



Tronox Management Pty Ltd

Cooljarloo West Proposal: Short Range Endemic Fauna, Pilot and Targeted Surveys

Final Report

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Cooljarloo West Proposal: Short Range Endemic Fauna, Pilot and Targeted Surveys

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Cover picture: Banksia woodland, Cooljarloo West.

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EXECUTIVE SUMMARY

Tronox Management Pty Ltd (Tronox) (previously Tiwest Pty Ltd) has operated the Cooljarloo mineral sands mine 175 km north of Perth since 1989. The mine was authorised by the Western Australian Minister for the Environment in 1988 under Ministerial Statement 37. The mine plan was subsequently modified with the following expansions:

- Dredge and/or dry mining of orebodies 27 200 and 28 000 in the southern portions of the tenement (Ministerial Statement 557); and
- Dry mining of Falcon deposit in the northern end of the tenement (Ministerial Statement 790).

The remaining dredge mine life at Cooljarloo is approximately 15 years and Tronox now proposes to develop additional resources to the west of the current operations to extend the Cooljarloo mine life. The additional resources are known as Cooljarloo West (the Proposal). Short-range endemic invertebrate species (SREs) were not assessed under the environmental impact assessments for the existing Cooljarloo mine operations. Likely impacts on SREs from mining activities associated with the Proposal include clearing of vegetation, which will cover an area up to 1710 ha. Additionally, groundwater drawdown (yet to be modelled) may cause decline of phreatophytic vegetation and associated change in SRE habitat.

Review of vegetation, soils, landforms and climate combined with field sampling suggested two prospective SRE habitats occur in the vicinity of the Proposal, namely *Melaleuca raphiophylla/Eucalyptus camaldulensis* forests on drainage basin/flats and *Melaleuca raphiophylla* forests associated with mound springs. The majority of the Proposal area comprised either heath or low open *Banksia/Eucalyptus* woodlands over heath on stabilised sand dunes; these habitats are very well connected and were considered not to be prospective SRE habitats.

The desktop review identified 72 species belonging to ten SRE groups in search area of 50 x 50 km around the Proposal. One of these species is a recognised SRE species (the snail *Bothriembryon perobesus*) and 14 other species were considered to be possible SRE species, although with low likelihood of actually being SREs (Rank 1). The desktop review also identified two listed species and 13 priority invertebrate species as possibly occurring within the Proposal on the basis of their habitat preferences

It was concluded on the basis of the relatively large list of listed and priority species possibly occurring in the vicinity of the Proposal, the relatively large list of SRE or possible SRE species, and the occurrence of two potential SRE habitats that a pilot survey of the Proposal area for SRE and listed/priority species was warranted.

The specific objectives of the pilot survey reported here, in conjunction with the earlier desktop survey, were:

- To determine the extent of SRE communities occurring, or likely to occur, within the Proposal.
- To identify any listed invertebrate species that may occur within the Proposal and to determine whether such species actually occur there.
- To evaluate the likelihood of threats to SRE and listed invertebrate species arising from mining within the Proposal.

The recognized SRE *Bothriembryon perobesus* and five possible SRE species were collected during the pilot survey compared with the two listed and 13 possible SREs identified in the larger search area surrounding the Proposal. *Bothriembryon perobesus* was collected as a single dead specimen outside

the area of disturbance. All five possible SRE species were collected outside the Proposal. Furthermore, available information suggests that none of the five possible SRE species collected during the survey is likely to actually be an SRE species. Consequently, it is considered that the threat to SRE species from Proposal development is very low.

Other than the Graceful Sun Moth (listed under the Commonwealth *Environmental Protection and Biodiversity Conservation Act 1999*) and snail *Bothriembryon perobesus* (a Priority 3 species under a State process), no listed or priority species was collected during the pilot survey. Fifty-five Graceful Sun Moths were collected in the vicinity of the Proposal but only one of which was recorded within the Proposal itself and that was outside the area proposed to be mined. The vast majority of Graceful Sun Moth specimens were collected from suitable habitat to the west of the Proposal and it is unlikely that the Proposal area is important for the species. *Bothriembryon perobesus* was found only outside the area of Proposal disturbance. Consequently, it is considered unlikely that any listed or priority occurs within the disturbance area of the Proposal and that the threat to such species from Proposal development is low.

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1. INTRODUCTION

Tronox Management Pty Ltd (Tronox) (previously Tiwest Pty Ltd) has operated the Cooljarloo mineral sands mine 175 km north of Perth since 1989 (Figure 1.1). The mine was authorised by the Western Australian Minister for the Environment in 1988 (under Ministerial Statement 37). The mine has subsequently been modified by the following expansions:

- Dredge and/or dry mining of ore bodies 27 200 and 28 000 in the southern portions of the tenement (Ministerial Statement 557); and
- Dry mining of the Falcon resource in the northern part of the tenement (Ministerial Statement 790).

The remaining dredge mine life of the approved Cooljarloo mine is approximately 15 years and Tronox now proposes to develop additional resources to the west of the current operations to extend the Cooljarloo mine life. The additional resources are known as Cooljarloo West (the Proposal) (Figure 1.1). The Proposal lies within the northern end of the Swan Coastal Plain Bioregion, in close proximity to the Lesueur Sandplain Subregion of the Geraldton Sandplains Bioregion.

Short range endemic (SRE) invertebrate species are defined in the Environmental Protection Authority's (EPA) 2009 Guidance Statement No. 20 as '*terrestrial and freshwater invertebrates that have naturally small distributions of less than 10,000 km²*'. In practice, assessment of risk to SRE species in Western Australia is focussed on up to 10 groups of terrestrial invertebrates (the SRE Groups) that are characterised by having high proportions of SRE species. The SRE Groups include some families of land snails (Gastropoda), freshwater mussels (Bivalvia), scorpions (Scorpionida), trapdoor and wall crab spiders (Araneae), false scorpions (Pseudoscorpionida), slaters (Isopoda), centipedes (Chilopoda), millipedes (Diplopoda), velvet worms (Onychophora) and megadrile earthworms (Oligochaeta) (EPA 2009). Their restricted ranges are often the result of events that fragmented historically broader distributions, such as the extensive flooding of inland Australia during the Cretaceous and progressive climatic aridification since the Miocene (Harvey 2002). As a result of drying, faunal groups originally associated with historically damp conditions tend to be restricted to relictual islands of cooler more humid habitats such as caves, rock piles, springs, southern slopes, vegetated gorges and drainage channels (Harvey 2002; EPA 2009). Over time, habitat fragmentation has sometimes led to speciation and an array of distinct taxa where previously there was one species. In addition to restricted ranges, SREs are characterised by limited capacity for dispersal, confinement to discontinuous habitats, slow growth rates, and low fecundity; all of which make them vulnerable to disturbance (Harvey 2002; Ponder and Colgan 2002).

SREs were not assessed under the environmental impact assessments of the existing Cooljarloo mine operations. However, desktop assessments were recently undertaken to assess the potential for SRE species to occur within the Proposal and the Falcon project (Bamford 2010; Bennelongia 2012).

The following report collates existing information on potential SREs, priority and endangered invertebrates, and the habitat types of these species. It evaluates the likelihood of SREs and other 'conservation significant' invertebrate species being present within the Proposal.

The specific objectives of the surveys reported here, in conjunction with the earlier desktop survey (Bennelongia 2012), were:

- To determine the extent of SRE communities occurring, or likely to occur, within the Proposal.
- To identify any listed invertebrate species that may occur within the Proposal and to determine whether such species actually occur there.
- To evaluate the likelihood of threats to SRE and listed invertebrate species arising from mining within the Proposal.

