Bennelongia Environmental Consultants

Roy Hill

South West Injection Borefield

Troglofauna Assessment

Prepared for:

Roy Hill

December 2019

Final Report

Short-Range Endemics I Subterranean Fauna

Waterbirds I Wetlands

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Troglofauna Assessment

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Report Number: 379

Report Version	Prepared by	Reviewed by	Submitted to Client	
			Method	Date
Draft	Anton Mittra		Email	22/11/2019
Final	Anton Mittra		Email	13/12/2019

BEC_Roy Hill SWIB_troglofauna_12xii2019_final.docx

EXECUTIVE SUMMARY

The Roy Hill Iron Ore Project ('the Project') is located 115 km north of Newman near the Fortescue Marsh. Roy Hill maintains a Water Management Strategy (RHWMS) for dewatering, water supply and surplus water disposal. Managed Aquifer Recharge (MAR) to dispose of excess water via reinjection in the South West Injection Borefield (SWIB) has the potential to increase groundwater levels. This could potentially remove habitat occupied by troglofauna above the existing water table.

This report presents the results of a field survey in the SWIB to characterise the troglofauna community and its constituent species. Subsequently, the potential impacts of MAR on troglofauna in the SWIB and the significance of these impacts are assessed. The assessment is based on the iteration of the RHWMS provided to Bennelongia at the time of writing (GHD 2019). The assessment does not consider potential impacts to troglofauna in areas outside the SWIB that may be affected by other components of the RHWMS.

Bennelongia previously reviewed existing geological and hydrogeological data and assessed the prospectivity of habitat in the SWIB for troglofauna. The assessment concluded that habitat prospectivity for troglofauna was moderate, with potential habitat in the SWIB consisting of unsaturated alluvials, which are extensive.

Bennelongia completed troglofauna sampling at a total of 21 bores throughout the SWIB in 2019. Each bore was sampled via scraping and two traps were also set in each bore with the exception of RHTB0014, in which a single trap was set. Traps were left in situ for a period of two-months. All invertebrates collected were examined for troglomorphic characteristics and, if troglofauna, identified to species or morphospecies level using existing taxonomic frameworks. Where a specimen could not be placed in a described species, it was assigned a morphospecies code (unless juvenile).

Three of the 21-bores sampled in the SWIB in 2019 yielded troglofauna, with three species recorded, including one-species of spider, one-species of millipede and one-species of dipluran. In addition, SMEC (2009) collected a pauropod in a stygofauna net sample taken in close proximity to the SWIB and within the predicted extent of mounding. A total of four troglofauna species have therefore been recorded within the SWIB and the predicted extent of mounding.

Overall, considering sampling effort and the resultant yields of troglofauna in terms of both abundance and the number of species, it is considered that the troglofauna community in the SWIB is depauperate and comprises species that are known, or are otherwise highly likely, to occur outside the predicted extent of mounding. A small number of subterranean aquatic species – stygofauna – were collected as bycatch during the current survey.

Due to the large extent of alluvial habitat, the known or likely ranges of species present and the small predicted extent of the mounding zone it is considered highly unlikely that any of the species present in the SWIB has a range confined to the mounding zone. Therefore, it is unlikely that troglofauna species in the SWIB face conservation-significant impacts as a result of the RHWMS.

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1. INTRODUCTION

The Roy Hill Iron Ore Project ('the Project') is located in the Pilbara region of Western Australia approximately 115 km north of Newman in the vicinity of the Fortescue Marsh (Figure 1). Roy Hill maintains a Water Management Strategy (RHWMS) for dewatering, water supply and surplus water disposal to ensure alignment with business, stakeholder and environmental objectives.

As part of Managed Aquifer Recharge (MAR), a component of the RHWMS, options are being explored to dispose of excess water via reinjection in the South West Injection Borefield (SWIB), which has the potential to increase groundwater levels. This could remove habitat occupied by troglofauna above the existing water table.

This report presents the results of a field survey in the SWIB to characterise the troglofauna community and its constituent species. Subsequently, the potential impacts of MAR on troglofauna in the SWIB and the significance of these impacts are assessed. The assessment is based on the iteration of the RHWMS provided to Bennelongia at the time of writing (GHD 2019). The assessment does not consider potential impacts to troglofauna in areas outside the SWIB that may be affected by other components of the RHWMS.

