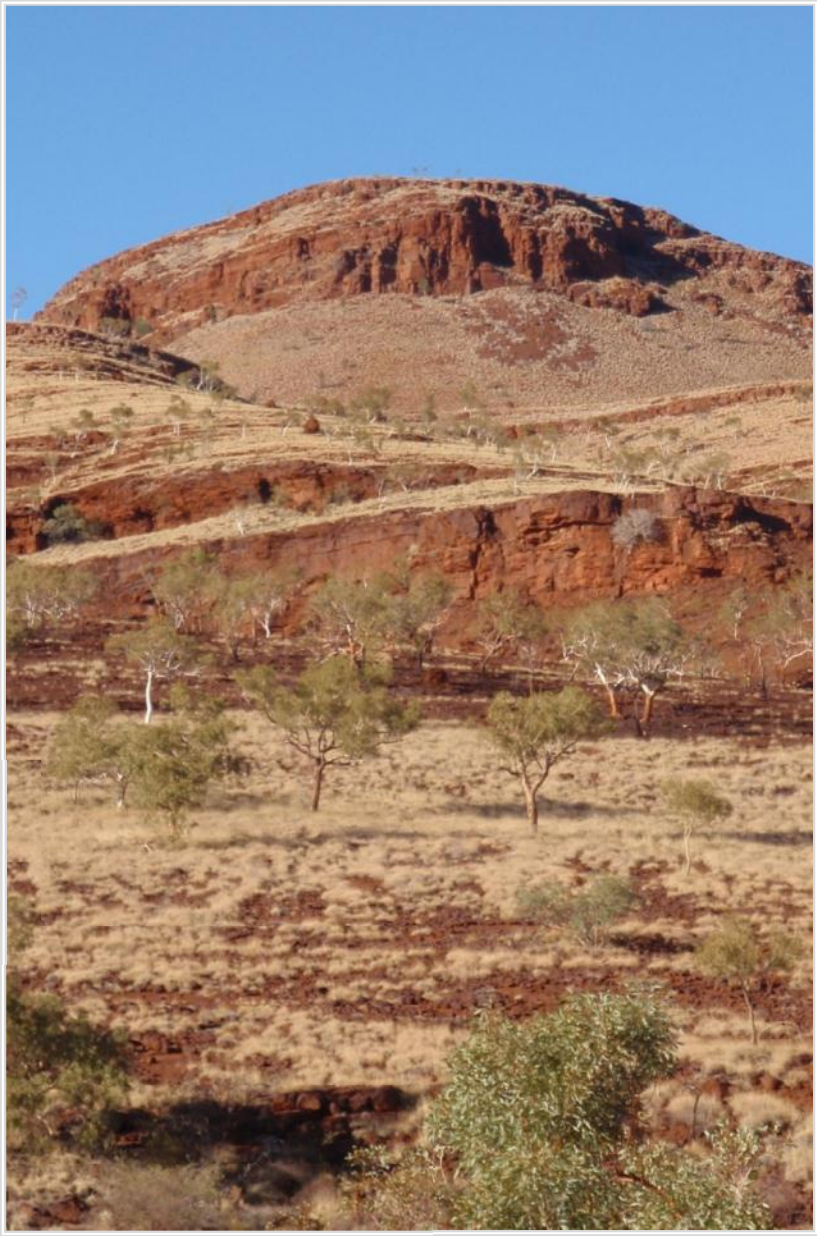
Bennelongia Environmental Consultants

Flinders Mines Ltd

Pilbara Iron Ore Project: Blacksmith Subterranean Fauna Surveys



Final Report

Prepared for Flinders Mines Ltd
by Bennelongia Pty Ltd

December 2011
Report 2011/137

Pilbara Iron Ore Project: Blacksmith Subterranean Fauna Surveys

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Cover photo: Delta deposit in the Blacksmith tenement, Hamersley Range

Client – Flinders Mines Ltd

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EXECUTIVE SUMMARY

Flinders Mines Limited is considering the mining of up to six iron ore deposits within the Blacksmith tenement (E47/882), approximately 60 km north-northwest of the central Pilbara town of Tom Price. The open cut mining and dewatering techniques proposed have the potential to impact subterranean fauna communities that inhabit rock voids above the water table (troglofauna) and deeper rock voids saturated by groundwater (stygofauna). Many species of subterranean fauna have restricted ranges and their conservation status may be vulnerable to impacts from large development projects.

Subterranean fauna surveys were conducted in existing mineral drill-holes at the four main deposits proposed for mining: Blackjack, Champion, Delta and Eagle, together with some limited surveys within the Ajax deposit. The survey techniques used meet the requirements laid out in Environmental Protection Authority (EPA) Guidance Statement No. 54a.

Troglofauna were surveyed using a combination of traps and drill-hole scrapes. Between June 2010 and September 2011, 245 troglofauna samples were collected from proposed mine pits (impact areas) and 211 samples were collected from areas beyond mine pit boundaries. Troglofauna specimens collected as by-catch during stygofauna surveys were included in troglofauna survey results.

Stygofauna were surveyed using haul nets. In the absence of groundwater drawdown predictions, all areas within the Blacksmith tenement were treated as impact areas for stygofauna. A total of 261 stygofauna samples were collected, and stygofauna specimens collected during troglofauna surveys were also included in stygofauna results.

Survey results and data analyses are summarised as follows:

- 66 troglofauna species of 19 Orders were collected:
  - Six orders of arachnids were recorded: Scorpionida, Pseudoscorpionida, Palpigradi, Schizomida, Araneae (spiders), and Opilionida (harvestmen).
  - The only crustacean order collected was Isopoda (slaters).
  - Two orders of centipede were recorded: Geophilomorpha and Scolopendromorpha.
  - Symphylans were represented by one order, Cephalostigmata.
  - Millipedes were represented by two orders: Polydesmida and Polyxenida.
  - Pauropods were represented by the only known order in this group (Pauropodina).
  - There were six orders of hexapods (Entognatha/Insecta): Diplura (bristletails), Thysanura (silverfish), Blattodea (cockroaches), Hemiptera (true bugs), Coleoptera (beetles), and Diptera (flies).

- 34 stygofauna species from 10 higher level groups were collected:
  - Turbellaria (flat worms);
  - Nematoda (round worms);
  - One order of Aphanoneura (suction-feeding worms);
  - One order of Oligochaeta worms – Tubificida;
  - One order of arachnids – Hydracarina (water mites); and
  - Five orders of crustaceans – Ostracoda, Copepoda, Syncarida, Amphipoda, and Isopoda (slaters).

The collection of 66 troglofauna species of 19 orders represents a rich troglofauna community for the Pilbara region, and the collection of 34 stygofauna species of 10 higher level groups represents a moderately rich stygofauna community.

The collection of a troglofaunal scorpion is of scientific interest because it is the first troglofaunal scorpion collected on the Australian mainland.

Twenty-two troglofauna species were recorded only within the proposed mine pits. These comprised a single species of scorpion, four species of pseudoscorpions, two species of isopods, a single species of geophilomorph and two species of scolopendromorph centipedes, one species of symphylan, seven species of dipluran, three species of beetles and one species of fly.

Sixteen stygofauna species have not been recorded outside the Blacksmith tenement. These comprised a single water mite species, six species of copepods, four species of syncarids, four species of amphipods and one species of isopod.

Examination of the numbers of animals collected and their distributions, together with information on the distributions of related subterranean species, and habitat characterisations, suggest that few, if any, of the 22 troglofauna and 16 stygofauna species known only from proposed impact areas are actually restricted to these proposed areas. The apparently restricted ranges of these species are likely to be artefacts of the difficulties associated with sampling low-abundance species and the limited access to drill-holes outside impact areas.

Suitable aquifers for stygofauna are likely to occur to the east, downstream of the Blacksmith tenement, as well as across the tenement.

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1. INTRODUCTION

Subterranean fauna are primarily invertebrate species that inhabit caves and the many small voids and tunnels that occur within some unconsolidated and rocky substrates. Many subterranean fauna species are short range endemics (SRE) with ranges of less than 10,000 km^2 (Harvey 2002; Eberhard *et al*. 2009). Most subterranean fauna species are characterised by limited dispersal abilities, slow growth rates, and low fecundity and many are dependent on discontinuous habitats (Gibert and Deharveng 2002). These characteristics make them vulnerable to extinction as a result of anthropogenic disturbance (Fontaine *et al.* 2007; Ponder and Colgan 2002).

Flinders Mines Limited (Flinders) is planning to commence its Pilbara Iron Ore Project by mining six deposits (Ajax, Blackjack, Champion, Delta, Eagle, and Paragon) located within the Blacksmith tenement (E47/882) which is one of two exploration tenements held by Flinders that are located approximately 60 km north-northwest of the central Pilbara town of Tom Price (Figures 1 and 2). The proposed open cut mining and mine pit dewatering techniques have the potential to remove or significantly disrupt the habitats of subterranean fauna species with very small ranges.

In recognition of the potential vulnerability of highly restricted species of subterranean fauna, the Environmental Protection Authority (EPA) has prepared guidance statements relating to EPA policy and the requirements for survey of subterranean fauna in environmental impact assessment (EPA 2003, 2007). In accordance with EPA requirements, this report:

- describes subterranean fauna communities within the Blacksmith tenement;
- evaluates the conservation status of subterranean fauna present; and
- presents an assessment of likely impacts on subterranean fauna as a result of the proposed mining.

2. HYDROGEOLOGY

Flinders' Pilbara Iron Project focuses on the youngest units of the Tertiary sediments within the Marillana Formation that overlies the Hamersley Group. The Hamersley Group was formed by chemical sedimentation of minerals in an ocean environment during the late Archean and early Proterozoic (2,500 million years ago). It contains several large units of alternating iron-rich and silica-rich layers called banded iron formation (BIF). Where BIF has been enriched by natural processes, it forms bedded iron deposits (BID) that may contain more than 60% iron.

The development of river drainage systems commenced during the Late Cretaceous to Early Tertiary (60 million years ago) (Beard 1998, van de Graaff *et al.* 1977). Eroded BID sediments accumulated in these ancient valleys and over time became coated and fused by percolating iron-enriched ground water forming channel iron deposits (CID) (Figure 2). Today, the ranges within the Blacksmith tenement are typically rugged, with prominent strike ridges and hills of outcropping rock that separate deep valleys in which thick sequences of iron-rich infill have been locally deposited (Golder 2010) (Figure 2).

Ephemeral creeks within the Blacksmith tenement all drain to the north-east into the Fortescue River. Delta, Eagle and Paragon ore deposits are located in the upper reaches of Weelumurra Creek, while Ajax, Blackjack and Champion are in the upper reaches of Caliwingina Creek, which is a different sub catchment of the Fortescue River.

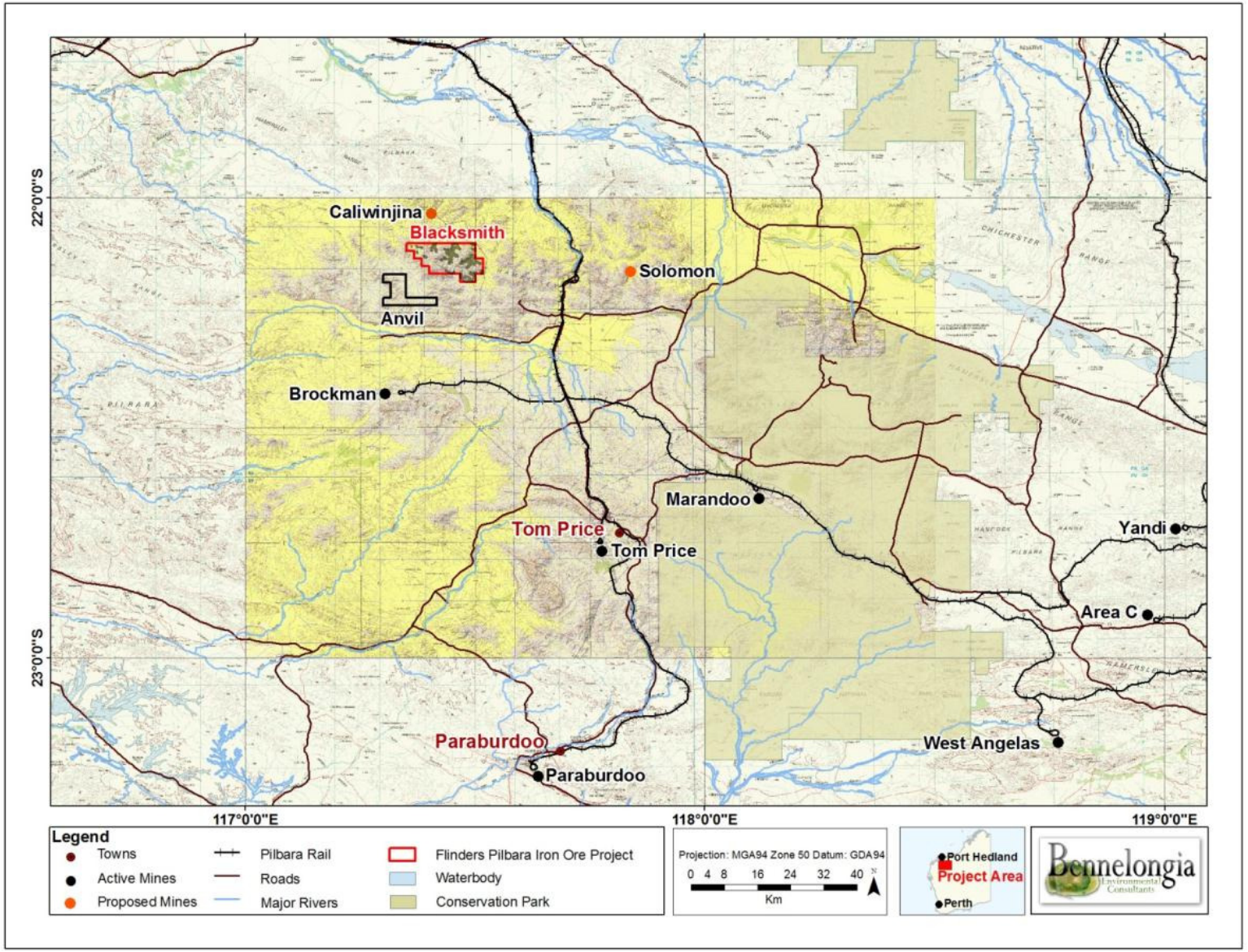


Figure 1. Location of the Blacksmith and Anvil tenements.
(The Blacksmith tenement is equivalent to the Study Area for this report).

Groundwater occurs throughout the Pilbara region in the Precambrian basement rocks, the Phanerozoic sedimentary basins and the Cainozoic valley deposits. Groundwater salinities are fresh (<3000 mg / L TDS) throughout the Pilbara, although localised areas of saline water occur where significant surface evaporation occurs, such as Fortescue Marsh (Commander 1989; Eberhard *et al.* 2005).

During initial groundwater investigations at Delta deposit, four key lithologies were identified in the valley systems of the Blacksmith tenement (Golder 2010). They are summarised as follows:

1. Recent surficial deposits - recent semi-consolidated alluvium and colluviums of BIF, chert and shale fragments with a fine silty/clay matrix;
2. CIDs - varying from fine hematite pisolites with variable amounts of colluvium fragments to semi-consolidated or competent hematite fragments with a hematite matrix;
3. BIDs - characteristically vuggy by nature, BIDs comprise goethite banding in hematite-rich rock, with minor secondary limonite/goethite; and
4. Basement rocks - chert, shale and unweathered BIF are all contained within the Brockman Iron Formation basement rocks.

The above lithologies contain three main aquifers, with the surficial aquifer being located in unconsolidated sediment; a deeper aquifer in CID and BID; and below that an aquifer in fractured basement rock of the Brockman Iron Formation. The surficial aquifer is restricted to larger valleys, and it is considered that only CID/BID and fractured basement rock aquifers occur in the ore deposits (see Golder 2010). Based on the situation at Delta deposit, it appears that only the lower sequences of CID are saturated, whereas the BID is fully saturated where present. Groundwater investigations suggest that transmissivity is highest in the BID, with CID and fractured rock having similar, reduced transmissivity.

Depth measurements taken during the subterranean fauna survey indicated that the water table is shallower at Ajax (maximum depth 26 m and average 17 m) than in other parts of the Blacksmith tenement (average depths 30 - 40 m at Blackjack, Champion and Eagle, though the range of depths recorded was large).

3. EXISTING INFORMATION ON SUBTERRANEAN FAUNA

Subterranean fauna include both terrestrial (troglofauna) and aquatic (stygofauna) species. Troglofauna occur in underground cavities, fissures and interstitial spaces above the water table. Stygofauna inhabit groundwater. Most subterranean fauna are invertebrates, although both troglofaunal reptiles and stygofaunal fish have been recorded in Western Australia (Whitely 1945; Aplin 1998).

The stygofauna of the Pilbara region are considered to be of global significance in terms of richness and diversity (Eberhard *et al*. 2009; Guzik et al. 2011) and emerging evidence indicates that the same is true for troglofauna (see Biota 2005a, 2006; Subterranean Ecology 2007; Bennelongia 2008a,b,d, 2009a,b).

3.1. Troglofauna

Early troglofauna research focussed on caves. However, surveys in the Pilbara during the past five years have demonstrated that troglofauna occur outside caves within various rock-forms of the Pilbara. The invertebrate groups containing troglofauna include: pseudoscorpions, spiders, palpigrads, schizomids, harvestmen, isopods, centipedes, millipedes, pauropods, symphylans, diplurans, silverfish, cockroaches, bugs, beetles and fungus-gnats. While diversity and abundance of troglofauna seem to be greatest in

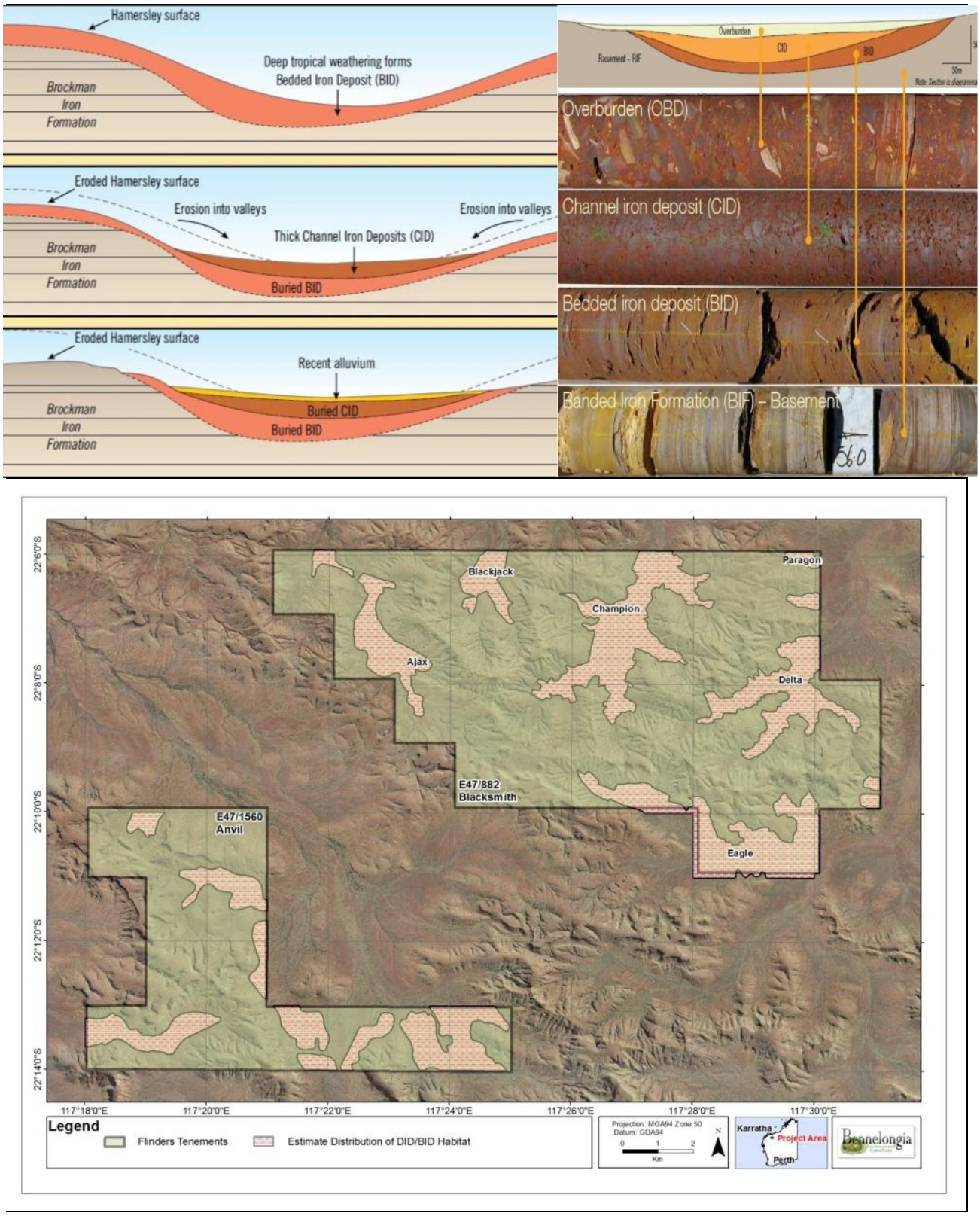


Figure 2. Formation and distribution of iron ore deposits in the Blacksmith and Anvil tenements.

the Pilbara, troglofauna occur in most regions of Western Australia and have been recorded from the Kimberley (Harvey 2001), Cape Range (Harvey *et al.* 1993), Barrow Island (Biota 2005b), the Mid-West (Ecologia 2008) and Yilgarn (Bennelongia 2009c), South-West (Biota 2005a) and Nullarbor (Moore 1995).

Most troglofauna surveys for environmental assessment have been in areas of pisolite and BIF. The micro-habitats used by troglofauna within these lithologies are yet to be fully characterised but it is inferred they occupy fissures and voids associated with weathering, enrichment and faulting. Knowledge of troglofauna outside mineralized habitats is poorly defined because mine development has been the primary motive for most surveys. However, it has been demonstrated that troglofauna also occur in calcrete and alluvium in the Pilbara (Edward and Harvey 2008; Rio Tinto 2008), Yilgarn (Barranco and Harvey 2008; Platnick 2008; Bennelongia 2009c) and elsewhere (Biota 2005a,b).

3.2. Stygofauna

Stygofauna surveys of the Pilbara commenced in the 1990s (Humphreys 1999), followed by a rapid increase in knowledge during the last decade as a result of the Pilbara Biodiversity Survey (see Eberhard *et al*. 2005, 2009). Calcrete and alluvium are typically considered to be the most productive habitats for stygofauna, although mafic volcanics may support rich populations and stygofauna occur in moderate richness in BIF (Halse *et al*. in preparation).