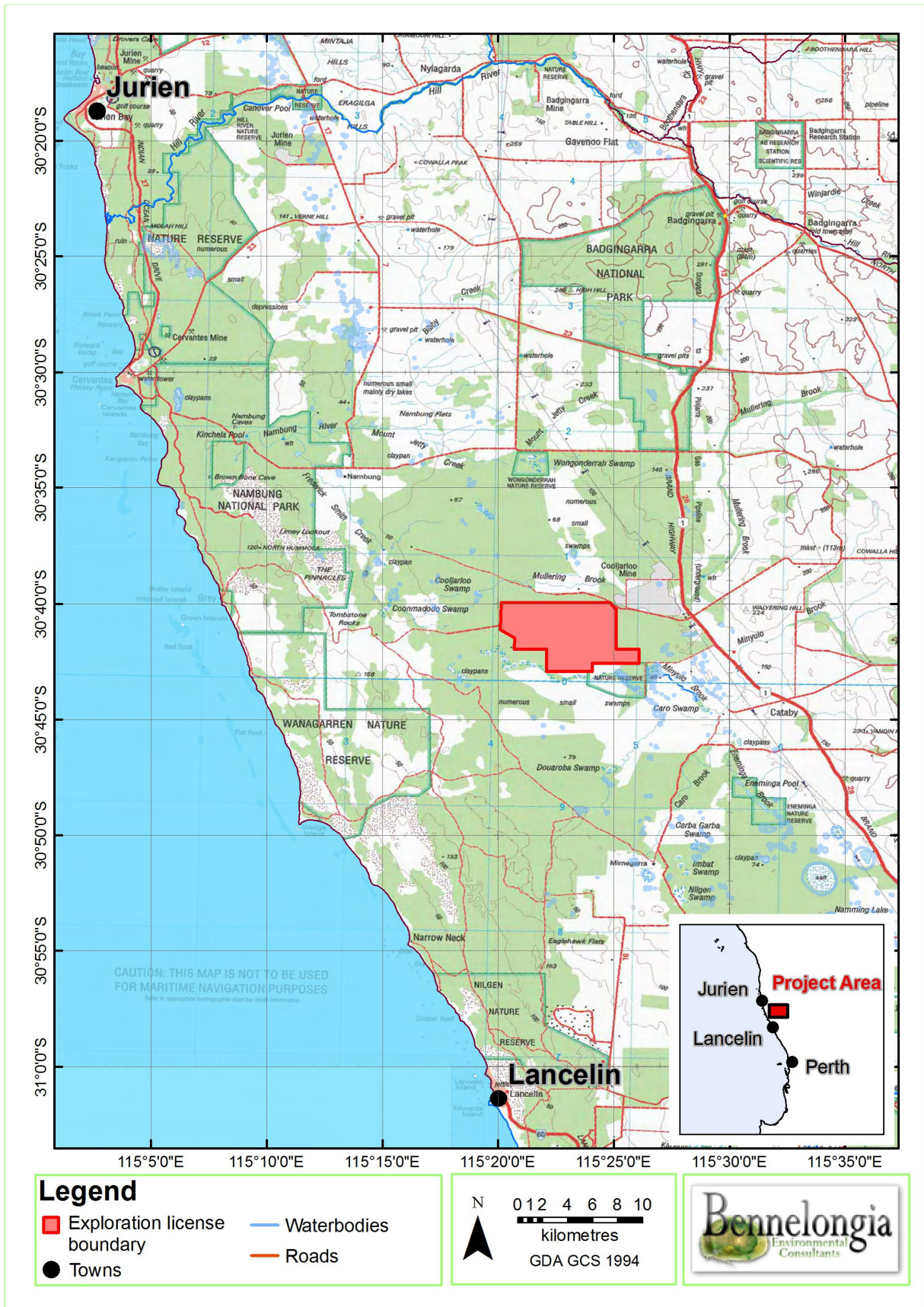


Figure 1-1. Location of the Proposal on the Northern Neck Swan Coastal Plain.

1.1. Description and Potential Impacts of the Proposal

The Proposal comprises three orebodies west of the existing Cooljarloo mine: namely, Harrier, Kestrel and Woolka (49.2, 83.6 and 210.4 ha, respectively). It is proposed that all three orebodies will be dredge-mined, as will corridors between the orebodies comprising roughly 35.7 ha. Key components and activities of the dredge-mining process include:

- Dredging (ore excavation) in an artificial pond, with the ore being pumped in slurry form to a floating concentrator.
- Washing and separating of ore via specific gravity to isolate the heavy mineral sands from tailings.
- Progressive backfilling of tailings into mined out areas to create the final post-mining landform.
- Obtaining water for processing from local groundwater, causing drawdown of groundwater around production bores.

In addition to the mining process, disturbance will result from relocating the dredge and potentially also the processing plant. The dredge will be relocated from the Cooljarloo mine to Cooljarloo West and back again by floating it along a 6 km channel. It is likely the channel will be 100 m wide and cover an area of 60 ha. In addition, there will be associated power lines, a pipeline and an access road. The pits, channel and infrastructure are likely to cover 378.9 ha. Further disturbance will be caused by possible clearing of up to 2 km around the orebodies and channel (but within the Proposal) for associated stockpiles and infrastructure. This cleared area may occupy up to 1331.1 ha, with the estimated total area of impact being 1710.0 ha.

The groundwater drawdown associated with proposed mining developments within the Proposal is yet to be modelled and the spatial extent of any drawdown is not known at this stage. If spatially extensive drawdown occurs as a result of the Proposal (in addition to potential drawdown from already-approved projects in the vicinity of the Proposal), it may have the potential to impact on groundwater-dependent vegetation. The watertable is relatively close to the surface in much of the Proposal (about 5-15 m below ground level; WorleyParsons 2013) and the impact on vegetation is currently being assessed.

For the purpose of assessing the effect on SRE species, two types of mine-related impacts are recognised in this report:

- *Primary Impacts* from proposed mining have the potential to threaten the persistence of SRE species through direct removal of habitat.
- *Secondary Impacts* reduce population densities rather than threaten species persistence. Reduction in the quality of SRE fauna habitat as a result of introduction of weeds and soil pathogens and changes to fire regimes are examples of secondary impacts.

Habitat loss is expected to occur as a result of:

- Land clearing for mining, stockpiles and infrastructure.
- Undefined but possible impacts on phreatophytic vegetation resulting from anticipated groundwater drawdown within the area surrounding the central mine area as a result of dredging and in the borefield to supply processing water.

2. DESKTOP REVIEW

A desktop review assessed whether any conservation listed invertebrate species or significant SRE communities were likely to occur within the Proposal (Bennelongia 2012). The likelihood of listed invertebrate species occurring within the Proposal was assessed by examining Department of Environment and Conservation (DEC) threatened and priority fauna lists for invertebrate species that occur in vegetation or landforms similar to those in the Proposal. The likelihood of SRE groups occurring within the Proposal was assessed by compiling records of species (mostly in the Western Australian

Museum database) belonging to SRE groups within a 50 by 50 km search area around the Proposal. Characterisation of local SRE habitat within a regional context was also used to further assess the potential for conservation significant SRE species to occur within the Proposal.

2.1. Potential SRE and Listed Species within the Proposal

One endangered invertebrate species listed under the Commonwealth *Environmental Protection and Biodiversity Conservation Act 1999* (EPBC Act), the Graceful Sun Moth (GSM) (*Synemon gratiosa*), was considered very likely to occur within the Proposal as its host plant species, *Lomandra hermaphrodita* and *Lomandra maritima*, are present in multiple habitat types (Appendix 1; see Woodman 2009). A Schedule 1 threatened species listed under the State *Wildlife Conservation Act 1950* (WCA Act), the bee *Neopasiphae simplicior*, may possibly occur within the Proposal (Appendix 1). Thirteen priority species are also known to occur in habitat with varying degrees of similarity to that in the Proposal (Appendix 1, see Bennelongia 2012 for information about conservation legislation and explanation of listing categories). The priority species consisted of molluscs (2 species), insects (10 species) and spiders (1 species).

