Appendix D

Subterranean Fauna Sampling at Balmoral South Iron Ore Project and adjacent area

Bennelongia Environmental Consultants

ACN 124 110 167

Postal address
PO Box 384
Wembley WA 6913

Street address
64 Jersey Street
Jolimont WA 6014

Phone (08) 9285 8722
Fax (08) 9285 8811

RISK TO TROGLOFAUNA FROM MINING AT BALMORAL SOUTH

Background

Nine species of troglofauna have been collected from Balmoral South, of which seven species are known from elsewhere: six within the Central Block mine lease and one from leaf litter at Cape Preston. The two species known only from the proposed Balmoral South mine pit are Polyxenida sp. B1 and *Trinemura* sp. B1 (nr *troglophila*). While it is not claimed that they represent the same species, Polyxenida sp. B1 is morphologically similar to species occurring in subterranean habitats of the Yilgarn and Pilbara and *Trinemura* sp. B1 (nr *troglophila*) is similar to the nominate species from Cape Range caves. The conservation significance of both species is discussed by Bennelongia (2008).

This risk assessment deals with the occurrence of the Balmoral South troglofauna community in the Cape Preston area, rather than examining the conservation status of individual species. The overall pattern of species distributions suggests that the Balmoral South community extends beyond the proposed Balmoral South mining area. Nearly all other sampling in the Cape Preston area was in the proposed Central Block mine pit, which is 2 km north of the Balmoral South.

Based on sampling to date, two inferences have been drawn regarding the wider distribution of the Balmoral South community (Bennelongia 2008):

(1) Because the community and its constituent species occur in the banded iron formation in the Central Block and proposed Balmoral South mine pits, they will also occur in banded iron formation in the intervening area (e.g. nr *Draculoides* sp. B1 and Coleoptera sp. B1 in Figures 5.3 and 5.4, Bennelongia 2008).

(2) The community and its constituent species probably occur much more widely in the banded iron formation of the Cape Preston area than the Balmoral South and Central Block leases.

The Balmoral South PER has also advanced a third proposition:

(3) the impact of the de-watering on troglofauna will be minimal because of indications that the atmosphere in voids will remain saturated with water vapour.

Risk assessment in relation to groundwater drawdown

This document provides an assessment of the risk to the Balmoral South troglofauna community, outside the proposed Balmoral South mine pit, as a result of groundwater drawdown. The document specifically addresses proposition (3) above by summarising available information relating to:

(4) The level of uncertainty that exists about the relationship between groundwater drawdown and fauna habitat.

Groundwater drawdown of up to 300 m will occur at Cape Preston when the approved Central Block (Ministerial Statement 635) and proposed Balmoral South mine pits are developed. There will be significant drawdown (arbitrarily assigned to be >25 m) through most of the banded iron formation in the Central Block and Balmoral South lease areas that will be left un-mined (Figures 5.3 and 5.4, Bennelongia 2008).

Troglofauna biology

Groundwater drawdown has been hypothesized to be a threat to troglofauna because it will reduce humidity of the subterranean habitat where the animals occur (Biota 2006). There is no information on the humidity requirements of troglofauna outside caves but it is likely that cave information can be applied to troglofauna in the general geological matrix.

Troglofauna in caves appear to require humidity greater than about 80 % (Humphreys et al. 1989; Humphreys 1990; Hadley et al. 1991), although species are likely to vary in this respect and periods of lower humidity may reduce activity rather than eliminate a species locally. Food in combination with availability of water appears to control activity and, presumably, population growth (Humphreys 1991; see also Weistein 1994).

Humidity in the matrix

Information on humidity of deep subterranean habitats, other than caves, is unavailable. However, some general principles of soil science and geology have been used to infer the likely situation.

In the Pilbara, only cyclones and monsoonal rain recharges the groundwater. Heavy rain moves in a front from the surface to the watertable (see Figs 1 & 2). As the recharge front moves through, only a small quantity of residual water is left in the pore spaces. Soil is then said to be at field capacity, which is determined by how much water is 'trapped' by the physical characteristics of the soil (Fig. 2). Over time after a rainfall within the plant root zone, water is evapo-transpired and the amount of soil water is very substantially reduced and surface layers will be dry. The root zone extends 5-10 m below the surface.

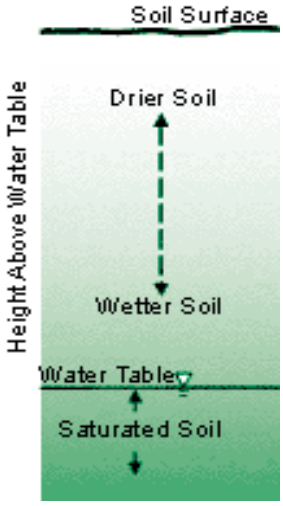

Fig.1. Soil water content increases with depth until all pore spaces are filled at the watertable (from Sand 2001).

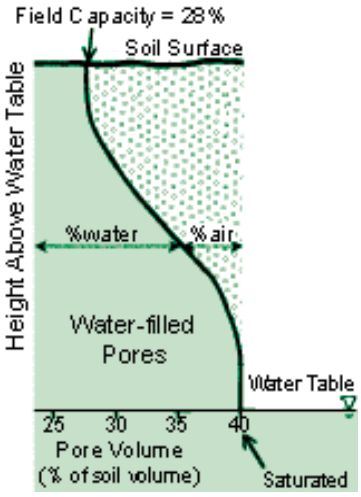

Fig. 2. Soil below the root zone will be at field capacity, which varies depending on soil type (Sands 2001).

Deeper than the root zone, however, there is no evapo-transpiration. Soils drain to field capacity as recharge moves down and then retain that water. The retained water maintains vapour pressure in interstitial spaces and humidity is very high (ca 100 %). Thus, humidity in subterranean systems is controlled mainly by distance from the root zone, rather than distance to the water table and even large groundwater drawdown has little effect on subterranean humidity.

It has been hypothesised that it is the existence of this stable, high subterranean humidity that originally caused troglofaunal species to move underground as their previously wet epigean environments dried (Weinstein 1994; Desutter-Grancolas & Grandcolas 1996).

Groundwater drawdown at Cape Preston

When de-watering occurs at Cape Preston, the subterranean habitat above the de-watered zone is expected to remain at field capacity with respect to the water it contains and, therefore, no change in humidity is expected.

Within the de-watered zone, small perched pools of water are expected to remain throughout the fractured rock after de-watering, especially if de-watering is achieved by drainage through pit walls and collection of the inflowing groundwater in sumps within the pit (Aquaterra 2008). Essentially, the de-watered area is being drained to field capacity and will remain a humid environment.

Some indication of the quantity of water likely to remain in subterranean habitats to be de-watered is given by the fact that long-term discharge into the Central Block pit is expected to remain at a level of at least 50 % of the discharge when the pit is first opened (0.9 compared 1.7 ML/day, Aquaterra 2008).

Troglofauna response to de-watering

In areas where groundwater drawdown is in the order of 25-50 m, it is considered likely that humidity in the habitat currently used by troglofauna will be maintained and there will be no impact on troglofauna occurrence.

In fact, it is likely that de-watering will increase the amount of habitat available to troglofauna as areas previously inundated by groundwater are drained. Some colonization by troglofauna moving downwards is considered likely, provided that the physical structure of the deeper habitat is similar to that currently occupied by troglofauna.

As troglofauna move deeper, however, there is likely to be an attenuation of food supply from the surface. Given that troglofauna population growth is likely to be controlled by food availability (see Humphreys 1991), population densities in deeper habitats are likely to be lower than in the habitats currently occupied by troglofauna at Cape Preston.

Summary of risk to troglofauna

It is unlikely that groundwater drawdown of the order of 25-50 m poses a threat to the Balmoral South troglofauna community where it occurs outside mine pits at Cape Preston. The principle threat from groundwater drawdown is thought to be decrease in humidity but such decrease appears unlikely at Cape Preston. There is both theoretical (Sanders 2001) and modeling (Aquaterra 2008) evidence suggesting there will be no change in humidity in the habitats currently occupied by the troglofauna community. It appears likely that drawdown will, in fact, increase the extent of available troglofauna habitat.

While it may also be the case that drawdown deeper than 50 m has no effect on troglofauna habitat, the risk assessment has not attempted to address this issue. Few areas outside the mine pits will experience such deep drawdown.

Further research

International Minerals (in conjunction with Mineralogy and Citic Pacific Mining) has committed to undertaking continued troglofauna monitoring and survey in the Cape Preston region to examine the distribution of troglofauna in areas that will not be mined, as well as the wider relationships between troglofauna at Cape Preston other western Pilbara ore-bodies and the relationships between troglofauna and leaf litter communities (Section 7.5.3 of the BSIOP PER (page 7-29).

It is proposed to extend this sub-regional program to investigate on the relationship between troglofauna and groundwater. This will be achieved by desktop review and through sampling troglofauna and measuring habitat parameters before and after de-watering.

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Author Stuart Halse *Date* 18 December 2008

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by Bennelongia Pty Ltd

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Bennelongia Pty Ltd
64 Jersey Street
Jolimont WA 6913
www.bennelongia.com.au
ACN 124 110 167

August 2008

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Contents

1.0 Introduction

The Balmoral South Iron Ore Project (the Balmoral South Project) (mineral leases 08/126 and 08/127) is located about 80 km south-west of Karratha near Cape Preston (Figure. 1.1). It is one of several ore bodies in the Cape Preston area. It is proposed to mine iron ore from Balmoral South Project area in an open pit that will require dewatering. The proposed pits at the Mineralogy Central Block Project (Central Block Project) and the Balmoral South Project are about 2 km apart.

This report presents the results of subterranean fauna sampling at Balmoral South Project area for the purposes of assessing the likely impact of mine development on subterranean fauna, which have been identified by the Environmental Protection Authority (EPA) as an issue for assessment (see EPA 2003). Results of sampling in surrounding areas, including the adjacent Central Block Project mine leases 08/123, 08/124 and 08/125), are provided for context.

The scope of this report was determined by IM. Conservation implications and assessment of the likely impacts of mine development are addressed in the Balmoral South Project Public Environmental Review (PER).

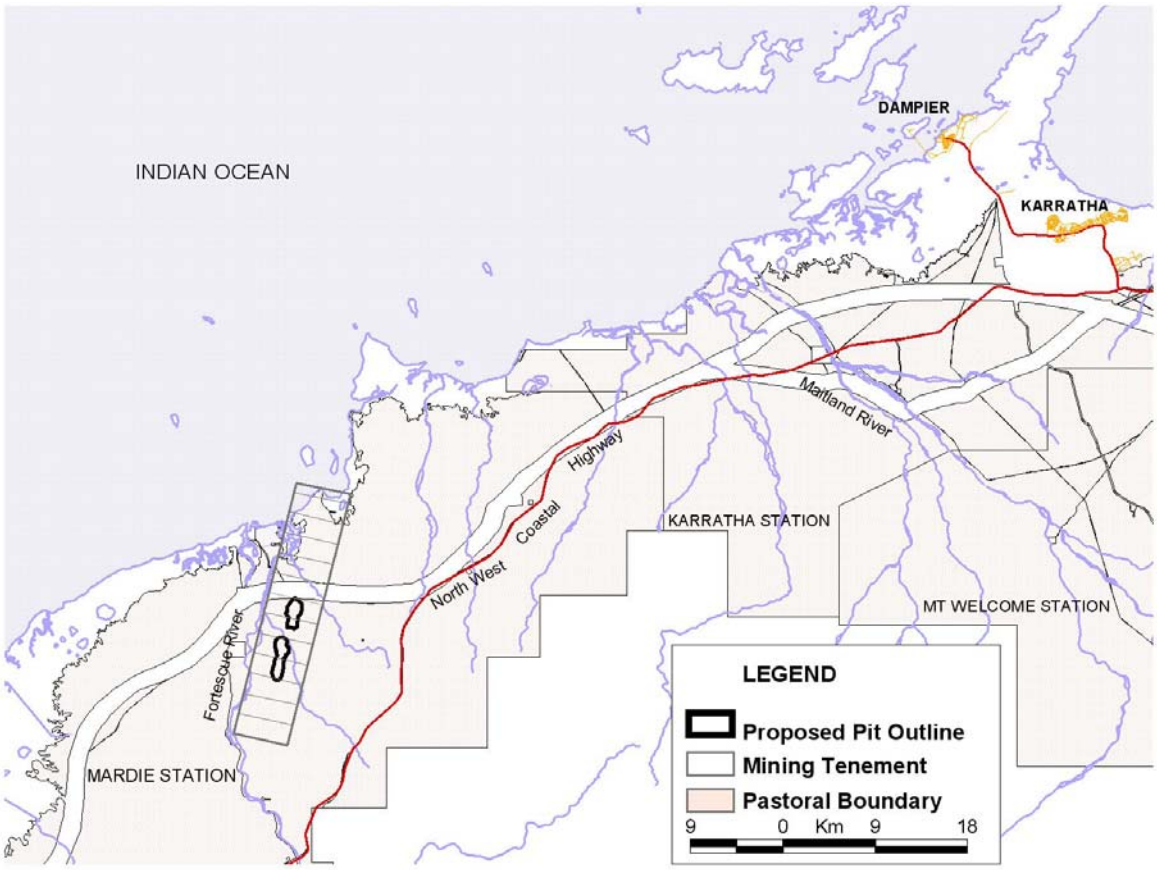


Figure. 1.1. Location of proposed mines in the Cape Preston area. Proposed pits at Central Block and Balmoral South are illustrated (Balmoral South is the southern pit)

2.0 Local geology and hydrogeology

The occurrence of subterranean fauna is strongly influenced by geology. The geology of the ore bodies in the Cape Preston area is best viewed within the context of the whole Pilbara Block, where it can be seen that the ore bodies are western outliers of the Hamersley Group (Figure 2.1). This Group occupies much of the southern Pilbara Block and contains prominent banded iron formations (BIFs).