The Pilbara is estimated to support between 500 and 550 stygofauna species, with the density of species being relatively uniform across the region (Eberhard *et al.* 2009). Stygofauna communities in the Pilbara are dominated by crustaceans with ostracods, copepods and amphipods contributing most of the animals and species (Eberhard *et al.* 2005; Halse *et al*. in preparation).

Stygofauna sampling in the Pilbara has been skewed towards areas of proposed development for water supply borefields and mine dewatering and the species richness reported in these habitats has been roughly proportional to sampling effort (Eberhard *et al.* 2005). Survey areas with more than 20 species are generally considered to be moderately species rich.

4. POTENTIAL IMPACTS FROM MINING

Activities that cause direct *habitat loss* are considered to be *primary* impacts that have the potential to lead to extinction of tightly restricted subterranean species. For proposed mining at Ajax, Blackjack, Champion, Delta, Eagle and Paragon deposits these primary impacts are:

1. *Pit excavation*. Removal of overburden and ore in the mining process has the potential to pose a significant risk to restricted troglofauna species.
2. *De-watering.* Drawdown of aquifers to prevent flooding of mine pits has the potential to pose a significant risk to stygofauna species unless the underlying aquifers also provide habitat.

The ecological impacts of activities that *reduce the quality* of subterranean fauna habitat have been little studied in Australia (or elsewhere) but it is considered that these impacts are more likely to reduce population size than cause species extinction (Scarsbrook and Fenwick 2003; Masciopinto *et al*. 2006). These impacts are therefore considered to be of *secondary* importance.

Mining activities at Ajax, Blackjack, Champion, Delta, Eagle and Paragon deposits that may result in secondary impacts to subterranean fauna include:

1. *De-watering below troglofauna habitat*. The impact of a lowered water table on subterranean humidity and therefore the quality of troglofauna habitat is poorly studied, but it may pose a

risk to troglofauna species in some cases. The extent to which humidity of the vadose zone is affected by depth to the water table is unclear. Given that pockets of residual water probably remain trapped throughout de-watered areas and keep the overlying substrate saturated with water vapour, de-watering may have minimal impact on the humidity in the unsaturated zone. In addition, troglofauna may be able to avoid undesirable effects of a habitat drying out by moving deeper into the substrate if suitable habitat exists at depth. Overall, de-watering outside the proposed mine pits is not considered to be a significant risk to troglofauna in the Blacksmith tenement.

2. *Overburden stockpiles*. These artificial landforms may cause localised reduction in rainfall recharge and associated entry of dissolved organic matter and nutrients because water runs off stockpiles rather than infiltrating through them and into the underlying ground. The effects of reduced carbon and nutrient input are likely to be expressed over many years and may be greater for troglofauna than stygofauna because lateral movement of groundwater is likely to transport carbon and nutrients from beyond areas covered by stockpiles. The extent of impacts on troglofauna will largely depend on the importance of chemoautotrophy in driving the subterranean system compared with infiltration-transported surface energy and nutrients. Stockpiles are unlikely to cause species extinctions, although population densities of species may decrease.
3. *Percussion from blasting*. Impacts on both stygofauna and troglofauna may occur through the physical effect of explosions. Blasting may also have indirect detrimental effects through altering underground structure (usually rock fragmentation and collapse of voids) and transient increases in groundwater turbidity. The effects of blasting are often referred to in grey literature but are poorly quantified and have not been related to ecological impacts. Any effects of blasting are likely to dissipate rapidly with distance from the pit and are not considered a significant risk to either stygofauna or troglofauna outside the proposed mine pits.
4. *Aquifer recharge with poor quality water*. Quality of recharge water usually declines during, and after, mining operations as a result of rock break up and soil disturbance (e.g. Gajowiec 1993; McAuley and Kozar 2006). Impacts can be minimised by management of surface water through the installation of drainage channels, and sumps and pumps in the mine pit to prevent recharge though the pit floor.
5. *Contamination of groundwater*. Any change or contamination of groundwater either during or after mining could impact subterranean communities. However, the risk of contamination from many sources; e.g. petroleum spills, can be minimised by engineering and management practices to ensure their containment.

5. METHODS

5.1. Survey Rationale

The subterranean fauna survey followed the recommendations of EPA Guidance Statement No 54a (EPA 2007). Sampling for troglofauna occurred within the Blacksmith tenement (E47/882) at Ajax, Blackjack, Champion, Delta and Eagle ore deposits, although sample effort was low at Ajax because of lack of drill-holes (Figure 2). No drill-holes were available for sampling at Paragon. Impact areas for troglofauna sampling were defined as the areas to be excavated for mine pits. Reference drill-holes, sampled to show the wider distribution of troglofauna species, were located outside the proposed pits but within the Blacksmith tenement (Figure 3).

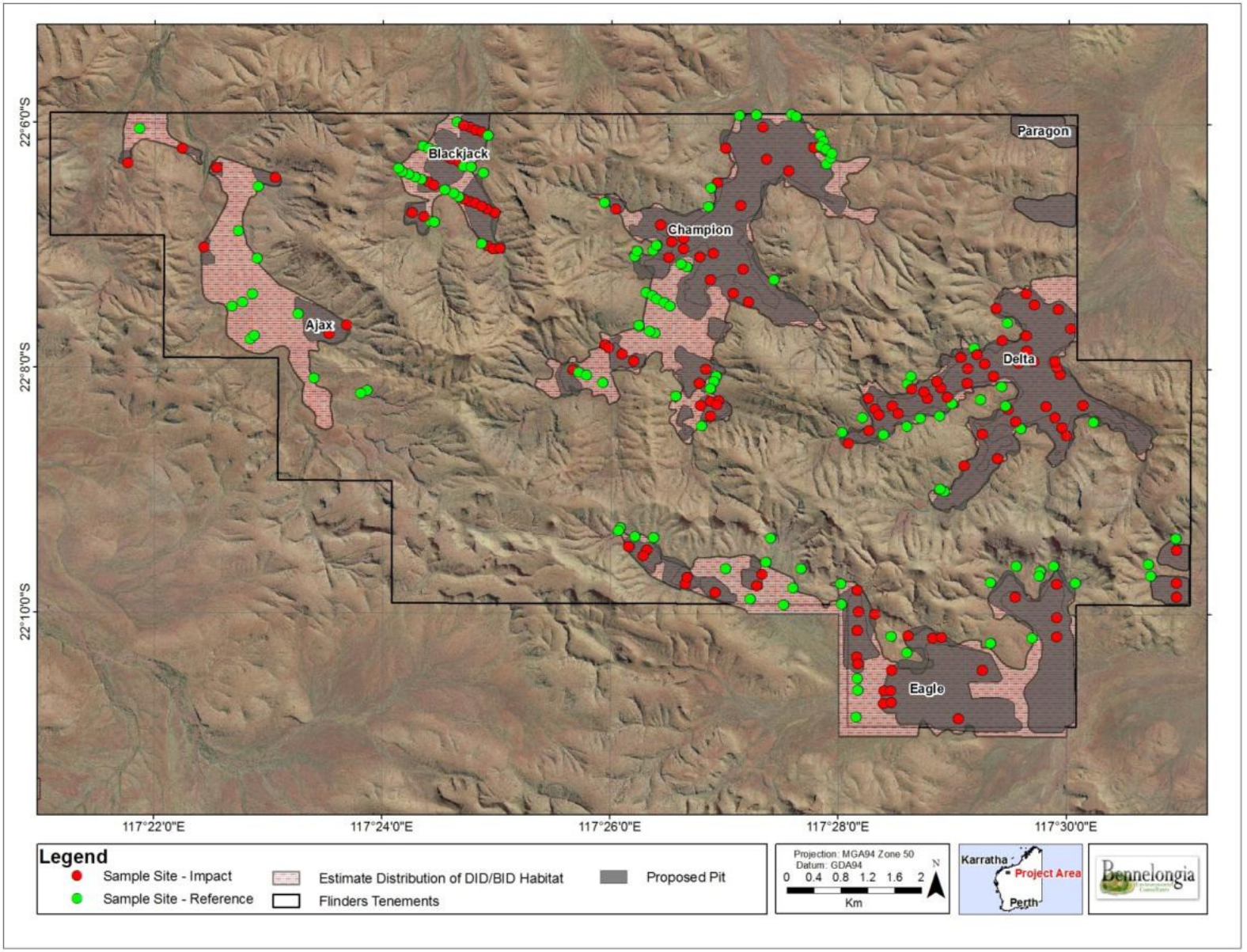


Figure 3. Distribution of drill-holes sampled for troglofauna.

Given that groundwater drawdown modelling was not available at the time of writing this report, a conservative approach has been adopted to stygofauna assessment. It was assumed that all drill-holes samples within the Blacksmith tenement will be impacted by mine pit dewatering. The distribution of sampled drill-holes is mapped in Figure 4.

Lists of the drill-holes sampled for troglofauna and stygofauna are provided in Appendices G and H.

5.2. Troglofauna Sampling

5.2.1. Sampling Methods

In nearly all cases, each troglofauna sample was collected using two separate techniques that provided two separate subsamples. The two techniques used were trapping and scraping.

1. *Trapping*. Custom made 270mm long and 70mm diameter cylindrical PVC traps, with entrance holes on the side and top, were used for trapping. Traps were baited with moist leaf litter, previously sterilised by microwaving, and lowered on nylon cord to within a few metres of the water table or end of the drill-hole. In every fourth drill-hole, a second trap was set mid-way down the drill-hole. Drill-holes were sealed while traps were set to minimise the ingress of surface invertebrates. Traps were retrieved seven or eight weeks later and their contents (bait and captured fauna) were emptied into a zip-lock bag and road freighted to the laboratory in Perth.
2. *Scraping*. Prior to setting traps, drill-holes were scraped. This was done using a weighted 150 µm mesh troglofauna net with variable aperture to best fit the diameter of the drill-hole. The net was lowered to the bottom of the drill-hole, or to the water table, and pulled back to the surface so that it scaped along the walls of the drill-hole. Each scrape comprised four drop and retrieve sequences with the aim of scraping any troglofauna off the walls and into the net. After each scrape, the contents of the net were transferred to a 125 ml vial and preserved in 100% ethanol.

In accordance with best practice, the scrape and trap (single or double) subsamples taken from a single drill-hole during each phase of the survey were combined as a single sample for the purposes of calculating sampling effort.

5.2.2. Sampling Effort

A total of 251 impact and 205 reference troglofauna samples were collected during four sampling phases between June 2010 and September 2011 (Table 1).

5.2.3. Other Sampling

Records of troglofauna collected as by-catch during the concurrent stygofauna sampling program (see Section 5.3) were included with the troglofauna survey results. These records provided additional information on the distributions and conservation significance of troglofauna species.

5.3. Stygofauna Sampling

5.3.1. Sampling Methods

Stygofauna sampling followed the methods outlined in Eberhard *et al*. (2005) and recommended by the EPA (2007). At each drill-hole, six net hauls were collected using weighted plankton nets; three hauls with a 50 µm mesh net and three with a 150 µm mesh net. After the net was lowered to the bottom of the bore, it was jerked up and down briefly to agitate benthic stygofauna into the water column prior to

slowly retrieving the net. Contents of the net were transferred to a 125 ml polycarbonate vial after each haul and preserved in 100% ethanol. Nets were washed between drill-holes to minimise contamination

Table 1. Numbers of troglofauna reference and impact samples collected.

Ore deposit	Ajax		Blackjack		Champion		Delta		Eagle		
No. of samples per deposit	20		87		129		100		120		
Site type	Ref.	Impact	Ref.	Impact	Ref.	Impact	Ref.	Impact	Ref.	Impact	Total
	Phase 1 (21 – 27 June 2010 to 18 – 19 August 2010)										
Scrape	-		-	-	-	-	18	42	-	-	60
Single trap	-		-	-	-	-	16	29	-	-	45
Double traps	-		-	-	-	-	2	13	-	-	15
No. of samples							18	42			60
	Phase 2 (13 – 17 September 2010 to 4 – 5 November 2010)										
Scrape	14	6	-	-	-	-	6	34	-	-	60
Single trap	11	5	-	-	-	-	6	24	-	-	46
Double traps	3	1	-	-	-	-	-	10	-	-	14
No. of samples	14	6					6	34			60
	Phase 3 (11 – 18 April 2011 to 13 – 17 June 2011)										
Scrape	-		21	23	30	30	-	-	29	31	164
Single trap	-		16	18	22	24	-	-	22	20	122
Double traps	-		5	4	8	6	-	-	7	11	41
No. of samples			21	23	30	30			29	31	164
	Phase 4 (26 – 31 July 2011 to 26 – 29 September 2011)										
Scrape	-		21	22	37	32	-	-	29	31	172
Single trap	-		18	15	22	25	-	-	22	24	126
Double traps	-		3	7	9	7	-	-	7	8	41
No. of samples			21	22	37	32			29	31	172
No. of troglofauna survey samples	14	6	42	45	67	62	24	76	58	62	456

The column heading "Ref." refers to reference sites.

between sites. Each set of six hauls from a single drill-hole made on the same day were combined as a single sample.

5.3.2. Other Sampling

Records of stygofauna collected as by-catch during concurrent troglofauna sampling were included in stygofauna survey results. These records provided additional information on the distributions and conservation status of stygofauna species.

5.3.3. Sampling Effort

A total of 261 samples were collected across the Blacksmith tenement during five sampling rounds between June 2010 and September 2011 (Table 2).

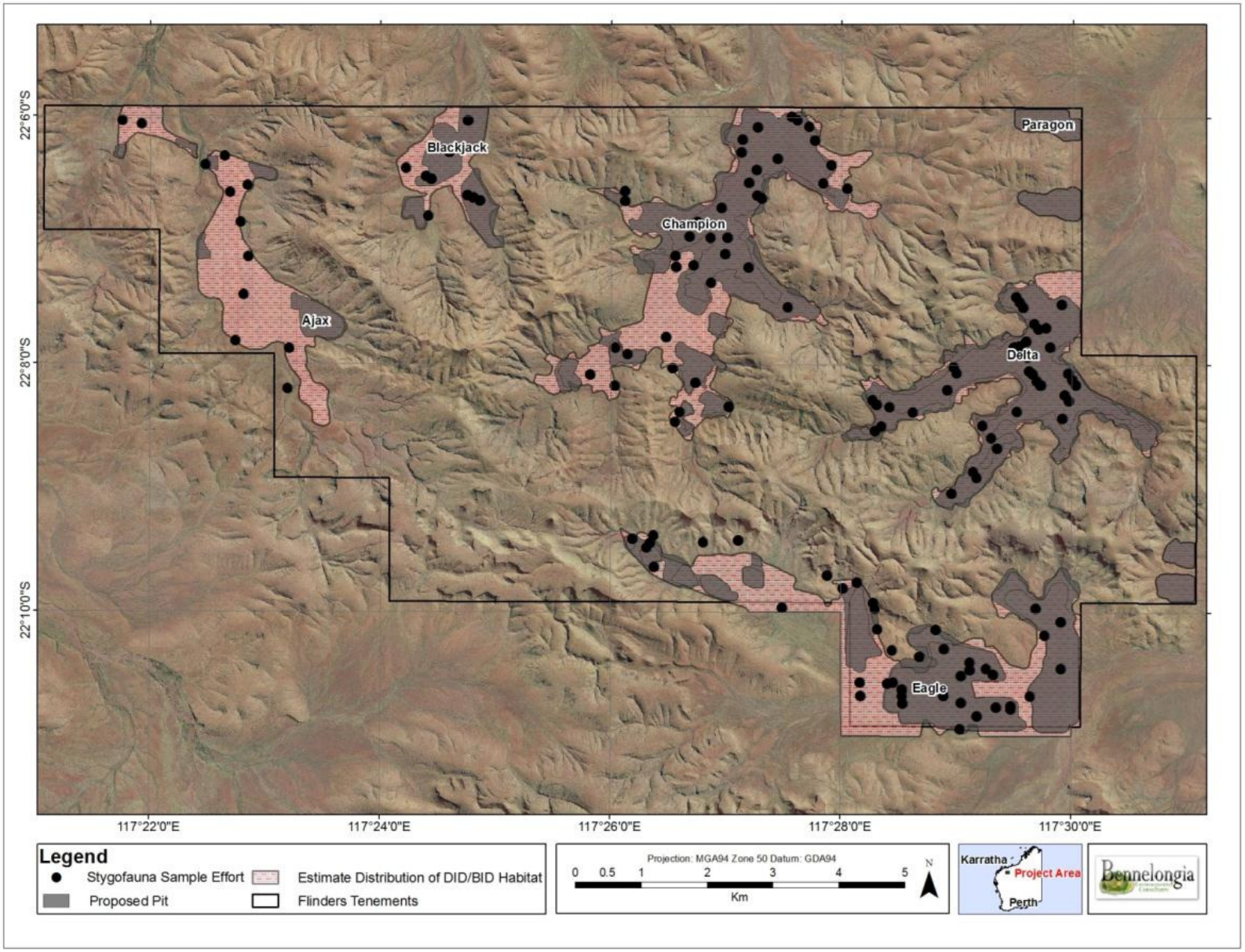


Figure 4. Locations of drill-holes sampled for stygofauna.

Table 2. Numbers of stygofauna samples collected.

Ore deposits / Survey Phase	Ajax	Blackjack	Champion	Delta	Eagle	No. of samples
Phase 1 21–23 June 2010	-	-	-	41	-	41
Phase 2 13–15 Sept. 2010	12	-	-	28	-	40
Phase 3 11–20 April 2011	-	10	35	-	35	80
Phase 4 14-16 June 2011	-	14	-	-	-	14
Phase 5 18–22 August 2011	--	14	37	-	35	86
No. of samples	12	38	72	69	70	261

5.4. Species Sorting and Identification

Troglofauna caught in traps were extracted from the leaf litter using Berlese funnels under halogen lamps. After about 72 hours, the ethanol and animal contents were removed and sorted. Litter from each funnel was also examined under a microscope for any remaining live or dead animals.

Preserved troglofauna scrapes and stygofauna samples were elutriated to separate animals from heavier sediment and sieved into size fractions (250, 90 and 53 µm) to remove debris and improve searching efficiency prior to sorting.

All samples were sorted under a dissecting microscope and troglofauna and stygofauna specimens were identified to species or morphospecies level using published and informal keys and reference to voucher collections. Specimens were dissected as necessary. Surface animals (especially terrestrial species) were identified only to Order level.

Representative specimens will be lodged with the WA Museum after the assessment process has been completed.

5.5. Compiling Species Lists

Troglofauna and stygofauna specimens that could not be identified to species or morphospecies level were included in estimates of species richness only if they could not belong to species already recorded. For example, immature or damaged cockroach specimens of the genus *Nocticola* sp., and mature specimens identified as the morphospecies *Nocticola* sp. B18 were treated as a single species because it was likely that the animals identified to genus *Nocticola* were, in fact, those already recorded as *Nocticola* sp. B18. The purpose of this criterion was to prevent higher level identifications falsely inflating species richness.

5.6. Personnel

Fieldwork was undertaken by Grant Pearson, Jim Cocking, Dean Main, Jeremy Quartermaine, Michael Curran and Sean Bennett. Sample sorting was done by Jane McRae, Mike Scanlon, Jim Cocking, Heather McLetchie, Grant Pearson, Dean Main, Michael Curran and Yoav Bar-Ness. Identifications were made by

Jane McRae, Dean Main, Mike Scanlon and Stuart Halse. Erich Volschenk of Phoenix Environmental Sciences provided advice regarding the scorpion identification.

6. RESULTS

6.1. Troglofauna

6.1.1. Troglofauna Occurrence and Abundance in the Survey Area

A rich troglofauna community with a total of 66 species from 19 Orders was recognized from 570 specimens collected by either designated troglofauna sampling or stygofauna by-catch (Appendix A, Figure 5). The community consisted of:

- Six Orders of arachnids: Scorpionida, Pseudoscorpionida, Palpigradi, Schizomida, Araneae (spiders), and Opilionida (harvestmen).
- One crustacean Order: Isopoda.
- Two Orders of centipede: Geophilomorpha and Scolopendromorpha.
- Symphylans were represented by the Order Cephalostigmata.
- Two Orders of millipedes: Polydesmida and Polyxenida.
- Pauropods were represented by the only known Order in this group: Pauropodina.
- Six orders of hexapods (Entognatha/Insecta): Diplura (bristletails), Thysanura (silverfish), Blattodea (cockroaches), Hemiptera (true bugs), Coleoptera (beetles), and Diptera (flies).

There was considerable variation in animal abundance between Orders with the insect Orders Blattodea, Hemiptera, and Coleoptera accounting for 51% of all troglofaunal specimens. More than half of the 66 species were collected in low abundance with 24 species represented by a single specimen (singleton) and 15 represented by just two specimens (Figure 6). The hemipteran species Meenoplidae sp. (46 specimens), the two cockroach species *Nocticola* sp. B1 and *Nocticola* sp. B22 (37 and 29 specimens, respectively), the beetle species Curculionidae Genus 1 sp. B10 (34 specimens) and the slater species *Hanoniscus* sp. B4 (29 specimens) were the numerically dominant species within the survey area (Figure 6).

Diplura with ten species and Coleoptera with nine species were the most species-rich Orders. In addition, the seven species of Araneae, six species of Pseudoscorpiona and five species of Schizomida represented well developed troglofaunal guilds of these groups.

No specimens belonged to a formally described species and, as with most troglofauna surveys, many species were new to science. As a consequence, none of the species collected is listed under State or Commonwealth legislation or policy frameworks as having an elevated conservation status.

6.1.2. Troglofauna Distributions among Ore Deposits

The number of specimens collected from the five ore deposits sampled ranged from 124 at Blackjack to 38 at Ajax, where the sampling effort was lowest. The average number of specimens collected per sample was relatively high at both Ajax and Blackjack, suggesting that troglofauna occur in greater abundance at these locations than the other ore deposits. At least 11 taxonomic orders were collected from each ore deposit, and the highest number of taxonomic orders collected at a single ore deposit was 15 at both Champion and Eagle (Figure 7). Seven orders were represented at all ore deposits, namely Schizomida, Isopoda, Cephalostigmata, Diplura, Blattodea, Hemiptera and Coleoptera.