2. SUBTERRANEAN FAUNA FRAMEWORK

Subterranean fauna includes aquatic stygofauna and air-breathing troglofauna. Both groups characteristically have reduced or absent eyes and are poorly pigmented due to lack of light. Subterranean fauna species in caves have often developed vermiform bodies and elongate sensory structures, though species in tighter, non-cave habitats in the wider landscape do not necessarily share these adaptations. Other typical morphological and physiological adaptations in underground species include wing reduction or loss, increased lifespan, a shift towards K-selection breeding strategy and decreased metabolism (Gibert and Deharveng 2002). Except for a few species of fish, all subterranean fauna species in Western Australia are invertebrates. This report focuses on troglofauna.

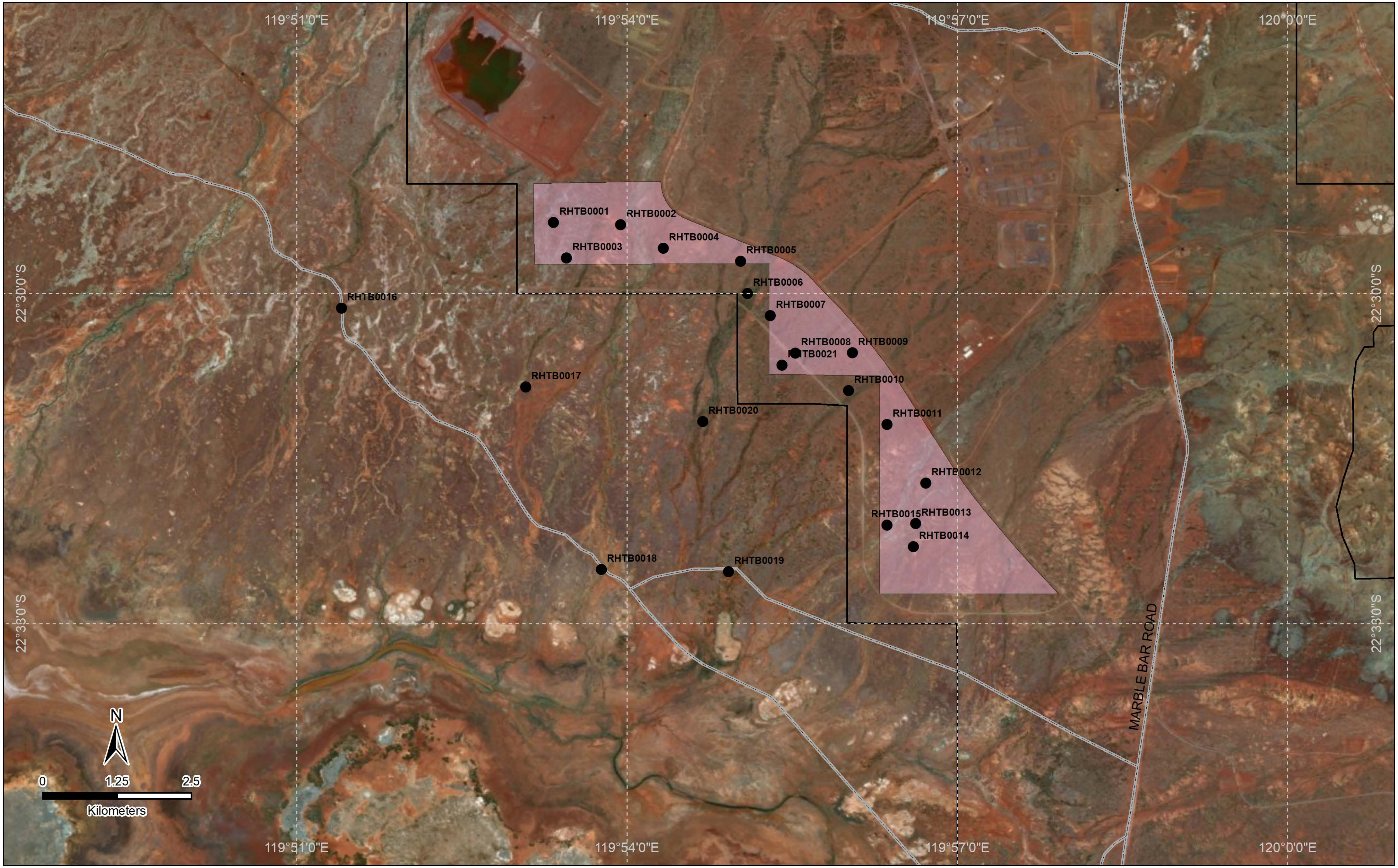
Although inconspicuous, subterranean fauna contribute markedly to the overall biodiversity of Australia. The Yilgarn, Pilbara and neighbouring regions of Western Australia are hotspots of subterranean faunal biodiversity, with an estimated 4,000 or more subterranean species likely to occur (Guzik *et al.* 2010), the majority of which remain undescribed. Most subterranean species satisfy Harvey's (2002) criteria for short-range endemism (SRE), having total range size of less than 10,000 km^2 and occupying discontinuous or fragmented habitats.