The proposed mines at the Balmoral South and Central Block Projects will be extracting lower grade, primary ore in BIF of the Brockman Iron Formation, in particular its Joffre Member (Figure 2.2). Unoxidised Joffre magnetite BIF can be beneficiated to produce a very high-grade concentrate (>68 % Fe) with low contaminants.

The Joffre Member has an average thickness of 300 m at the Balmoral South and Central Block Projects and is overlain by Yandicoogina Shale and, in places, silica breccias. Whaleback Shale and Dales Gorge Members of the Brockman Iron Formation occur below the Joffre Member. There is minor faulting at the Balmoral South and Central Block Projects and a series of thin dolerite dykes intrude along these faults (average thickness 4 m).

Depth to groundwater within the Balmoral South Project is about 20-35 m and water is mostly fresh (1500-7000 mg L^{-1} TDS), although more saline water has also been recorded. Depth to groundwater in the surrounding alluvium is 5-15 m and groundwater has similar salinity (600-7000 mg L^{-1} TDS).

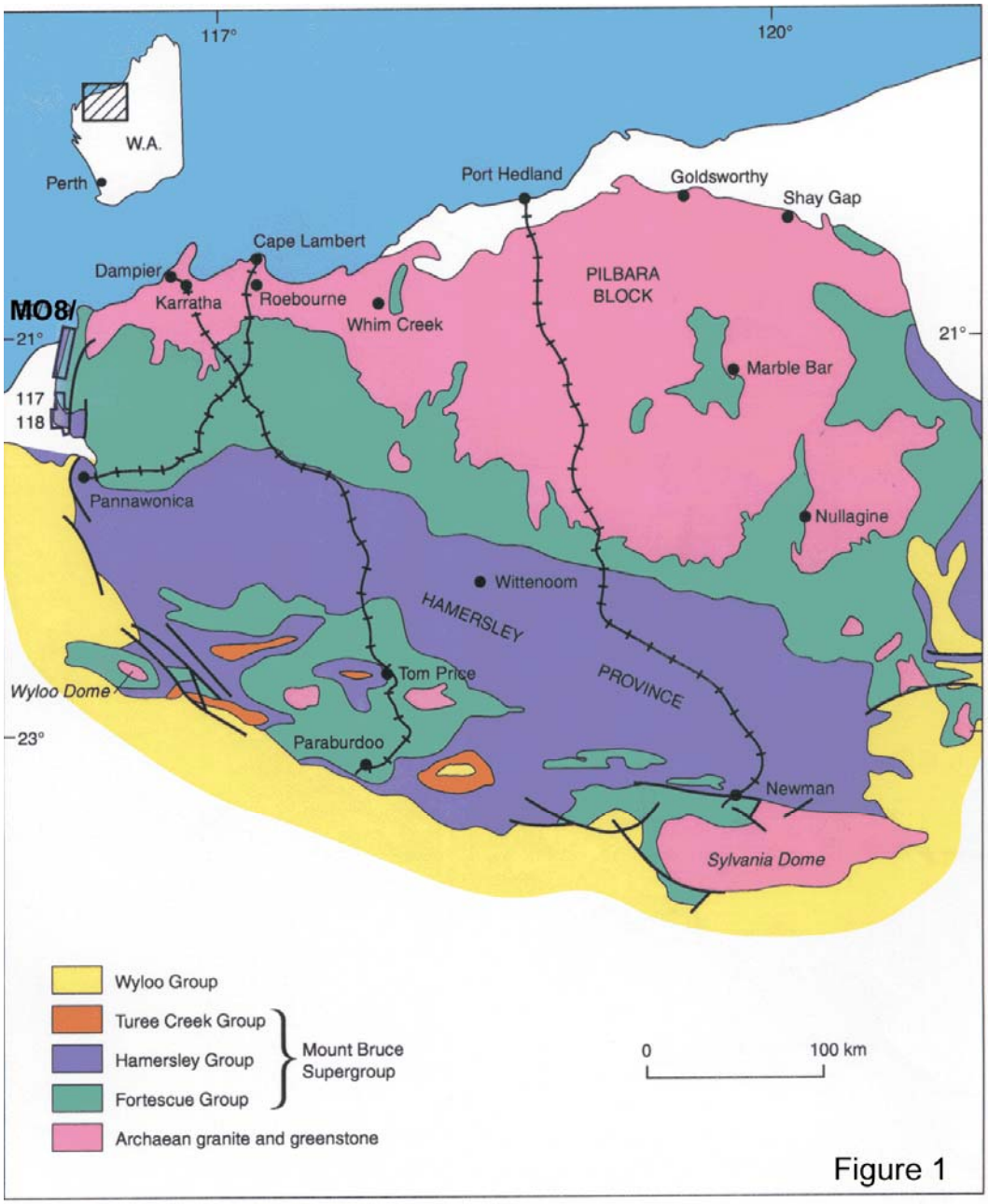


Figure 2.1. Regional geology of the Pilbara, showing the distribution of major geological groups. Central Block and Balmoral South lie within the M08 series of mine leases marked on the left side of the map (prepared by Mineralogy Pty Ltd).

3.0 Subterranean fauna of the sub-region

Subterranean fauna is a term used to describe animals that spend all, or most of, their life cycles underground and possess morphological adaptations to an underground existence. Most commonly, these are loss of eyes and skin pigmentation and a vermiform body shape. Some subterranean animals retain eyes, usually reduced in size.

There are two kinds of subterranean animals: stygofauna and troglofauna. Stygofauna are aquatic and occur in groundwater. Troglofauna are air-breathing and occur in underground cavities and small fissures above the water table. Nearly all subterranean fauna are invertebrates, although both

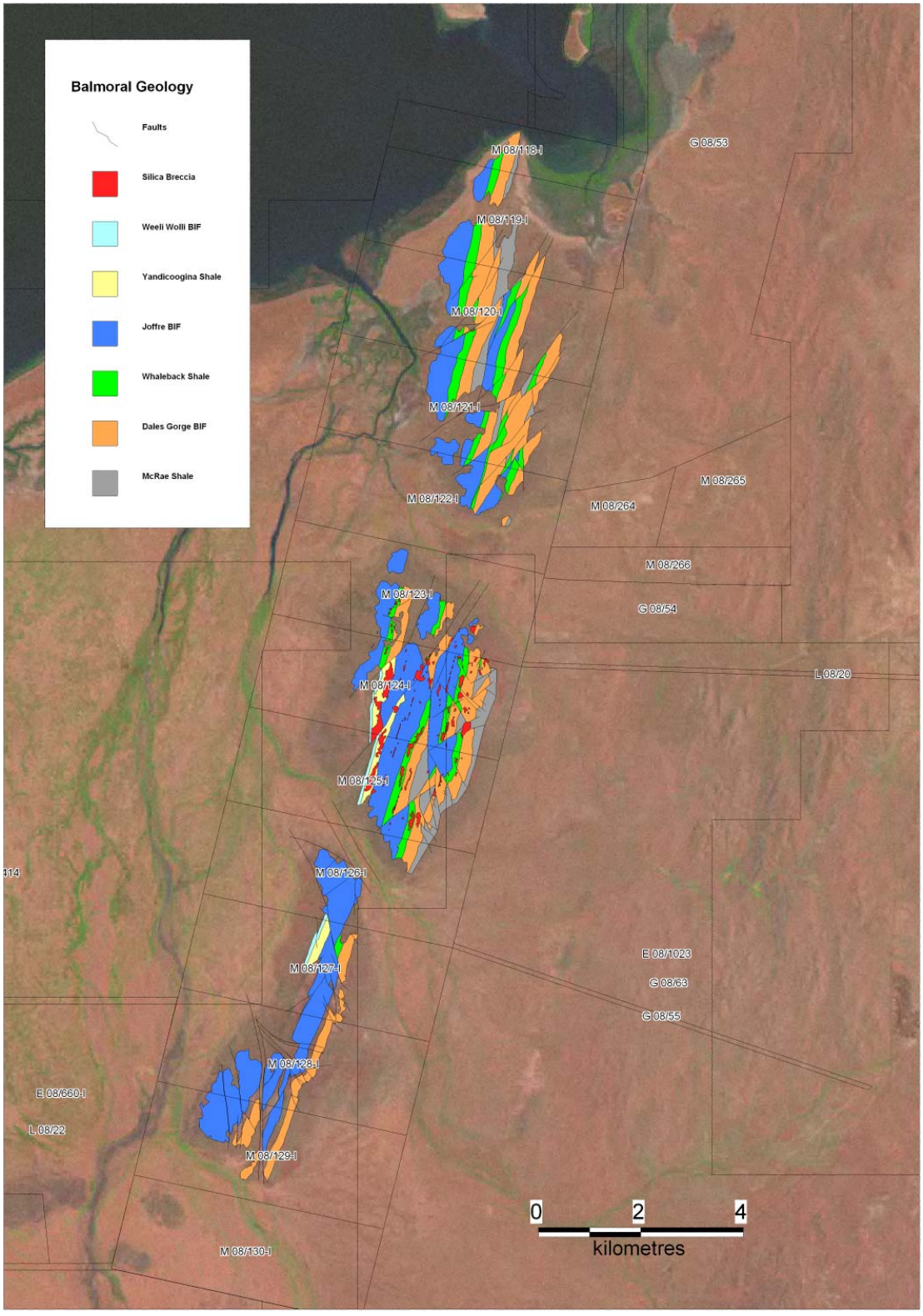


Figure 2.2. Geology of outcropping sections of the orebody at Cape Preston. The outlines of mine leases 08/123, 08/124, 08/125 (Central Block) and 08/126, 08/127 (Balmoral South) are shown. The Fortescue River is on the western side of the leases (prepared by Mineralogy Pty Ltd).

stygofaunal fish and troglofaunal reptiles have been recorded in Western Australia (e.g. Whitely 1945, Aplin 1998).

3.1 Stygofauna

The Pilbara region is recognized as a global hotspot for stygofauna. About 350 species were collected during a regional survey between 2002 and 2005 and analysis of collection patterns suggest that 500-550 species occur in the region (Eberhard et al. 2008). There is relatively little geographic variation in numbers of stygofauna species occurring across the Pilbara but a high proportion of species have localized distributions. In fact, it was estimated that about 70 % of species have ranges of <10,000 km^2, the criterion suggested by Harvey (2002) as defining short range endemic species (SREs).

Somewhat in contrast to the regional picture, the coastal plain alluvium supports a rich fauna of species that mostly occur across several river catchments or, at least, are widely distributed along a catchment (Halse et al. in prep.). Despite their comparatively widespread occurrence, some of the species probably meet the criterion for SREs because their distribution, extending a distance of 200 km or more, is a narrow linear one along a river catchment or the coastal plain.

3.2 Troglofauna

Troglofauna have only recently become a focus of environmental assessment in the Pilbara and there is relatively little information about their distribution, although knowledge is accumulating rapidly. Including Cape Preston, four areas with significant troglofaunal communities are currently known in the western Pilbara. The areas are the pisolitic mesas of the Robe Valley (Biota 2006), the Cane River deposits (Biota, unpublished data) to the south and south-west, respectively, of Cape Preston and the Ord Ranges between Port Hedland and the De Grey River (Subterranean Ecology 2007). Coastal communities of troglofauna also occur at Cape Range and Barrow Island (Humphreys 1993, Biota 2005). Troglofauna are widespread in the eastern Pilbara (Bennelongia 2008a, b).