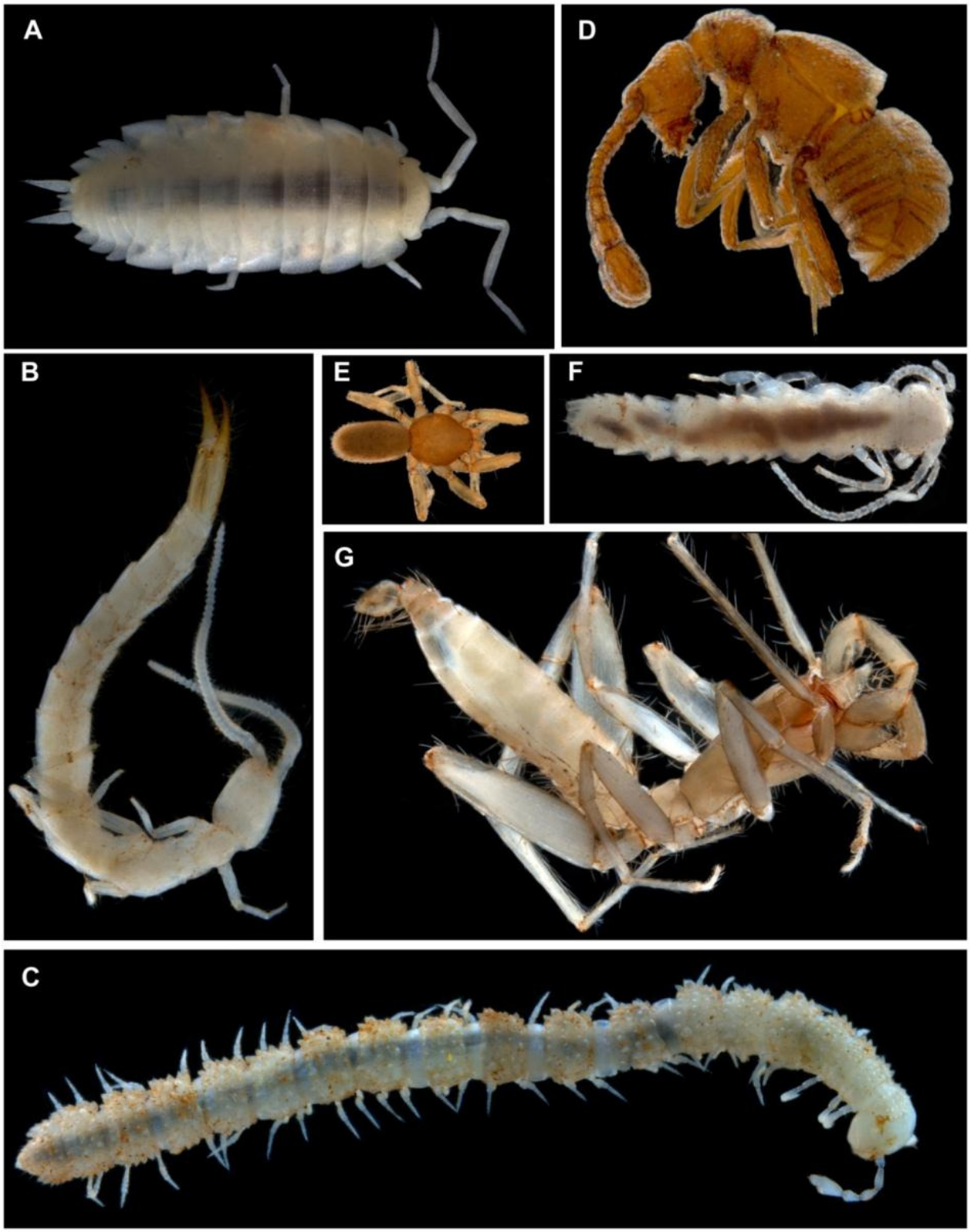


Figure 5. Troglofauna species collected within the Blacksmith Study Area.
(A) *Hanoniscus* sp. B4; (B) Japygidae sp. B4 (=Japygidae sp. S1); (C) Dalodesmidae sp. B2;
(D) Pselaphinae sp. B1; (E) Oonopidae sp. B16; (F) *Subtrinemura* sp. B1; (G) *Paradraculoides* sp. B3.

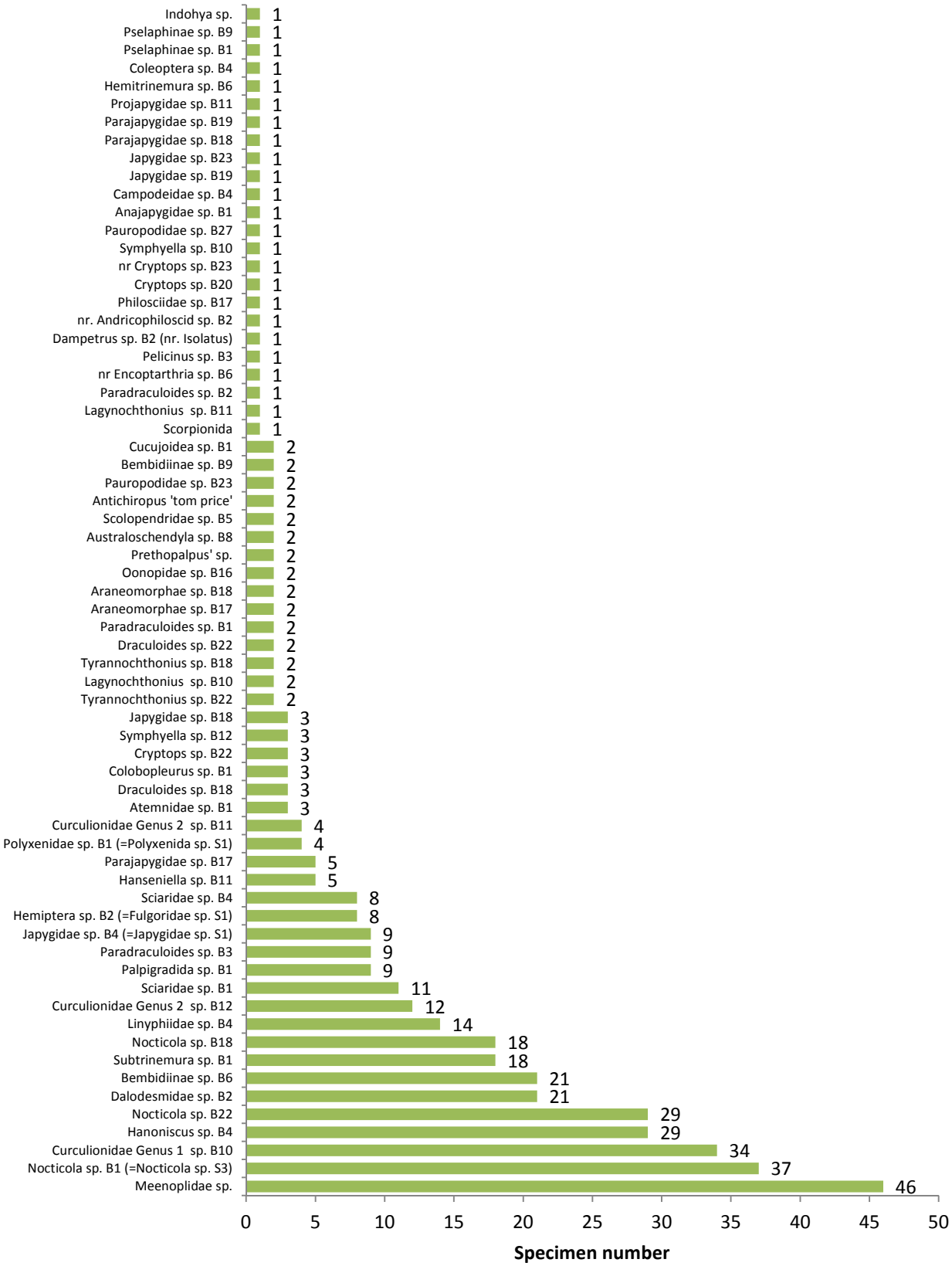


Figure 6. Capture abundance of each troglofauna species.

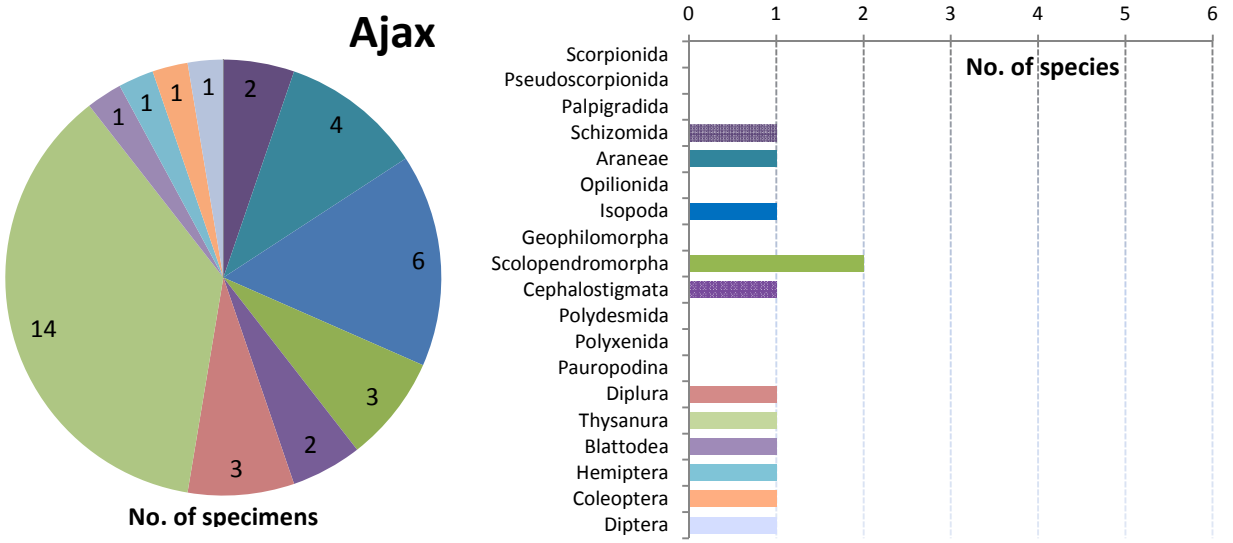
Table 3. The distribution of troglofauna specimens and species among the five ore deposits.

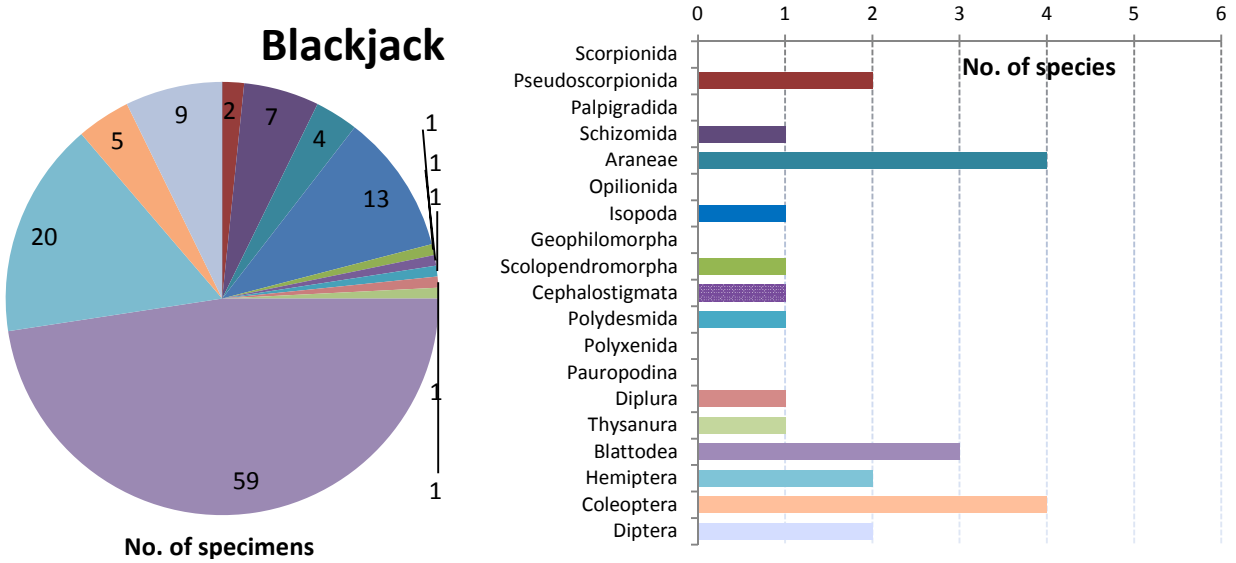
	Ajax	Blackjack	Champion	Delta	Eagle
Number of samples (number of stygofauna sample drill-holes with troglofauna bycatch)	20 +(2)	87+(15)	129+(20)	100+(9)	120+(13)
Number of specimens	38	124	89	87	85
Average number of specimens per sample	1.73	1.22	0.60	0.80	0 64
Number of species	12	24	30	26	31
No. species represented by a single specimen within the study area	1	4	3	8	8
No. species collected with >1 specimen within the study area (multiple specimen species)	11	20	27	18	23
Percentages of multiple specimen species shared with other ore deposits[1]					
	Ajax	Blackjack	Champion	Delta	Eagle
Ajax		35	26	28	26
Blackjack	64		63	50	52
Champion	64	85		50	78
Delta	45	45	33		30
Eagle	55	60	67	39	

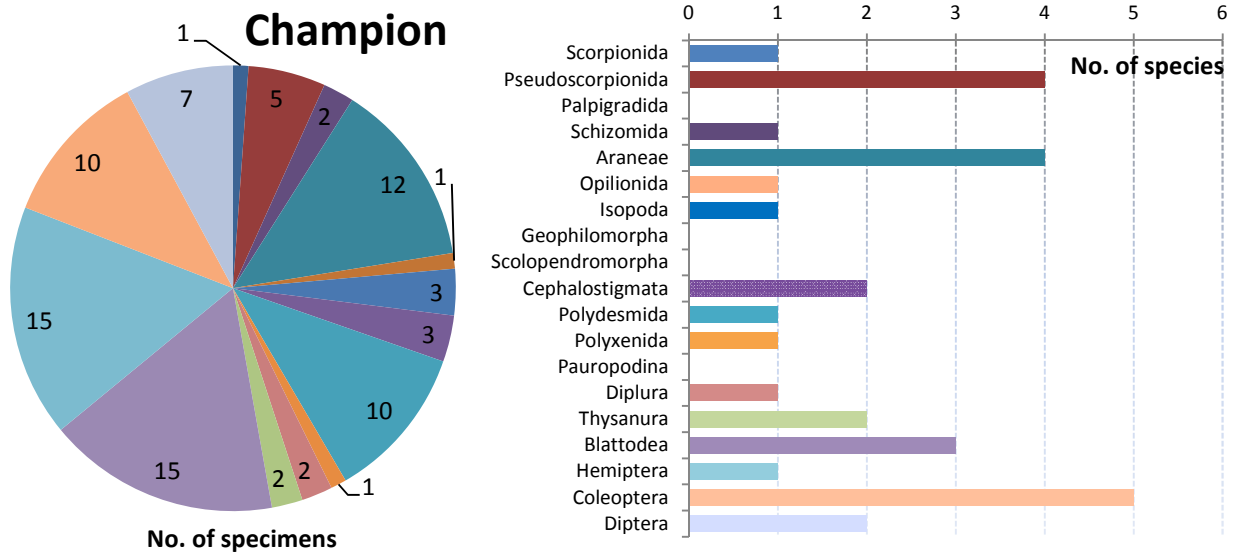
[1]Because each deposit has a different number of multiple-specimen species, two percentage values have been presented for each combination of deposits; e.g. the when considering the percentage of species shared between Champion and Eagle, the 18 shared species represent 67 % of the 27 multiple-specimens species at Champion and 78% of the 23 multiple-specimens species at Eagle.

Overall, there was considerable evidence that a single troglofauna community occurs throughout the Blacksmith tenement. The slater *Hanoniscus* sp. B4 (Figure 5), the cockroach *Nocticola* sp. B18 and the beetle, Curculionidae Genus 1 sp. B10 were collected from all five deposits. An analysis of the sampling results at the taxonomic level of Order suggested there is a disjunction between the more western Blackjack and Champion deposits and the more eastern deposits of Delta and Eagle (Figure 7). However, when the proportions of shared species were examined, Champion and Eagle deposits shared a similar proportions of species (67% and 78% respectively) to that shared between Champion and Blackjack (63% and 85%) (Table 3). Delta deposit appeared to be less well connected with Blackjack, Champion and Eagle than these three were with each other; Delta shared only 30-50% of species with other deposits, depending on the comparison made (Table 3). There was too little sampling at Ajax for meaningful analysis of the relationships of this deposit but on the basis that it shares the same widespread species it is considered to be part of the same community.

Despite the conclusion that the Blacksmith tenement contains a single troglofauna community, it appears that some species may be locally restricted within the tenement. This is seen most clearly amongst the schizomid species where *Draculoides* sp. B18 and *Paradraculoides* sp. B2 were collected only at Delta, *Draculoides* sp. B22 only at Eagle, *Paradraculoides* sp. B3 only at Blackjack and Champion and *Paradraculoides* sp. B1 at Ajax.


Ajax
2
4
6
3
2
3
14
1
1
1
1
1
No. of specimens
0 1 2 3 4 5 6
No. of species
Scorpionida
Pseudoscorpionida
Palpigradida
Schizomida
Araneae
Opilionida
Isopoda
Geophilomorpha
Scolopendromorpha
Cephalostigmata
Polydesmida
Polyxenida
Pauropodina
Diplura
Thysanura
Blattodea
Hemiptera
Coleoptera
Diptera


Blackjack
2
7
4
13
1
1
1
1
1
59
20
5
9
No. of specimens
0 1 2 3 4 5 6
No. of species
Scorpionida
Pseudoscorpionida
Palpigradida
Schizomida
Araneae
Opilionida
Isopoda
Geophilomorpha
Scolopendromorpha
Cephalostigmata
Polydesmida
Polyxenida
Pauropodina
Diplura
Thysanura
Blattodea
Hemiptera
Coleoptera
Diptera


Champion
1
5
2
12
1
3
3
10
2
2
1
15
10
7
No. of specimens
0 1 2 3 4 5 6
No. of species
Scorpionida
Pseudoscorpionida
Palpigradida
Schizomida
Araneae
Opilionida
Isopoda
Geophilomorpha
Scolopendromorpha
Cephalostigmata
Polydesmida
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Pauropodina
Diplura
Thysanura
Blattodea
Hemiptera
Coleoptera
Diptera

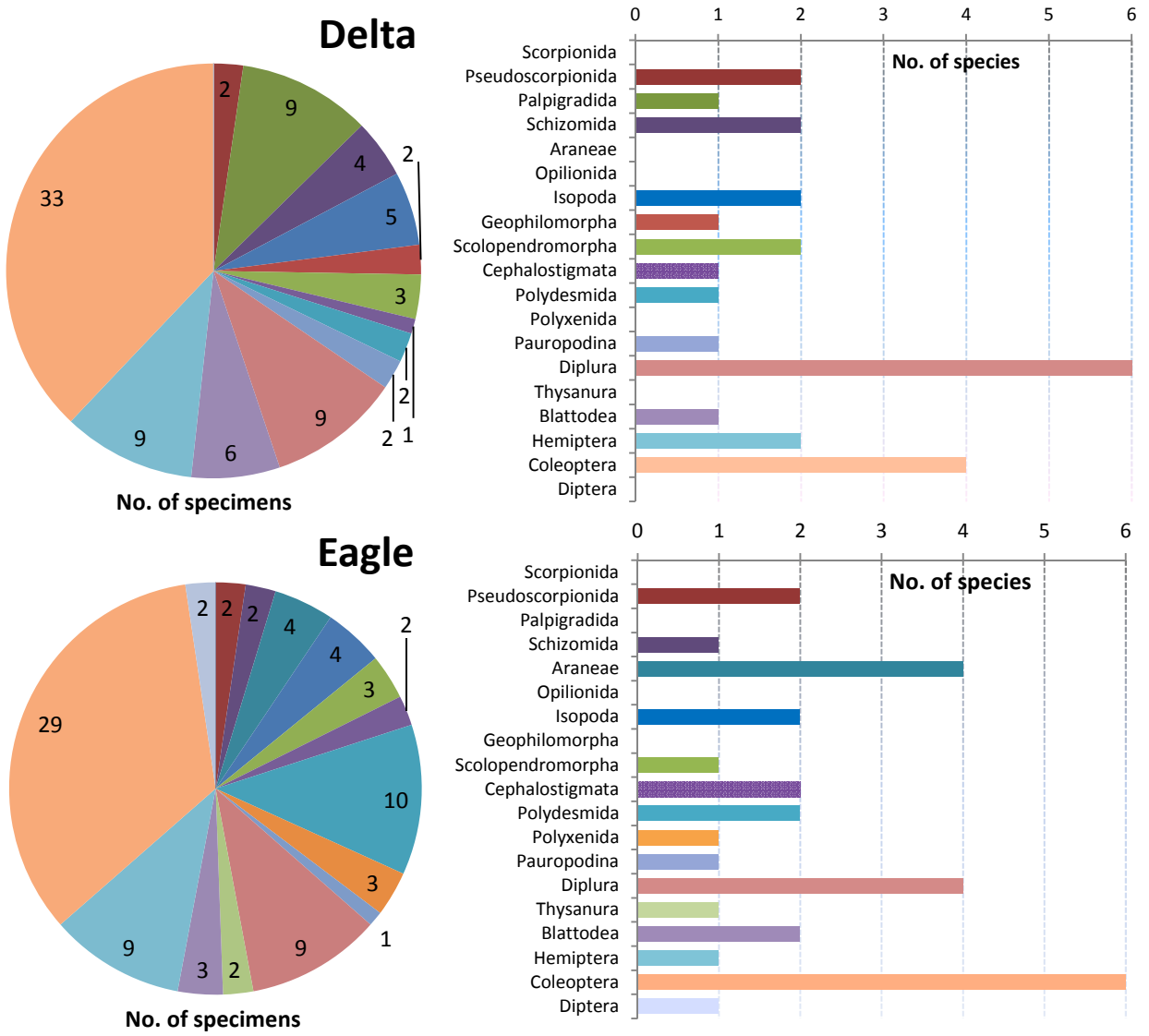


Figure 7. Specimen and species numbers belonging to each Order collected at the five deposits within the Study Area.