The Museum database had records of 72 species belonging to ten SRE groups in the search area. Applying the SRE classification process outlined in Appendix 2 to the 72 species suggested, there is one recognised SRE species and 14 Rank 1 Possible SRE species. Rank 1 species are recognised as the least likely to be SREs out of the three categories of possible SRE species (i.e. usually species in this group are not actually SREs). The known SRE species was the gastropod *Bothriembryon perobesus*, and the Rank 1 species included spiders (2 species), scorpions (2 species), millipedes (6 species), gastropods (1 species) and insects (1 species) (Appendix 3).

2.2. Habitat Characterisation

Review of information in previous survey reports (Bamford 2010), orthophotos and climate data suggested that there are areas of prospective SRE habitat within the Proposal. These include seasonally damp swales, mound springs and riparian vegetation associated with other hydrological features, and a few small, gentle slopes (Bennelongia 2012). The riparian habitat associated with rivers and drainage lines is reasonably well connected in comparison with the less connected patches of potential SRE habitat in swales and other depressions. To the north and south of the Proposal there is extensive habitat fragmentation, and the habitat features listed above may be poorly represented outside of the Proposal in a natural condition.

2.3. Rationale for field survey

Given the likely occurrence of at least one listed species and some SRE species within the Proposal, it was recommended that field survey be conducted to support the assessment of impacts of the proposed development on SREs and listed invertebrates (see EPA 2009). It was considered that a pilot-scale survey for SREs would be adequate to assess the level of threat to SRE species from the Proposal because:

- The likelihood of potential SRE habitats occurring in and being confined to the Proposal area is low.
- Relatively few SRE species have been recorded in the vicinity of the Proposal.
- The likely area affected directly by vegetation clearing is considered relatively small considering that the host landscape lacks strong topographic features that might restrict the occurrence of SRE habitats.

Given the conservation significance of the endangered GSM and the high likelihood of it occurring within the Proposal, it was determined that a full-scale targeted survey was required for this species (Bishop

2010a). Ad hoc surveys were undertaken to determine whether the other listed and 13 priority species occur within the Proposal.

3. METHODS

3.1. Pilot Scale Survey for SREs and Listed Species

The approach and methods used in the field survey for SRE species in a Study Area covering the Proposal and near vicinity up to 19 km from the Proposal boundary were based on EPA Guidance Statement 20 (2009). The approach for listed and priority species was based on relevant literature for each species at the same sites as for SREs, except for GSM (see Section 3.2).

Sample effort for SRE species was concentrated on drainage basins/flats supporting medium forests, which is not a common habitat in the Proposal but was considered to be a potential SRE habitat (Table 3.1, Figures 3.1 and 3.2). Some sampling also occurred in stabilised sand dunes supporting woodlands over heath (a non-prospective SRE habitat within the Proposal) to document the pattern of species distributions across the landscape.

Ten SRE Groups were targeted in the survey: land snails, scorpions, trapdoor spiders, wall crab spiders, false scorpions, slaters, centipedes, millipedes, earthworms and velvet worms (see Appendix 3 and Bennelongia 2012).

Table 3.1. Location and habitat of survey site and survey type.

Survey site	Latitude	Longitude	Location	Survey intensity	Habitat(s)	
					Landform*	Broad vegetation types
Site 01	-30.67186	115.35836	Impact	Moderate	SS	woodland, heath
Site 02	-30.68194	115.35283	Impact	Moderate + light trap	SS	forest, woodland, heath
Site 03	-30.69369	115.40822	Impact	Comprehensive	SS	woodland, heath
Site 04	-30.67253	115.41436	Impact	Moderate	SS	heath
Site 05	-30.67289	115.40033	Impact	Moderate	SS	woodland, heath
Site 06	-30.64969	115.34522	Reference ¹	Moderate	DF	thicket
Site 07	-30.53078	115.22061	Reference	Moderate	SS; DF	woodland, heath; thicket
Site 08	-30.54144	115.22503	Reference	Moderate	DF	thicket, samphires
Site 09	-30.75739	115.43578	Reference	Moderate	SS	woodland, heath
Site 10	-30.60664	115.29167	Reference ¹	Moderate	SS	woodland, heath
Site 11	-30.77122	115.60858	Reference	Ad hoc	GS	heath
Site 12	-30.55581	115.31142	Reference	Ad hoc	DF	thicket, heath
Site 13	-30.66536	115.46706	Reference	Ad hoc	DF	thicket
Site 14	-30.71383	115.50853	Reference	Ad hoc	DF	forest, grassland
Site 15	-30.65572	115.35800	Reference ¹	Light trap	SS	woodland, heath
Site 16	-30.67561	115.37336	Impact	Light trap	DF	heath
Site 17	-30.55619	115.35206	Reference	Ad hoc	DF	forest, sedges
Site 18	-30.74783	115.55900	Reference	Ad hoc	DF	forest, grassland
Site 19	-30.64739	115.35897	Reference ¹	Ad hoc	DF	heath
Site 20	-30.67978	115.34556	Impact	Light trap	SS	woodland, heath
Site 21	-30.67206	115.40303	Impact	Light trap	SS	woodland, heath
Site 22	-30.74419	115.31897	Reference	Light trap	PD	heathland (<i>Lomandra</i>)
Site 23	-30.67203	115.40239	Impact	Ad hoc	SS	woodland, heath
Site 24	-30.68536	115.31364	Reference	Ad hoc	SS	heath
Site 25	-30.67103	115.40531	Impact	Ad hoc	SS	forest, woodland, heath

*SS, stabilised sand dunes; DF, drainage basins/flats; GS, Gingin Scarp; PD, parabolic dunes. ¹inside the Proposal but outside proposed mining areas.