The four troglofauna communities currently known from the western Pilbara contain 7 - 9 Orders each, with centipedes, schizomids, pseudoscorpions, bristle-tails, silverfish, beetles and slaters all represented in at least three communities, which have similar compositions (more detail is provided in section 6.2).

4.0 Methodology

4.1 Sampling strategies and effort

Subterranean fauna sampling occurs in bores drilled for geological investigation or groundwater monitoring. This report describes stygofauna and troglofauna sampling undertaken at the Balmoral South Project. It also describes the program of sampling undertaken at the Central Block Project and in surrounding alluvium and volcanics.

The first subterranean fauna sampling in the area was undertaken at Central Block, where 46 bores were sampled twice for stygofauna in March and October 2001 (i.e. 92 samples). Methodology and results of this sampling were provided in Austeel (2002) and are not repeated here.

Similar methods were used during the Balmoral South sampling and more recent sampling at, and around, the Central Block Project. The sampling programs are described in chronological order to show how knowledge of the fauna has accumulated.

This sampling commenced in mid-2007 and, by August 2008, 62 stygofauna, 177 troglofauna and 31 surface litter samples were collected. Allocation of effort between impact and reference bores is described below.

4.1.1 Stygofauna

Fourteen stygofauna samples were collected west of the Fortescue River in May 2007 by Biota Environmental Sciences to provide information about stygofaunal occurrence in a potential water supply aquifer for the Central Block Project (Table 4.1, Figure 4.1). A further 19 stygofauna samples were collected in June 2007 by Bennelongia to document the distribution of an oniscoid isopod (now referred to as Philosciidae sp. B1 and considered to be troglofauna), which was collected in 2001 and considered at that time by the EPA to be potentially restricted to the proposed mine pit in the Central Block Project. The Biota and Bennelongia samples were collected from outside the impact zone of the Central Block and Balmoral South mines (i.e. the pits and associated de-watering cones) (Figure 4.1, Bennelongia 2007) and were used as reference samples for the Balmoral South mine.

Twenty-two impact samples of stygofauna (11 in both February and June 2008) were collected from the mine pit and de-watering cone of the Balmoral South Project (Table 4.2, Figure 4.1). The aim of this sampling was to demonstrate that the stygofaunal community of Balmoral South Project was a geographic extension of the community found outside the zone of mining impact. The level of impact zone sampling was less than recommended by EPA (2007) guidelines for a stand-alone mine in an area rich in stygofauna but takes into account previous sampling at the Central Block Project (Austeel 2002) and the depauperate community that was shown to exist. Therefore, a low (pilot study) level of sampling was employed with the objective of confirming that, like the Central Block Project, the Balmoral South Project has a relatively depauperate stygofauna community, within the richer coastal plain community, and that the ore body community consists of widespread species.

Table 4.1. Sampling effort for subterranean fauna in 2007 and 2008 associated with Central Block (see Figures 4.1 & 4.2 for bore locations)

Numbers of styofauna samples collected and the different kinds of troglofauna sampling undertaken. Most troglofauna samples consisted of a scrape and a single or double trap (S trap = single trap, D trap = one shallow and one deep trap)

		Impact				Control			
	Date	Samples	Scrapes	S trap	D trap	Samples	Scrapes	S trap	D trap
Troglofauna	Aug-07	9	0	5	4	-			
	Sep-07	56	53	39	17	0			
	Feb-08	52	52	35	17	0			
	Total	117	88	74	32	0			
Stygofauna	May-07	0				14[1]			
	Jun-07	7				19			
	Total	7				33			

[1] collected by Biota Environmental Sciences

4.1.2 Troglofauna

Troglofauna investigation began in August 2007 after stygofauna sampling in June had collected animals that were undoubtedly significant troglofauna (schizomid Nr *Draculoides* sp. B1) at bore CPM009 within the proposed Central Block mine pit. Furthermore, examination of Philosciidae sp. B1 (the isopod found in 2001) from bore CPM010 suggested that it was also troglofauna. Nine samples were collected in August within the pit area (Table 4.1, Figure 4.2).

A bigger troglofauna sampling program was then initiated in the Central Block Project area in September 2008 with 56 samples being collected inside the proposed mine pit (Figure 4.2). A

second round of sampling, using the same bores, occurred in February 2008. The samples from the Central Block Project represent reference samples in the sense that they are outside the impact of the Balmoral South mine and are indicative of the community in the ore body to the north, much of which will remain unmined.

Impact zone sampling for troglofauna within the Balmoral South Project was undertaken in February and June 2008 with 30 samples each date, either within the proposed mine pit or from nearby areas of very substantial groundwater drawdown (Table 4.2, Figure 4.3). This represents a level of troglofauna sampling that meets EPA (2007) recommendations for impact areas.

Table 4.2. Sampling effort for subterranean fauna in February and June 2008 at Balmoral South
Each troglofauna sample consisted of a scrape and a single or double trap (S trap = single trap, D trap = one shallow and one deep trap)

		Impact			
	Date	Samples	Scrapes	S trap	D trap
Troglofauna	Feb-08	30	30	20	10
	June-08	30	30	20	10
	Total	60	60	40	20
Stygofauna	Feb-08	11			
	June-08	11			
	Total	22			

Troglofauna are a focus of environmental assessment because they live entirely underground. This provides very limited capacity of dispersal compared with animals at the surface and, accordingly, a high proportion of troglofauna have very restricted ranges (Gibert & Deharveng 2002). However, animals possessing troglomorphic characters, which would be considered troglofauna if collected below ground, are occasionally collected at the surface after rain. Therefore, 11 litter samples were collected in the Cape Preston vicinity in February 2008, and a further 20 in April, to examine whether any troglofauna species from the Central Block or Balmoral South Projects occurred at the surface (Table 4.3, Figure 4.4). Any species occurring at the surface is likely to be distributed across all ore bodies in the vicinity of Cape Preston.

Table 4.3 Litter sampling in February and April 2008 in the vicinity of Cape Preston

	Date	Grab samples
Litter	Feb-08	11
	Apr-08[1]	20

[1] 14 in early April, 6 at end of April

4.2 Sampling methods

Sampling adhered to the subterranean fauna protocols advocated by the EPA (2007), except for the addition of scraping as a means of capturing troglofauna (see below). Fieldwork was undertaken by Mike Scanlon, Jim Cocking, Jane McRae and Peter Cocking.

4.2.1 Troglofauna

Troglofauna sampling consisted of trapping and scraping. For the purposes of calculating the number of samples collected, a sample was considered to consist of both scraping and setting one or two traps in the borehole.

Scraping occurred immediately prior to setting traps. A small, reinforced stygofauna net was lowered to the bottom of the bore and dragged back to the surface along the bore walls. The process was repeated four times. Troglofauna on the walls were scraped into the net. Contents of the net were preserved in 100 % ethanol.

Trapping consisted of placing PVC tubes, measuring 270 x 70 mm and baited with moist leaf litter, down bores. These troglofauna traps had holes drilled in the sides of the PVC, an open top end and closed bottom. Litter was sterilized by microwaving prior to being put in the trap. Traps were set a few metres above the water table or the bottom of the bore and, in approximately every fourth bore, a second trap was set mid-way between the bottom bore and the surface. Bores were capped to minimize ingress of surface invertebrates. Traps remained in place 8 weeks before they were retrieved and their contents (including leaf litter) were emptied into a zip-lock bag and sent to the laboratory for processing.

Sampling dates given in this report refer to the month when the scrape was taken and trap was set, although trap contents were retrieved two months later (i.e. in April for a February sampling event).

4.2.2 Stygofauna

Stygofauna sampling by Bennelongia followed the methods of the Pilbara Biological Survey (Eberhard et al. 2005). Biota Environmental Sciences used a similar protocol. Six net hauls were collected from each bore using a weighted plankton net, which was lowered to the bottom of the bore, bounced up and down to stir up sediment, and then slowly retrieved so that it filtered both stirred up sediment and the water column. Contents of the net were transferred to a polycarbonate vial after each haul and then contents were preserved onsite in 100 % ethanol at the completion of sampling. Three net hauls were made with a 50 µm mesh net and three with a 150 µm mesh net. Nets were washed in a decontaminant solution between bores to minimize contamination between sites.

A field meter was used to measure electrical conductivity and pH at each bore.

4.2.3 Litter fauna

Handfuls of litter were collected from the south side of rock faces, from sheltered rock crevices and along creek lines and stored in zip-lock bags until returned to the laboratory.

4.3 Sample sorting and species identification

4.3.1 Troglofauna

Troglofauna were extracted from the leaf litter in troglofauna traps in the laboratory using Berlese funnels. These consisted of a container with a funnel into which the contents of the zip-lock bag were emptied. A light was placed above the container and a flask of ethanol was aligned beneath the funnel. Troglofauna and soil animals move away from the light and heat of the lamp, down the funnel and fall into the ethanol in the flask (EPA 2007). After about 72 h, the ethanol container was removed and the contents (soil, litter and animals) were sorted under a dissecting microscope. Litter from each funnel was also searched under a microscope for any remaining animals.

Preserved scrapes from each bore were sorted under a dissecting microscope after elutriation to separate animals from heavier sediment, and sieving into size fractions using 250, 90 and 53 µm mesh sieves to remove litter and improve searching efficiency.

All animals were picked out of the samples and checked for possession of troglomorphic characters. Surface and soil-dwelling species were identified only to Order level and data on them are not

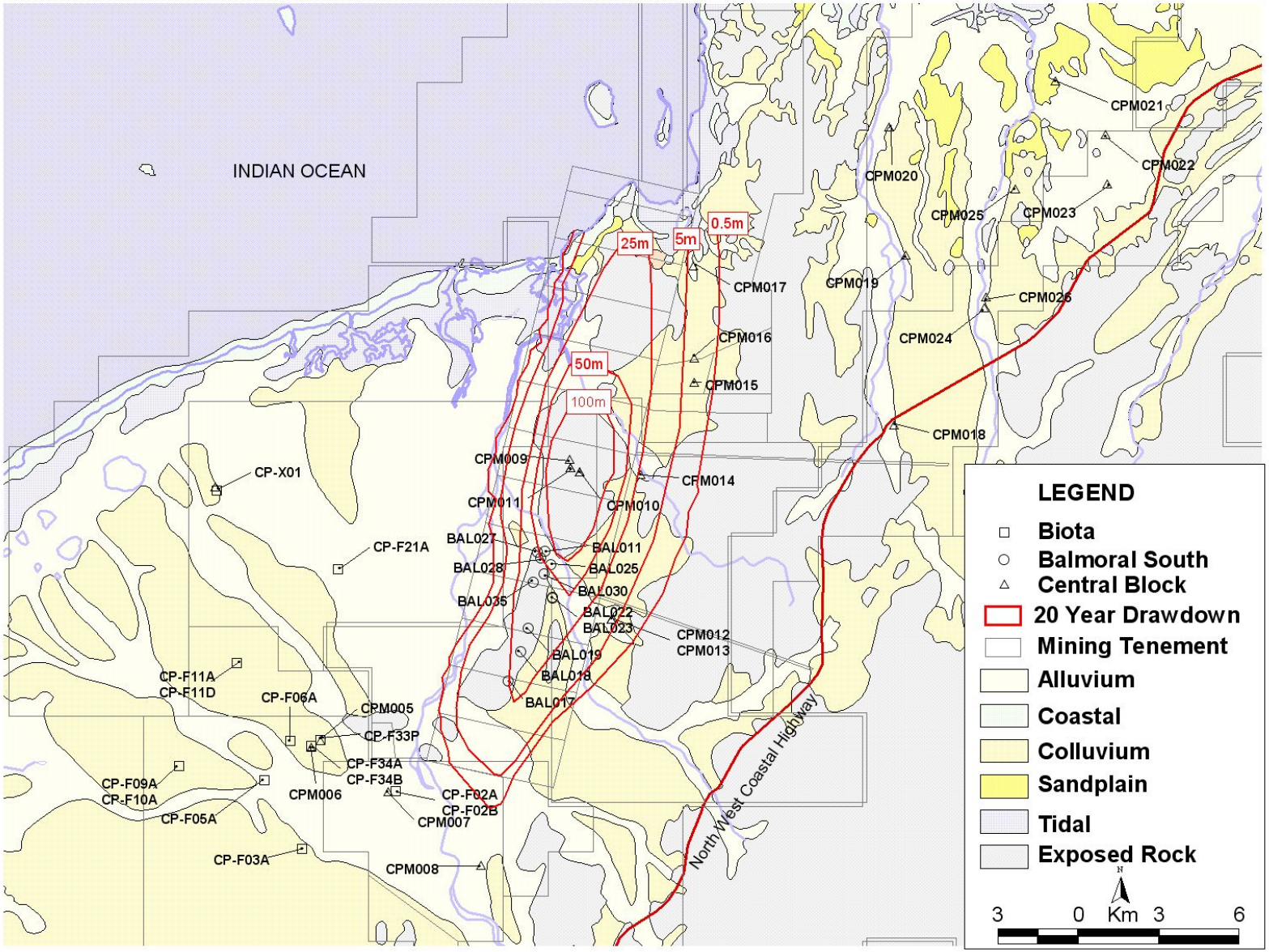


Figure 4.1. Locations of bores where stygofauna collected by Bennelongia in the vicinity of Cape Preston. Both the Balmoral South and Central Block Projects are included