Altogether, 42 of the 66 troglofauna species were collected in the Blacksmith tenement on multiple occasions or from multiple drill-holes. Thirty-one of these species were collected from more than one ore deposit within the tenement, suggesting that species with highly restricted distributions are relatively uncommon. The remaining 11 species (including four schizomid species) were collected from only one deposit. However, because only one of these 11 species was represented by more than 3 specimens it is probable that sampling issues have led to ranges being underestimated in most, if not all, cases. The collection of nine specimens of Palpigradida sp. B1 from a single deposit (Delta) illustrates how difficult it is to document species' ranges, especially at the fine-scale required for assessment. Despite being collected only at Delta in the Blacksmith tenement, Palpigradida sp. B1 is widespread across the Pilbara (Bennelongia unpublished data) and, presumably, within most deposits of the Blacksmith tenement as well.

6.1.3. Distribution of Troglofauna in Relation to Proposed Impact Areas

Fifty-four troglofauna species were collected from proposed impact areas within the Blacksmith tenement. Nine of these are known to be widespread in the Pilbara or the area outside the Blacksmith tenement (Appendix A). They are:

- Palpigradida sp. B1;
- the polyxenid millipede Polyxenidae sp. B1;
- the dipluran Japygidae sp. B4;
- the cockroach *Nocticola* sp. B1;
- the three species of true bugs, Hemiptera sp. B2, Meenoplidae sp., and Pselaphinae sp. B1;
- the silverfish *Subtrinemura* sp. B1; and
- the fly Sciaridae sp. B1.

A further 23 species recorded within impact areas were collected from reference areas within the tenement (Appendix A).

The remaining 22 species were collected only from proposed impact areas (Table 4, Appendix C). These were:

- a single species of scorpion;
- four species of pseudoscorpion;
- two species of isopods;
- a single species of geophilomorph and two species of scolopendromorph centipedes;
- one species of symphylan;
- seven species of dipluran;
- three species of beetles; and
- one species of fly.

The collection of a troglobitic scorpion (Figure 8) is of considerable scientific interest because this is the first record of a troglobitic scorpion in mainland Australia.

Seventeen of the species known only from impact areas were singletons (represented by one specimen) and only one species, the fly Sciaridae sp. B4, was represented by more than three specimens.

6.1.4. Troglofauna species determinations

Of the total 570 troglofauna specimens collected from the Study Area, 147 were juvenile, the wrong sex for identification or consisted only of parts of the animal. These specimens included 83 *Nocticola* sp. cockroaches, together with 25 *Draculoides* sp. and 19 *Paradraculoides* sp. schizomids (Appendix B). None of these 147 higher order specimens represented species not already listed in Appendix A.

Table 4. Troglobitic species collected only from impact areas.

Higher Taxonomic Groups	Species	Blackjack	Champion	Delta	Eagle	Total No. specimens
Arachnida						
Scorpionida	Scorpionida sp. [A]	-	1	-	-	1
Pseudoscorpionida	Atemnidae sp. B1	1	1	1		3
	Indohya sp.	-	-	-	1	1
	Lagynochthonius sp. B11	1	-	-	-	1
	Tyrannochthonius sp. B22	-	2[2]	-	-	2
Crustacea						
Isopoda	nr *Andricophiloscia* sp. B2	-	-	1	-	1
	Philosciidae sp. B17	-	-	-	1	1
Chilopoda						
Geophilomorpha	*Australoschendyla* sp. B8	-	-	2[2]	-	2
Scolopendromorpha	*Cryptops* sp. B22	-	-	-	3	3
	nr *Cryptops* sp. B23	1	-	-	-	1
Symphyla						
Cephalostigmata	*Symphyella* sp. B10	-	-	1	-	1
Entognatha						
Diplura	Anajapygidae sp. B1	-	-	1	-	1
	Campodeidae sp. B4	-	-	1	-	1
	Japygidae sp. B19	-	-	1	-	1
	Japygidae sp. B23	-	-	-	1	1
	Parajapygidae sp. B18	-	-	1	-	1
	Parajapygidae sp. B19	-	-	1		1
	Projapygidae sp. B11	-	-	-	1	1
Insecta						
Coleoptera	Coleoptera sp. B4	-	-	-	1	1
	Cucujoidea sp. B1	-	1	1	-	2
	Pselaphinae sp. B9	-	-	-	1	1
Diptera	Sciaridae sp. B4	6[2]	2	-	-	8
TOTALS		Total number of restricted species				
9 Orders	22 species	4	5	10	7	

The small superscript numbers represent the number of sample bores from which specimens were collected if samples at that deposit were collected from more than one drill-hole.

[A] Family affiliation of the specimen still to be determined (Erich Volschenk pers. comm.)

Figure 8. First troglobitic scorpion recorded on mainland Australia (identification undetermined)

6.2. Stygofauna

6.2.1. Stygofauna Occurrence and Abundance

A moderately rich stygofauna community with a total of 34 species, from 10 Orders or higher level groups, was characterised from 2906 specimens collected at either designated stygofauna sampling drill-holes or as by-catch from troglofauna sampling. The 10 higher level groups were:

- Turbellaria or flat worms;
- Nematoda or round worms;
- Aphanoneura or suction-feeding worms;
- the Oligochaeta worm order Tubificida;
- the arachnid order Hydracarina or water mites; and
- five orders of crustaceans – Ostracoda, Copepoda, Syncarida, Amphipoda, and Isopoda (slaters).

Seven of the 34 species have previously been formally described and catalogued. They are: two ostracods - *Limnocythere stationis* (although there is doubt about whether the Pilbara specimens do belong to this cosmopolitan species) and *Meridiescandona facies*; and five copepods - *Diacyclops humphreysi humphreysi*, *Diacyclops sobeprolatus*, *Mesocyclops brooksi, Microcyclops varicans,* and *Thermocyclops aberrans.* None of the species is currently listed or has an elevated conservation status. A full list of the species collected with comments on their distribution is presented in Appendix D and photographs of a selection of stygofauna species are provided in Figure 9.

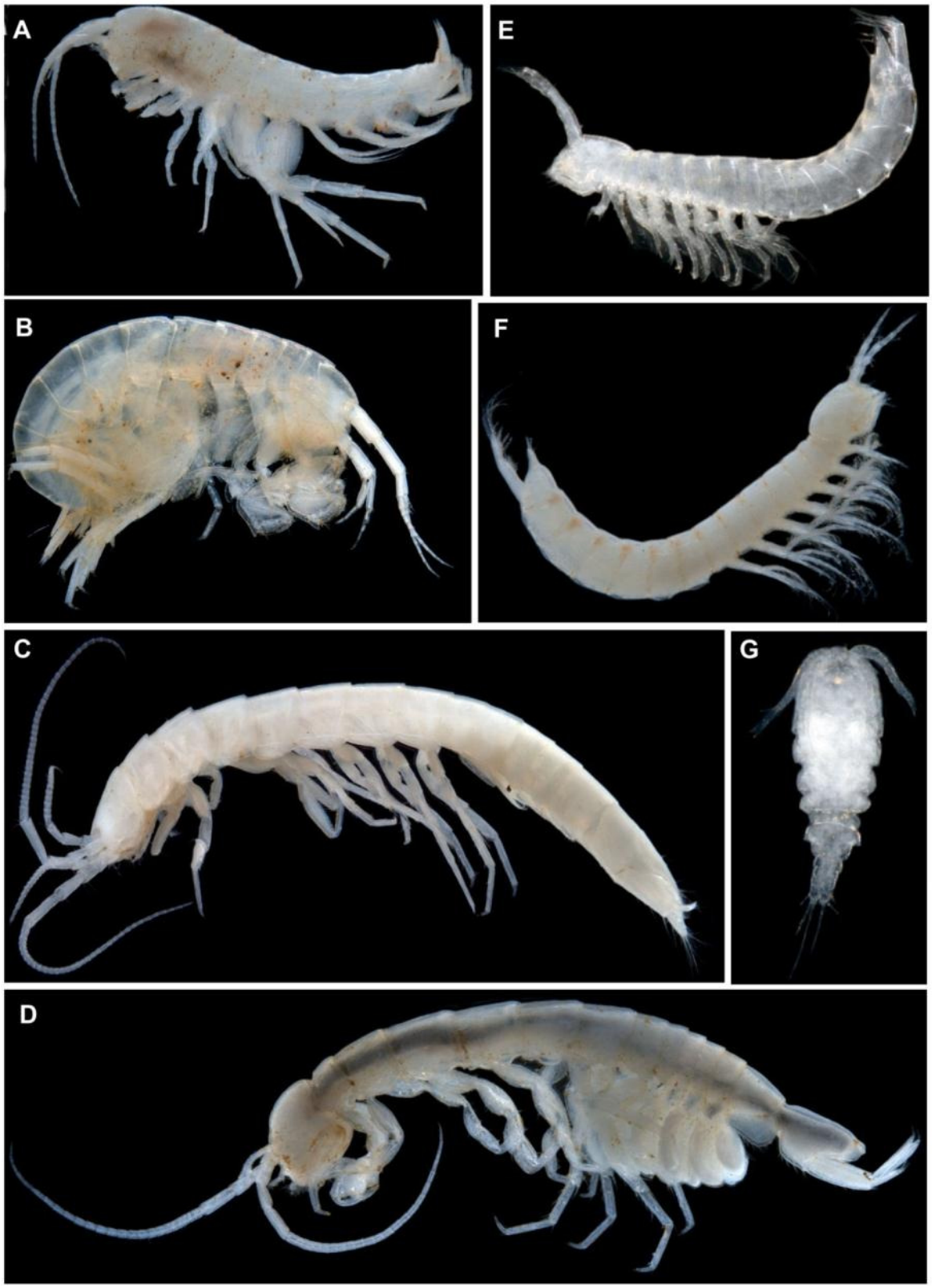


Figure 9. Stygofauna species collected within the Blacksmith Study Area.
(A) Paramelitidae (nr *Pilbarus*) sp. B5; (B) Neonipharidae sp. B1; (C) *Pygolabis* sp. B5; (D) *Pilbarophreatoicus* sp. B2; (E) *Atopobathynella* sp. B3; (F) *Billibathynella* sp. B3; (G) *Anzcyclops* sp. B1.

The tubificid worms, together with copepod and syncarid crustaceans, were the most abundant stygofaunal groups and together accounted for over 86% of specimens. Copepods were the most species rich order, with 12 species.

Stygofauna species abundance ranged between one and 639 specimens (Figure 10). Twelve species had an abundance of less than five specimens, and three species (the water mite Pezidae sp. B1, ostracod species ?*Meridiescandona facies*, and copepod species *Fierscyclops* sp. B5 (nr *supersensus*)) were represented by single specimens. The most abundantly collected species were the copepod *Microcyclops varicans* with 427 specimens, and the syncarid *Billibathynella* sp. B3 (Figures 9 and 10).

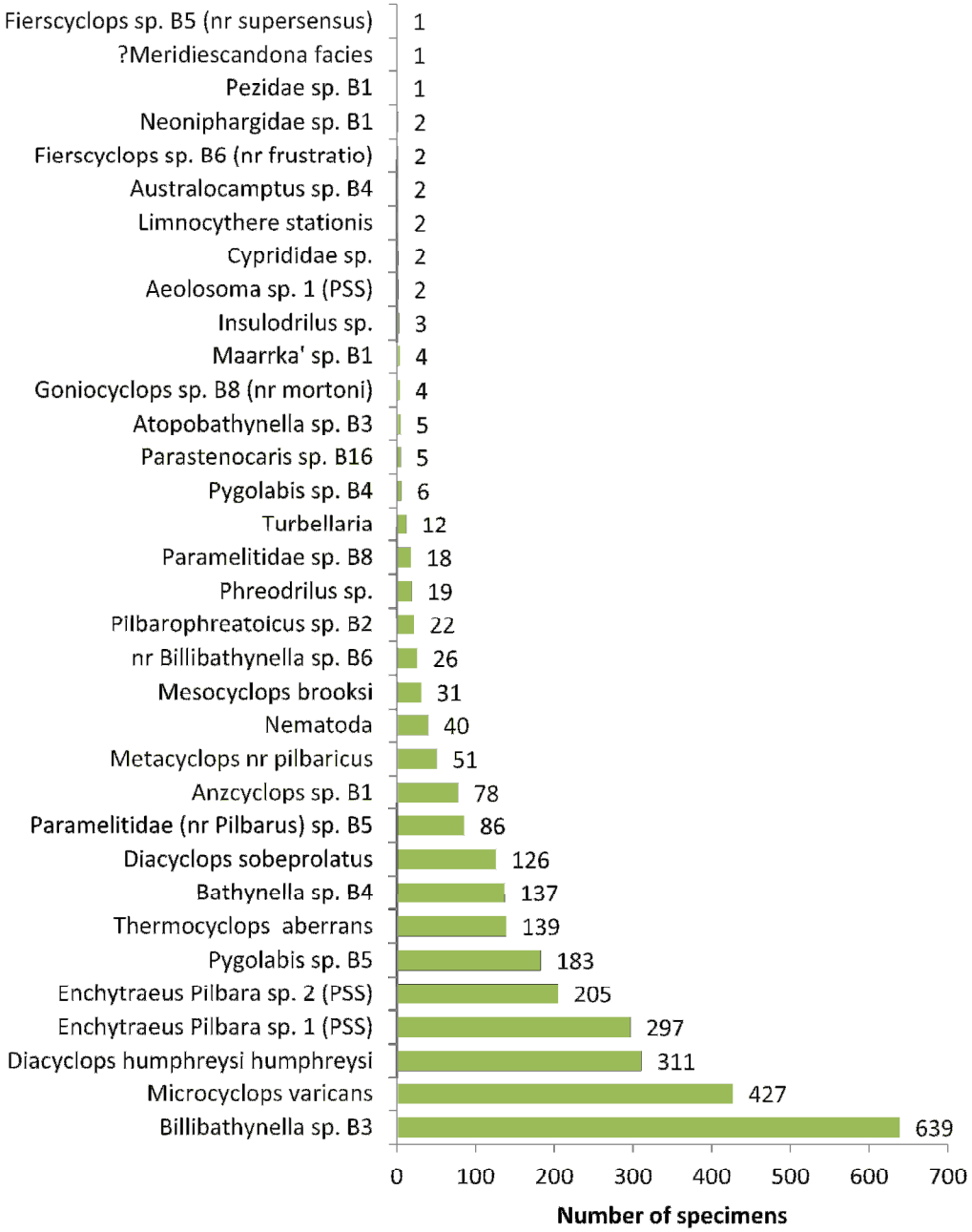


Figure 10. Capture abundance of each stygofauna species within the survey area.

6.2.2. Stygofauna Distributions among Ore Deposits

The distribution of specimens and species among the five ore deposits is presented in full in Appendix D and summarised in Figure 11 and Table 5.

Table 5. The distribution of stygofauna specimens and species among the five ore deposits

	Ajax	Blackjack ore deposit	Champion ore deposit	Delta ore deposit	Eagle ore deposit
Number of samples +(number of troglofauna sample drill-holes with stygofauna by catch)	12+(9)	38+(11)	72+(27)	69+(7)	70+(21)
Number of specimens	443	301	921	538	696
Average number of specimens per sample	21.1	6.14	9.3	7.1	7.65
Number of species	11	6	17	13	19
No. species represented by a single specimen within the study area	0	0	2	0	1
No. species collected with >1 specimen within the Study Area (multiple-specimen species)	11	6	15	13	18

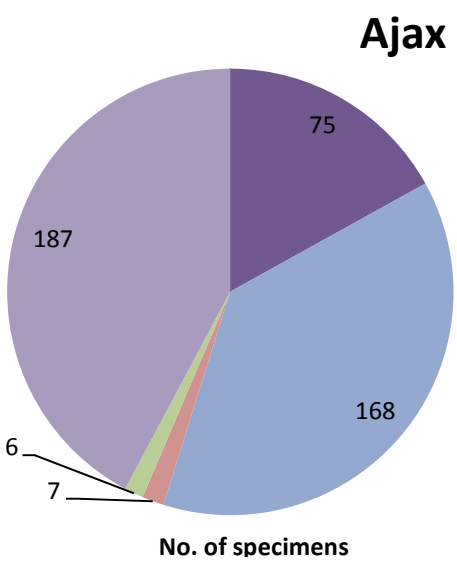
Percentages of multiple specimen species shared with other ore deposits

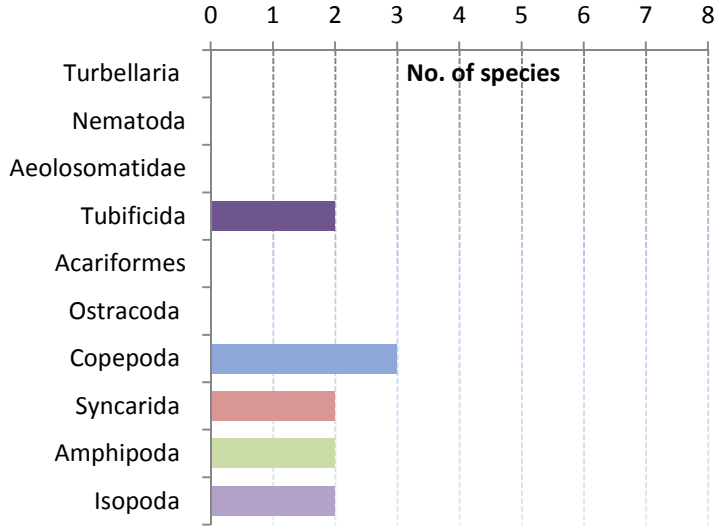
	Ajax	Blackjack	Champion	Delta	Eagle
Ajax		17	20	54	22
Blackjack	9		40	23	28
Champion	27	100		39	61
Delta	64	50	33		33
Eagle	36	83	73	46	

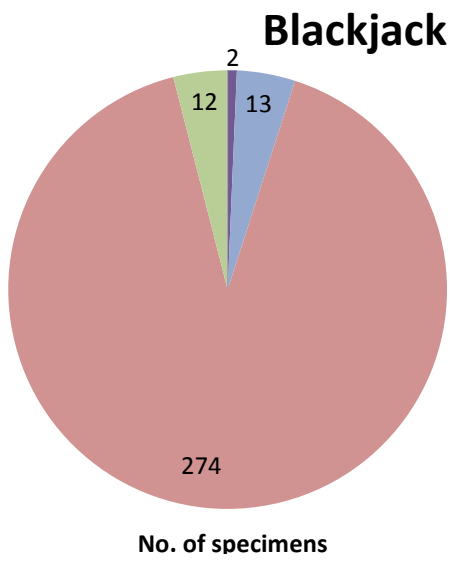
Because each deposit has a different number of multiple-specimen species, two percentage values have been presented for each combination of deposits; e.g. the when considering the percentage of species shared between Champion and Eagle, the 11 shared species represent 73 % of the 15 multiple-specimens species at Champion and 61% of the 18 multiple-specimens species at Eagle.

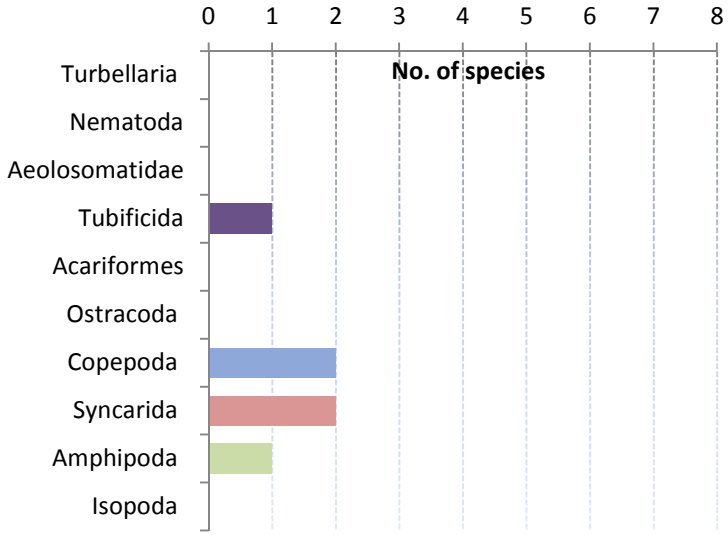
The number of specimens collected at each ore deposit ranged from 301 at Blackjack to 921 at Champion. The average number of specimens collected per sample was two or three times higher at Ajax (21.1) than at the other ore deposits (6.14 – 9.3).

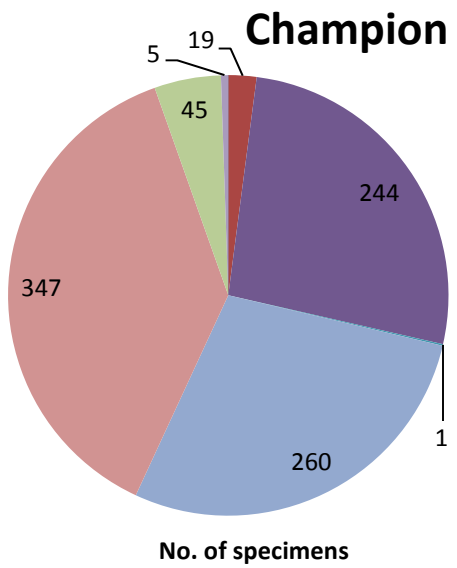
The highest number of species collected at a single deposit was 19 at Eagle. The lowest number of species (6) was recorded at Blackjack, which contained a subset of the species at other deposits. As with troglofauna, there was evidence of a single stygofauna community occurring throughout the Blacksmith tenement and eight species occurred in four or five of the deposits surveyed. Three of these species (the worms *Enchytraeus* Pilbara sp. 1 (PSS) and *Phreodrilus* sp. and copepod *Diacyclops humphreysi humphreysi*) occur across the Pilbara (Appendix D). The other five species are known only from the Study Area (the copepods *Anzcyclops* sp. B1 and *Thermocyclops aberrans*, syncarids *Bathynella* sp. B4 and *Billibathynella* sp. B3 and the amphipod Paramelitidae (nr *Pilbarus*) sp. B5). An analysis of the sampling results based on the abundance of different orders suggested, as with troglofauna, that the eastern Delta and Eagle deposits were more similar to each other than to the western Blackjack and Champion deposits (Figure 11). However, Blackjack, at which there was lower sampling effort, had substantially fewer species than Champion and the richness of copepods at Champion suggested similarity with Eagle.