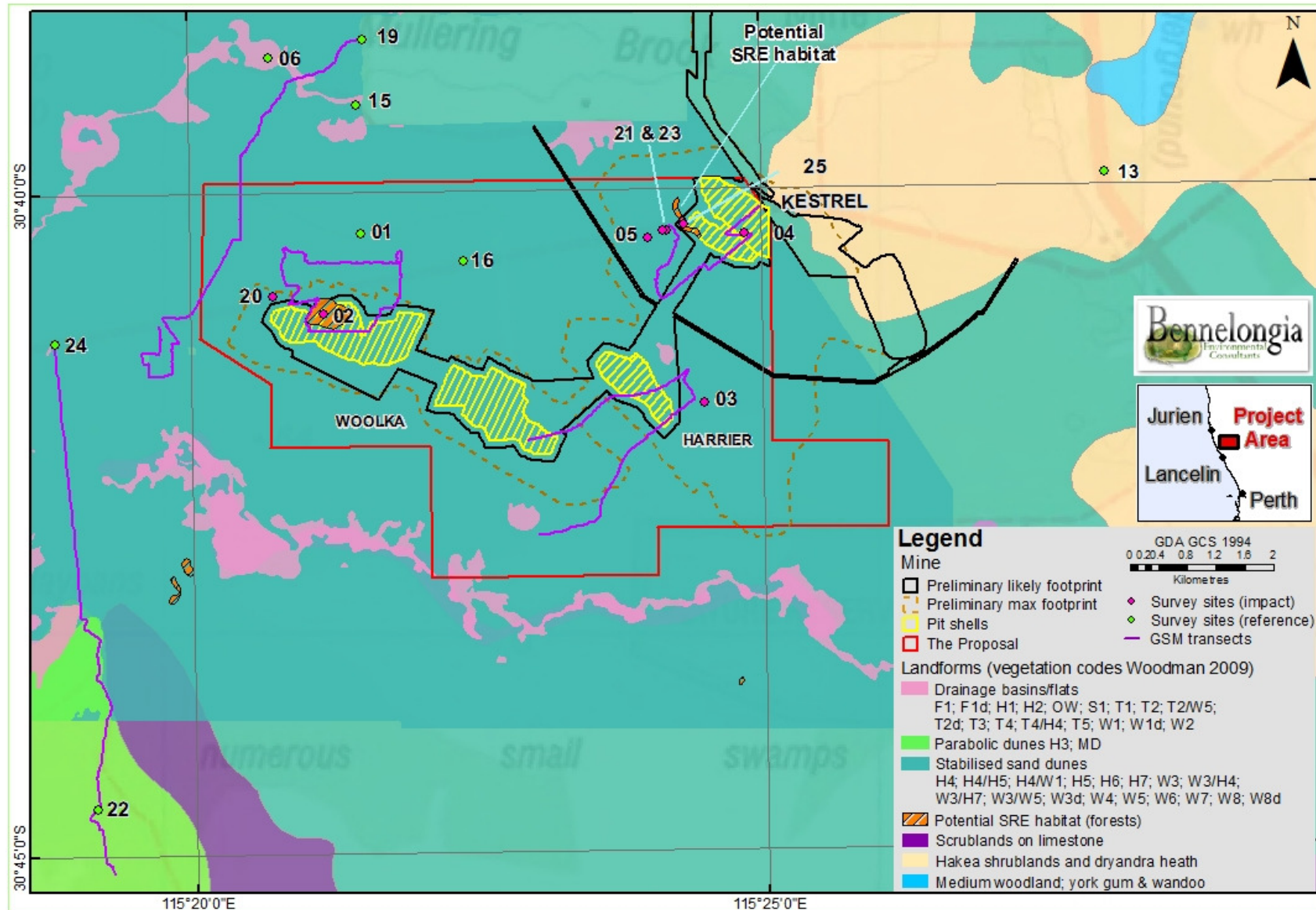


Figure 3-2. Detail of sampling within the Proposal.

3.1.1. Sampling effort

A total of 25 sites were sampled for SREs and priority or listed species. Three field trips were conducted from 29 October to 3 November, 17 to 19 December 2012 and 7 to 13 March 2013. This includes the time of peak activity (spring) for many of the listed species. One site was sampled comprehensively for SREs and listed species, nine were sampled at moderate intensity and ten at an ad hoc level (hand foraging only). Selected listed or priority species were sampled at a further five sites with light traps (Table 3.1).

Sampling effort at each comprehensively sampled site comprised 10 wet pit traps, 10 mixed soil and litter samples, hand foraging and other sampling techniques. Moderate intensity sampling involved five wet pit traps, five mixed soil and litter samples and hand foraging. Further details on sampling methods are provided below in Section 3.1.2. Photos of the sites are provided in Appendix 4. All sampling occurred within 200 m of site centroids.

3.1.2. Sampling methods

Details of sampling methods are given below:

- 1) Wet pit traps were placed 20 to 100 m apart and left open for seven weeks. Each trap comprised a 300 mm length of cylindrical PVC (110 mm diameter) with a white plastic bucket lid for a roof, which was attached to, and raised 5-20 mm above, the trap using metal brackets. The lid minimised the drift of debris and access by vertebrates into the traps. A tight-fitting polypropylene jar inside the trap was filled with 800 ml of propylene glycol to preserve all invertebrates that fell into the trap. The traps were distributed among the range of microhabitats present at the site. This included areas of accumulated litter in shady areas such as beneath trees, shrubs and near logs and out in the open.
- 2) Mixed soil and litter samples were collected from a representative range of microhabitats. Samples were placed in calico bags and transported live to the laboratory.
- 3) Hand foraging consisted of searching crevices and under boulders, logs and bark in a range of microhabitats, especially where litter had accumulated. Vegetation and flowers were swept-netted for priority listed invertebrates. Numbers of trapdoor spider burrows were counted, representative burrows were excavated and specimens within them were retained to link species with burrow morphologies. Cup traps were set at the entrances to scorpion burrows and checked each morning. The cup traps were removed at the end of the field trip or once an animal was caught. All areas within a site that displayed some variation in habitat characteristics were searched. Invertebrates caught while foraging were preserved in 100% ethanol and stored for four days below 4°C.
- 4) Ultraviolet light traps were set overnight from 1700 to 0600. During the October/November survey, traps were set at sites 02 and 15 for five and four consecutive nights, respectively. In the December field trip, one light trap was set at Site 16 for two nights. During the March fieldwork, traps were set for two nights at sites 21 and 22, and one night at site 20.

3.1.3. Sample Sorting and Species Identification

The contents of wet pit traps were washed and sieved using a 250 µm base sieve that let propylene glycol and fine debris pass through but retained all animals. The retained samples were sorted under a dissecting microscope to extract fauna specimens belonging to the target invertebrate groups.

Soil and litter samples were sorted using two sieves (16 mm and 2 mm). Litter retained by the sieves was checked for fauna, and then discarded. The component of the sample passing through the 2 mm sieve was sorted under a MagiLamp™ and all fauna present were picked out.

All animals picked from samples were identified to Order level and all specimens belonging to target SRE Groups and priority or listed invertebrates were identified to species or morphospecies level using published and unpublished keys, unless damaged or otherwise unsuitable for identification. Specimens were dissected as required and viewed under dissecting and compound microscopes.

3.1.4. Habitat analysis

Relationships between the sites, based on plant diversity and percentage vegetation cover, were assessed using ordination routines in the Ginkgo software package (Ainsa 2005). Plant species cover values were square-root transformed to reduce the leverage of dominant species and associations were calculated using the Bray-Curtis dissimilarity matrix. Sites were projected into ordination space using non-metric multi-dimensional scaling.

3.2. Targeted GSM Survey

The approach and methods used in the targeted survey for GSM were conducted in accordance with the Department of Environment and Conservation (DEC) survey guidelines for GSM (Bishop *et al.* 2010a).

3.2.1. Sample Effort

Five transects were surveyed with a total survey length of 32 km. Three transects were selected within the proposed mining area at the Proposal, with a total length of 16 km. Two reference transects with a total length of 16 km were selected where *Lomandra hermaphrodita* was known to occur to match sampling efforts inside the proposed mining area (Figure 3.1 and Figure 3.2). The length of individual transects in areas proposed for mining varied according to the size of the area to be impacted (Table 3.3).

Each transect was surveyed four times on separate dates. It was determined that four repeat surveys were appropriate because of the dominance of heath and the good visibility through open low *Banksia* woodland.

Table 3.2. Survey areas and transect lengths.

Deposit	Survey Area	Transect Length	Broad Vegetation Types
Harrier	49.2 ha	6 km	Heathland; open low <i>Banksia/Eucalyptus</i> woodland
Kestrel	83.6 ha	4 km	Heathland; open low <i>Banksia/Eucalyptus</i> woodland
Woolka	210.4 ha	6 km	open low <i>Banksia/Eucalyptus</i> woodland
Reference 1		8 km	Heathland; open low <i>Banksia/Eucalyptus</i> woodland; Melaleuca thicket
Reference 2		8 km	Heathland

3.2.2. Survey Timing

The GSM survey was conducted from 7 to 13 March 2013, during the peak flight period of GSM. Within these dates, transects were mostly surveyed between 10 am and 3 pm when GSM is most active (Bishop *et al.* 2010a), although some surveys either began before 10 am or were not completed until close to 4 pm when temperatures exceeded 25°C. Each transect was surveyed in optimal conditions of sunny weather and winds below 18 km/h at least once.