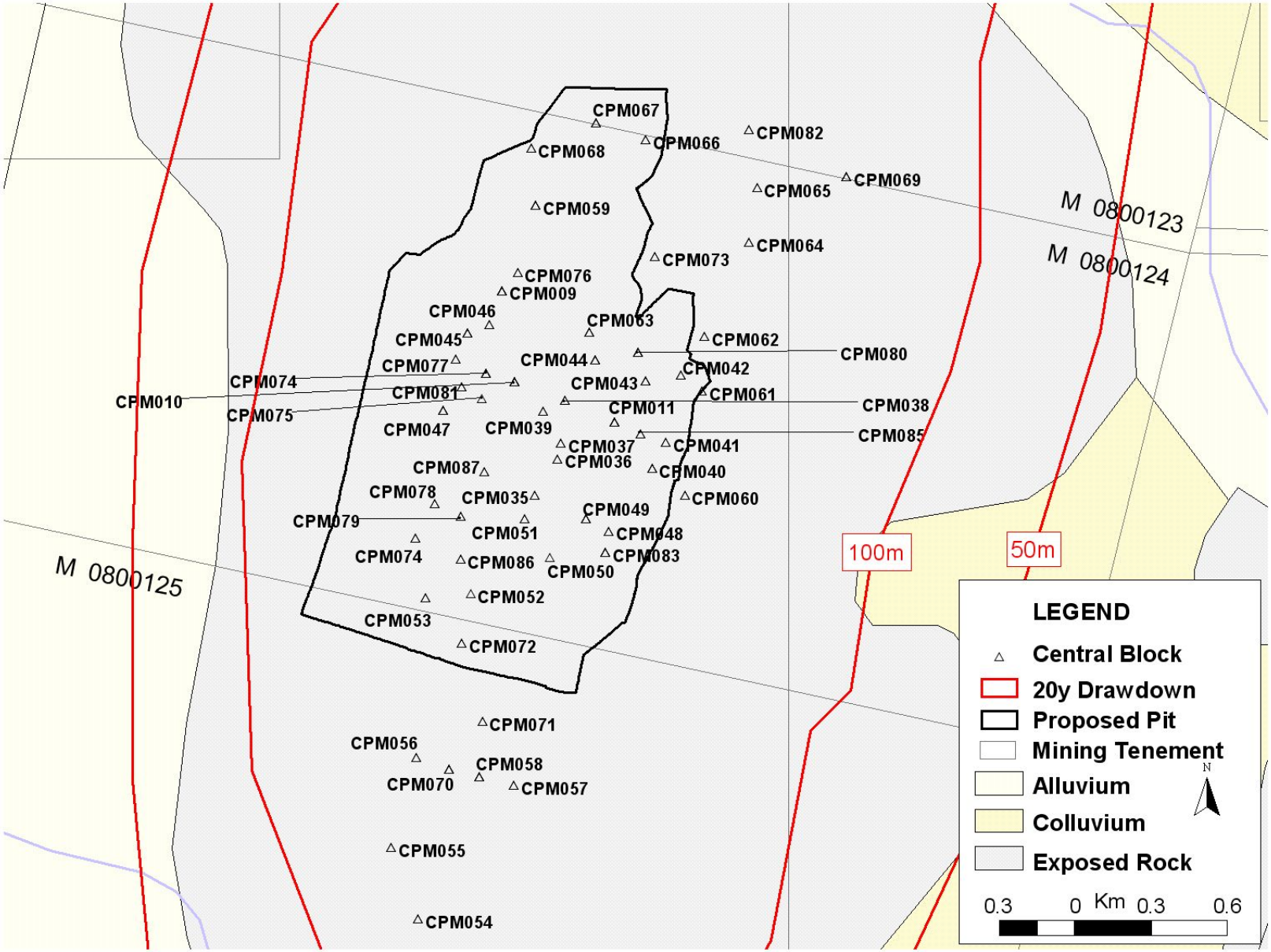


Figure 4.2. Locations of bores at Central Block where troglofauna collected. Outline of the 7 year pit is shown

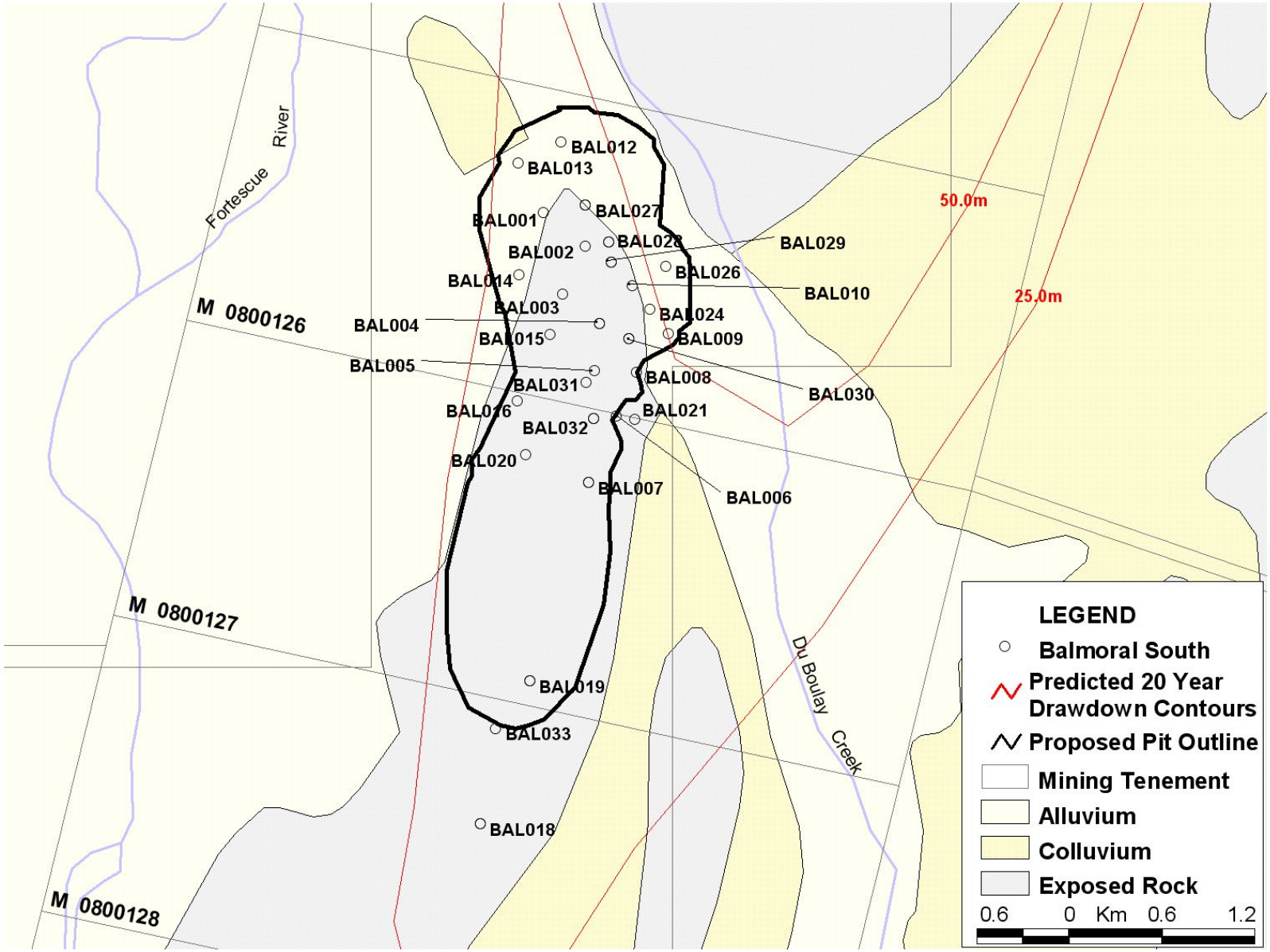


Figure 4.3. Locations of bores at Balmoral South where troglofauna collected. Outline of proposed pit is shown

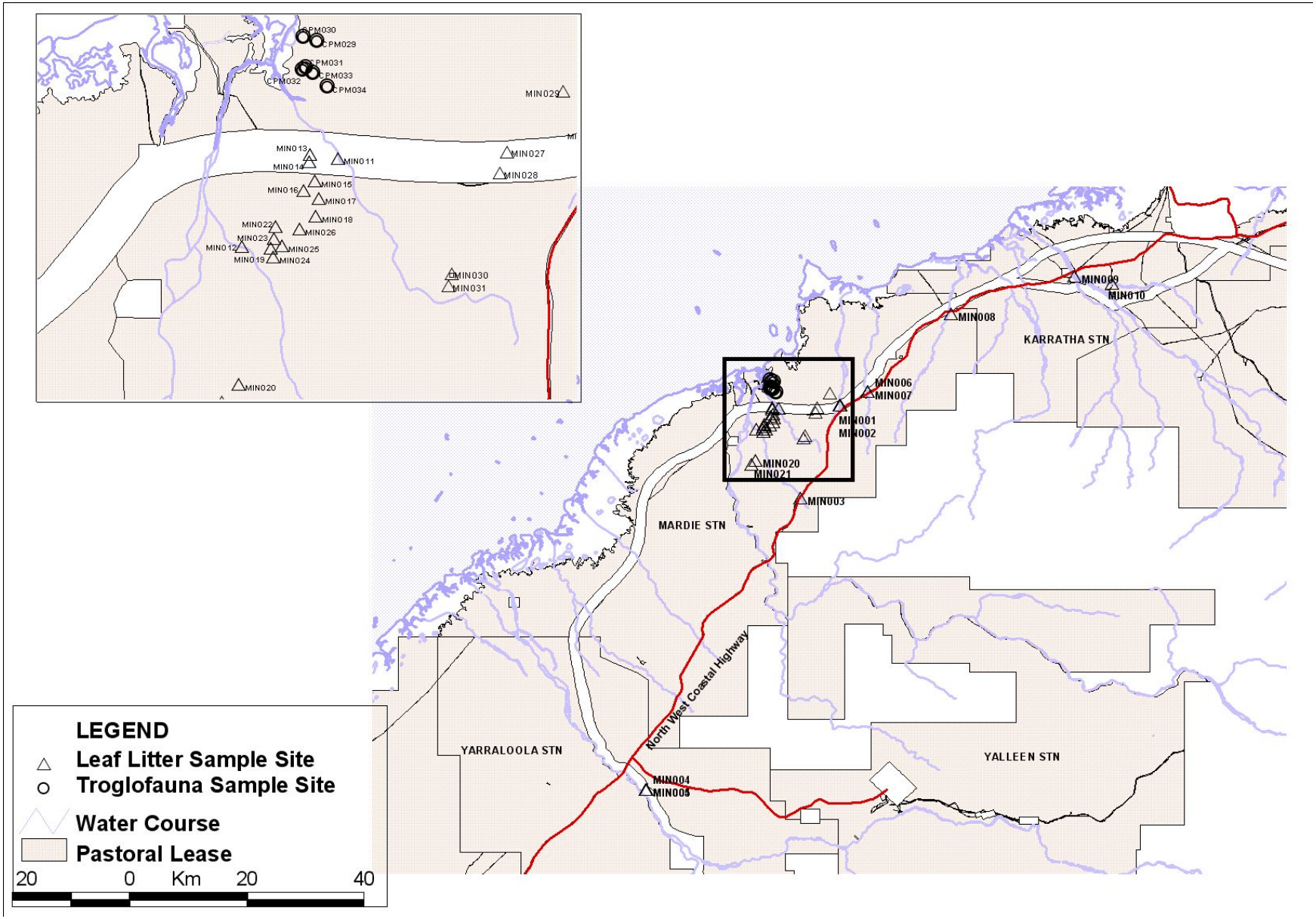


Figure 4.4. Sites in the vicinity of Cape Preston where litter collected

Table 5.1. Stygofauna sampling results
From Cape Preston area and Balmoral South Project in May/June 2007 and February 2008

Site	Date	Samples	Species	Animals/sample	Species/sample	Restricted sp.
Cape Preston	May	14	17	-	3	-
	June	26	51	56	5.3	-
Balmoral South	February	11	13	3.4	1.4	0
	June	11	9	19	1.5	0

Table 5.2. Troglofauna sampling results
From Central Block and Balmoral South Projects in September 2007 and February 2008

Site	Date	Samples	Species	Animals/sample	Species/sample	Restricted sp.
Central Block	September	56	15	1.46	0.71	-
	February	52	8	0.73	0.40	-
Balmoral South	February	30	5	0.37	0.17	1
	June	30	6	0.33	0.20	

presented here. Troglofauna were, as far as possible, identified to species or morpho-species level, unless damaged, juvenile or the wrong sex for identification, as stipulated by Table 3.4 of EPA (2007). Identifications were made under dissecting and compound microscopes and animals were dissected as necessary. Unpublished and informal taxonomic keys were used to assist identification of taxa for which no published keys exist. Representative animals will be lodged with the Western Australian Museum once the assessment process is complete.