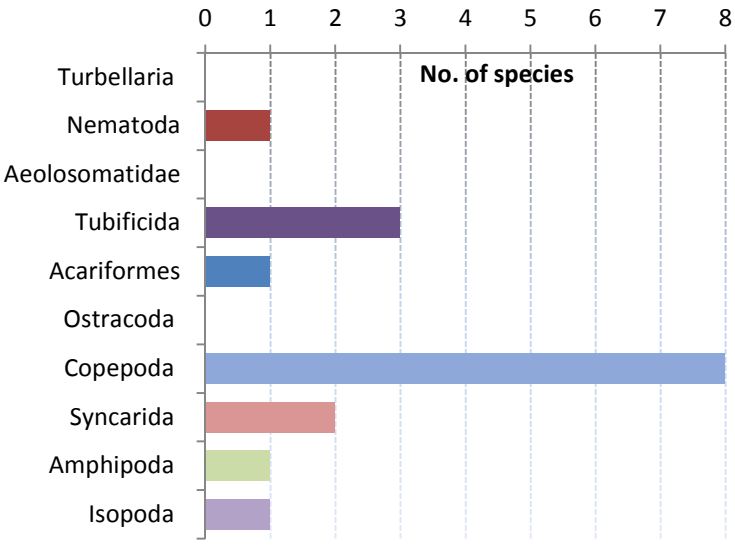

Ajax
75
187
168
6
7
No. of specimens


0 1 2 3 4 5 6 7 8
No. of species
Turbellaria
Nematoda
Aeolosomatidae
Tubificida
Acariformes
Ostracoda
Copepoda
Syncarida
Amphipoda
Isopoda


Blackjack
2
12
13
274
No. of specimens


0 1 2 3 4 5 6 7 8
No. of species
Turbellaria
Nematoda
Aeolosomatidae
Tubificida
Acariformes
Ostracoda
Copepoda
Syncarida
Amphipoda
Isopoda


Champion
5
19
45
244
347
260
1
No. of specimens


0 1 2 3 4 5 6 7 8
No. of species
Turbellaria
Nematoda
Aeolosomatidae
Tubificida
Acariformes
Ostracoda
Copepoda
Syncarida
Amphipoda
Isopoda

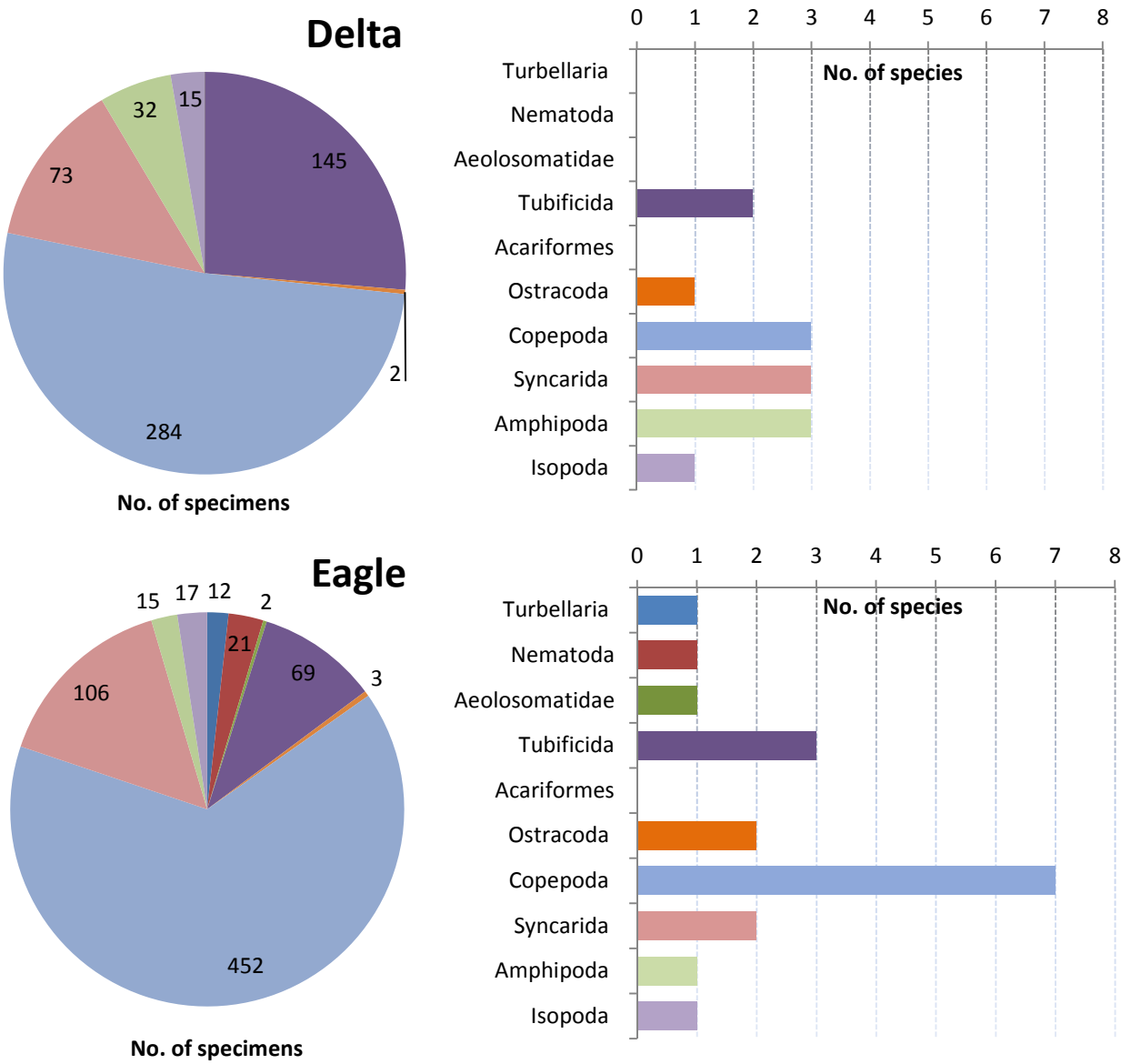


Figure 11. The relative abundance of stygofauna animals at each deposit at the taxonomic level of order.

Analysis of the proportions of shared species (Table 5) highlighted that Blackjack contained a subset of the species at Champion, and that Champion and Eagle shared higher percentages of species (73 and 61% respectively), than the percentages shared between Champion and Delta (33 and 46% respectively) (Table 5). Thus, as with troglofauna, Delta deposit appeared to be less well connected with Blackjack, Champion and Eagle than these three were with each other. There was too little sampling at Ajax for meaningful analysis of the relationships of this deposit but its sampled community structure was similar to Blackjack (Figure 11) and it is considered to support the same community as other parts of the Study Area.

Thirteen of the 31 species collected from multiple drill-holes or on multiple occasions were found at a single ore deposit. However, the remaining 58% of multiple-specimen species were collected from more than one deposit, highlighting the connectedness of the community across the Blacksmith tenement.

6.2.3. Distribution of Stygofauna in Relation to the Proposed Impact Area

For the purpose of assessment prior to the determination of groundwater drawdown cones, all 34 stygofauna species collected within the Study Area were interpreted as occurring within the area to be to impacted by proposed mining. A search of published literature and records of the Pilbara Biodiversity Survey (Halse *et al*. in preparation) confirmed that 14 stygofauna species in the Study Area also occur in considerable abundance outside it. These species are:

- the Aphanoneura worm *Aeolosoma* sp. 1 (PSS);
- all four tubificid worms;
- all three species of ostracods; and
- six of the 12 species of copepods.

In addition, two of the isopod species, *Pilbarophreatoicus* sp. B2 (Figure 9), and *Pygolabis* sp. B4 have been recorded to the north of the Study Area.

Live material and serial sectioning are required to identify nematode and turbellarian worms and, therefore, the EPA does not require their inclusion in environmental impact assessment. Thus, 16 of the 34 stygofauna species being assessed have not been shown to occur beyond the Study Area (Table 6, Appendix F). These species are:

- the water mite Pezidae sp. B1;
- six species of copepods;
- four species of syncarids;
- four species of amphipods; and
- one species of isopod.

The highest number of restricted species collected at a single deposit was nine at Champion, and the lowest number (5) was collected at both Ajax and Blacksmith (Table 6). Nine of the 16 species were collected from only one ore deposit.

6.2.4. Stygofauna Species Determinations

Of the 2906 stygofaunal specimens collected within the Study Area, the sex, developmental stage or condition of seven specimens prevented their inclusion in the analysis of stygofauna species richness, abundance and distribution (Appendix E). The seven specimens that could not be identified to species are likely to represent species already listed in Appendix D.

7. DISCUSSION

7.1. Regional Context

The 66 troglofauna and 34 stygofauna species collected within the Study Area represent high, and moderately high, species richness in comparison with other Pilbara surveys.

Blacksmith tenement appears to be located in an area that is rich in troglofauna and surveys at nearby mine sites have also documented rich troglofauna communities. At the Firetail deposits (part of the Solomon Project) 45 species were recorded from 263 samples (Bennelongia 2010). However, larger numbers of species have been collected elsewhere in the Pilbara with more than 70 species recorded in the mesas of the Robe valley (M.S. Harvey, pers. comm.), and 49 species recorded at Area C, which is 185 km southeast of the Blacksmith tenement, during sampling until late 2008 (Bennelongia 2009a).

Table 6. Stygofauna species known only from the Study Area.

Higher taxonomic Groups	Species	Species occurrence					Total No. of specimens
		Ajax	Blackjack	Champion	Delta	Eagle	
Arachnida							
Hydracarina							
	Pezidae sp. B1	-	-	1	-	-	1
Crustacea							
Copepoda							
	Anzcyclops sp. B1	-	9^{2}	22^{6}	-	47^{6}	78
	Australocamptus sp. B4	-	-	-	-	2	2
	Fierscyclops sp. B5 (nr *supersensus*)	-	-	1	-	-	1
	Fierscyclops sp. B6 (nr *frustratio*)	-	-	-	-	2	2
	Goniocyclops sp. B8 (nr *mortoni*)	-	-	4	-	-	4
	Parastenocaris sp. B16	-	4	1	-	-	5
Syncarida							
	Atopobathynella sp. B3	5^{2}	-	-	-	-	5
	Bathynella sp. B4	-	1	13^{4}	48^{2}	75^{9}	137
	Billibathynella sp. B3	-	273^{6}	334^{31}	1	31^{9}	639
	nr *Billibathynella* sp. B6	2	-	-	24^{6}	-	26
Amphipoda							
	Maarrka' sp. B1	-	-	-	4^{2}	-	4
	Neoniphargidae sp. B1	2	-	-	-	-	2
	Paramelitidae (nr Pilbarus) sp. B5	4^{3}	12^{4}	45^{9}	10^{4}	15^{8}	86
	Paramelitidae sp. B8	-	-	-	18^{4}	-	18
Isopoda							
	Pygolabis sp. B5	181^{3}	-	-	2^{2}	-	183
TOTALS		Total number of restricted species					
	16 species	**5**	**5**	**9**	**7**	**7**	

The small number in superscript represents the number of sample drill-holes from which specimens were collected if samples at that deposit were collected from more than one drill-hole.

Surrounding areas also have similar stygofauna values to those of the Blacksmith tenement. Twenty-seven species were recorded at the Valley of the Kings deposits (parts of the Solomon Project) approximately 50 km east of the Blacksmith tenement (Subterranean Ecology 2011) and at the West Pilbara Iron Ore Project, 130 km to the west, 37 stygofauna species were collected (Biota 2010a).

7.2. Factors Affecting Species Yields

The number of troglofauna species, in particular, collected at the Blacksmith tenement is greater than reported in most surveys. While this indicates that the area is rich in troglofauna, methodological differences between survey teams mean that comparisons with some other surveys probably exaggerate the richness of the Blacksmith tenement. For troglofauna, methodological differences include the total number of samples collected and whether:

- scraping is conducted as well as trapping (scraping yields about twice as many specimens on average);
- the animals collected during scraping and trapping of the same drill-hole during the same sampling round are treated as one sample or two samples;
- all orders with recognized troglobitic members are treated as potential troglofauna; and
- specimens in all of the groups specified by EPA Guidance Statement 54a (EPA 2007) are identified to species level.

Bennelongia employed trapping and scraping and treated the results from a single drill-hole during the same sampling round as one sample, whereas they are sometimes considered as two samples in other studies (e.g. Subterranean Ecology 2010).

Bennelongia reported as troglofauna all species belonging to groups recognized as containing troglobites if the species displayed troglomorphic characteristics, such as absence of eyes, reduced pigmentation, very well developed sensory organs and elongated appendages. Some surveys exclude many such species, despite possessing troglomorphies, unless they have been verified as troglobitic rather than being deep soil fauna. The application of this approach may result in exclusion of about half of the orders usually recognized as containing troglofauna (e.g. Biota 2011 excluded specimens of Palpigradida, Araneae, Opilionida, Isopoda, Symphyla, Pauropoda and Hemiptera from assessment, although in some cases the support for exclusion was that few troglomorphies were visible). Only 34 of the 66 species identified at the Blacksmith tenement belonged to the eight orders recorded as troglofauna in the West Pilbara Iron Ore Project troglofauna assessment (Biota 2011).

7.3. Species Restricted to Blacksmith Tenement Impact Areas

The true distributions of species that occur in low abundance are difficult to determine without very large sampling effort over the possible extent of the species' range. Sixteen of the 22 troglofauna species recorded only in proposed impact areas were collected as single specimens and only one species was represented by more than three specimens. Restricted stygofauna species were generally represented by higher numbers of specimens. However, two species were represented by only a single specimen and an additional three species were represented by only two specimens. Thus, the currently known ranges of most of the species 'restricted' to impact areas is clearly an underestimate of the true range. When species are collected only once, information on their range is limited to a point estimate of where they occur and there is no information about the likely extent of their ranges.

Additional data that can assist in predicting the likelihood of the ranges of 'restricted' species extending beyond the proposed impact areas include information on the biology and distributions of related species and on the distribution of subterranean fauna habitat and the degree of connectivity of the Blacksmith habitat with surrounding areas.

7.3.1. Biological Attributes of Restricted Troglofauna Species

Biological information relating to the 22 troglofauna species known only from impact areas provides some evidence that the distributions of 14 of these species may, or is likely to, extend beyond the proposed impact areas. This conclusion is explained in the following subsections, which consider each restricted troglofauna species.

Scorpionida

The collection of a troglobitic scorpion is of scientific interest. The nearest record of a troglobitic scorpion is on Barrow Island (*Aops oncodactylus*), which is approximately 250 km from the Study Area

and of a different geology. The scorpion specimen collected just within the proposed Champion impact area is distinctly different from the Barrow Island species and the scorpion family to which it belongs, remains undetermined.

Few troglobitic scorpion species have been recorded worldwide: 11 species in Mexico; one each in Ecuador and Sarawak; one on Christmas Island (Humphreys and Eberhard 2001); one on Barrow Island, and now the species that was collected in Blacksmith tenement. Until the collection of this single troglobitic scorpion near the boundary of the proposed impact area at Champion deposit (Appendix C), no other troglobitic scorpions had been recorded on mainland Australia.

The absence of other similar troglobitic scorpion species in the Pilbara provides no guidance on the potential for a wider distribution of the new scorpion species.

Pseudoscorpionida

Four species of Pseudoscorpionida have been collected only from impact sites within the Study Area:

- Atemnidae sp. B1 represented by three specimens collected from Blackjack, Champion, and Delta;
- *Indohya* sp. represented by a single specimen at Eagle;
- *Lagynochthonius* sp. B11 represented by a single specimen at Blackjack; and
- *Tyrannochthonius* sp. B22 represented by two specimens at Champion.

All species of pseudoscorpions in the Study Area were collected in low abundance (<4 animals) but the pseudoscorpions collected from multiple drill-holes were well dispersed among the deposits. *Tyrannochthonius* sp. B22 was the only multiple-specimen species collected from a single deposit.

At least four species of pseudoscorpions co-occurred at Delta, including the closely related *Tyrannochthonius* sp. B18 and *Tyrannochthonius* sp. B22, which demonstrates that pseudoscorpions do not have mutually exclusive ranges. This, together the fact that species with multiple records appear to be dispersed, suggests that it is unlikely that any species is restricted to a single deposit and, furthermore, that species are probably distributed through the matrix between deposits. Thus, it is expected that further sampling would show no species is restricted to impact areas.

Isopods

Two species of isopods were collected only from impact sites within the Study Area:

- nr *Andricophiloscia* sp. B2 was represented by a single specimen collected at Delta; and
- Philosciidae sp. B17 was represented by a single specimen collected at Eagle.

Philosciids are relatively rare in the Pilbara and some of the recorded morphospecies appear to have tightly restricted ranges (Bennelongia 2008c). Little can be said about the likely ranges of nr. *Andricophiloscia* sp. B2 and Philosciidae sp. B17.

Chilopoda

Three species belonging to two orders of Chilopoda were collected only from impact sites within the Study Area:

- *Australoschendyla* sp. B8 was represented by two animals collected from two drill-holes at Delta;
- *Cryptops* sp. B22 was represented by three animals collected from one drill-hole at Eagle; and
- nr *Cryptops* sp. B23 was represented by a single specimen from Blackjack.

All species of centipedes collected by Bennelongia in the Pilbara have been recorded in low abundance. However, when specimens have been recorded from multiple drill-holes, they have usually been shown to have large ranges compared with other troglofauna. For example, the two species of centipede found at Area C in the Central Pilbara are known to have linear ranges of at least 27 and 90 km, respectively (Bennelongia 2009a). Thus, it is likely that further sampling would show that the three species extend beyond the Study Area and it is unlikely that any of the species is restricted to the impact areas.

Symphyla

Symphyella sp. B10 was represented by one specimen at Delta. However, the two other symphylan species in the Blacksmith tenement, *Hanseniella* sp. B11 and *Symphyella* sp. B12, were both collected at three deposits. It is considered likely that *Symphyella* sp. B10 is more widespread within the Study Area and probably extends into other deposits and the intervening matrix. It is unlikely to be restricted to the Delta impact area.

Diplura

Seven species of Diplura were collected only from impact areas within the Study Area:

- Anajapygidae sp. B1 represented by a single animal at Delta;
- Campodeidae sp. B4 represented by a single animal at Delta;
- Japygidae sp. B19 represented by a single animal at Delta;
- Japygidae sp. B23 represented by a single animal at Eagle;
- Parajapygidae sp. B18 represented by a single animal at Delta;
- Parajapygidae sp. B19 represented by a single animal at Delta; and
- Projapygidae sp. B11 represented by a single animal at Eagle.

Nine of the ten species of dipluran collected in the Study Area were recorded in only one deposit; the remaining species Japygidae sp. B4 was collected at Blackjack, Champion and Eagle deposits and is widespread in the Pilbara (Bennelongia 2009a). Six of the 'restricted' species occurred at Delta (a seventh species at Delta was also found in the surrounding reference area). Whether the apparent concentration of low-abundance species at Delta reflects the characteristics of local habitat or a sampling artefact is unclear.

There is almost no available information on the ranges of troglofaunal campodeid, anajapygid and projapygid diplurans but the limited information on parajapygids suggests they may sometimes have tightly restricted ranges (Bennelongia unpublished data). In contrast, troglofaunal japygids are considered to relatively widespread in the Pilbara (Halse 2010), as was illustrated by the occurrence of the widespread Pilbara species Japygidae sp. B4 at Blackjack, Champion and Eagle deposits. It is expected that further sampling will show wider occurrence of the japygid species at Delta (either in the surrounding reference area or more widely). Little can be said about the likely distribution of the other species known only from impact areas.

Coleoptera

Three species of beetles were collected only from impact drill-holes within the Study Area:

- Coleoptera sp. B4 was recorded as one specimen at Eagle;
- Cucujoidea sp. B1 was represented by two specimens at Champion and Delta; and
- Pselaphinae sp. B9 was recorded as a single animal at Eagle.

Of the nine beetle species collected within the Study Area, seven (including the 'restricted' Cucujoidea sp. B1) occurred at multiple deposits or are known to occur outside the Study Area. Thus, despite beetles being regarded as a group with small ranges (Halse 2010), it is unlikely that any beetle species are restricted to impact areas in the Blacksmith tenement. In the case of Cucujoidea sp. B1, it is likely that further sampling would show the occurrence of animals between Champion and Delta and perhaps more widely. It is also likely that Pselaphinae sp. B9 will be shown to be more widespread, like the related Pselaphinae sp. B1, which was represented by a single animal in the Study Area but is known to be more widespread in the Pilbara. Little can be said about Coleoptera sp. B4 other than, given that other beetles appear unlikely to be restricted at the scale of impact areas, it is unlikely that Coleoptera sp. B4 will be so restricted.

Diptera

The fly Sciaridae sp. B4 was represented by eight specimens in three samples from Blackjack and Champion. However, the related Sciaridae sp. B1, which occurred widely in the Blacksmith tenement, is found throughout the Hamersley Range and perhaps more widely. Thus, it seems likely that further sampling would show wider occurrence of Sciaridae sp. B4.

7.3.2. Biological Attributes of Restricted Stygofauna Species

Biological information relating to the 16 restricted stygofauna species provides some evidence that the distributions of nine of these species may, or are likely to, extend beyond the proposed impact areas. This conclusion is explained in the following subsections, which consider each restricted stygofauna species.

Hydracarina

A species of mite, Pezidae sp. B1, was collected as a singleton at Champion deposit. Other members of the Pezidae family have been collected from a wide range of locations in the Pilbara and it is considered unlikely that will be restricted to the Study Area. Most stygofaunal mites are widespread (M. Harvey pers. comm.).

Copepoda

Six species of Copepoda are known only from the Study Area:

- *Anzcyclops* sp. B1 represented by 78 specimens from Blackjack, Champion and Eagle;
- *Australocamptus* sp. B4 represented by two specimens from Eagle;
- *Fierscyclops* sp. B5 (nr *supersensus*) represented by one animal from Champion;
- *Fierscyclops* sp. B6 (nr *frustratio*) recorded as two specimens from Eagle;
- *Goniocyclops* sp. B8 (nr *mortoni*) recorded as four specimens from Champion; and
- *Parastenocaris* sp. B16 represented by five animals from Blackjack and Champion.

Although collected only from the impact area, *Anzcyclops* sp. B1 was collected from multiple deposits in moderately high abundance. The similarly distributed *Metacyclops* sp. B1 (nr *pilbaricus*), also collected only from the Blacksmith tenement impact area during this survey but is known to extend north-east into the Fortescue valley. It is therefore unlikely that *Anzcyclops* sp. B1 is restricted to the area of groundwater drawdown associated with the Blacksmith tenement.

The other copepod species known only from the Study Area were collected in low abundance. Little can be said about their likely ranges beyond the Blacksmith tenement.

Syncarida

Four species of syncarids are known only from the Study Area:

- *Atopobathynella* sp. B3 was represented by five specimens from Ajax;
- *Bathynella* sp. B4 was represented by 137 animals from Blackjack, Champion, Delta and Eagle;
- *Billibathynella* sp. B3 was recorded as 639 animals from Blackjack, Champion, Delta and Eagle; and
- nr *Billibathynella* sp. B6 was represented by 26 specimens from Ajax and Delta.

