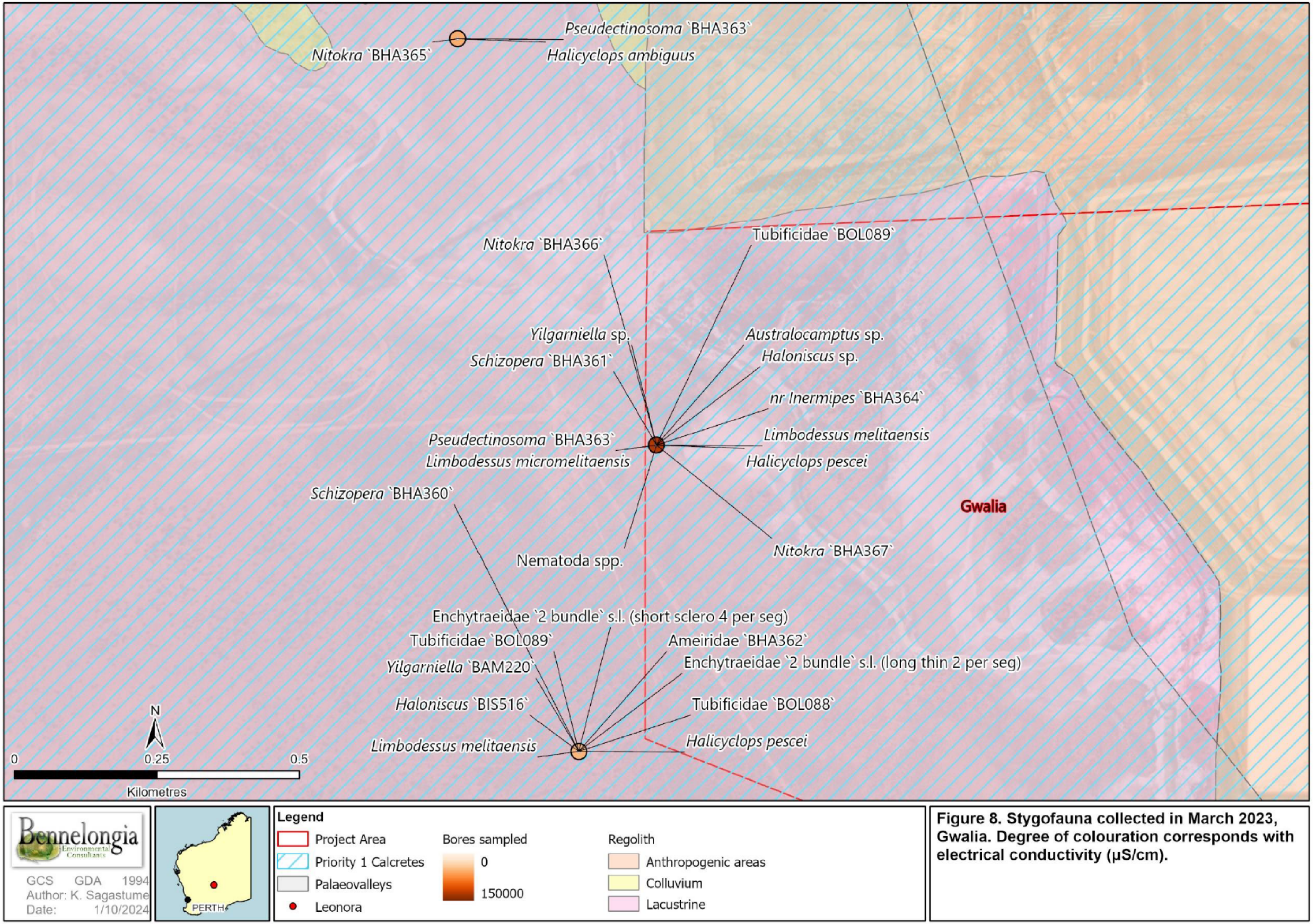


Figure 8. Stygofauna collected in March 2023, Gwalia. Degree of colouration corresponds with electrical conductivity (µS/cm).

The kinds of population expansion that lead to such patterns of co-existing sister taxa are probably driven by changes in groundwater dynamics. For example, rainfall events trigger a cascade of changes, temporarily augmenting in turn the populations of microbes in the calcrete, the first-order consumers of those microbes (usually crustaceans), and ultimately the apex predators, often beetles (Saccò *et al.* 2021).

3.3.1. Conclusion

Overall, the small size (2.5 km^2, the smallest of any calcrete known in the Yilgarn) and isolation of the Melita Calcrete probably contributed to generating a rich styogofaunal community; this richness was reflected in the survey. The 2m drawdowns for Tower Hill intersect a small fraction of the Melita Calcrete PEC, a community which has already been impacted by the historical Gwalia developments. The most significant drawdowns will occur to the north and south of the Project largely confined to mafic formations which provide most of the dewatering yield. Limited propagation will occur to the west due to the presence of impermeable granite bedrock and the Gwalia TSF which act as natural barriers (Pennington Scott 2024).

The rich stygofaunal community identified through the survey shows evident signs of having acclimated to any changes in groundwater regimen as a result of mining at Gwalia, which has been ongoing for over a century. Groundwater drawdown occurred during the original establishment of the Gwalia mine pit and the Tower Hill drawdown likely intersects this. Given the historical groundwater impacts over these overlapping areas, further cumulative impact over the stygofaunal community is unlikely.

Based on the information presented in this assessment, the expected impact of the Project activities on stygofauna is minimal. Of the specimens collected during the survey, only one new species (*Nitocrella* \`BHA368\`) was found outside the Melita Calcrete. Although being collected from just outside (4.5 m) the margin of the mine pit, *Nitocrella* \`BHA368\` was found in a habitat type that is extensive; accordingly, it is unlikely that this species will be negatively affected by Project development. Thus, despite the unexpectedly high diversity of stygofauna collected in the survey, the Project is not expected to affect stygofauna conservation values.

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