Sorting was done by Jane McRae, Megan Phillips and Heather McLetchie. Identifications were made by Jane McRae.

4.3.2 Stygofauna

Preserved stygofauna samples were elutriated in the laboratory to separate out heavy sediment particles and then the samples were sieved into size fractions using 250, 90 and 53 µm mesh sieves to improve searching efficiency. All animals were picked out of the samples and identified using the same techniques described for troglofauna (section 4.3.1). Nomenclature of undescribed species follows that used in the Pilbara Biological Survey (Halse et al. in prep).

Sorting was done by Jane McRae, Mike Scanlon and Jim Cocking. Identifications were made by Jane McRae, Jim Cocking (amphipods), Mike Scanlon (oligochaetes) and Stuart Halse (ostracods).

4.3.3 Litter fauna

The same techniques were used with litter as for troglofauna traps. Sorting was done by Jane McRae, Jim Cocking and Megan Phillips. Identifications were made by Jane McRae.

5.0 Results

51 Stygofauna

At least 54 species of stygofauna have been collected from the Cape Preston area. This represents a typical level of richness for Pilbara stygofaunal communities sampled intensively (see Eberhard et al.

2008). Results of stygofauna sampling are summarized in Table 5.1. A species list is provided in Appendix 1.

The Balmoral South Project supported less than one-third the numbers of stygofaunal animals and species found in reference bores (mostly in alluvium to the west of Central Block) in May and June 2007, which suggests the stygofaunal community at the mine site is depauperate. All 15 stygofauna species present at the Balmoral South Project have been recorded outside the zone of impact of both the Balmoral South and Central Block Projects (Appendix 1). The community consisted of nematods (1 species), worms (1), mites (1), ostracods (3), copepods (6), thermosbaenacids (1) and amphipods (2).

5.2 Troglofauna

Sampling at the Balmoral South Project yielded a total of nine species of troglofauna. With five and six species collected, respectively, in the February and June sampling sessions, but only two species common to both sessions, the community almost certainly consists of more than nine species (Tables 5.2 & 5.3). Six of the species found at the Balmoral South Project are known to occur at Central Block and *Cryptops* sp. B2 (nr *australis*) appears to be the same species as recorded in surface leaf litter at Cape Preston (see section 5.3). The species recorded to date only from Balmoral South are Polyxenida sp. B1 and *Trinemura* sp. B1 (nr *troglophila*). Given the current state of troglofauna taxonomy, it is unclear whether the other species are more widely distributed but *Trinemura* sp. B1 (nr *troglophila*) is similar to the nominate species from Cape Range caves (Smith 1998) and Polyxenida sp. B1 is similar to species occurring in subterranean habitats of the Yilgarn and Pilbara.

At least 22 species of troglofauna have been collected from the Central Block and Balmoral South Projects (Appendices 2 & 3). This represents a rich troglofaunal community according to current

Table 5.3. Species of troglofauna collected

From Central Block (CB) and Balmoral South (BS) Projects. Number of records of each species at the two mines is shown

Species	CB	BS	Species	CB	BS
Pseudoscorpion			Parajapygidae sp. B1	3	0
Pseudoscorpionida sp. B2	2	2	Japygidae sp.[1]	1	0
Schizomid			Japygidae sp. B1	2	0
Nr *Draculoides* sp. B1	15	4	Japygidae sp. B2	1	0
Slater			Japygidae sp. B3	1	0
Haloniscus sp. B1	3	2	Campodeidae sp. B1	2	0
Philosciidae sp. B1	3	0	Procampodeidae sp.	1	0
Isopoda sp.	2	0	**Silverfish**		
Centipede			Atelurinae sp.[1]	3	0
Chilopoda sp	1	1	Atelurinae sp. B1	10	0
Cryptops sp. B1 (nr spinifer)	1	0	Atelurinae sp. B2	1	0
Cryptops sp. B2 (nr *australis*)	0	2	*Hemitrinemura* sp. B1	6	1
Geophilomorpha sp.	1	0	*Trinemura* sp. B1 (nr *troglophila*)	0	1
Millipede			**Beetle**		
Polyxenida sp. B1	0	1	Curculionidae sp. B3	3	0
Bristle-tail			Coleoptera sp. B1	7	1

[1] Could not be identified to species level, probably a species already recorded from Central Block

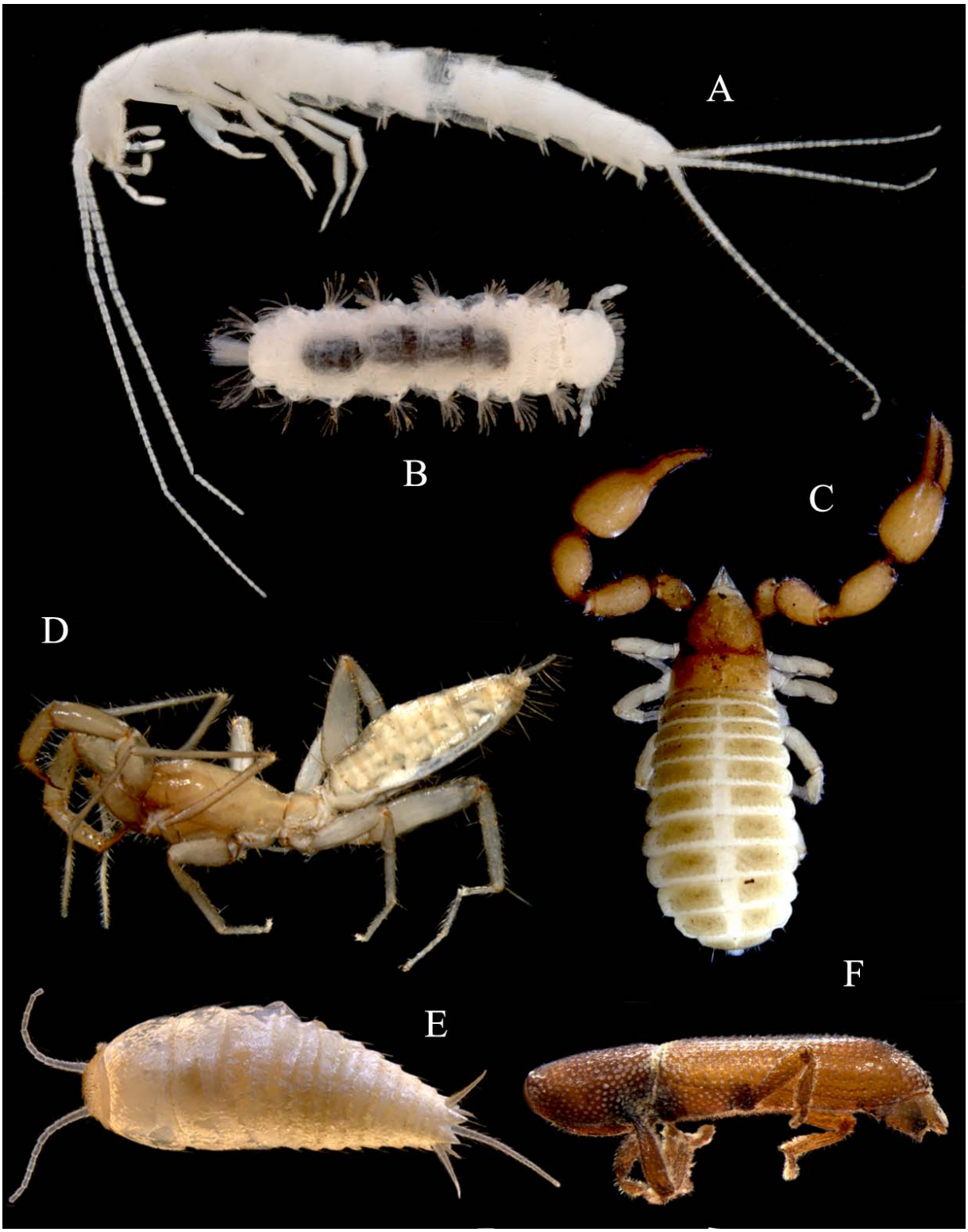


Figure 5.1. Troglofauna species. A, *Trinemura* sp. B1 *(*nr *troglophila)*, silverfish; B, Polyxenida sp. B1, millipede; C, Pseudoscorpionida sp. B2, pseudoscorpion; D, Nr *Draculoides* sp. B1, schizomid; E, Atelurinae sp. Bx, silverfish; F, Curculionidae sp. B3, beetle

knowledge. The high species richness was matched by a high capture rate of animals, especially in September 2007 (1.46 animals per trap whereas 0.20-0.25 is more typical, Subterranean Ecology 2007). Some of the species collected belong to iconic troglofauna groups (e.g. schizomids, Figure5.1) or very widespread taxa that are strongly modified for troglofaunal existence (e.g. curculionid beetles, Figure 5.1).

Taken together, sampling yields were relatively low at the Balmoral South Project (average 0.35 animals per sample) compared with 1.11 animals per sample at Central Blaock (Table 5.2). Balmoral South appears to be less favourable troglofauna habitat, although low trapping rates may have been the result of external factors rather than reflecting animal abundance. Of the 22 known species recorded at both Projects, 15 were recorded in September sampling at Central Block. An additional four species were recorded in February (three from Central Block and one from Balmoral South) and two species in June. The species collected are listed in Table 5.3.

A plot of the abundance of all species at the Balmoral South and Central Block Projects suggests that the probability of collecting some of the species is low because they are naturally rare (Figure 5.2). This abundance-detectability relationship is a key factor in environmental assessment, with the rarer species in the community requiring very large sampling effect to detect them reliably.

It is unlikely that knowledge of the troglofauna present at the Balmoral South Project is complete but, despite collecting rates being lower than at Central Block, sufficient animals have been collected to show the basic taxonomic structure of the community, which shows considerable overlap with Central Block (Figures 5.3 & 5.4).

5.3 Surface litter

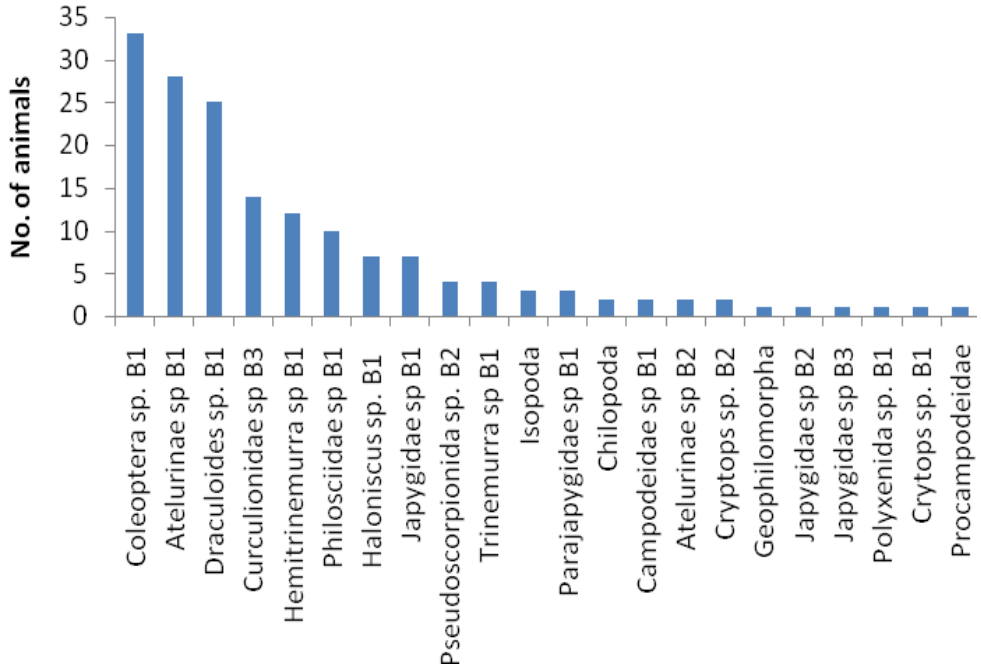
Surface litter sampling provided few animals in February but yielded relatively high numbers of animals in early April, with up to nine Orders being present in a sample (Appendix 4). Six species that may be troglofaunal were recorded: a centipede *Crytops* sp. B1 (nr *australis*), a silver fish belonging to the family Japygidae, a symphylan of the genus *Hanseniella*, an isopod belonging to the genus *Haloniscus* s.l., a pauropod and a pseudoscorpion that, although it had eyes, was white and possessed other troglomorphic features.