Stygofaunal syncarid species are usually considered to have small ranges (Guzik *et al*. 2008), although there is evidence that ranges increase with sampling effort (Camecho and Valdecasas 2008). Given the high numbers in which they were collected and their widespread occurrence within the Study Area, it is likely that both *Bathynella* sp. B4 and *Billibathynella* sp. B3 occur outside the drawdown cone associated with the Blacksmith tenement. The species nr *Billibathynella* sp. B6 was recorded at both the eastern and western end of the Study Area, suggesting it probably extends beyond the Blacksmith tenement. *Atopobathynella* sp. B3 was collected in low numbers from a single deposit and little can be said about its likely range.

Amphipoda

Four species of amphipods are known only from the Study Area:

- *Maarrka* sp. B1 was represented by four specimens from Delta;
- Neoniphargidae sp. B4 was represented by two specimens from Ajax;
- Paramelitidae (nr *Pilbarus*) sp. B5 was collected as 86 animals from all five deposits; and
- Paramelitidae sp. B8 was collected as 18 specimens from Delta.

The occurrence of Paramelitidae (nr *Pilbarus*) sp. B5 in moderately high numbers across the Study Area suggests that it is likely to extend beyond the groundwater drawdown associated with mining at the Blacksmith tenement. Little can be said about the likely ranges of the other three species except that most paramelitid species have tributary scale ranges (Finston et al. 2007, 2011) and, therefore, are unlikely to be restricted to the Blacksmith tenement in the upper part of the Weelumurra Creek catchment. The likely range of Neoniphargidae sp. B4 is unknown.

Isopoda

A single species of isopod *Pygolabis* sp. B5 is known only from Ajax in high numbers and from Delta as two animals. The related *Pygolabis* sp. B4 occurs in the Study Area and farther north. Given that other known *Pygolabis* species have ranges that are substantially larger than the Study Area (Keable and Wilson 2006), it is expected that further sampling would collect *Pygolabis* sp. B5 outside the groundwater drawdown associated with proposed mining in the Blacksmith tenement.

7.3.3. Subterranean Fauna Habitat

High species richness in faunal communities usually indicates the presence of specialist, as well as generalist, species. As a consequence, species-rich communities are likely to be characterised by complex patterns of habitat partitioning with some species being patchily distributed.

There is currently little or no understanding of the specific habitat requirements of individual subterranean fauna species and, therefore, habitat characterisation and mapping have limited value in predicting finer scale occurrence of patchily distributed specialist subterranean species. However, habitat characterisation and mapping have considerable value in explaining observed patterns of species occurrence and predicting the spatial extent of subterranean fauna communities.

With regard to troglofauna, proposed mining would disturb nearly 17.86 km^2, or 68%, of the 26.36 km^2 of Tertiary valley deposit habitat that occurs within Blacksmith Tenement E47/882 (Table 7) and the percentage disturbance at individual ore deposits would range from 17% at Ajax to 100% at Paragon. However, troglofauna habitat is unlikely to be restricted to the Tertiary valley deposits planned for mining at the Blacksmith Tenement. Much, or most, of the tenement has some direct habitat connectivity with the Tertiary valley deposits planned for mining through the hardcap and intervening BIF lithologies (Figure 2). Therefore, it is expected that the troglofauna community in the Study Area will

Table 7. Proposed disturbance of Tertiary valley deposits within Blacksmith Tenement.

Deposit	Estimated Distribution of DID/BID Habitat (km^2)	Proposed Pit Areas (km^2)	% Potential Habitat Disturbed
Ajax	3.48	0.59	17
Blackjack	1.65	1.18	72
Champion	7.76	5.30	68
Delta	4.92	4.70	96
Eagle	7.87	5.41	69
Paragon	0.68	0.68	100
Total	**26.36**	**17.86**	**68**

be broadly distributed across the 108 km^2 Blacksmith tenement, of which less than 17% will be disturbed. In addition, large areas of Tertiary valley deposits occur beyond the Blacksmith Tenement, including more than 11 km^2 in the adjacent Anvil Tenement E47/.

Suitable aquifers for stygofauna are likely to occur to the east, downstream of the Blacksmith tenement, as well as across the tenement.

8. CONCLUSIONS

The collection of 66 troglofauna species of 19 Orders, and 34 stygofauna species of 10 higher level groups, represents a rich troglofauna and a moderately rich stygofauna community for the Pilbara region.

The collection of a troglofaunal scorpion is of scientific interest because it is the first record of a troglofaunal scorpion from the Australian mainland.

Twenty-two troglofauna species were recorded only within the proposed mine pits. These comprised the single species of scorpion, four species of pseudoscorpions; two species of isopods; a single species of geophilomorph and two species of scolopendromorph centipedes, one species of symphylan, seven species of dipluran, three species of beetles and one species fly.

Sixteen stygofauna species have not been recorded outside the Blacksmith tenement, which, in the absence of groundwater drawdown modelling, was treated as the potential impact area. These comprised a single water mite species, six species of copepods, four species of syncarids, four species of amphipods and one species of isopod.

Examination of the distributions and abundances of collected animals, information on the distributions of related subterranean species, and habitat characterisations, suggest that few, if any, of the 22

troglofauna and 16 stygofauna species known only from proposed impact areas are actually restricted to these areas. The apparently restricted ranges of these species are likely to be artefacts of the difficulties associated with sampling low-abundance species and the limited access to drill-holes outside impact areas.

Approximately 17% of the Blacksmith tenement will be disturbed by mining.

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APPENDICES

Appendix A. Troglofauna species recorded at the Survey Area with known distributions indicated.

Higher taxonomic Groups	Lowest level of identification	Ajax		Blackjack		Champion		Delta		Eagle		Total specimen numbers	Known outside impact area?
		Ref.	Impact	Ref.	Impact	Ref.	Impact	Ref.	Impact	Ref.	Impact		
Arachnida													
	Scorpionida												
	Scorpionida sp.						1					1	No
	Pseudoscorpionida												
	Atemnidae sp. B1				1		1		1			3	No
	Indohya sp.										1	1	No
	Lagynochthonius sp. B10						1			1		2	Yes, in reference hole
	Lagynochthonius sp. B11				1							1	No
	Tyrannochthonius sp. B18					1			1			2	Yes, in reference hole
	Tyrannochthonius sp. B22						2					2	No
	Palpigradida												
	Palpigradida sp. B1								9			9	Widespread in central Pilbara [1, 2]
	Schizomida												
	Draculoides sp. B18							2	1			3	Yes, in reference holes
	Draculoides sp. B22									1	1	2	Yes, in reference hole
	Paradraculoides sp. B1	2										2	Yes, in reference holes

Higher taxonomic Groups	Lowest level of identification	Ajax		Blackjack		Champion		Delta		Eagle		Total specimen numbers	Known outside impact area?
		Ref.	Impact	Ref.	Impact	Ref.	Impact	Ref.	Impact	Ref.	Impact		
	Paradraculoides sp. B2							1				1	Yes, in reference hole
	Paradraculoides sp. B3			6	1	2						9	Yes, in reference holes
Araneae													
	Araneomorphae sp. B17					1					1	2	Yes, in reference hole
	Araneomorphae sp. B18					1				1		2	Yes, in reference holes
	Linyphiidae sp. B4	4		1		7	2					14	Yes, in reference holes
	nr *Encoptarthria* sp. B6									1		1	Yes, in reference hole
	Oonopidae sp. B16				1					1		2	Yes, in reference holes
	Pelicinus sp. B3			1								1	Yes, in reference hole
	'Prethopalpus' sp.				1	1						2	Yes, juveniles in reference holes
Opilionida													
	Dampetrus sp. B2 (nr *isolatus*)					1						1	Yes, in reference hole
Crustacea													
Isopoda													
	Hanoniscus sp. B4	6		10	3	2	1	3	1	1	2	29	Yes, in reference holes
	nr Andricophiloscia sp. B2								1			1	No
	Philosciidae sp. B17										1	1	No
Chilopoda													
Geophilomorpha													
	Australoschendyla sp. B8								2			2	No

Higher taxonomic Groups	Lowest level of identification	Ajax		Blackjack		Champion		Delta		Eagle		Total specimen numbers	Known outside impact area?
		Ref.	Impact	Ref.	Impact	Ref.	Impact	Ref.	Impact	Ref.	Impact		
Scolopendromorpha													
	Colobopleurus sp. B1	2						1				3	Yes, in reference holes
	Cryptops sp. B20	1										1	Yes, in reference hole
	Cryptops sp. B22										3	3	No
	nr *Cryptops* sp. B23				1							1	No
	Scolopendridae sp. B5							1	1			2	Yes, in reference hole
Symphyla													
Cephalostigmata													
	Hanseniella sp. B11	2					2				1	5	Known only from impact and Yes, in reference holes
	Symphyella sp. B10								1			1	No
	Symphyella sp. B12				1		1			1		3	Yes, in reference hole
Diplopoda													
Polydesmida													
	Antichiropus 'tom price'									2		2	Yes, in reference holes
	Dalodesmidae sp. B2				1	5	5	1	1	3	5	21	Yes, in reference holes
Polyxenida													
	Lophoproctidae sp. B1					1				1	2	4	Widespread in central Pilbara [1, 2]
Pauropoda													
Pauropodina													
	Pauropodidae sp. B23							1	1			2	Yes, in reference hole

Higher taxonomic Groups	Lowest level of identification	Ajax		Blackjack		Champion		Delta		Eagle		Total specimen numbers	Known outside impact area?
		Ref.	Impact	Ref.	Impact	Ref.	Impact	Ref.	Impact	Ref.	Impact		
	Pauropodidae sp. B27									1		1	Yes, in reference hole
Entognatha													
Diplura													
	Anajapygidae sp. B1								1			1	No
	Campodeidae sp. B4								1			1	No
	Japygidae sp. B18	3										3	Yes, in reference hole
	Japygidae sp. B19								1			1	No
	Japygidae sp. B23										1	1	No
	Japygidae sp. B4				1		2				6	9	Widespread in central Pilbara [1, 2]
	Parajapygidae sp. B17								4	1		5	Yes, in reference holes
	Parajapygidae sp. B18								1			1	No
	Parajapygidae sp. B19								1			1	No
	Projapygidae sp. B11										1	1	No
Insecta													
Thysanura													
	Hemitrinemura sp. B6					1						1	Yes, in reference hole
	Subtrinemura sp. B1	14		1		1					2	18	Yes, in reference holes and Solomon deposit [3]
Blattodea													
	Nocticola sp. B1			2	31	2					2	37	Widespread in central Pilbara [1, 4]
	Nocticola sp. B18		1	3		7		5	1		1	18	Yes, in reference holes

Higher taxonomic Groups	Lowest level of identification	Ajax		Blackjack		Champion		Delta		Eagle		Total specimen numbers	Known outside impact area?
		Ref.	Impact	Ref.	Impact	Ref.	Impact	Ref.	Impact	Ref.	Impact		
	Nocticola sp. B22				23	6						29	Yes, in reference holes
Hemiptera													
	Hemiptera sp. B2		1	2				4	1			8	Widespread in central Pilbara [1, 4]
	Meenoplidae sp.				18	7	8	4		4	5	46	Widespread in central Pilbara [1, 4]
Coleoptera													
	Bembidiinae sp. B6			1		3		4	6	4	3	21	Yes, in reference holes
	Bembidiinae sp. B9					1					1	2	Yes, in reference holes
	Coleoptera sp. B4										1	1	No
	Cucujoidea sp. B1						1		1			2	No
	Curculionidae Genus 1 sp. B10	1		2		4		17	2	5	3	34	Yes, in reference holes
	Curculionidae Genus 2 sp. B11				1			3				4	Yes, in reference holes
	Curculionidae Genus 2 sp. B12					1				4	7	12	Yes, in reference holes
	Pselaphinae sp. B1				1							1	Widespread in central Pilbara [1, 2]
	Pselaphinae sp. B9										1	1	No
Diptera													
	Sciaridae sp. B1	1			3	2	3			1	1	11	Widespread in Hamersley Range [1]
	Sciaridae sp. B4				6		2					8	No
Total number of specimens		**36**	**2**	**29**	**95**	**57**	**32**	**47**	**40**	**33**	**52**	**423**	

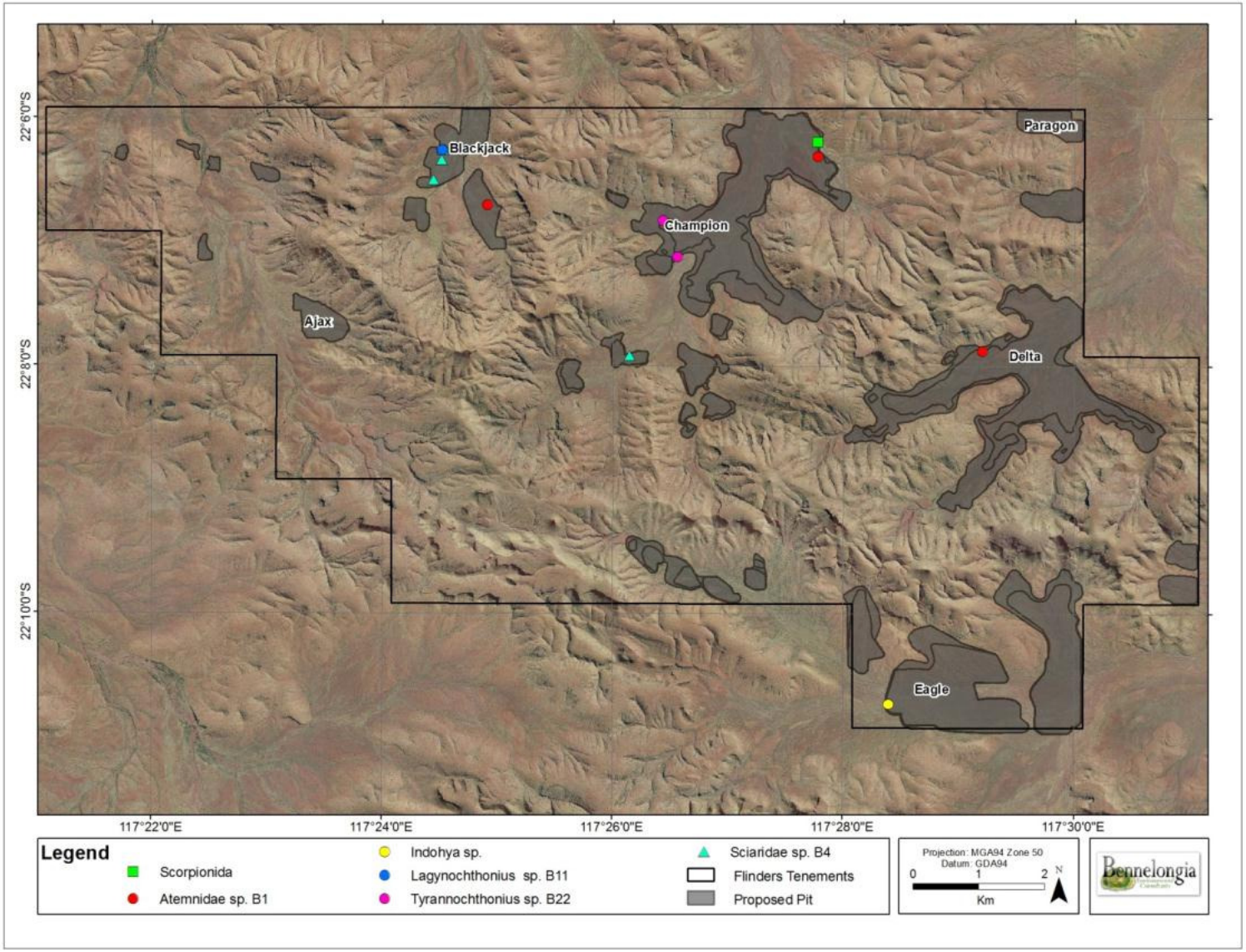
Species highlighted in orange have not been recorded outside the proposed impact areas in the Blacksmith Study Area.
[1], Bennelongia 2009a; [2], Bennelongia 2009c; [3] Bennelongia 2010; [4], Bennelongia 2008b

Appendix B. Higher order troglofauna Identifications

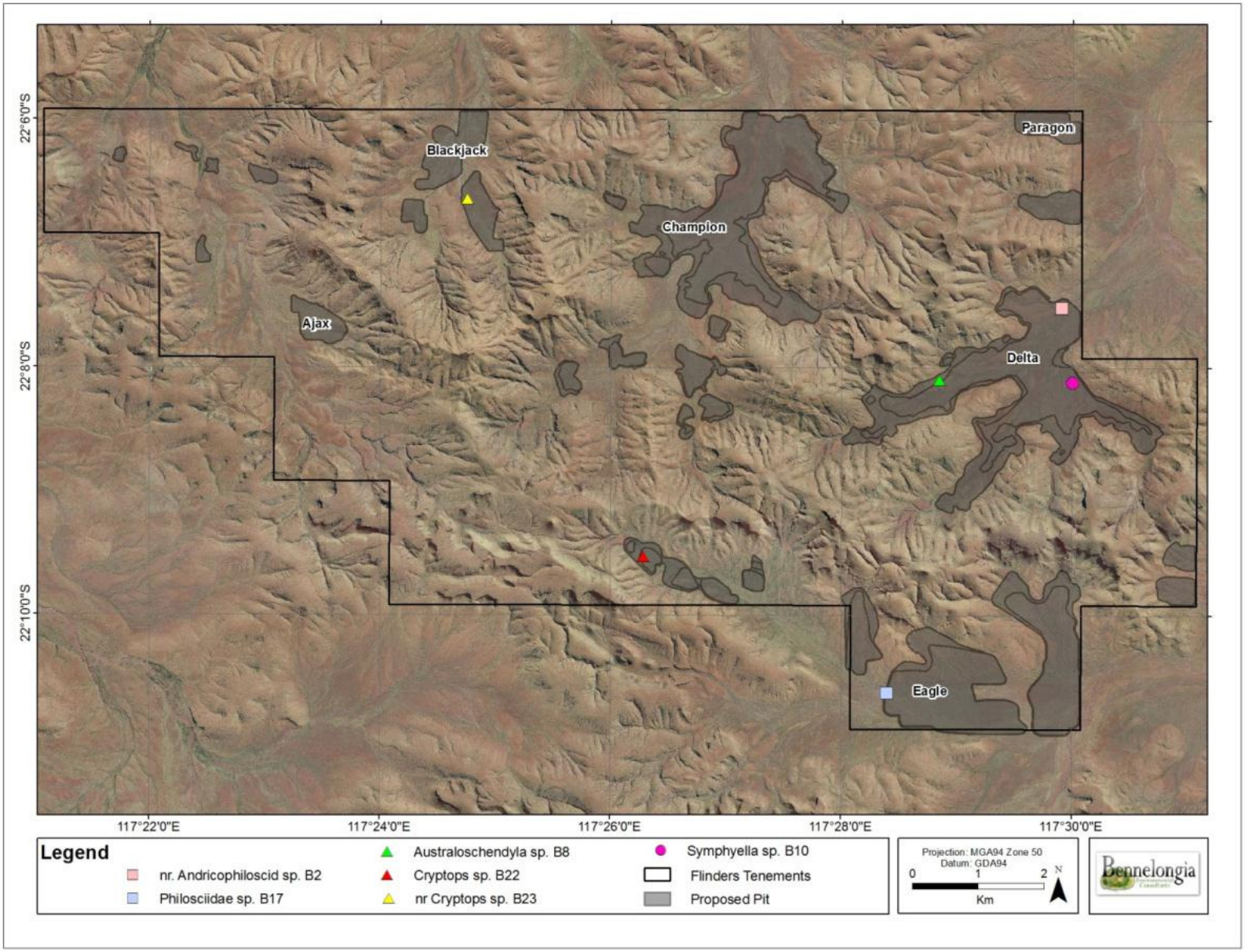
(specimens not included in the analysis of species richness and abundance).

Lowest level of identification	Ajax	Blackjack		Champion		Delta		Eagle		
	Ref.	Ref.	Impact	Ref.	Impact	Ref.	Impact	Ref.	Impact	Total specimen numbers
Arachnida										
Schizomida										
Draculoides sp.	1	3	1	6	3	3	1	4	3	**25**
Paradraculoides sp.	-	4	7	4	4	-	-	-	-	**19**
Schizomida sp.	2	-	2	-	1	-	-	-	-	**5**
Araneae										
nr *Encoptarthria* sp.	-	-	-	2	-	2	-	1	-	**5**
Entognatha										
Diplura										
Japygidae	1	-	-	-	-	-	1	1	-	**3**
Insecta										
Thysanura										
Nicoletiinae	-	-	-	-	-	-	-	-	2	**2**
Subtrinemura sp.	-	-	-	1	1	-	-	-	-	**2**
Blattodea										
Nocticola sp.	5	8	44	5	10	-	2	1	8	**83**
Coleoptera										
Curculionidae Genus 1 sp.	-	-	-	1	-	1	-	-	1	**3**
TOTALS	**9**	**15**	**54**	**19**	**19**	**6**	**4**	**7**	**14**	**147**

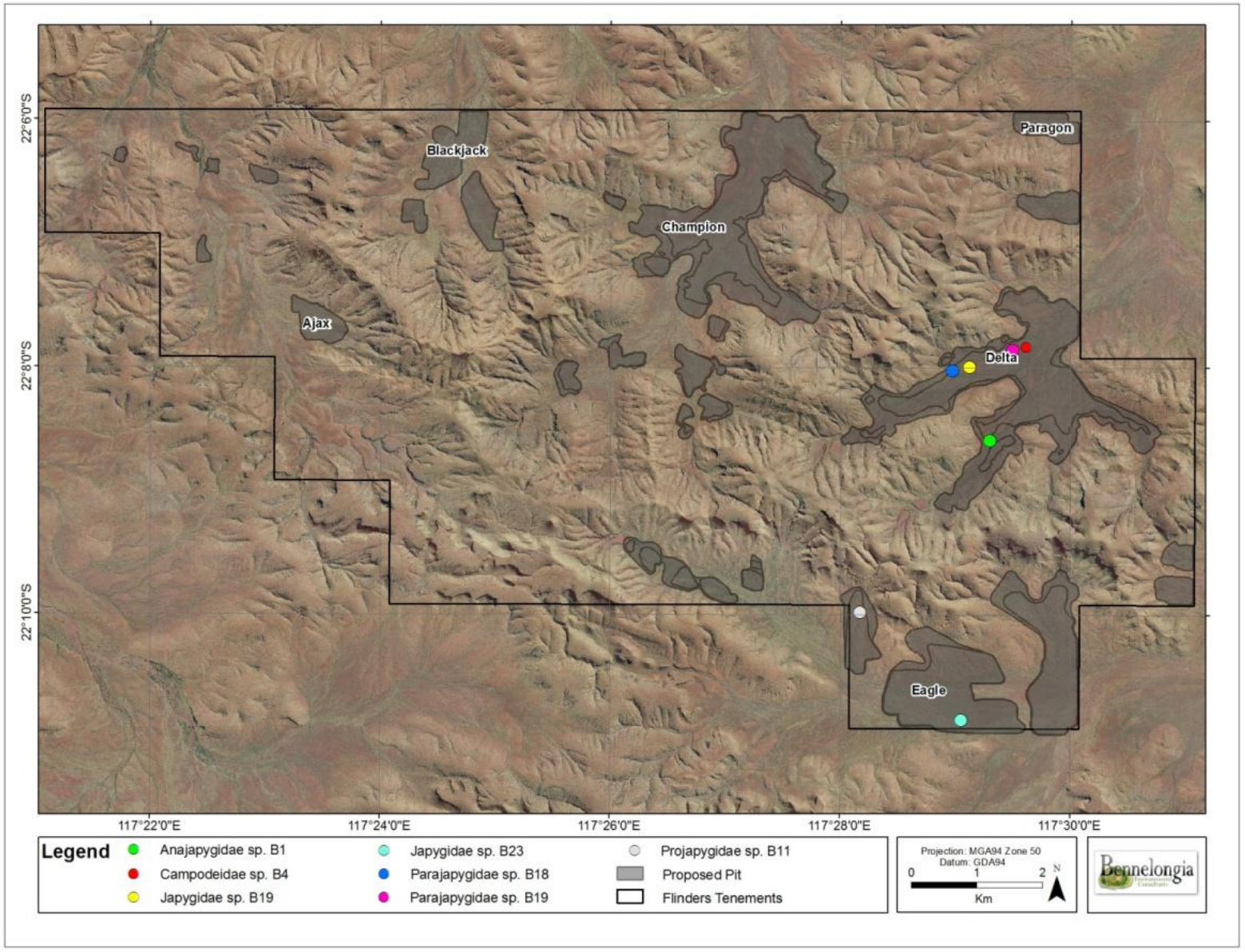
Appendix C. Mapped distributions of restricted troglofauna species.