3.2.3. Survey Methodology

A visual search for GSM was conducted within 10 m wide transects and all animals present were identified and recorded. A representative number of voucher animals were collected for final identification in the laboratory and lodgement at the WA Museum.

Weather conditions for each transect survey were recorded including air temperature, estimated cloud cover and wind speed and direction.

Ad hoc searching for Graceful Sun Moths was also carried out during the SRE survey and when relocating between transects.

3.3. Genetic Characterisation of Species

It is common for specimens to be collected in a life stage that is not amenable to species level identification based on morphology, e.g. the specimens may be juvenile or the wrong sex. In some cases to understand species boundaries and determine the ranges of potentially conservation significant species, DNA analysis was undertaken at the South Australian Museum.

3.4. Personnel

Bennelongia surveys were undertaken by Michael Curran, Sean Bennett, Jeremy Quartermaine and Grant Pearson. Samples were sorted by Michael Curran, Sean Bennett, Jeremy Quartermaine, Lucy Gibson, Mike Scanlon and Jane McRae. Identifications were made by Michael Curran, Dean Main, Jeremy Quartermaine, Sean Bennett and Jane McRae with assistance from specialist taxonomists as required (Table 3.4). Representative specimens of nearly all species in SRE Groups have been lodged with the Western Australian Museum.

Table 3.3. Specialist taxonomists who provided assistance with specimen identifications and SRE status.

SRE Group	Taxonomist	Affiliation
Isopods	Simon Judd	Private consultant
Pseudoscorpions	Mieke Burger & Amber Beavis	Western Australian Museum

3.5. Habitats Sampled

Two landforms occur within the Proposal – stabilised sand dunes and swales, which are mostly referred to in this report as drainage basins/flats (see Figure 3.1 and Figure 3.2). Three additional landforms occur outside the Proposal – limestone ridges, parabolic dunes and the Gingin Scarp. Habitats within the latter two landforms were sampled in an ad hoc way by foraging to document patterns of species distribution across the landscape. Parabolic dunes support the extensive vegetation type 1026 of Beard (1979) but this and the vegetation types on limestone and the Gingin Scarp are not prospective SRE habitats as defined by Harvey (2002) and EPA (2009).

Drainage basins and flats

The drainage basins and flats comprised either:

- *Melaleuca* thicket, occasionally with samphires fringing wetlands.
- Medium open/closed forest of *Eucalyptus camaldulensis* or *Melaleuca raphiophylla* over grassland or sedges.
- Heathland.

Medium open/closed forest is considered prospective SRE habitat. It is moderately well-connected but poorly represented across the Proposal. *Melaleuca* thicket and heathland are very well-connected and were considered unlikely to be prospective SRE habitat. Medium open/closed forest includes vegetation

codes S1, T1, T2, T3, T4 and T5 of Woodman (2009) (see photos of sites 06, 08, 12, 13 in Appendix 4). *Melaleuca* thicket includes W1, W2, F1 (sites 14, 17, 18 in Appendix 4); and heathland includes H1, H2 (photos of sites 07, 16, 19 in Appendix 4).

Stabilised sand dunes

- Low open woodland of *Banksia/Eucalyptus* over heath.
- Heathland (*Allocasuarina, Banksia, Melaleuca seriata, Hakea* and occasional *Nuytsia floribunda*).
- Medium open forest of *Melaleuca raphiophylla* over sedges, occurred in small patches associated with mound springs (Bamford 2009/Woodman 2009).

Open forest of *Melaleuca raphiophylla* over sedges and associated with mound springs is considered to be a prospective SRE habitat (see photo of site 02 in Appendix 4) and is represented by W4 (Woodman 2009). This habitat type is not well connected or represented in the Proposal. Low open woodland and heathland are akin to vegetation codes H4, H5, H6, H7, W2, W3, W5, W6, W7 and W8 as described by Woodman (2009) (see photos of sites 01, 03, 05, 07, 09, 10, 15, 20, 21, 23 in Appendix 4). These two habitats are not prospective SRE habitat as they are widespread and well-connected.

3.6. Rainfall during sampling

A total of 77.7 mm of rain was recorded between the 29 October to 19 December 2012 and SRE activity is likely to have been high during this sampling period.

4. RESULTS

4.1. Pilot Scale Survey

4.1.1. SRE species

A total of 489 animals belonging to ten SRE Groups and at least 42 species within those groups were collected. Based on available knowledge, 37 of the 43 species were considered not, or unlikely to be, SREs. The other six species included one recognised SRE and five species that were considered to be possible SRE species (Table 4.1) under the framework for determining SRE status outlined in Appendix 2. All five fitted the Rank 1 category of possible SREs, meaning the likelihood of these species actually being SREs is low. Thus, assignment of the species as SREs was precautionary. It should be noted that none of the 14 Rank 1 SRE species previously recorded in the search area was found in the Survey Area during the pilot survey.

Table 4.1. Species collected from SRE Groups within the Proposal and classified as possible SREs.

Higher Order	Species	No. Animals	Sites		Range (linear/notes)	Habitat*		SRE Status
			Impact	Reference		Landform	Vegetation	
Gastropoda								
Sigmurethra								
Orthalicidae	<i>Bothriembryon perobesus</i>	8		03	-	SS	fwh	P1
Crustacea								
Isopoda								
Armadillidae	<i>Acanthodillo</i> sp. B09	2	No	13	-	DF	t	R1
Philosciidae	<i>Trichorhina</i> sp. B14	4	No	13	-	DF	t	R1
Oligochaeta								
-	<i>Oligochaeta</i> sp.	1	No	14	-	DF	fg	R1
Arachnida								
Pseudoscorpionida								
Olpiidae	<i>Euryolpium</i> 'sp.'	2	No	08	-	DF	ts	R1
Chilopoda								
Geophilomorpha								
Mecistocephalidae	<i>Mecistocephalus</i> sp. B07	1	No	14	-	DF	fg	R1

* DF, drainage basin/flats; SS, stabilised sand dunes; f, forest; t, thicket; g, grassland; w, woodland; h, heath.

The purpose of the pilot survey was to confirm the conclusions of desktop review, rather than to conduct a complete inventory of SRE species in the Proposal and determine the conservation status of those species. Nevertheless, both impact and reference areas were sampled. The recognised SRE snail (and Priority 1 species), *Bothriembryon perobesus*, was collected within the impact area of the Proposal but is known from previous survey to occur outside the Proposal. All five Rank 1 SREs, *Acanthodillo* sp. B09, *Trichorhina* sp. B14, *Oligochaeta* sp., *Mecistocephalus* sp. B07 and *Euryolpium* 'sp.' were collected only from reference sites outside the Proposal (Table 4.1).

The five Rank 1 SRE species were collected from drainage basins/flats, comprising *Melaleuca* thickets or *Eucalyptus camaldulensis* over grasses. These habitats are continuous and well-connected outside the Proposal. *Bothriembryon perobesus* was collected as a single dead specimen from stabilised dunes, which are extensive outside the Proposal and are not considered to be a habitat likely to support SREs.

Further information on species in the different SRE Groups is given below:

4.1.2. Spiders

Three species of mygalomorph spiders were collected during the survey. These species occurred in habitat of stabilised sand dunes supporting woodlands and heath, which is widespread and well-connected outside the Proposal and is not considered prospective SRE habitat. A few specimens were not identified to morphospecies level as they were too juvenile. None of the potential SRE or listed mygalomorph spiders identified in the desktop survey was recorded during the field survey.