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 species are highly susceptible to anthropogenic threats. For troglofauna, the primary threat from mining is usually considered to be excavation, although augmenting the groundwater table by reinjection also has the potential to flood (and therefore remove) existing troglofauna habitat. In Western Australia the Environmental Protection Authority (EPA) requires consideration of subterranean fauna as part of environmental impact assessment (EPA 2016a, b, c).

Some troglofauna species, termed troglobites, are obligate inhabitants of subterranean spaces above the water table, while others termed troglophiles have some affinity with surface and soil habitats. Troglophiles are usually considered to have larger distributions than troglobites as a result of greater dispersal opportunities. Trogloxenes are species that use subterranean habitats opportunistically.

3. HABITAT

Bennelongia (2018b) reviewed existing geological and hydrogeological data and assessed the prospectivity of habitat in the SWIB for troglofauna. The assessment considered that habitat



Bennelongia Environmental Consultants

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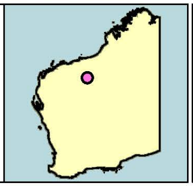
Author: A. Mittra
Date: 02-09-2019



Legend

Revised Development Envelope
SWIB
Troglofauna sample bore
Road

Figure 1. Location and layout of the South West Injection Borefield (SWIB) and bores sampled for troglofauna.

prospectivity for troglofauna was moderate[1], with potential habitat in the SWIB consisting of unsaturated alluvial cover material.

The moderately extensive continuity of the alluvial cover throughout and outside the SWIB is illustrated by the geological model depicted in cross sections in Appendix C of the Life of Mine Water Management Strategy (GHD 2019). Previous surveys in the region (e.g. Bennelongia 2018a) have demonstrated that troglofauna occur at variable levels of abundance and richness, depending on local situation, in the upper alluvial and detrital units flanking the Fortescue Marsh. Limiting factors on troglofauna habitat throughout the SWIB were considered to include depth to water, which was reported to be 5–20 m (Roy Hill 2018) and the degree of development of subterranean spaces, for which there was limited information.

4. FIELD SURVEY METHODS

The current assessment is based on a field survey targeting troglofauna species using two complimentary sampling methods, scraping and trapping, in accordance with sampling guidelines (EPA 2016b). Previous records of troglofauna species in the immediate vicinity of the SWIB were also compiled from the Bennelongia database, which is considered to be more or less comprehensive and contains data from work undertaken by both Bennelongia and other consultants (where available), as well as published literature and incorporated into the list of species present.

A total of 21 uncased exploration drill holes (bores) were sampled for troglofauna within the SWIB (Figure 1). Each bore was sampled via scraping and two traps were also set in each bore with the exception of RHTB0014, in which a single trap was set. This bore had partially collapsed at a depth of about 5 m. Traps were left in situ for a period of two-months.

Scrape samples (scrapes) were collected immediately prior to setting traps using a troglofauna net (150 µm mesh) that was lowered to the bottom of the hole (or to the watertable) and scraped back to the surface along the walls of the hole. Each scrape comprised at least four sequences of lowering and retrieving the net to give adequate coverage over the inner surface of the hole. Scrapes were preserved in 100% ethanol and kept on ice in the field prior to refrigeration at the conclusion of work.