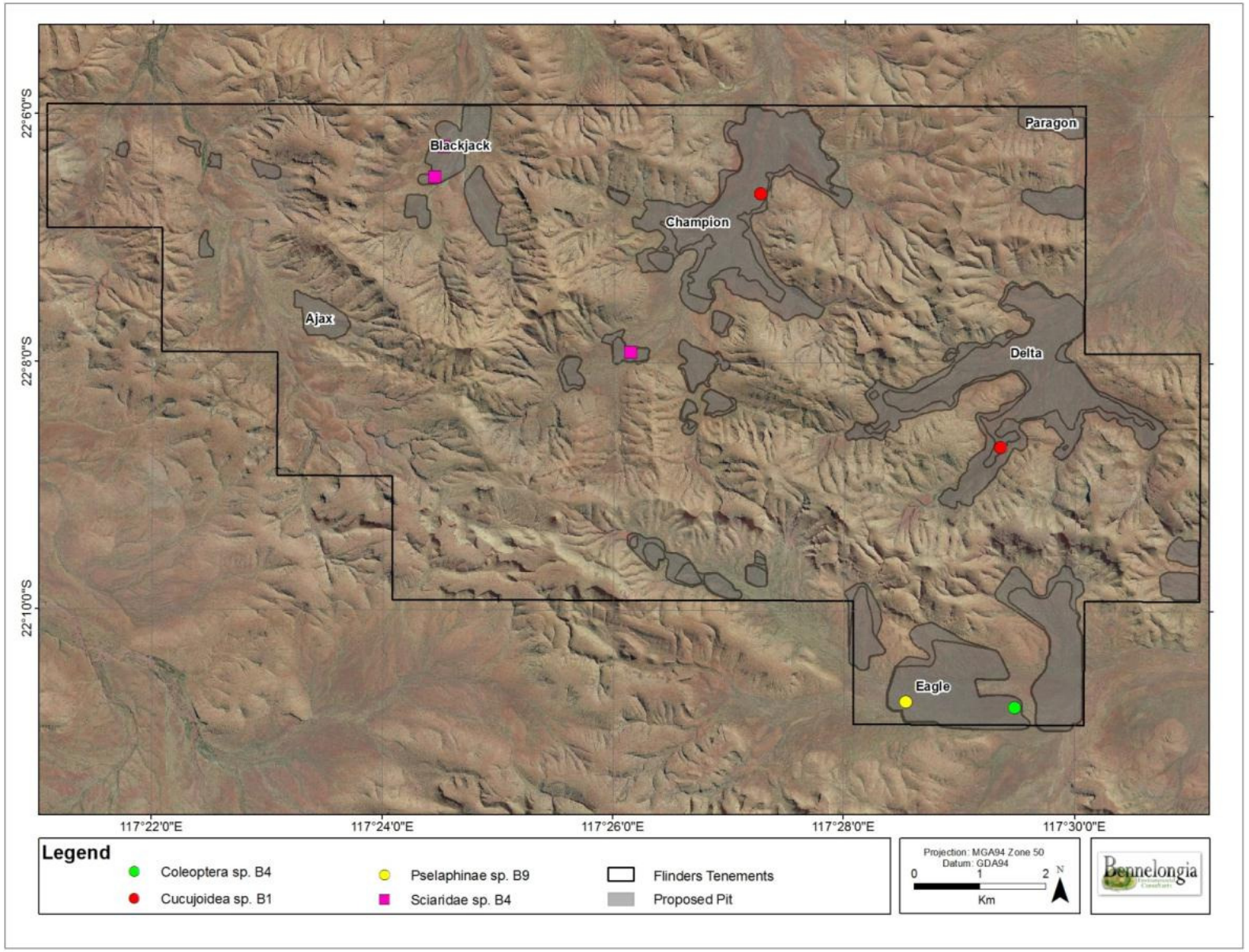
Locations at which restricted scorpionida and pseudoscorionida species of troglofauna were collected.



Locations at which restricted isopod, centipede and symphylan species of troglofauna were collected.



Locations at which restricted troglofaunal dipluran species were collected.



Locations at which restricted troglofaunal insect species were collected.

Appendix D. Stygofauna species recorded at the Survey Area with known distributions indicated.

Highest taxonomic groups	Lowest level of identification	Ajax	Blackjack	Champion	Delta	Eagle	Total specimen numbers	Known outside impact area
Nematoda								
-	Nematoda			19		21	40	Not assessed in EIAs
Turbellaria								
-	Turbellaria					12	12	Not assessed in EIAs
Aphanoneura								
Aeolosomatidae								
	Aeolosoma sp. 1 (PSS)					2	2	Yes, widespread in Pilbara [1]
Oligochaeta								
Tubificida								
	Enchytraeus Pilbara sp. 1 (PSS)		2	231		64	297	Yes, widespread in Pilbara [1]
	Enchytraeus Pilbara sp. 2 (PSS)	62			143		205	Yes, widespread in Pilbara [1]
	Phreodrilus sp. [A]	2		12	2	3	19	Yes, widespread in Pilbara [1]
	Insulodrilus sp. [B]			1		2	3	Yes, widespread in Pilbara [1]
Arachnida								
Acariformes								
	Pezidae sp. B1			1			1	No
Crustacea								
Ostracoda								
	Cyprididae sp.					2	2	Yes, no restricted Cyprididae species in Pilbara [2]
	Limnocythere stationis				2		2	Yes, widespread in Pilbara [2]
	?*Meridiescandona facies* [C]					1	1	Yes, widespread in Pilbara [3]
Copepoda								
	Anzcyclops sp. B1		9	22		47	78	No
	Australocamptus sp. B4					2	2	No
	Diacyclops h. humphreysi	37		107	160	7	311	Yes, widespread in Pilbara [4]

Highest taxonomic groups	Lowest level of identification	Ajax	Blackjack	Champion	Delta	Eagle	Total specimen numbers	Known outside impact area
	Diacyclops sobeprolatus	14			112		126	Yes, widespread in Pilbara [4]
	Fierscyclops sp. B5 (nr *supersensus*)			1			1	No
	Fierscyclops sp. B6 (nr *frustratio*)					2	2	No
	Goniocyclops sp. B8 (nr *mortoni*)			4			4	No
	Mesocyclops brooksi			31			31	Yes, widespread in Australia [4]
	Metacyclops sp. B1(nr *pilbaricus*)			29		22	51	Yes, widespread in Fortescue Valley [5]
	Microcyclops varicans			65		362	427	Yes, cosmopolitan [4]
	Parastenocaris sp. B16		4	1			5	No
	Thermocyclops aberrans	117			12	10	139	Widespread in Pilbara [4]
Syncarida								
	Atopobathynella sp. B3	5					5	No
	Bathynella sp. B4		1	13	48	75	137	No
	Billibathynella sp. B3		273	334	1	31	639	No
	nr *Billibathynella* sp. B6	2			24		26	No
Amphipoda								
	Maarrka sp. B1				4		4	No
	Neoniphargidae sp. B1	2					2	No
	Paramelitidae (nr *Pilbarus*) sp. B5	4	12	45	10	15	86	No
	Paramelitidae sp. B8				18		18	No
Isopoda								
	Pilbarophreatoicus sp. B2			5		17	22	Yes, occurs farther north [5.]
	Pygolabis sp. B4	6					6	Yes, occurs farther north [5.]
	Pygolabis sp. B5	181			2		183	No

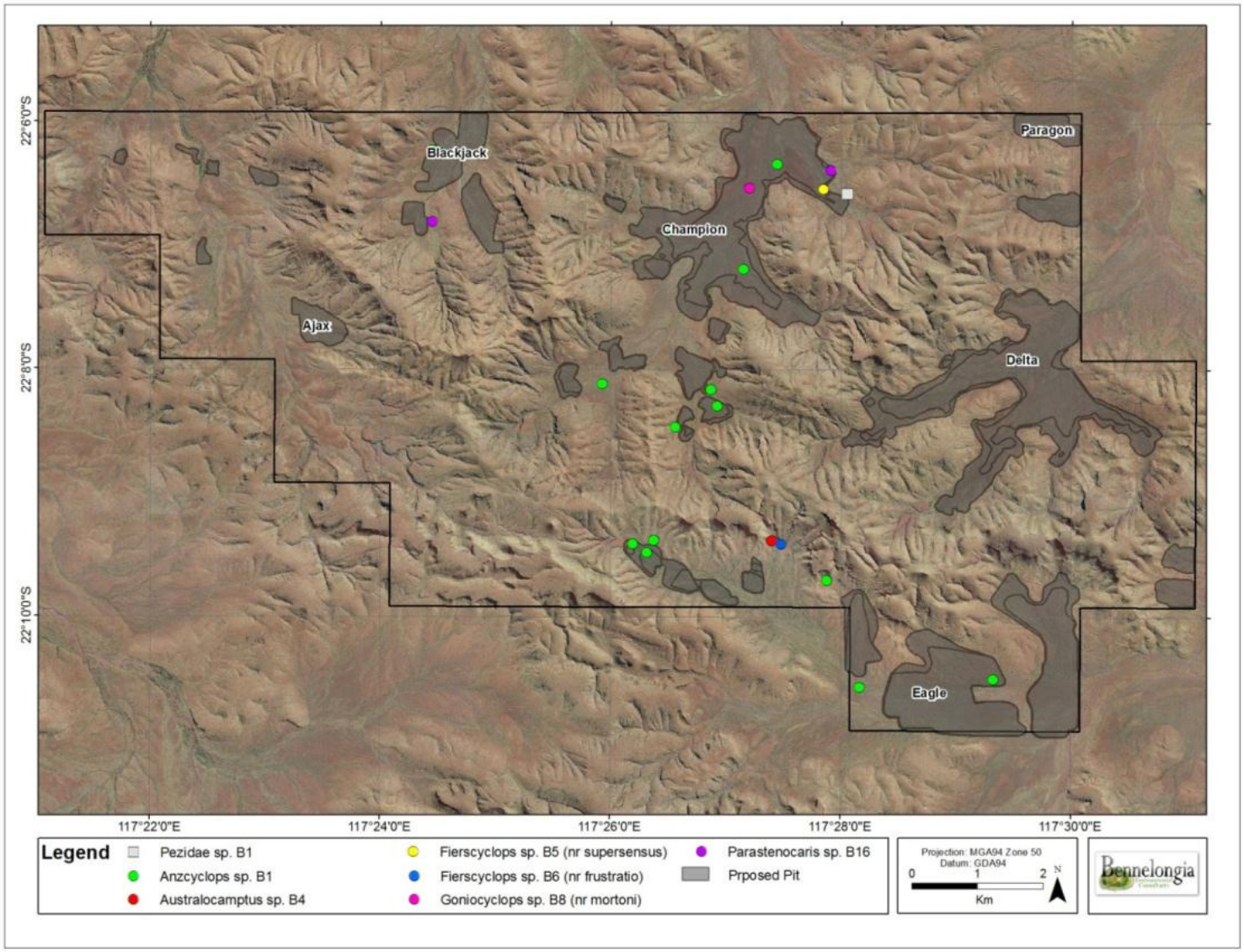
Species highlighted in orange have not been recorded outside the proposed impact areas in the Blacksmith Study Area.
[A], Phreodrilid with dissimilar ventral chaetae in previous reports; [B], Phreodrilid with similar ventral chaetae; [C], single damaged valve; [1], Halse *et al*. in prep.; [2], Reeves *et al*. (2007); [3], Karanovic 2007; [4], Karanovic 2006; [5], Bennelongia unpublished data.

Appendix E. Higher order stygofauna identifications.

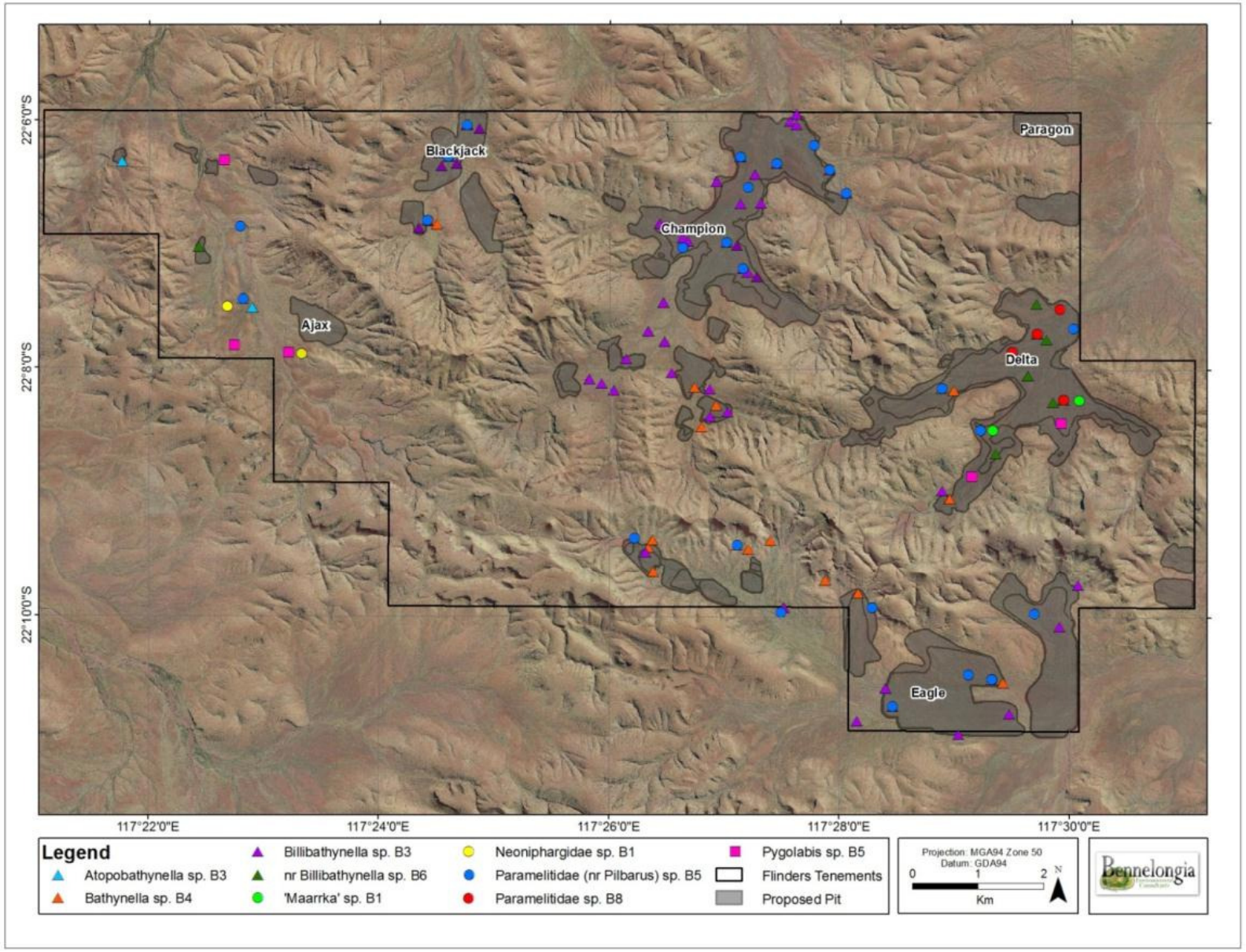
Specimens not included in analyses of species richness and abundance.

Lowest level of identification		Ajax	Blackjack	Champion	Delta	Eagle	Total specimen numbers
Oligochaeta							
Tubificida							
	Enchytraeidae	-	-	3	-	1	**4**
Crustacea							
Copepoda		-					
	Parastenocaris sp.	-	-	-	-	1	**1**
Syncarida							
	Parabathynellidae	-	-	2	-	-	**2**
	TOTALS	**0**	**0**	**5**	**0**	**2**	**7**

Appendix F. Mapped distributions of restricted stygofauna species.



Locations at which restricted water mite and copepod stygofauna species were collected.



Locations at which restricted syncarid, amphipod and isopod stygofauna species were collected.

Appendix G. Drill-holes sampled for troglofauna.

Deposit	Troglofauna drill-hole code	Site type	Latitude	Longitude
Ajax	HPRC0800	Impact	-22.1062	117.3757
Ajax	HPRC0802	Impact	-22.1075	117.3842
Ajax	HPRC0818	Control	-22.1245	117.3795
Ajax	HPRC0820	Control	-22.1261	117.3876
Ajax	HPRC0824	Control	-22.1294	117.3806
Ajax	HPRC0826	Control	-22.1276	117.3947
Ajax	HPRC0827	Impact	-22.1288	117.3921
Ajax	HPRC0831	Control	-22.1348	117.3899
Ajax	HPRC0844	Impact	-22.117	117.3738
Ajax	HPRC0853	Control	-22.129	117.3812
Ajax	HPRC0865	Control	-22.1369	117.3968
Ajax	HPRC0866	Control	-22.1364	117.3977
Ajax	HPRC0867	Control	-22.1234	117.381
Ajax	HPRC0870	Control	-22.1251	117.378
Ajax	HPRC0874	Control	-22.1185	117.3816
Ajax	HPRC0875	Control	-22.1148	117.3789
Ajax	HPRC0879	Control	-22.1087	117.3818
Ajax	HPRC0883	Impact	-22.1036	117.3707
Ajax	HPRC0888	Control	-22.1009	117.3644
Ajax	HPRC0892	Impact	-22.1055	117.3627
Blackjack	HPRC0362	Control	-22.1283	117.4389
Blackjack	HPRC0401	Control	-22.1017	117.4153
Blackjack	HPRC0402	Impact	-22.101	117.4135
Blackjack	HPRC0403	Impact	-22.1003	117.4117
Blackjack	HPRC0404	Control	-22.0999	117.4107
Blackjack	HPRC0405	Control	-22.1068	117.4146
Blackjack	HPRC0406	Control	-22.106	117.4128
Blackjack	HPRC0407	Impact	-22.1053	117.4111
Blackjack	HPRC0408	Impact	-22.1046	117.4093
Blackjack	HPRC0409	Control	-22.1038	117.4075
Blackjack	HPRC0410	Control	-22.1032	117.4058
Blackjack	HPRC0411	Impact	-22.1122	117.4163
Blackjack	HPRC0412	Impact	-22.1113	117.4143
Blackjack	HPRC0412A	Impact	-22.1114	117.4144
Blackjack	HPRC0413	Impact	-22.1171	117.417
Blackjack	HPRC0414	Impact	-22.1171	117.4161
Blackjack	HPRC0415	Impact	-22.1107	117.4126

Deposit	Troglofauna drill-hole code	Site type	Latitude	Longitude
Blackjack	HPRC0416	Control	-22.1101	117.411
Blackjack	HPRC0417	Control	-22.1091	117.409
Blackjack	HPRC0418	Impact	-22.1084	117.4073
Blackjack	HPRC0419	Control	-22.1077	117.4056
Blackjack	HPRC0420	Control	-22.107	117.4037
Blackjack	HPRC0421	Control	-22.1135	117.4075
Blackjack	HPRC0422	Impact	-22.1128	117.4059
Blackjack	HPRC0423	Impact	-22.1123	117.4042
Blackjack	HPRC0424	Control	-22.1134	117.4069
Blackjack	HPRC0425	Control	-22.1074	117.4046
Blackjack	HPRC0426	Impact	-22.1118	117.4151
Blackjack	HPRC0427	Control	-22.1059	117.4117
Blackjack	HPRC0428	Control	-22.1035	117.4067
Blackjack	HPRC0429	Impact	-22.1012	117.4144
Blackjack	HPRC0430	Control	-22.0999	117.4107
Blackjack	HPRC0431	Impact	-22.1044	117.4087
Blackjack	HPRC0432	Impact	-22.1049	117.4099
Blackjack	HPRC0433	Control	-22.1062	117.4023
Blackjack	HPRC0434	Control	-22.1066	117.4028
Blackjack	HPRC0435	Impact	-22.108	117.4065
Blackjack	HPRC0436	Control	-22.1096	117.4103
Blackjack	HPRC0437	Impact	-22.1104	117.4117
Blackjack	HPRC0438	Impact	-22.111	117.4134
Blackjack	HPRC0439	Impact	-22.1168	117.4153
Blackjack	HPRC0440	Control	-22.1164	117.4144
Blackjack	HPRC0441	Impact	-22.1006	117.4126
Champion	CHUNK01	Impact	-22.1033	117.4499
Champion	CHUNK02	Impact	-22.1314	117.4349
Champion	CHUNK03	Impact	-22.1378	117.4478
Champion	HPPRC0618	Impact	-22.1064	117.4592
Champion	HPRC0329	Impact	-22.1177	117.4482
Champion	HPRC0352	Control	-22.1249	117.4419
Champion	HPRC0353	Control	-22.1239	117.4399
Champion	HPRC0360	Control	-22.1285	117.4397
Champion	HPRC0361	Control	-22.1277	117.4374
Champion	HPRC0364	Impact	-22.1383	117.4488
Champion	HPRC0374	Impact	-22.1324	117.4367
Champion	HPRC0376	Impact	-22.1302	117.4324
Champion	HPRC0377	Impact	-22.1306	117.4329
Champion	HPRC0379	Control	-22.1353	117.4321