4.1.3. Pseudoscorpions

Pseudoscorpions were the second most diverse group collected, with at least seven species from four families. Several animals could not be identified to morphospecies level owing to the lack of taxonomic framework, including *Euryolpium* 'sp.'. This species was classified as potential Rank 1 SRE for two reasons: firstly, it was collected from only one location, albeit a single, well-connected habitat outside the Proposal and, secondly, there are no other records of *Euryolpium* within the search area.

4.1.4. Scorpions

Four *Lychas* specimens from the Buthidae family were collected during the surveys in non-prospective SRE habitat and they were not considered to be SREs. The buthid family contains many widespread species, three of which occur in the search area and are not SREs. No *Urodacus* or *Isometroides* scorpions were recorded.

4.1.5. Centipedes

Although some species of Geophilomorpha centipedes are SREs (Harvey 2002), two of the four species collected within the Proposal were widespread or recorded in non-prospective SRE habitat and were therefore not considered to be SREs. One species, *Mecistocephalus* sp. B07, was considered a Rank 1 SRE because it was collected at one location within a single, moderately well-connected habitat outside the Proposal. Seven other centipede species were collected from the families Scolopendromorpha, Lithobiomorpha, Scutigermorpha, all of which are widespread species and not SREs (Harvey 2002).

4.1.6. Millipedes

A single widespread millipede species, *Antichiropus whistleri*, was collected within the Proposal and this identification was confirmed using DNA sequencing (Dolman 2013). Polyxenid millipedes were also recorded, but are unlikely to be SREs (Harvey 2002).

4.1.7. Land Snails

Two species of *Bothriembryon* were recorded within the Survey Area, with a single specimen of the recognised SRE species, *Bothriembryon perobesus*, found within the impact area of the Proposal. It was collected at Site 03 (close to Harrier orebody) in the widespread stabilised sand dunes habitat. This is a Priority 1 species and also listed as Endangered C2b in the IUCN Red List of Threatened Species 2012. However, *Bothriembryon perobesus* has a linear range of more than 100 km across multiple habitats extends up to 50 km inland. Some widespread/cosmopolitan slugs and snails were also recorded and are not SREs.

4.1.8. Crustaceans

Isopods were the most diverse group recorded in the survey. Two species, *Acanthodillo* sp. B09 and *Trichorhina* sp. B14, were considered to be potential Rank 1 SREs. Most of the species occurred in high abundance and are known to be widespread. One aquatic amphipod species *Austrochiltonia subtenuis* was also recorded; it is a widespread species and not an SRE.

4.1.9. Worms

One individual earthworm was recorded outside the Proposal in drainage basins/flats supporting a *Eucalyptus camaldulensis* forest over grass. This habitat is well-connected but somewhat prospective for SREs. Species identification is currently in progress; for the present the worm is not considered to be an SRE although Western Australian earthworms are highly diverse and often small ranges (Allan Wills, DEC, pers. comm.).

4.2. Listed or Priority Species

Other than the GSM, which was surveyed separately (see below), only one of 14 listed or priority species (*Bothriembryon perobesus*) previously known from the search area were recorded during the pilot survey, despite a very large number of species (and nearly 7000 animals) from the associated classes or orders being collected (see Appendices 1, 3 and 5). The survey methodologies employed included techniques specific to each listed or priority species. In most cases, the species were expected to be collected and survey was precautionary. However, it is perhaps surprising that the cricket *Austrosaga spinifer* was not collected.

4.3. Targeted Graceful Sun Moth Survey

Fifty-five specimens of Graceful Sun Moth were recorded from the survey transects (Table 4.2). No specimens were recorded within the proposed mining activities in the Proposal. One specimen was recorded within the Proposal but outside the proposed mining activities. The remaining 54 animals were recorded along the two reference transects. Two animals were recorded on transect 2 (north of the Proposal) and the remaining 52 along transect 1 (to the west of the Proposal).

Reference transect 1 had the highest cover (7.5% by area) of *Lomandra hermaphrodita* of all transects (the northern half of this transect comprised no *Lomandra* compared to 5-30% *L. hermaphrodita* along the southern half). Woolka had the highest cover of *L. hermaphrodita* of transects within the proposed mining areas at the Proposal (2% by area).

Table 4.2. GSM survey transect results.

Transect	Site	GSM count	Lomandra cover	Landform	Vegetation types*
1	Woolka	1	2%	Stabilised sand dunes	Open <i>Banksia/Eucalyptus</i> woodland over heath
2	Harrier	0	< 0.1%	Stabilised sand dunes	Heathland type 1; open low <i>Banksia/Eucalyptus</i> woodland over heath
3	Kestrel	0	< 0.1%	Stabilised sand dunes	Heathland type 1; open low <i>Banksia/Eucalyptus</i> woodland over heath
4	Ref #1	2	0.5%	Stabilised sand dunes; drainage basins/flats	Heathland type 1; Melaleuca thicket; open low <i>Banksia/Eucalyptus</i> woodland over heath
5	Ref #2	52	7.5%	Parabolic dunes; stabilised sand dunes	Heathland type 1; heathland type 2

*Heathland type 1, *Allocasuarina*, *Banksia*, *Melaleuca seriata*, *Nuytsia*, *Hakea*; heathland type 2, *Lomandra hermaphrodita*, *Melaleuca seriata*, *Regelia ciliate*, *Acacia lasiocarpa* var. *lasiocarpa*.

4.4. Habitat Characterisation

Prior to survey, there were considered to be two potential SRE habitats within the Proposal. These were:

- Forest on drainage basins/flats comprising 4.81 ha (Woodman vegetation codes W1 and W2).
- Open *Melaleuca raphiophylla* forest on stabilised dunes comprising 18.0 ha (vegetation codes W4 and the edge of a patch of H4 on the northwestern edge of the Kestrel orebody) (see Figure 3.1 and Figure 3.2).

Sampling results suggested SRE species are more likely to occur in drainage flats than stabilised with five of the six SRE or possible SRE species occurring there. The exception was *Bothriembryon perobesus* which, although considered to be an SRE species, has a known range that is large for an SRE. *Bothriembryon perobesus* occurred in stabilised dunes as was expected from previous records of the species. Three of the possible SRE species in drainage basin/flats occurred in thickets; two occurred in open forest over grassland.

The pattern of occurrence of all species in SRE Groups was examined for the 10 sites sampled intensively or moderately. Number of species collected at a site ranged from five at site 08 in drainage basin/flats to 18 at site 05 on stabilised dune. There was no obvious relationship between species richness and landscape, vegetation or amount of litter (Appendix 6).

Multidimensional analysis based on the floristics of the 10 comprehensively or moderately well sampled sites showed that sites 04 (heath only) and 08 (thicket and samphire) are floristically quite different from the other sites (Figure 4.1, Appendix 6). Sites 06 (thicket) and 07 (woodland, heath, thicket) also appear to be different. The differences are probably largely attributable to landscape, with sites 06 and 08 being in drainage basin/flats and 07 being a mix of drainage basin and stabilised dune.