One litter species, *Crytops* sp. B1 (nr *australis*), was also collected in bores at Balmoral South (BAL013 and 018). Three troglofaunal species of Japygidae were collected during bore sampling at Cape Preston, although they were different from the species in surface litter. The other potential troglofauna species found in litter species also belong to groups known to have troglofaunal representatives in the Pilbara. *Haloniscus* s.l. isopods occur commonly underground in the Pilbara and Yilgarn and symphylans of the genus *Hanseniella* have been recorded deep underground in the eastern Pilbara. Pauropods have been recorded underground in both the western and eastern Pilbara, while pseudoscorpions are common in the Pilbara at subterranean, as well as surface, sites.

6.0 Summary

6.1 Stygofauna

The stygofauna present at the Balmoral South Project are a 15-species subset of the 54-species stygofauna community in the Cape Preston area. All species found at the Balmoral South Project occur more widely in the Cape Preston area or beyond (Table 6.1).



Fig**ure 5.2. Relative abundances of different troglofauna species**. Based on all sampling at Central Block and Balmoral South. It appears that a few species are abundant with a substantial proportion of the species in the community occurring at very low density

The sampling of stygofauna in the Cape Preston area in 2007 gave similar results to the original sampling used to obtain environmental approval for the Central Block Project (Austeel 2002), which showed a fauna consisting of amphipods, isopods, thermosbaenacids, copepods, ostracods, mites, oligochaetes and turbellarians. The only higher order groups added in 2007 were rotifers, nematodes and snails.

The only species of stygofauna apparently restricted to the Cape Preston vicinity is the amphipod Nr *Norcapensis* sp. 2, which occurs in alluvium west of the Fortescue River. The restricted distribution of this species is probably an artefact of insufficient sampling. Species such as the thermosbaenacid *Halosbaena tulki*, copepods *Diacyclops humphreysi humphreysi* and *Stygoridgewayia trispinosa*, and worms *Dero furcata* and *Pristina longiseta* have ranges extending beyond the Pilbara (Poore & Humphreys 1992; Pinder & Brinkhurst 1994; Karanovic 2006; Tang et al. 2008).

6.2 Troglofauna

Troglofauna studies in the Pilbara are in their infancy and perspectives on what constitutes rich sites and typical species range are still evolving. It appears that the troglofauna community at the Balmoral South Project is part of a larger Cape Preston community that extends southwards from the Central Block Project (Figures 5.3 & 5.4). Two-thirds of the nine species recorded at the Balmoral South Project have been collected to the north in Central Block, with the June sampling session at Balmoral South adding to the list of species common to the two areas. It is likely that further sampling will show even greater similarity of communities and that the Balmoral South Project supports a moderately species-rich fauna, albeit at lower animal densities than at Central Block.

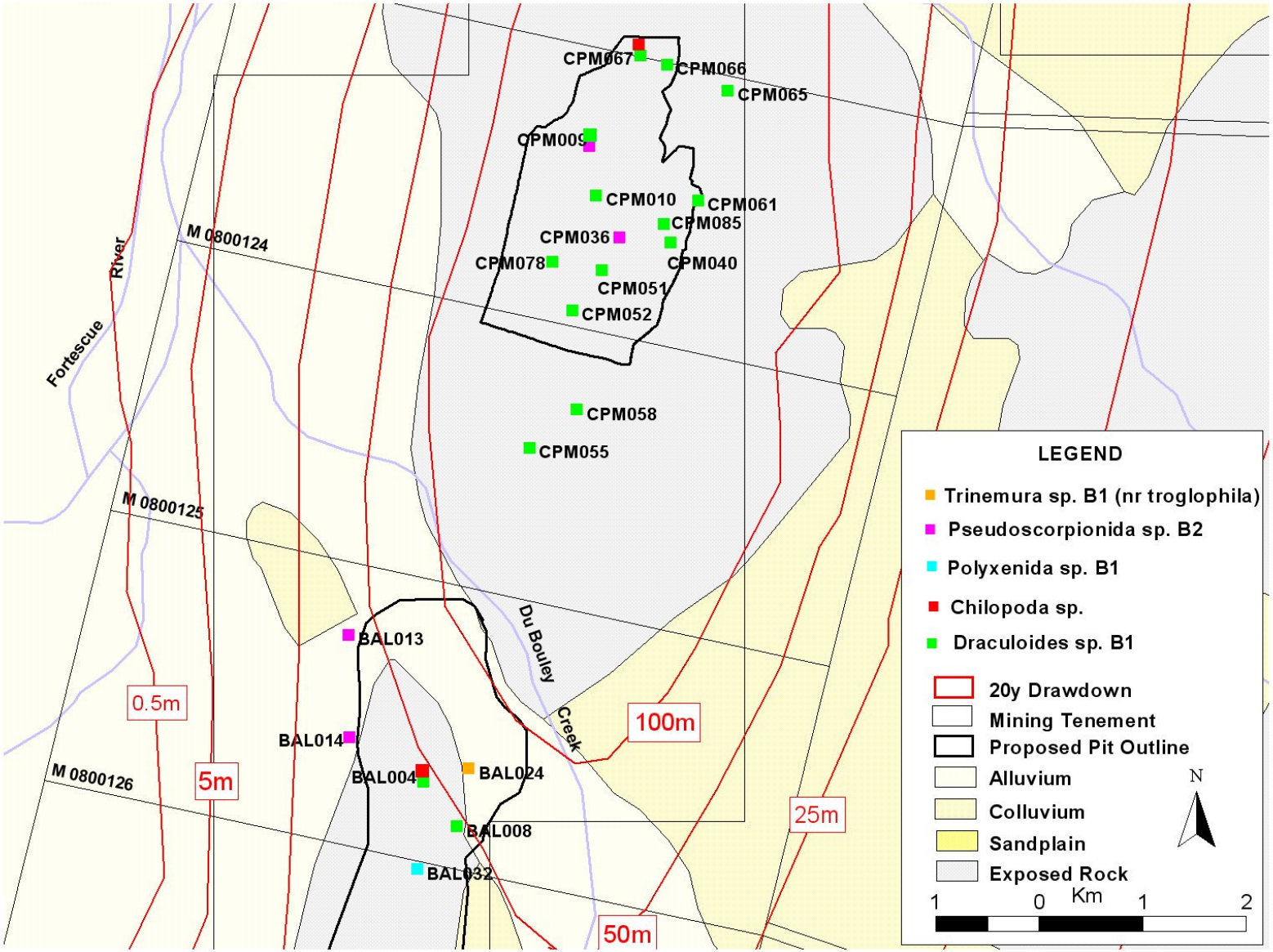


Figure 5.3. Bores in the Cape Preston area where species occurring at Balmoral South were recorded. Note that all species other than Polyxenida sp. B1 and *Trinemurra* sp. B1 (nr *troglophila*) occur through both ore bodies

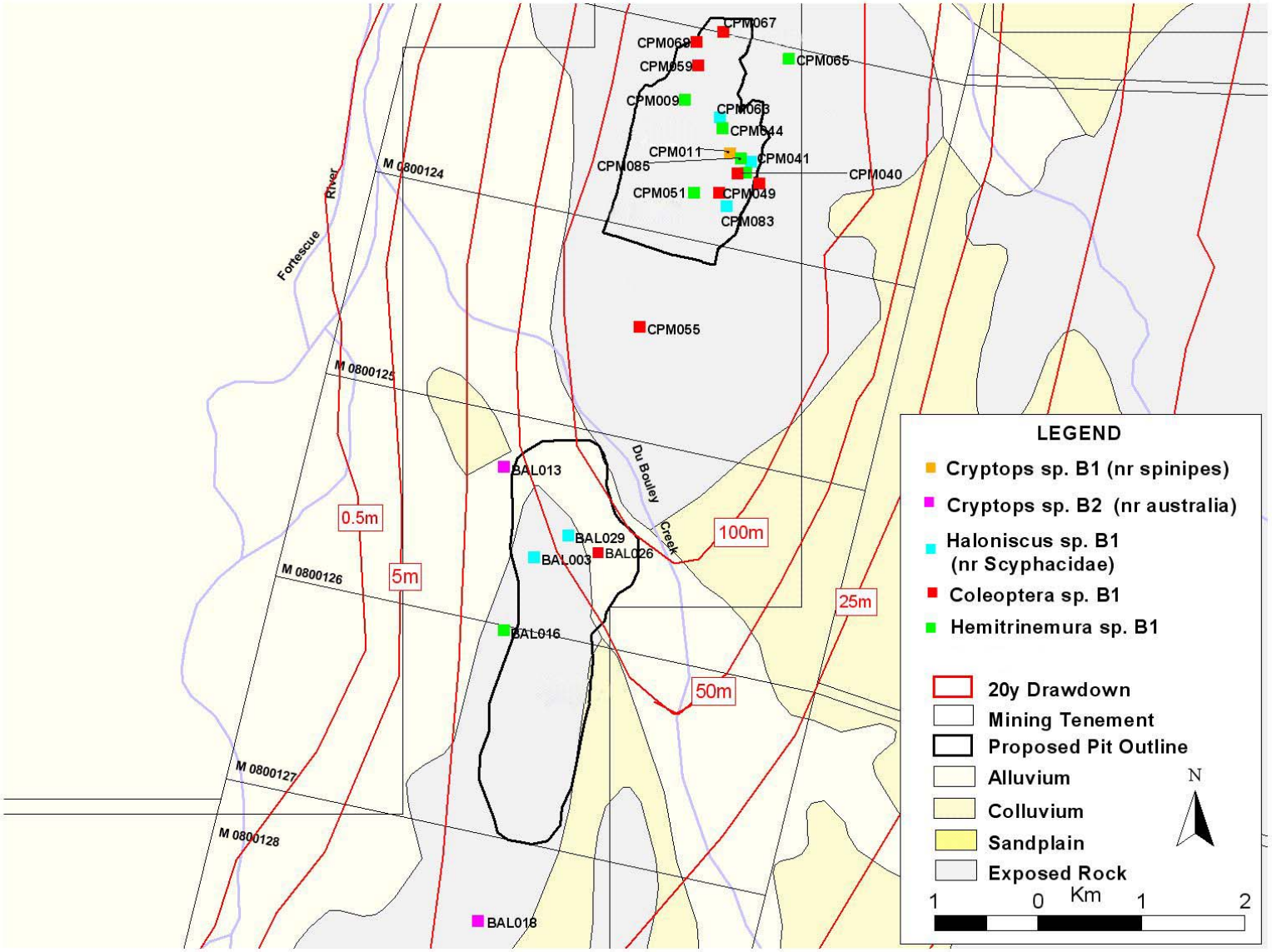


Figure 5.4. Bores in the Cape Preston area where species occurring at Balmoral South were recorded. Note that all species other than *Crytops* sp. B1 (nr *troglophila*) occur at Central Block

Table 6.1. Known distributions of the 8 stygofauna species collected at the Balmoral South Project
These species were discriminated to species level (the other 5 taxa were identified as Nematoda, Enchytraeidae, Acariformes, *Nedsia* sp, Bogidiellidae and ranges could not be assessed)

Species	Distribution
Humphreyscandona fovea	Western Fortescue catchment[1]
Areacandona fortescueiensis	Western Fortescue catchment[1]
Stygoridgewayia trispinosa	Cape Range, Pilbara coast[2]
Halicyclops roachi	Pilbara coast, Barrow Is.[3]
Diacyclops humphreysi humphreysi	Western Australia[3]
Diacyclops h. s. str X *unispinosus*	Barrow Is., western Pilbara[1,4]
Stygonitocrella unispinosa	Pilbara[1,4]
Parastenocaris jane	Pilbara[1]

[1]Karanovic 2007; [2]Tang et al. 2008; [3]Karanovic 2006; [4]Halse et al in prep.