Deposit	Troglofauna drill-hole code	Site type	Latitude	Longitude
Champion	HPRC0381	Control	-22.1339	117.4286
Champion	HPRC0383	Impact	-22.1336	117.4278
Champion	HPRC0394	Impact	-22.1081	117.4488
Champion	HPRC0396	Control	-22.0989	117.4519
Champion	HPRC0398	Impact	-22.1198	117.4525
Champion	HPRC0503	Impact	-22.1156	117.4439
Champion	HPRC0504	Impact	-22.1147	117.4422
Champion	HPRC0505	Impact	-22.1138	117.4405
Champion	HPRC0510	Impact	-22.1005	117.4554
Champion	HPRC0526	Control	-22.1174	117.4371
Champion	HPRC0531	Control	-22.1244	117.4411
Champion	HPRC0532	Control	-22.1234	117.4394
Champion	HPRC0534	Control	-22.1231	117.4384
Champion	HPRC0535	Control	-22.1275	117.4374
Champion	HPRC0538	Control	-22.1343	117.4297
Champion	HPRC0551	Control	-22.1015	117.4638
Champion	HPRC0553	Impact	-22.1032	117.4628
Champion	HPRC0569	Control	-22.0987	117.4596
Champion	HPRC0577	Control	-22.0988	117.4545
Champion	HPRC0586	Control	-22.0991	117.4603
Champion	HPRC0614	Impact	-22.1048	117.4559
Champion	HPRC0638	Control	-22.1088	117.4478
Champion	HPRC0643	Impact	-22.1111	117.4522
Champion	HPRC0651	Control	-22.1113	117.4475
Champion	HPRC0682	Control	-22.1212	117.4571
Champion	HPRC0685	Control	-22.1108	117.4323
Champion	HPRC0687	Impact	-22.1117	117.4339
Champion	HPRC0708	Control	-22.1166	117.4399
Champion	HPRC0709	Control	-22.1173	117.4394
Champion	HPRC0712	Control	-22.1181	117.4368
Champion	HPRC0722	Control	-22.1371	117.4428
Champion	HPRC0724	Impact	-22.1334	117.4471
Champion	HPRC0726	Impact	-22.1354	117.4462
Champion	HPRC0733	Control	-22.1344	117.4487
Champion	HPRC0734	Control	-22.1351	117.4484
Champion	HPRC0735	Control	-22.136	117.4478
Champion	HPRC0737	Impact	-22.1384	117.4464
Champion	HPRC0744	Impact	-22.1378	117.4491
Champion	HPRC0746	Impact	-22.1398	117.4479
Champion	HPRC0747	Control	-22.1412	117.4466

Deposit	Troglofauna drill-hole code	Site type	Latitude	Longitude
Champion	HPRC0778	Impact	-22.1161	117.4421
Champion	HPRC0779	Impact	-22.117	117.4438
Champion	HPRC0782	Impact	-22.1182	117.4463
Champion	HPRC0911	Impact	-22.1183	117.4417
Champion	HPRC0913	Control	-22.1191	117.4435
Champion	HPRC0914	Control	-22.1195	117.4444
Champion	HPRC0918	Impact	-22.1213	117.4478
Champion	HPRC0922	Impact	-22.1231	117.4511
Champion	HPRC0925	Impact	-22.1243	117.4533
Champion	HPRC0961	Control	-22.104	117.4655
Champion	HPRC0962	Control	-22.1047	117.4653
Champion	HPRC0963	Control	-22.1054	117.4647
Champion	HPRC1010	Control	-22.1034	117.4646
Champion	HPRC1011	Control	-22.1031	117.4639
Champion	HPRC1012	Control	-22.1023	117.4642
Delta	A2223	Impact	-22.1361	117.4773
Delta	GPRC2087	Impact	-22.1326	117.4879
Delta	HPRC0201	Control	-22.1405	117.5038
Delta	HPRC0206	Impact	-22.1331	117.4984
Delta	HPRC0212	Impact	-22.1405	117.4924
Delta	HPRC0239	Impact	-22.1422	117.4876
Delta	HPRC0241	Impact	-22.1455	117.4898
Delta	HPRC0243	Control	-22.15	117.482
Delta	HPRC0245	Impact	-22.1399	117.4981
Delta	HPRC0246	Impact	-22.1384	117.4969
Delta	HPRC0257	Control	-22.1383	117.4909
Delta	HPRC0268	Impact	-22.1278	117.5004
Delta	HPRC0272	Impact	-22.134	117.4989
Delta	HPRC0278	Impact	-22.1294	117.4904
Delta	HPRC0279	Impact	-22.1325	117.4928
Delta	HPRC0281	Impact	-22.1413	117.4992
Delta	HPRC0282	Impact	-22.1423	117.4999
Delta	HPRC0283	Control	-22.1414	117.4932
Delta	HPRC0286	Impact	-22.1464	117.485
Delta	HPRC0287	Control	-22.1496	117.4815
Delta	HPRC0292	Impact	-22.1382	117.5022
Delta	HPRC2002	Impact	-22.1435	117.4681
Delta	HPRC2004	Control	-22.1419	117.4671
Delta	HPRC2006	Control	-22.1423	117.4731
Delta	HPRC2032	Control	-22.1354	117.4766

Deposit	Troglofauna drill-hole code	Site type	Latitude	Longitude
Delta	HPRC2038	Impact	-22.1353	117.4853
Delta	HPRC2041	Control	-22.1375	117.4873
Delta	HPRC2051	Impact	-22.125	117.4896
Delta	HPRC2054	Control	-22.127	117.4912
Delta	HPRC2057	Impact	-22.1308	117.494
Delta	HPRC2063	Impact	-22.1322	117.4981
Delta	HPRC2064	Impact	-22.1252	117.4986
Delta	HPRC2071	Control	-22.14	117.4701
Delta	HPRC2073	Impact	-22.1417	117.471
Delta	HPRC2077	Impact	-22.1388	117.4913
Delta	HPRC2079	Impact	-22.1388	117.4718
Delta	HPRC2081	Impact	-22.1396	117.4724
Delta	HPRC2084	Impact	-22.1374	117.4709
Delta	HPRC2089	Impact	-22.1314	117.4867
Delta	HPRC2090	Control	-22.1305	117.4863
Delta	HPRC2093	Impact	-22.1343	117.4892
Delta	HPRC20941	Control	-22.1357	117.4904
Delta	HPRC2104	Impact	-22.1384	117.4744
Delta	HPRC2106	Impact	-22.1394	117.4753
Delta	HPRC2107	Control	-22.1411	117.4766
Delta	HPRC2109	Control	-22.1401	117.4785
Delta	HPRC2116	Control	-22.1397	117.4813
Delta	HPRC2119	Impact	-22.1374	117.4795
Delta	HPRC2120	Impact	-22.1365	117.479
Delta	HPRC2123	Control	-22.1343	117.4771
Delta	HPRC2125	Control	-22.138	117.4831
Delta	HPRC2126	Impact	-22.1372	117.4824
Delta	HPRC2128	Impact	-22.1359	117.4814
Delta	HPRC2129	Impact	-22.135	117.4809
Delta	HPRC2145	Impact	-22.1333	117.4854
Delta	HPRC2147	Impact	-22.1318	117.4843
Delta	HPRC2148	Impact	-22.1318	117.4843
Delta	HPRC2158	Impact	-22.1288	117.4939
Delta	HPRC2174	Impact	-22.1245	117.4951
Delta	HPRC2176	Impact	-22.1231	117.4939
Delta	HPRC2238	Impact	-22.1323	117.4951
Eagle	EUNK01	Impact	-22.1735	117.4694
Eagle	EUNK02	Control	-22.1755	117.4694
Eagle	EUNK03	Impact	-22.1787	117.4744
Eagle	EUNK04	Impact	-22.1771	117.4743

Deposit	Troglofauna drill-hole code	Site type	Latitude	Longitude
Eagle	EUNK05	Impact	-22.1743	117.4744
Eagle	HPRC0032	Impact	-22.1689	117.4694
Eagle	HPRC0035	Impact	-22.1634	117.4694
Eagle	HPRC0036	Control	-22.1647	117.4538
Eagle	HPRC0037	Impact	-22.1629	117.4546
Eagle	HPRC0038	Impact	-22.1613	117.4554
Eagle	HPRC0039	Control	-22.1597	117.4561
Eagle	HPRC0049	Impact	-22.1671	117.4985
Eagle	HPRC0073	Control	-22.1631	117.46
Eagle	HPRC0075	Impact	-22.1638	117.4486
Eagle	HPRC0077	Control	-22.1606	117.4501
Eagle	HPRC0087	Impact	-22.1638	117.4486
Eagle	HPRC0089	Impact	-22.1626	117.4443
Eagle	HPRC0090	Impact	-22.1618	117.4445
Eagle	HPRC0096	Control	-22.1564	117.4567
Eagle	HPRC0099	Control	-22.1654	117.4586
Eagle	HPRC0102	Control	-22.1808	117.4693
Eagle	HPRC0104	Control	-22.1771	117.4695
Eagle	HPRC0107	Impact	-22.1725	117.4693
Eagle	HPRC0112	Impact	-22.1664	117.4696
Eagle	HPRC0131	Control	-22.1605	117.4611
Eagle	HPRC04019	Control	-22.1615	117.4959
Eagle	HPRC1016	Control	-22.1706	117.4889
Eagle	HPRC3801	Impact	-22.1643	117.516
Eagle	HPRC3803	Impact	-22.1624	117.516
Eagle	HPRC3808	Impact	-22.1579	117.516
Eagle	HPRC3810	Control	-22.1563	117.5159
Eagle	HPRC3811	Control	-22.1599	117.5119
Eagle	HPRC3813	Control	-22.1614	117.5122
Eagle	HPRC4001	Control	-22.1624	117.5013
Eagle	HPRC4007	Impact	-22.1626	117.4985
Eagle	HPRC4009	Control	-22.1601	117.4981
Eagle	HPRC4010	Impact	-22.1697	117.4985
Eagle	HPRC4020	Control	-22.1608	117.4961
Eagle	HPRC4038	Control	-22.1623	117.4888
Eagle	HPRC4060	Control	-22.1699	117.4949
Eagle	HPRC4072	Impact	-22.1644	117.4924
Eagle	HPRC4077	Control	-22.1601	117.4926
Eagle	HPRC4091	Control	-22.1654	117.467
Eagle	HPRC4094	Control	-22.1626	117.467

Deposit	Troglofauna drill-hole code	Site type	Latitude	Longitude
Eagle	HPRC4101	Impact	-22.1668	117.4719
Eagle	HPRC4106	Control	-22.1698	117.4743
Eagle	HPRC4109	Impact	-22.1696	117.4768
Eagle	HPRC4111	Control	-22.1719	117.4766
Eagle	HPRC4116	Impact	-22.1698	117.4817
Eagle	HPRC4118	Impact	-22.1588	117.4381
Eagle	HPRC4119	Impact	-22.1581	117.4386
Eagle	HPRC4121	Control	-22.1564	117.4396
Eagle	HPRC4122	Impact	-22.1576	117.436
Eagle	HPRC4124	Control	-22.1562	117.4369
Eagle	HPRC4126	Control	-22.1555	117.4345
Eagle	HPRC4127	Control	-22.155	117.4348
Eagle	HPRC4157	Impact	-22.1809	117.4842
Eagle	HPRC4212	Impact	-22.1789	117.4733
Eagle	HPRC4214	Impact	-22.1772	117.4733
Eagle	HPRC4222	Impact	-22.1699	117.4804
Eagle	HPRC4249	Impact	-22.1743	117.4877

Appendix H. Drill-holes sampled for stygofauna.

Deposit	Stygofauna drill-hole code	Site type	Latitude	Longitude
Ajax	HPRC0801	Control	-22.10538889	117.3774667
Ajax	HPRC0804	Control	-22.10927778	117.3807778
Ajax	HPRC0807	Control	-22.11425	117.3797778
Ajax	HPRC0825	Control	-22.13027778	117.3790278
Ajax	HPRC0830	Control	-22.13122222	117.3868611
Ajax	HPRC0833	Control	-22.13669444	117.3865556
Ajax	HPRC0842	Control	-22.12402778	117.38025
Ajax	HPRC0846	Control	-22.11025	117.3782778
Ajax	HPRC0871	Control	-22.11894444	117.3808889
Ajax	HPRC0881	Control	-22.10652778	117.3746944
Ajax	HPRC0887	Control	-22.10108333	117.3654722
Ajax	HPRC0890	Control	-22.10063889	117.3626389
Blackjack	HPRC0412	Impact	-22.11133333	117.4143333
Blackjack	HPRC0415	Impact	-22.11066667	117.4125833
Blackjack	HPRC0418	Impact	-22.10844444	117.4073333
Blackjack	HPRC0420	Control	-22.10697222	117.4036667
Blackjack	HPRC0424	Control	-22.11338889	117.4068889
Blackjack	HPRC0431	Impact	-22.10436111	117.4086944
Blackjack	HPRC0432	Impact	-22.10486111	117.4099444
Blackjack	HPRC0435	Impact	-22.10802778	117.4065
Blackjack	HPRC0438	Impact	-22.11097222	117.4134167
Blackjack	HPRC0441	Impact	-22.10058333	117.4126111
Champion	FLIUNK01	Control	-22.12236111	117.4477778
Champion	GPX539	Impact	-22.132	117.4357222
Champion	HPDD0034	Impact	-22.11613889	117.4446389
Champion	HPRC0310	Impact	-22.111	117.4551389
Champion	HPRC0326	Impact	-22.12030556	117.45325
Champion	HPRC0328	Impact	-22.11852778	117.4498056
Champion	HPRC0333	Impact	-22.11433333	117.4413889
Champion	HPRC0359	Control	-22.12966667	117.4413056
Champion	HPRC0363	Impact	-22.13908333	117.4504167
Champion	HPRC0375	Impact	-22.13116667	117.4339444
Champion	HPRC0378	Control	-22.13622222	117.4339444
Champion	HPRC0380	Control	-22.13477778	117.4303611
Champion	HPRC0388	Control	-22.12027778	117.4427222
Champion	HPRC0390	Control	-22.11136111	117.4353611

Deposit	Stygofauna drill-hole code	Site type	Latitude	Longitude
Champion	HPRC0395	Impact	-22.10480556	117.4521389
Champion	HPRC0504	Impact	-22.11466667	117.4421667
Champion	HPRC0553	Impact	-22.10322222	117.4628333
Champion	HPRC0555	Impact	-22.11061111	117.4544722
Champion	HPRC0557	Impact	-22.10897222	117.464
Champion	HPRC0560	Impact	-22.1065	117.4651389
Champion	HPRC0561	Control	-22.10966667	117.4675
Champion	HPRC0571	Impact	-22.11630556	117.4501667
Champion	HPRC0573	Impact	-22.09997222	117.4593611
Champion	HPRC0574	Impact	-22.10047222	117.4602778
Champion	HPRC0576	Impact	-22.10133333	117.4619722
Champion	HPRC0589	Impact	-22.10138889	117.4544722
Champion	HPRC0610	Impact	-22.10302778	117.4523333
Champion	HPRC0616	Impact	-22.10561111	117.4573889
Champion	HPRC0623	Impact	-22.10716667	117.4543333
Champion	HPRC0636	Impact	-22.10891667	117.4533056
Champion	HPRC0653	Impact	-22.11227778	117.4492778
Champion	HPRC0676	Impact	-22.12566667	117.4588889
Champion	HPRC0683	Control	-22.11	117.4353611
Champion	HPRC0716	Control	-22.13386111	117.4423056
Champion	HPRC0727	Impact	-22.13580556	117.4455833
Champion	HPRC0731	Impact	-22.13977778	117.4432778
Champion	HPRC0732	Control	-22.14113889	117.4426389
Champion	HPRC0753	Impact	-22.11419444	117.4458611
Champion	HPRC0758	Impact	-22.11630556	117.4501667
Champion	HPRC0912	Impact	-22.11872222	117.4426667
Champion	HPRC0915	Impact	-22.11997222	117.4452778
Champion	HPRC0919	Control	-22.12027778	117.4427222
Champion	HPRCUNK99	Impact	-22.11633333	117.44775
Delta	HP00222	Impact	-22.13602778	117.5005833
Delta	HPDD0020	Impact	-22.13608333	117.4955
Delta	HPDD0022	Impact	-22.13961111	117.4920833
Delta	HPRC00252	Impact	-22.15072222	117.4826111
Delta	HPRC0205	Impact	-22.13452778	117.4995
Delta	HPRC0209	Impact	-22.12852778	117.4951944
Delta	HPRC0211	Impact	-22.12561111	117.4929444
Delta	HPRC0219	Impact	-22.14852778	117.4863056
Delta	HPRC0224	Impact	-22.14052778	117.4986667
Delta	HPRC0226	Impact	-22.13458333	117.4943056

Deposit	Stygofauna drill-hole code	Site type	Latitude	Longitude
Delta	HPRC0234	Impact	-22.13908333	117.4736389
Delta	HPRC0248	Impact	-22.13605556	117.4954444
Delta	HPRC0250	Impact	-22.13097222	117.4915833
Delta	HPRC0254	Impact	-22.14463889	117.4892222
Delta	HPRC0255	Impact	-22.14316667	117.4883611
Delta	HPRC0270	Impact	-22.12522222	117.4985
Delta	HPRC0271	Impact	-22.13533333	117.5000556
Delta	HPRC0273	Impact	-22.12780556	117.4945833
Delta	HPRC0274	Impact	-22.12491667	117.4924444
Delta	HPRC0277	Impact	-22.12419444	117.4918889
Delta	HPRC0280	Impact	-22.13416667	117.4938056
Delta	HPRC0284	Impact	-22.14152778	117.4870556
Delta	HPRC0285	Impact	-22.14772222	117.48575
Delta	HPRC2007	Impact	-22.14163889	117.4724444
Delta	HPRC2015	Impact	-22.13972222	117.477
Delta	HPRC2056A	Impact	-22.13016667	117.4933889
Delta	HPRC2060	Impact	-22.13094444	117.4968333
Delta	HPRC2065	Impact	-22.13097222	117.4915833
Delta	HPRC2074	Impact	-22.14227778	117.4715556
Delta	HPRC2076	Impact	-22.13555556	117.4948889
Delta	HPRC2079	Impact	-22.13877778	117.4718056
Delta	HPRC2082	Impact	-22.13877778	117.4718056
Delta	HPRC2083	Impact	-22.13813889	117.4711944
Delta	HPRC2127	Impact	-22.13675	117.4819722
Delta	HPRC2136	Impact	-22.13444444	117.4833056
Delta	HPRC2137	Impact	-22.13369444	117.4828889
Delta	HPRC2149	Impact	-22.13227778	117.4935833
Delta	HPRC2151	Impact	-22.13077778	117.4925
Delta	HPRC2194	Impact	-22.12838889	117.49625
Delta	HPRC3042	Impact	-22.13822222	117.4996111
Delta	HPRC3043	Impact	-22.13741667	117.4990278
Eagle	HPRC0008	Impact	-22.17794444	117.4940278
Eagle	HPRC0027	Control	-22.178	117.4695278
Eagle	HPRC0028	Control	-22.17616667	117.4694167
Eagle	HPRC0045	Impact	-22.17425	117.4985
Eagle	HPRC0069	Impact	-22.17616667	117.4743056
Eagle	HPRC0079	Control	-22.15708333	117.4518056
Eagle	HPRC0080	Impact	-22.16066667	117.4396944
Eagle	HPRC0094	Control	-22.15708333	117.4518056

Deposit	Stygofauna drill-hole code	Site type	Latitude	Longitude
Eagle	HPRC0098	Control	-22.16608333	117.4581944
Eagle	HPRC0133	Control	-22.15733333	117.4467222
Eagle	HPRC1139	Impact	-22.1795	117.4891389
Eagle	HPRC4011	Impact	-22.16791667	117.4985278
Eagle	HPRC4059	Impact	-22.16975	117.4961389
Eagle	HPRC4064	Impact	-22.16619444	117.4948889
Eagle	HPRC4089	Control	-22.16177778	117.4646389
Eagle	HPRC4093	Control	-22.16344444	117.467
Eagle	HPRC4095	Control	-22.16266667	117.469
Eagle	HPRC4099	Control	-22.16894444	117.472
Eagle	HPRC4102	Impact	-22.16622222	117.4716111
Eagle	HPRC4103	Control	-22.16541667	117.4713611
Eagle	HPRC4105	Control	-22.17177778	117.4740556
Eagle	HPRC4114	Impact	-22.17166667	117.4816111
Eagle	HPRC4119	Impact	-22.15805556	117.4385556
Eagle	HPRC4120	Impact	-22.15738889	117.4390278
Eagle	HPRC4121	Control	-22.15641667	117.4395833
Eagle	HPRC4123	Impact	-22.15686111	117.4365278
Eagle	HPRC4131	Impact	-22.17969444	117.4913056
Eagle	HPRC4132	Impact	-22.17933333	117.4912778
Eagle	HPRC4148	Impact	-22.18063889	117.4864167
Eagle	HPRC4156	Impact	-22.18244444	117.4839167
Eagle	HPRC4158	Impact	-22.17883333	117.4840833
Eagle	HPRC4170	Impact	-22.17791667	117.4815833
Eagle	HPRC4190	Control	-22.17263889	117.4780278
Eagle	HPRC4205	Impact	-22.17894444	117.4756389
Eagle	HPRC4206	Impact	-22.17797222	117.4755278
Eagle	HPRC4221	Impact	-22.169	117.4804444
Eagle	HPRC4240	Impact	-22.17444444	117.4853611
Eagle	HPRC4241	Impact	-22.17341667	117.4853056
Eagle	HPRC4249	Impact	-22.17427778	117.4876667
Eagle	HPRC4254	Impact	-22.17508333	117.48875
Eagle	HPRCUNK96	Impact	-22.17522222	117.4840556
Eagle	HPRCUNK97	Impact	-22.17711111	117.4755833
Eagle	HPRCUNK98	Impact	-22.17627778	117.4733889