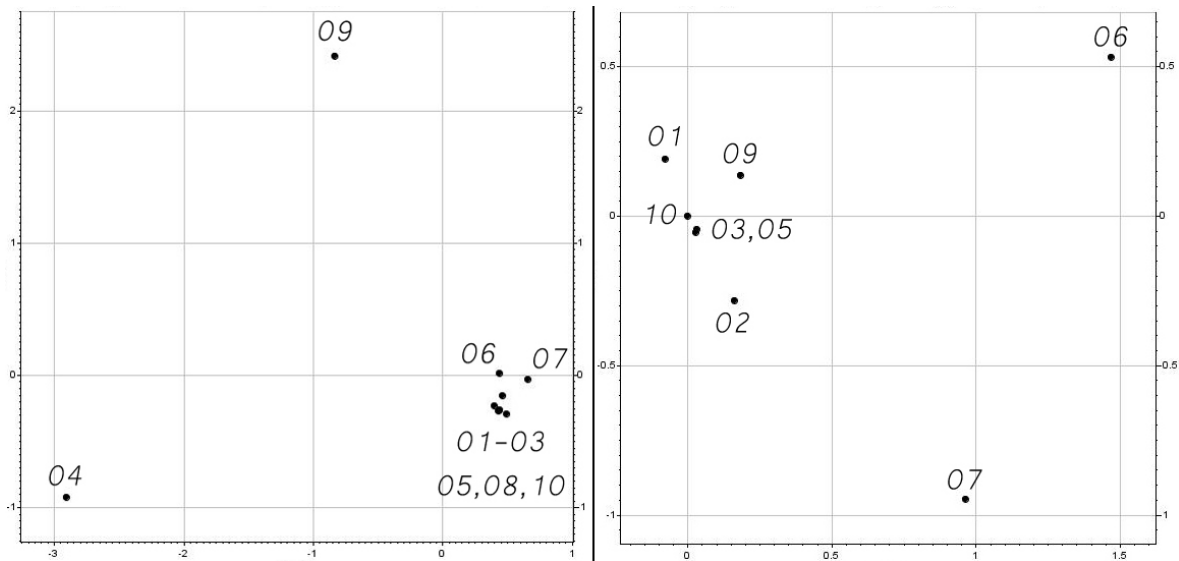


Figure 4-1. Ordination of sites based on floristics.

All sites in left hand ordination. Outlying sites 04 and 09 removed in right hand ordination to examine relationship between other sites.

It was also considered possible that GSM would occur at the Proposal because of the occurrence of species of *Lomandra*. In fact, all but three records of GSM were from the westernmost (reference) transect where the abundance of *Lomandra hermaphrodita* was greatest. Possibly there is a threshold cover value of *Lomandra*, below which GSM rarely occur.

5. DISCUSSION

The only listed or priority invertebrate species known to occur within the Proposal are GSM and *Bothriembryon perobesus*. It is considered unlikely that any other listed or priority species occurs within the Proposal. No SRE or possible SRE species is known to occur within the proposed area of disturbance at the Proposal and, based on results of the desktop and pilot surveys, it is considered unlikely that any SRE species do occur there.

SRE species

The desktop review identified 72 species belonging to ten SRE Groups within in a 50 by 50 km search area around the Proposal. Of these species, one is a recognized SRE and 14 are Rank 1 SRE species (Appendix 3). The pilot scale survey collected the recognized SRE species *Bothriembryon perobesus* but none of the 14 Rank 1 species. A further five Rank 1 species were present among the 43 species belonging to SRE Groups collected during the pilot survey.

The very limited overlap in the species lists of the desktop review and pilot survey suggests that the 115 species recorded by the two surveys under-represents the number of species belonging to SRE Groups in the vicinity of the Proposal. On the other hand, the one SRE and 19 Rank 1 species identified in the desktop review and pilot survey are a substantial over-estimate of the number of actual SRE species in the vicinity of the Proposal. This is because the Rank 1 SRE category is an extremely precautionary one that principally reflects lack of life history information about species collected in very low numbers rather than likelihood of a species being an SRE. More accurate identification of possible SRE species is unlikely until accumulated survey information provides substantially more life history information for the Western Australian fauna than currently exists.

The pilot survey showed there is low likelihood of any SRE species occurring in the area of mining. If, however, an SRE species does occur in the proposed disturbance area there is very low likelihood that its conservation status will be affected by development because of the moderately well connected nature of all habitats and vegetation types.

Habitat characterisation

The pilot survey showed habitat characterisation had limited value for predicting the occurrence of possible SRE species. The only recognized SRE species collected (*Bothriembryon perobesus*) occurred in stabilised dunes, a widespread habitat that lacked any of the characteristics outlined as suitable for SREs in EPA (2009). The Rank 1 species were all found in drainage basin/flats, which may be viewed as a prospective SRE habitat (although not emphasized in EPA 2009). However, this habitat is not a tightly defined one and often intergrades into stabilised dunes.

Listed/priority species

Only two of the two listed and 13 priority species that it was considered may possibly occur in the Proposal were collected. These were the GSM and *Bothriembryon perobesus*.

Fifty-five GSM were collected in the vicinity of the Proposal but only one animal was recorded within the Proposal itself. This was outside the proposed area of mining. The vast majority of GSM specimens were collected from the westernmost reference transect in stabilised parabolic dunes, which had higher abundance of *Lomandra hermaphrodita* than other transects. The single transect within the Proposal where a GSM was recorded had more *L. hermaphrodita* cover than the other two impact transects.

The pilot survey showed that GSM is abundant in the vicinity of the Proposal but is uncommon within the Proposal. It is unlikely that GSM occurs within the proposed disturbance area and the conservation status of the species will not be affected by development.

Occurrence of *Bothriembryon perobesus* is discussed above. Its conservation status will not be affected by development.

Despite considerable and varied survey effort for other listed or priority species, none was collected and it is concluded that the species are unlikely to occur within the Proposal. In many cases (e.g. the bee *Hylaeus globuliferus*), the species were included in surveyed because they are known from habitat similar to that in the Proposal area but the current known distributions of the species are well removed from the Proposal. On the basis of current information, it is unlikely that development will affect the conservation status of any listed or priority species.

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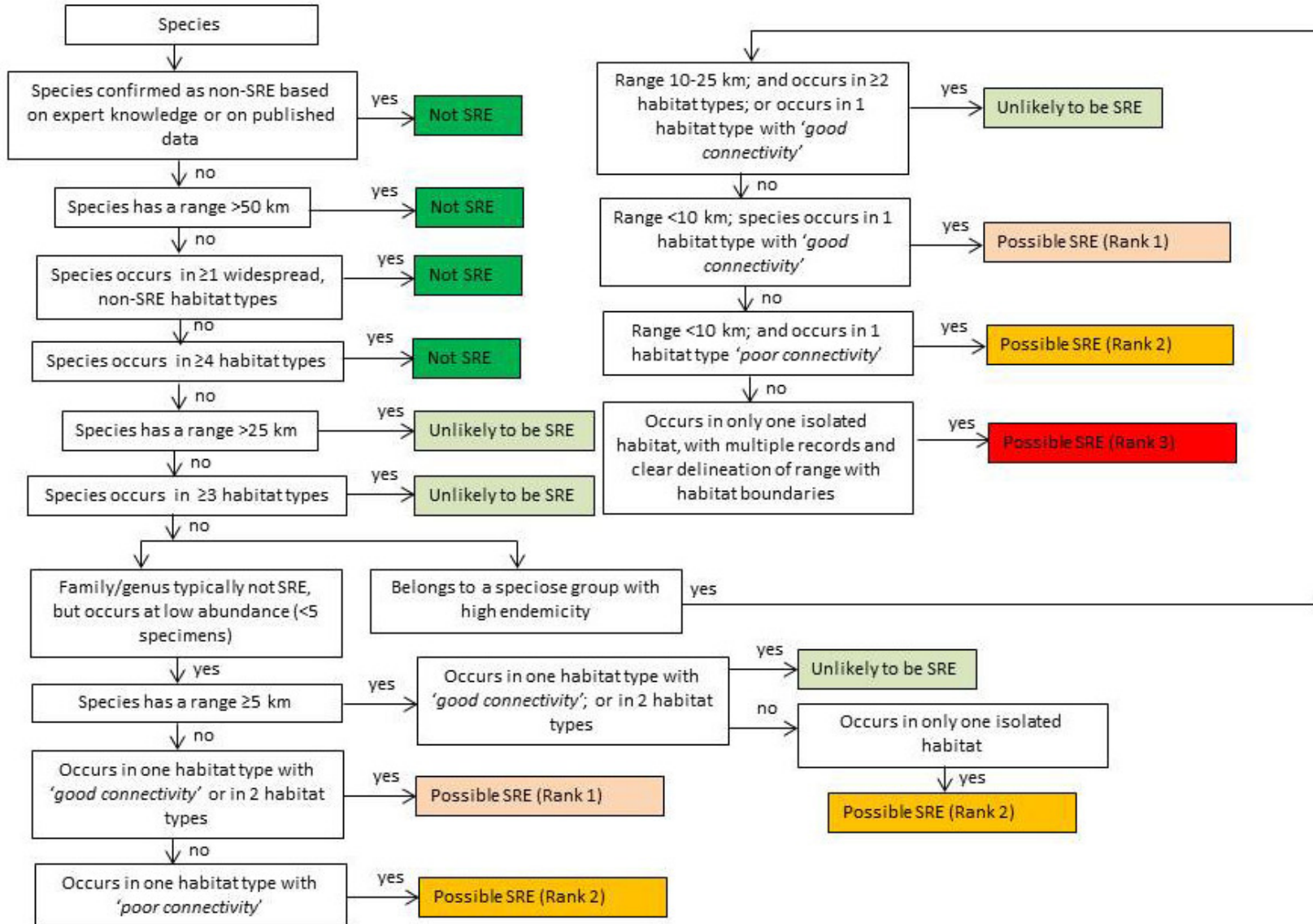
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APPENDICES