Table 6.2 Higher level composition of troglofauna communities in the western Pilbara
Robe data from Biota (2006), Pardoo from Subterranean Ecology (2007), Cane to the south-west of Cape Preston from Biota (unpublished), Cape Preston from this study

Higher taxa	Robe	Pardoo	Cane	Cape Preston
Pseudoscorpion	1	1	1	1
Schizomid	1		1	1
Spider	1	1		
Millipede	1	1		1
Centipede	1	1		1
Slater		1	1	1
Pauropod		1		
Bristle-tail	1	1	1	1
Silverfish	1	1	1	1
Cockroach	1			
Beetle		1	1	1

Of the three species found at the Balmoral South Project but not Central Block, morphological identification suggested the centipede *Cryptops* sp. B2 (nr *australis*) occurs in surface litter outside the Project areas. Polyxenida sp. B1 is indistinguishable, with the current state of troglofauna taxonomy in Western Australia, from many other troglofauna millipedes across the Pilbara and larger collections and genetic investigation are required to assess its distribution. Polyxenida millipedes appear to be nearly always collected in low numbers. The silverfish *Trinemura* sp. B1 (nr *troglophila*) is closely related to the nominate species found at Cape Range, but is treated as a separate species because the extra tooth on the outer claws of the legs is central rather than sub-apical and there are differences in the anemone-like structures on the base of the male cerci. While current collections have recorded *Trinemura* sp. B1 (nr *troglophila*) only from the Balmoral South Project, where it was a singleton record, the related genus *Hemitrinemurra* has been recorded at both the Balmoral South and Central Block Projects. It is expected that further collecting will show *Trinemura* sp. B1 (nr *troglophila*) extends beyond the Balmoral South Project area.

The focus of much troglofauna work has been on the restricted nature of most species but troglofauna communities at different outcrops across the western Pilbara similar higher level taxonomic

compositions (Table 6.6). Perhaps this extends to the common occurrence of some species at multiple outcrops as well. With 22 species, the Cape Preston area is richer than other western Pilbara outcrops, perhaps because sampling effort was greater than elsewhere as a result of both scraping and trapping (see Bennelongia 2008a,b) and a greater proportion of the community has been documented. Totals of 10-11 species of troglofauna were collected at the Ord Range (Subterranean Ecology 2007) and at Mesa A in the Robe Valley (Biota 2006b), although extrapolation of sampling results suggests that Mesa A actually supports 22-25 species. Other areas on the mid-west coast of Western Australia known to support troglofauna are Barrow Island with 14 species (Biota 2005) and Cape Range with 12 species after initial exploration (Harvey et al. 1993). Over time the number of species known from Cape Range has increased to 41 troglofauna and cave-dwelling surface species (WRC 1999).

6.3 Sampling issues

Sampling effort for stygofauna in the impact area of the Balmoral South Project was relatively low (22 samples) but results repeated the pattern of previous, extensive sampling in 2001 (Austeel 2002). It appears that the ore body community is depauperate and a subset of the community in the surrounding area. Stygofauna of the surrounding area were adequately documented through sampling in 2007 and 2008 by Biota Environmental Sciences and Bennelongia (40 samples).

Combined sampling effort for troglofauna in the impact zones of the mines at the Balmoral South and Central Block Projects has been high (147 samples) with 60 samples collected from the Balmoral South Project to comply with EPA (2007) guidelines. Yields at Central Block were two times higher in September than February (Table 5.2), perhaps because extensive rain in February and March (142 mm and 63 mm at Karratha) caused silt to wash down bores and temporarily reduced their use by troglofauna. Yields at the Balmoral South Project were similar in February and June. Average yields across the two sampling events at both the Central Block (1.11 animals per sample) and Balmoral South Projects (0.35 animals per sample) exceeded the yield of much previous assessment work (0.20-0.25, see Subterranean Ecology 2007).

6.4 Evidence for wider distributions

None of the 13 stygofauna species recorded at the Balmoral South Project is restricted to the impact area of mining and de-watering. As discussed above (section 6.1), all species that could be identified to species level (rather than a higher level morphotype, i.e. Nematoda sp.) are known to extend beyond the Cape Preston area (Table 6.1). Troglofauna species within the subterranean fauna community at the Balmoral South and Central Block Projects are unlikely to be as widely distributed as the groundwater species below them but available evidence suggests these troglofauna occur throughout the Cape Preston orebodies. For example, the schizomid Nr *Draculoides* sp. B1, which has previously been used as an indicator of whether or not stygofauna can move within, or between, geological features (Biota 2005, 2006a) occurs across both Central Block and Balmoral South (Figure 5.3). Genetic and morphological investigations have confirmed that Nr *Draculoides* sp. B1 is a single species (Bennelongia unpublished data).

As already discussed (section 6.2), only three troglofaunal species recorded at the Balmoral South Project are not known from Central Block. One of those species, *Cryptops* sp. B2 (nr *australis*), has been collected at the surface outside the the Balmoral South Project area. Polyxenida sp. B1 and *Trinemurra* sp. B1 (nr *troglophila*) were both collected as single individuals, so that current collecting cannot be regarded as representative of their ranges, which remain unknown. Given that all other species in the Balmoral South Project community extend beyond the mine area it is likely that these two species also do.

The discovery of other animals in surface litter, besides *Cryptops* sp. B2 (nr *australis*), with troglofaunal characteristics opens up the possibility that some troglofauna species come to the surface occasionally and disperse. Such animals will be unlikely to have the extremely small ranges that characterize troglofauna of the Robe Valley, which appear to be restricted to single mesas (Biota 2006). There is already evidence of wide distribution of some troglofauna with both morphological and genetic work suggesting that a species of cockroach in the family Nocticolidae, possessing all the morphological characteristics of troglofauna, extends 250 km in the eastern Pilbara (Bennelongia 2008a).

6.5 Additional sampling

A program of additional sampling over the next 3-5 years is proposed to provide further information about the occurrence of troglofauna in the Cape Preston sub-region (Bennelongia 2008c).

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Appendix 1 A. Stygofauna sampling results for June 2007 in vicinity of Cape Preston showing number of animals caught. Bores CPM009-011 are within the Central Block Project pit. Bores CPM014 is near 25 m drawdown contour, bores CPM015-017 will experience <5 m drawdown. Bores CPM001-003 are in the Robe catchment

	CPM001 1	CPM002 1	CPM003 1	CPM004 1	CPM005 1	CPM006 1	CPM007 1	CPM008 1	CPM009 1	CPM010 1	CPM011 1	CPM012 1	CPM013 1	CPM014 1	CPM015 1	CPM016 1	CPM017 1	CPM018 1	CPM019 1	CPM020 1	CPM021 1	CPM022 1	CPM023 1	CPM024 1	CPM025 1	CPM026 1
Rotifer																										
Bdelloidea sp.														15												
Flatworm																										
Turbellaria sp.																						2				
Roundworm																										
Nematoda sp.				50		1								6					5	1						
Snail																										
Hydrobiidae sp. B1 (cf *Gyralulus*)	4			50		30						5								1						
Worm																										
Aphanoneura sp.		1																								
Phreodrilus peniculus																							8			
Phreodrilus n. sp. WA32 (PSS)[1]						4																				
Insulodrilus sp.			1																							
Phreodrilid with dissimilar ventral chaetae													10						6					15		
Phreodrilid with similar ventral chaetae				1																						
Tubificidae stygo type 5[1]		3																								
Dero furcata																						7				
Pristina longiseta																			30							
Enchytraeidae																				2						
Oligochaeta												1														2
Nereidae (cf *Nemenermeris*)																					2					
Mite																										
Acariformes	1								1													2				
Seed shrimp																										
Gomphodella hirsuta		10	4	20																						1
Deminutiocandona aenigma							3																			
Humphreyscandona fovea			1	9		10						9					5									
Humphreyscandona imperfecta																	1							3		
Humphreyscandona woutersi	10	30					1													2						
Humphreyscandona sp.					1																					
Areacandona fortescueiensis					20																		3	2		
Areacandona sp.				6													1									

	CPM001 1	CPM002 1	CPM003 1	CPM004 1	CPM005 1	CPM006 1	CPM007 1	CPM008 1	CPM009 1	CPM010 1	CPM011 1	CPM012 1	CPM013 1	CPM014 1	CPM015 1	CPM016 1	CPM017 1	CPM018 1	CPM019 1	CPM020 1	CPM021 1	CPM022 1	CPM023 1	CPM024 1	CPM025 1	CPM026 1
nr *Amphitriticandona*		1				1											1									
Candonocypris fitzroyi																						1				
Cypretta seurati																										30
Cyprinotus kimberleyensis																						10			40	1
Sarscypridopsis ochracea[1]																			34			1				
Copepod																										
Stygoridgewayia trispinosa	13		1	1	3				100			1						5								2
Microcyclops varicans																			1							
Metacyclops mortoni																									70	
Halicyclops roachi		1	1			10						1	5				2	3	2				3			1
Mesocyclops sp.																			1							
Diacyclops humphreysi humphreysi						1																				
Diacyclops humphreysi unispinosus	3												1				3	1	2				20	10		2
Diacyclops humphreysi s.str. X *unispinosus*		6									1															
Stygonitocrella unispinosa		25																	5			1				43
Elaphoidella humphreysi					7	100																				
Parastenocaris jane						30							2				1		7			20	7			
Schizopera roberiverensis	1	2															3									
Abnitocrella halsei																	1			1						
Thermosbaenid																										
Halosbaena tulki	1		1			300			3			5					5		1							10
Scud																										
Nedsia sp.																			1	1						
Nedsia hurlberti						1																				
Nedsia nr *hurlberti*			3										1	2			7									
Nedsia sculptilis group						1			18															5		5
nr *Norcapensis* sp. 2																										
Paramelitidae sp. 2 (PSS)[1]	1																									9
Bogidiellidae	3	2															1		1							2
Amphipoda sp																										
Slater																										
Haptolana yarraloola		1		1		1																				
No invertebrates recorded								0							0	0										

[1] Terminology used in Pilbara Biological Survey (Halse et al. in prep.)

Appendix 1 B. Stygofauna sampling results for May 2007 on the Fortescue River floodplain west of Central Block showing the species collected

	CP-F02A	CP-F02B	CP-F03A	CP-F05A	CP-F06A	CP-F09A	CP-F10A	CP-F11A	CP-011D	CP-F21A	CP-F33P	CP-F34A	CP-F34B	CP-X01
Rotifer														
Bdelloidea sp														
Flatworm														
Turbellaria sp.									1					
Roundworm														
Nematoda sp.														
Snail														
Hydrobiidae sp. B1 (cf *Gyralulus*)														
Worm														
Aphanoneura sp.														
Phreodrilus peniculus														
Phreodrilus n. sp. WA32 (PSS)[1]														
Insulodrilus sp.														
Phreodrilid with dissimilar ventral chaetae			1			1								
Phreodrilid with similar ventral chaetae			1											
Tubificidae stygo type 5[1]														
Dero furcata														
Pristina longiseta														
Enchytraeidae														
Oligochaeta														
Nereidae (cf *Nemenermeris*)														
Mite														
Acariformes														
Seed shrimp														
Gomphodella hirsuta														
Deminutiocandona aenigma														
Humphreyscandona fovea						1		1		1		1		
Humphreyscandona imperfecta														
Humphreyscandona woutersi														
Humphreyscandona sp.														
Areacandona fortescueiensis														
Areacandona sp.						1					1			
nr *Amphitriticandona*						1								
Candonocypris fitzroyi														
Cypretta seurati														
Cyprinotus kimberleyensis														
Sarscypridopsis ochracea[1]														
Copepod														
Stygoridgewayia trispinosa		1		1	1		1	1	1	1	1			
Microcyclops varicans														
Metacyclops mortoni														
Halicyclops roachi								1	1			1		
Mesocyclops sp.														
Diacyclops humphreysi humphreysi				1					1					
Diacyclops humphreysi unispinosus														
Diacyclops humphreysi s.str.X *unispinosus*														
Stygonitocrella unispinosa														
Elaphoidella humphreysi									1		1			
Parastenocaris jane														
Schizopera roberiverensis														

	CP-F02A	CP-F02B	CP-F03A	CP-F05A	CP-F06A	CP-F09A	CP-F10A	CP-F11A	CP-011D	CP-F21A	CP-F33P	CP-F34A	CP-F34B	CP-X01
Abnitocrella halsei														
Thermosbaenid														
Halosbaena tulki										1				
Scud														
Nedsia sp.														
Nedsia hurlberti		1	1				1	1	1	1			1	
Nedsia nr *hurlberti*		1			1	1		1						
Nedsia sculptilis group														
nr *Norcapensis* sp 2						1								
Paramelitidae sp. 2 (PSS) [1]														
Bogidiellidae														
Amphipoda sp				1										
Slater														
Haptolana yarraloola										1				
No invertebrates recorded	0													0

[1] Terminology used in Pilbara Biological Survey (Halse et al. in prep.)