Cylindrical PVC traps with numerous apertures were baited with moist leaf litter and lowered on nylon cord to depths considered to give the best sampling coverage along the length of the hole. The leaf litter bait had been collected from either the Yilgarn or Pilbara, wetted, allowed to decompose over weeks or months and sterilised via microwaving. Holes were capped at the surface while traps were set over a period of two-months to minimise the collection of surface invertebrates. Scrape and trap samples within the same site were treated as sub-samples of a single sample for reporting purposes.

In the laboratory the preserved contents of scrapes were screened into size fractions (250 µm and 90 µm) to remove debris and improve searching efficiency and sorted under a dissecting microscope. Troglofauna were extracted from the leaf litter in traps using Tullgren funnels under incandescent lamps: light and heat from the lamps drives troglofauna (and other invertebrates) out of the litter towards the base of the funnel and into a collection vial containing 100% ethanol. The contents of each collection vial were sorted under a dissecting microscope. Litter from each funnel was also examined under a microscope for any remaining animals.

All invertebrates collected were examined for troglomorphic characteristics and, if troglofauna, identified to species or morphospecies level using existing taxonomic frameworks. Where a specimen could not be placed in a described species, it was assigned a morphospecies code (unless juvenile).

[1] Likely to host some subterranean species, although at least one environmental factor (e.g. depth to water) points to a limited assemblage in terms of richness and/or abundance.

5. RESULTS

Three of the 21-bores sampled in the SWIB in 2019 yielded troglofauna, with three species recorded, including one-species of spider, one-species of millipede and one-species of dipluran (Table 1). In addition, SMEC (2009) collected a pauropod in a stygofauna net sample taken in close proximity to the SWIB and within the predicted extent of mounding (Figure 2; Table 1) as predicted by modelling (GHD 2019). Photographs of specimens, other than the pauropods which is not available for examination, are presented in

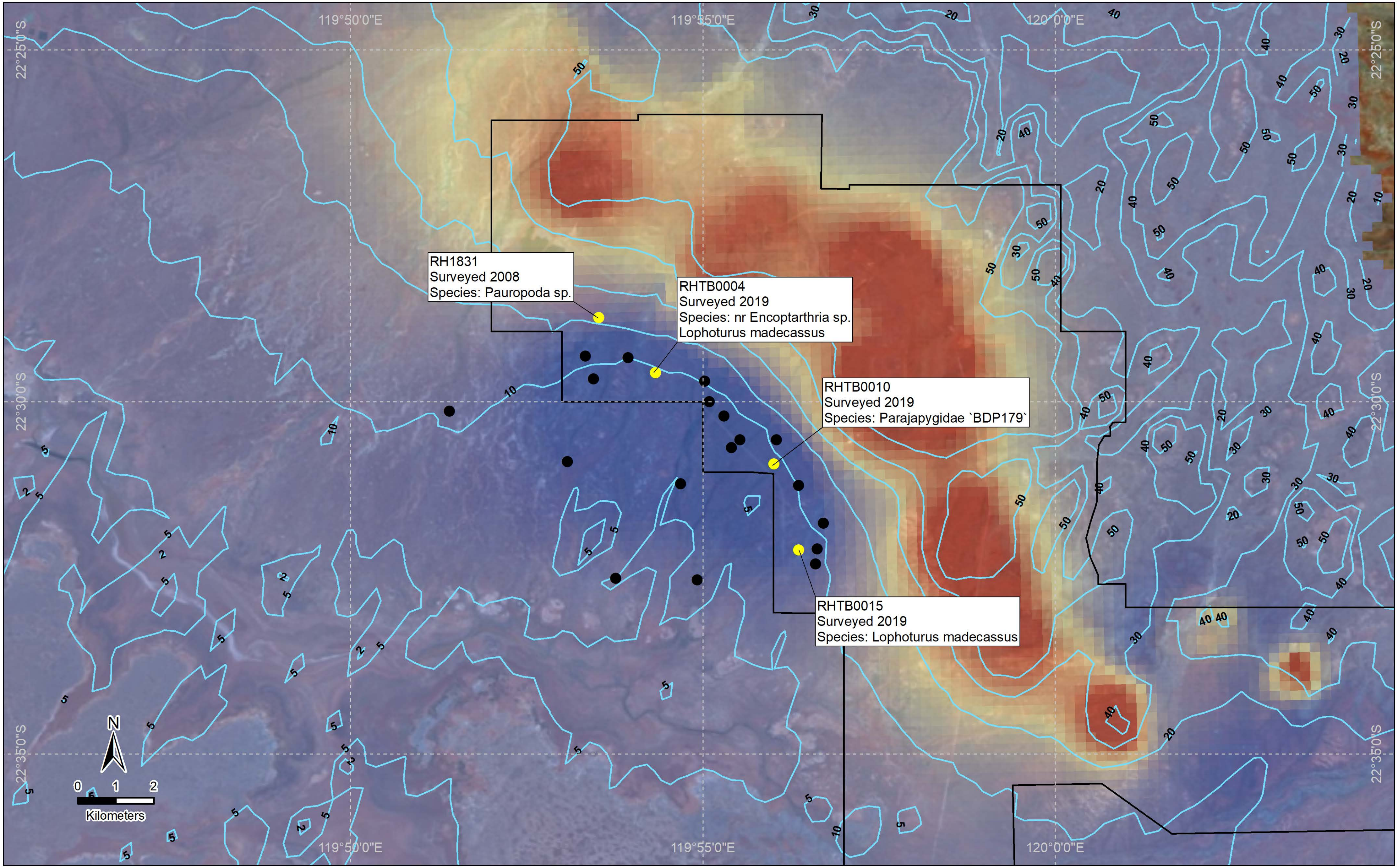
A total of four troglofauna species have therefore been recorded within the SWIB and the predicted extent of mounding (Figure 2). The range and ecological status of each species are discussed in Section 5.1 below.