Appendix 1 C. Stygofauna sampling results for February and June 2008 at the Balmoral South Project showing the number of each species collected (note that not all species in list collected at Balmoral South)

	BAL011 4	BAL012 4	BAL017 4	BAL018 4	BAL019 4	BAL022 4	BAL023 4	BAL025 4	BAL027 4	BAL030 4	BAL035 4
Rotifer											
Bdelloidea sp.											
Flatworm											
Turbellaria sp.											
Roundworm											
Nematoda sp.			2f								
Snail											
Hydrobiidae sp. B1 (cf *Gyralulus*)											
Worm											
Aphanoneura sp.											
Phreodrilus peniculus											
Phreodrilus n. sp. WA32 (PSS)[1]											
Insulodrilus sp.											
Phreodrilid with dissimilar ventral chaetae											
Phreodrilid with similar ventral chaetae											
Tubificidae stygo type 5[1]											
Dero furcata											
Pristina longiseta											
Enchytraeidae	2j		6f,3j							1j	100j
Oligochaeta											
Nereidae (cf *Nemenermeris*)											
Mite											
Acariformes			1j				1f				
Seed shrimp											
Gomphodella hirsuta											
Deminutiocandona aenigma											
Humphreyscandona fovea	1f	1f									
Humphreyscandona imperfecta											
Humphreyscandona woutersi										1j	
Humphreyscandona sp.											
Areacandona fortescueiensis	5f, 10j									10j	
Areacandona sp.											
nr *Amphitriticandona*											
Candonocypris fitzroyi											
Cypretta seurati											
Cyprinotus kimberleyensis											
Sarscypridopsis ochracea[1]											
Copepod											
Stygoridgewayia trispinosa	10j					1f	1j		1f		
Microcyclops varicans											
Metacyclops mortoni											
Halicyclops roachi	10j					1f					
Mesocyclops sp.											
Diacyclops humphreysi humphreysi	1j					6f					
Diacyclops humphreysi unispinosus											
Diacyclops humphreysi s.str .X *unispinosus*									4f		
Stygonitocrella unispinosa	1f						3j		1f		
Elaphoidella humphreysi											
Parastenocaris jane						2f					
Schizopera roberiverensis											
Abnitocrella halsei											
Thermosbaenid											
Halosbaena tulki	1j										
Scud											
Nedsia sp.	2j				1j	4f					
Nedsia hurlberti											
Nedsia nr *hurlberti*											
Nedsia sculptilis group											
nr *Norcapensis* sp 2											
Paramelitidae sp. 2 (PSS) [1]											

	BAL011 4	BAL012 4	BAL017 4	BAL018 4	BAL019 4	BAL022 4	BAL023 4	BAL025 4	BAL027 4	BAL030 4	BAL035 4
Bogidiellidae						1f					
Amphipoda sp.											
Slater											
Haptolana yarraloola											
No invertebrates recorded				0	0			0		0	0

[1] Terminology used in Pilbara Biological Survey (Halse et al. in prep.)

Appendix 2. Troglofauna sampling results for September 2007 and February 2008 at Central Block showing the number of each species collected. Suffix indicates date of sampling; 1, stygofauna sampling in June 2007; 2, August 2007; 3, September 2007, 4, February 2008. The highlighted rows represent identification only to family level (because animals damaged)

	CPM009 1	CPM009 3	CPM009 4	CPM010 1	CPM010 2	CPM010 3	CPM011 2	CPM011 3	CPM011 4	CPM029 2	CPM034 2	CPM035 4	CPM036 4	CPM037 4	CPM038 3	CPM038 4	CPM039 4	CPM040 3	CPM040 4	CPM041 3	CPM042 4	CPM043 4	CPM044 3	CPM044 4	CPM045 4	CPM046 4	CPM047 4	CPM048 4	CPM049 3	CPM049 4	CPM051 3	CPM051 4	CPM052 3
No troglofauna									0			0		0		0	0		0			0			0	0	0	0		0		0	
Pseudoscorpionida sp. B2			1										1																				
Nr Draculoides sp. B1	1		1			1		1										1													1		2
Haloniscus sp. B1																				2													
Philosciidae sp. B1				1	8																												
Isopoda																																	
Chilopoda																																	
Cryptops sp. B1																																	
Geophilomorpha																																	
Parajapygidae sp. B1							1								1																		
Japygidae																																	
Japygidae sp. B1							1																										
Japygidae sp. B2																																	
Japygidae sp. B3																																	
Campodeidae sp. B1																																	
Procampodeidae																																	
Atelurinae																															1		
Atelurinae sp. B1		2	2							9	4		1		3			1				1											
Atelurinae sp. B2																							2										
Hemitrinemurra sp. B1			4					1										1				1									1		
Curculionidae sp. B3																					1												
Coleoptera sp. B1																		5											2				

Appendix 2 contd

	CPM053 4	CPM054 4	CPM055 3	CPM055 4	CPM056 4	CPM057 3	CPM058 3	CPM058 4	CPM059 3	CPM059 4	CPM060 3	CPM060 4	CPM061 4	CPM062 3	CPM062 4	CPM063 3	CPM063 4	CPM064 4	CPM065 3	CPM065 4	CPM066 4	CPM067 3	CPM067 4	CPM068 3	CPM068 4	CPM069 4	CPM070 4	CPM071 3	CPM071 4	CPM073 3	CPM073 4	CPM074 4	CPM076 4
No troglofauna	0	0			0							0			0		0	0			0				0	0	0				0	0	0
Pseudoscorpionida sp. B2																																	
Nr *Draculoides* sp. B1				1				1					1						2	2		1											
Haloniscus sp. B1																2																	
Philosciidae sp. B1										1																							
Isopoda											2																						
Chilopoda																						1											
Cryptops sp. B1																																	
Geophilomorpha						1																											
Parajapygidae sp. B1																											1						
Japygidae																													1				
Japygidae sp. B1																						6											
Japygidae sp. B2														1																			
Japygidae sp. B3																			1														
Campodeidae sp. B1						1			1																								
Procampodeidae																						1											
Atelurinae																						1	1										
Atelurinae sp. B1				2																									2				
Atelurinae sp. B2																																	
Hemitrinemurra sp. B1																				3													
Curculionidae sp. B3							5	8																									
Coleoptera sp. B1			1						1		5											16		2									

Appendix 2 contd

	CPM077 4	CPM078 4	CPM079 4	CPM081 4	CPM082 4	CPM083 4	CPM084 4	CPM085 4	CPM087 3	CPM087 4
No troglofauna	0		0	0	0		0			0
Pseudoscorpionida sp. B2										
Nr *Draculoides* sp. B1		1						1		
Haloniscus sp. B1						1				
Philosciidae sp. B1										
Isopoda										
Chilopoda										
Cryptops sp. B1										
Geophilomorpha										
Parajapygidae sp. B1										
Japygidae										
Japygidae sp. B1										
Japygidae sp. B2										
Japygidae sp. B3										
Campodeidae sp. B1										
Procampodeidae										
Atelurinae										
Atelurinae sp. B1										
Atelurinae sp. B2										
Hemitrinemurra sp. B1										
Curculionidae sp. B3										
Coleoptera sp. B1										

Appendix 3. Troglofauna sampling results for February and June 2008 at the Balmoral South Project showing the number of each species collected. February catches marked with 'f', June with'j'. The highlighted rows represent identification only to family level (because animals damaged)

	BAL001 4	BAL002 4	BAL003 4	BAL004 4	BAL005 4	BAL006 4	BAL007 4	BAL008 4	BAL009 4	BAL011 4	BAL012 4	BAL013 4	BAL014 4	BAL015 4	BAL016 4	BAL017 4	BAL018 4	BAL019 4	BAL020 4	BAL021 4	BAL024 4	BAL026 4	BAL027 4	BAL028 4	BAL029 4	BAL030 4	BAL031 4	BAL032 4	BAL033 4	BAL034 4
No troglofauna	0	0			0	0	0		0	0	0		0	0	0	0	0	0	0	0	0		0	0		0	0	0	0	0
Pseudoscorpionida sp. B2												1j	1j																	
Draculoides sp. B1				5f				1f,1j																						
Haloniscus sp. B1			1																					1						
Philosciidae sp. B1																														
Isopoda																														
Polyxenida sp. B1																											1j			
Chilopoda				1f																										
Cryptops sp. B2												1f					1j													
Geophilomorpha																														
Parajapygidae sp. B1																														
Japygidae																														
Japygidae sp. B1																														
Japygidae sp. B2																														
Japygidae sp. B3																														
Campodeidae sp. B1																														
Procampodeidae																														
Atelurinae																														
Atelurinae sp. B1																														
Atelurinae sp. B2																														
Trinemurra sp B1																					4j									
Hemitrinemurra sp. B1															1j															
Curculionidae sp. B3																														
Coleoptera sp. B1																						1f								

Appendix 4. Animals found in litter samples collected in February and April 2008. The number of higher level taxonomic groups, number of possible troglofauna species and number of animals collected in each sample is shown. Possible trogofauna appear in bold type. G, no. of higher level groups; T, no. of troglofauna species; A, no. of animals

Site	Groups collected	G	Tsp	A
MIN001	Diptera	1	0	3
MIN002	Acarina, Coleoptera	2	0	18
MIN003	Coleoptera	1	0	6
MIN004	-	0	0	0
MIN005	Coleoptera	1	0	4
MIN006	Coleoptera, Diptera	2	0	5
MIN007	Coleoptera	1	0	1
MIN008	Diptera lavae	2	0	2
MIN009	Arachnida, Acarina, Collembola, Lepismatidae, Blattidae, Isoptera, Coleoptera	7	0	12
MIN010	Acarina, Coleoptera	2	0	6
MIN011	Acaina, Collembola, Lepismatidae, Coleoptera	4	0	9
MIN012	Collembola, Lepismatidae	2	0	4
MIN013	Oligochaeta, Acarina, ***Haloniscus***, Lepismatidae, Curculionida, Coleoptera, Diptera	7	1	11
MIN014	Acarina, Collembola, Diptera	3	0	18
MIN015	Nemotoda, Lepismatidae	2	0	11
MIN016	Chilopoda, Lepismatidae, Diptera	3	0	2
MIN017	Olphiidae, Acarina, Collembola, Lepismatidae, Isoptera, Coleoptera	6	0	7
MIN018	Nemotoda, Acarina, Collembola, Lepismatidae, Coleoptera, Diptera,	6	0	19
MIN019	Nematoda, Oligochaerta, Acarina, ***Cryptops* sp. B2 (nr *australis*)**, **Japygidae**, Collembola, Polyosteriinae Coleoptera, Diptera	9	2	31
MIN020	Nematoda, Acarina, Collembola, Lepismatidae, Coleoptera, Diptera	6	0	15
MIN021	Acarina, Armagillae, Collembola, Lepismatidae	4	0	6
MIN022	Acarina, Collembola, Lepismatidae	3	0	2
MIN023	Nematoda, Arachnida, Acarina, Armadillidae, ***Hanseniella***, Collembola, Lepismatidae, Diptera	8	1	49
MIN024	Oligochaeta, Acarina, Armillidae, ***Cryptops* sp. B2 (nr *australis*)**, Collembola, Isoptera, Coleoptera, Diptera	8	1	45
MIN025	Nematoda, Olphiidae, Acarina, Armillidae, Collembola, Lepismatidae, Isoptera	7	0	40
MIN026	Nematoda, Lepismatidae, Hemiptera	3	0	3
MIN027	Acarina, Collembola, Coleoptera	3	0	4
MIN028	Acarina, Collembola, **Pseudoscorpionida**, **Pauropoda**, Coleoptera	5	2	6
MIN029	Nematoda, Acarina, Collembola, Isoptera, Coleoptera	5	0	24
MIN030	Isoptera, Coleoptera	2	0	31
MIN031	Acarina, Collembola, Isoptera, Diptera	4	0	22

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