Overall, considering sampling effort and the resultant yields of troglofauna in terms of both abundance and the number of species, it is considered that the troglofauna community in the SWIB is depauperate and comprises species that are known, or are otherwise highly likely, to occur outside the predicted extent of mounding.

Table 1. Troglofauna species collected in the South West Injection Borefield in 2019 and during previous sampling programs (indicated by asterisks; SMEC 2009).
Numbers are total abundance.

Higher Classification	Lowest Identification	Bore				Comments
		RH1831	RHTB0004	RHTB0010	RHTB0015	
Arthropoda						
Arachnida						
Araneae						
Gnaphosidae	nr *Encoptarthria* sp.		3			Juvenile specimens whose precise range unknown but habitat indicates a moderately extensive local distribution.
Diplopoda						
Polyxenida						
Lophoproctidae	*Lophoturus madecassus*		1		1	Pan-tropical distribution[1]
Entognatha						
Diplura						
Parajapygidae	Parajapygidae `BDP179`			1		Precise range uncertain but habitat indicates a moderately extensive local distribution.
Pauropoda						
	Pauropoda sp.*	1				Ecology unclear as specimen unavailable and habitat data inconclusive.

[1]Car *et al.* 2013.



Bennelongia Environmental Consultants

GCS_GDA_1994
Author: A. Mittra
Date: 21-11-2019

Legend

Water level change (m) Scenario 1, Dec 2026
High : 13.37
Low : -75.49

Depth to water (m) Scenario 1, Dec 2026

Revised Development Envelope

Troglofauna sample (2019)

Troglofauna recorded

Figure 2. Records of troglofauna in the SWIB and the estimated extent of mounding resulting from managed aquifer recharge during a peak injection period (December 2026; Roy Hill 2019).

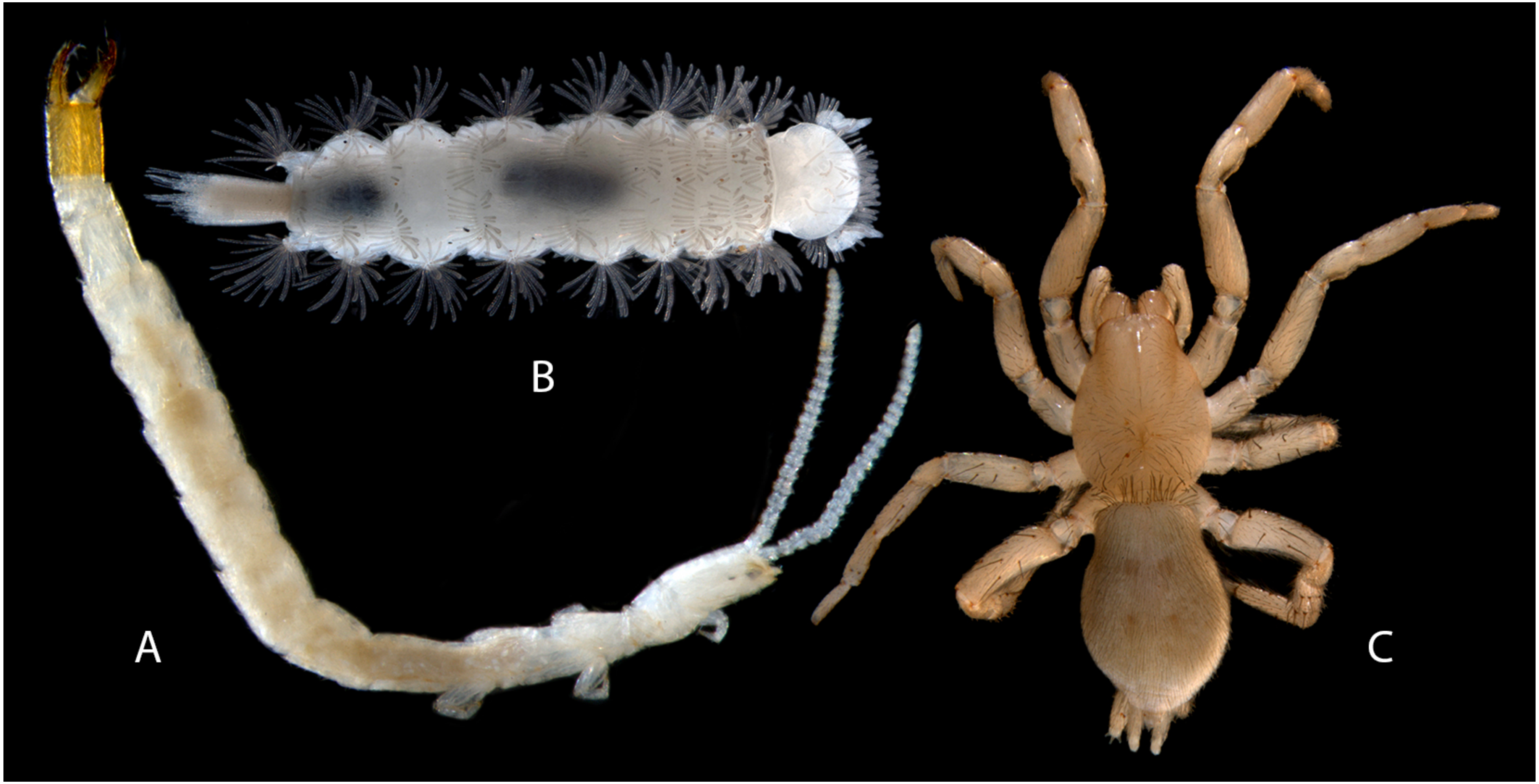


Plate 1. Photographs of troglofauna species collected in the South West Injection Borefield in 2019.

A) Parajapygidae `BDP179`

B) *Lophoturus madecassus*

C) nr *Encoptarthria* sp.

5.1. Species accounts

The range and ecological status of each of the species of troglofauna recorded are discussed below.

nr *Encoptarthria* sp.

Three-juveniles of this genus-level identification of the spider family Gnaphosidae were recorded in bore RHTB0004 in traps deployed at depths of 9 m and 14 m. The three specimens are highly likely to belong to the same species. Gnaphosids are commonly recorded in troglofauna surveys in the Pilbara and the genus nr *Encoptarthria* has been recorded throughout the region by Bennelongia. Data from the Western Australian Museum show the genus has also been recorded in the Murchison region.

Two species of nr *Encoptarthria*, as well as some juveniles, have been recorded 12–21 km northeast of bore RHTB0004 and it would be reasonable to expect that the animals from the SWIB belong to one of these species, though morphological alignments are not possible with juvenile specimens. Moreover, the extent of alluvial cover within SWIB and the associated mounding area and beyond GHD (2019) supports the notion that the species of nr *Encoptarthria* collected from the SWIB is probably moderately widespread and will have a range that extends beyond the impact of mounding. Based on records in the Bennelongia database for morphospecies of nr *Encoptarthria* from the Pilbara that have been collected from two locations or more, species in the genus have a median linear range of 6.38 km.

Lophoturus madecassus

Single specimens of this pincushion millipede of the family Lophoproctidae were collected from two bores, RHTB0004 in a trap at a depth of 9 m and RHTB0015 in a trap at a depth of 6 m. *Lophoturus madecassus* is a widely-recorded species in Pilbara troglofauna surveys but was originally collected and described from surface leaf litter in Madagascar and has a pan-tropical distribution (Car *et al.* 2013). It appears to be a trogloxene that uses subterranean habitats opportunistically rather than being an obligate subterranean species.

Parajapygidae `BDP179`

This species of dipluran was recorded as a singleton in bore RHTB0010 in a scrape that extended to the water table at a depth of 14 m. While it is not possible to discern the precise collection depth of this species, it is clear that it was inhabiting the alluvial cover unit which, as illustrated by GHD (2019), is extensive.

The taxonomic framework for troglofaunal species of Parajapygidae is far from complete, despite the family often being recorded in troglofauna surveys in the Pilbara, though it is considered that the family will likely prove to contain many geographically-confined species (Koch 2009). Extensive sampling at Christmas Creek and neighbouring deposits by Bennelongia (Bennelongia 2018a and references therein; Bennelongia unpublished) has recorded five species of Parajapygidae, two of which have known linear ranges of 26.2 km and 35.5 km, respectively. The remaining species are known from single sites. While the range of Parajapygidae `BDP179` remains unknown, it is highly likely that the species occurs outside the extent of the mounding area due to the extent of suitable habitat.

Pauropoda sp.

This species was collected in a stygofauna net sample by SMEC (2009) and those authors reported it (and a number of other potential troglofauna in the wider Roy Hill project area) as a “deep soil form”. The precise collection depth and therefore habitat for this species is unclear, other than that it was collected somewhere between surface and the watertable (25 m). There is also some uncertainty about the ecology of this species, in part because the specimen was not available for examination by Bennelongia, and also due to the incomplete taxonomic framework for pauropods. Indeed, the same uncertainty exists for most pauropods recorded in troglofauna samples in the Pilbara (Halse and Pearson 2014), though it is considered likely that troglobitic species exist, especially given the low moisture content of Pilbara soils and the physiological challenges of avoiding desiccation as a very small animal.

Based on 15 records in the Bennelongia database of morphospecies that have been collected from two or more holes in the Pilbara, species of pauropod have a median linear range of 15.7 km. The mean range is much larger at 122 km. Despite limited taxonomic and ecological information for Pauropoda sp., the small predicted extent of mounding and the relatively large extent of alluvial habitat suggest that the species is highly unlikely to face a significant threat from reinjection.

5.2. Stygofauna

A small number of subterranean aquatic species – stygofauna – were collected as bycatch during the current survey (Table 2) and, undoubtedly, more species would be recorded if targeted methods for stygofauna were employed in the SWIB.

Table 2. Stygofauna species recorded as bycatch during troglofauna sampling in the SWIB in 2019. Numbers are total abundance.

Higher identification	Lowest identification	Bore			
		RHTB0006	RHTB0016	RHTB0018	RHTB0019
Annelida					
Clitellata					
Enchytraeida					
Enchytraeidae	Enchytraeidae `3 bundle` s.l. (short sclero)			1	
Arthropoda					
Malacostraca					
Amphipoda					
Paramelitidae	Paramelitidae Genus 2 sp. B11				5
Maxillopoda					
Harpacticoida					
Ameiridae	*Parapseudoleptomesochra* `BHA261`			7	
Canthocamptidae	Canthocamptidae `BHA262`	1			
Nematoda	Nematoda spp.		1		10

6. POTENTIAL IMPACTS ON TROGLOFAUNA

The potential impacts of mining and related operations on subterranean fauna can be broadly divided into primary impacts, namely the impacts causing possible extinction or threat to the persistence of local populations through direct removal of habitat, and secondary impacts that degrade habitat rather than remove it and therefore mostly only reduce population densities. Secondary impacts include pollutants, altered water chemistry, mine blasting and changes to energy and nutrient pathways.

The potential primary impact of reinjection on troglofauna is mounding and subsequent habitat loss via flooding. Any troglofauna species whose distribution was entirely bounded by the mounding zone would face severe reductions or extinction if the rise in the water table was large enough to remove all suitable habitat, although in reality the severity of impact will depend on the height and expanse of mounding, available habitat remaining in unflooded strata and the geological habitat preferences of the species. Injection in SWIB is predicted to form a groundwater mound in an area of up 10 km long and 6 km wide (Figure 2; GHD 2019). It is considered that an adequate proportion of the mounding area received sampling coverage to assess potential impacts to troglofauna (Figure 2).

As detailed in Section 5, the troglofauna community in the SWIB is depauperate, especially compared to communities documented in various locations elsewhere in the region. One of the species recorded, *Lophoturus madecassus*, is very widespread globally and is not considered further. The other three species recorded have ranges that are uncertain, in part due to limited taxonomic information. Nevertheless, due to the large extent of alluvial habitat, the ranges of related species and the moderately small predicted extent of the mounding zone it is considered highly unlikely that any of the species present in the SWIB has a range confined to the mounding zone. Therefore, it is considered unlikely that troglofauna species in the SWIB face conservation-significant impacts as a result of the RHWMS.

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Appendix 1. Bores sampled for troglofauna in the SWIB by Bennelongia in 2019 and site details.

Bore	Latitude	Longitude	Sample date	Trap collect date	Depth to water (m)	End of hole (m)	Scrape	Trap depth 1 (m)	Trap depth 2 (m)
RHTB0001	-22.48922196	119.8889145	23/07/2019	26/09/2019	14		Yes	7	13
RHTB0002	-22.48958822	119.8990389	23/07/2019	26/09/2019	15		Yes	9	13
RHTB0003	-22.49460695	119.8908907	23/07/2019	26/09/2019	10		Yes	4	9
RHTB0004	-22.49312437	119.9055111	23/07/2019	26/09/2019		15	Yes	9	14
RHTB0005	-22.49512058	119.9172049	23/07/2019	26/09/2019	16		Yes	10	15
RHTB0006	-22.49998115	119.9182705	23/07/2019	26/09/2019	11.5		Yes	6	10
RHTB0007	-22.50336637	119.9217069	23/07/2019	26/09/2019	14		Yes	7	13
RHTB0008	-22.50904025	119.925526	23/07/2019	26/09/2019	13		Yes	7	12
RHTB0009	-22.5089729	119.934171	23/07/2019	26/09/2019	16		Yes	9	15
RHTB0010	-22.51470921	119.9335487	23/07/2019	26/09/2019	14		Yes	8	13
RHTB0011	-22.51981526	119.9394004	23/07/2019	26/09/2019		7	Yes	4	6
RHTB0012	-22.52872625	119.9452723	23/07/2019	26/09/2019	14		Yes	7	13
RHTB0013	-22.53484759	119.9437454	23/07/2019	26/09/2019	9		Yes	6	8
RHTB0014	-22.5383641	119.943387	23/07/2019	26/09/2019		5	Yes	4	-
RHTB0015	-22.53508284	119.939368	23/07/2019	26/09/2019	12		Yes	6	11
RHTB0016	-22.50218723	119.8568116	23/07/2019	26/09/2019		10	Yes	5	9
RHTB0017	-22.51416208	119.8847038	23/07/2019	26/09/2019	10		Yes	6	9
RHTB0018	-22.54180544	119.896126	23/07/2019	26/09/2019	4.5		Yes	2	3
RHTB0019	-22.54216534	119.9153896	23/07/2019	26/09/2019	5	10	Yes	2	4
RHTB0020	-22.51940487	119.9114779	23/07/2019	26/09/2019	8	10	Yes	4	7
RHTB0021	-22.51085085	119.9235064	23/07/2019	26/09/2019			Yes	5	9