Appendix 1. Listed threatened & priority species of the Swan Coastal Plain & Midwest that may occur in the Proposal.

Species	DEC	IUCN (or EPBC)	Habitat	Locality/Distribution	Likelihood of occurrence	Expected habitat type in the Proposal
Molluscs						
<i>Bothriembryon perobesus</i>	P1	Endangered C2b ver 2.3	Guilderton Sandplain	40 km SSE Lancelin (Breure 2011)	Likely	Stabilised sand dunes
<i>Westralunio carteri</i>	P4	Least Concern ver 3.1	Freshwater rivers of the southwest (Klunzinger <i>et al.</i> 2012)	Restricted to the Moore & Kent River Basins, and Goodga and Waychinicup Rivers	Unlikely	-
Insects						
<i>Austroconops mcmillani</i>	P2	-	Selected wetlands from Yanchep and Darkan	Yanchep, Armadale, Darkan wetlands (Borkent and Craig 2004)	Possible	Drainage basins/flats
<i>Austromerope poultoni</i>	P2	-	Jarrah forest and sandplain (Faithfull, Majer <i>et al.</i> 1985)	SE Pinjarra and S Manjimup	Possible	Stabilised sand dunes
<i>Austrosaga spinifer</i>	P3	Vulnerable B1+2bd ver 2.3	Genus occurs in heath habitats	7.5 km east Cervantes (Rentz 1993)	Very likely	Heath over stabilised sand dunes
<i>Hylaesus globuliferus</i>	P3	-	<i>Adenanthos cygnorum</i> , <i>Banksia attenuata</i>	Neerabup and Melaleuca Conservation Park; across the south-west (PaDIL 2012)	Likely	<i>Banksia</i> woodland over stabilised sand dunes
<i>Leioproctus contrarius</i>	P3	-	<i>Gompholobium aristatum</i> and possibly <i>Leschenaultia stenosepala</i> (ATA Environmental 2003) in Jarrah/Wandoo forest	Perth and Stirling Range (Michener 1965)	Unlikely	-
<i>Neopasiphae simplicior</i>	EN	Critically endangered (EPBC)	<i>Banksia</i> woodland, specifically flowers of <i>Goodenia filiformis</i> , <i>Lobelia tenulor</i> , <i>Angianthus preissianus</i> , <i>Vellia</i> sp.	Forrestdale & Welshpool, Port Gregory (DSEWPC 2012)	Unlikely	-
<i>Synemon gratiosa</i>	P4	Endangered (EPBC)	<i>Lomandra hermaphrodita</i> and <i>L. maritima</i> ; parabolic dunes, followed by <i>Banksia</i> woodland (Bishop <i>et al.</i> 2010b)	Near the coast from Bunbury to Leeman	Very likely	Parabolic dunes; <i>Banksia</i> woodland over stabilised sand dunes
<i>Phasmodes jeeba</i>	P2	-	Coastal heath, amongst grasses and low herbaceous vegetation, especially where there is flower	19 km NNE Jurien (Rentz 1993)	Unlikely	-
<i>Psacadonotus seriatus</i>	P1	Vulnerable B1+2bd ver 2.3	Low coastal heath	Champion Bay, Geraldton (Rentz 1993)	Unlikely	-
<i>Throscodectes xederoides</i>	P3	Endangered B1+2bd ver 2.3	Western sandplain; white sand and heath with <i>Banksia</i> spp.	68 km E Lancelin (Rentz 1985)	Possible	Heath over stabilised sand dunes
<i>Throscodectes xiphos</i>	P1	Endangered B1+2bd ver 2.3	Information unavailable, refer to <i>T. xederoides</i>	Jandakot, Perth (Rentz 1985)	Unlikely	-
<i>Trichosternus relictus</i>	P1	-	Under logs in <i>Eucalyptus</i> woods	Margaret River (Darlington 1953)	Unlikely	-
Spiders						
<i>Aganippe castellum</i>	P4	-	Flood-prone depressions, flats with myrtaceous shrub communities (Inglis 2008) and BIF ranges (Bennelongia 2011)	Avon Wheatbelt and Southern Cross IBRA subregions (Inglis 2008); 100 km NW. Kalgoorlie (Bennelongia 2011)	Unlikely	-

Appendix 2. Flow Chart of Criteria Used to Assess SRE Status



Appendix 3. SRE and possible SRE species recorded in the search area.

Higher Group	Species	IBRA7 subregion, Beard Vegetation Unit & Range/Conservation Significance	SRE Status	Source/ Reference	Likelihood of occurrence	Expected habitat type in the Proposal
Arachnida						
Araneae						
Barychelidae	<i>Idiommata</i> `sp. indet.`	SWA02, Bassendean, 1030	R1	WAM records	Likely	Low woodland; <i>Banksia attenuata</i> & <i>B. menziesii</i>
	<i>Synothele</i> `sp. nov.`	SWA02, Guilderton, 1026	R1	WAM records	Likely	Shrublands/heath
Idiopidae	<i>Aganippe</i> `MYG221`	GES02, Bassendean, 1030; one location	R1	WAM records	Likely	Low <i>Banksia</i> woodland over heath on stabilised sand dunes
	<i>Aganippe</i> `MYG222`	GES02, Bassendean, 1030; two locations	R1	WAM records	Likely	Low <i>Banksia</i> woodland over heath on stabilised sand dunes
Scorpiones						
	<i>Urodacus</i> `SCO007, bullsbrook`	SWA02, Jurien, 1029; one location	R1	WAM records	Unlikely	Scrublands on limestone
	<i>Urodacus</i> `sp. nov. Gairdner Range`	GES02, Le Sueur, 1031; one location	R1	WAM records	Possible	Shrublands/dryandra heath
Diplopoda						
Polydesmida						
Paradoxosomatidae	<i>Antichiropus</i> `cooljarloo 2`	GES02, Bassendean, 1030; one record	R1	WAM records	Very likely	Low woodland; <i>Banksia attenuata</i> & <i>B. menziesii</i>
	<i>Antichiropus</i> `DIP016`	GES02, Marchagee, 551; one record	R1	WAM records	Possible	Shrublands; <i>Allocasuarina campestris</i> thicket
	<i>Antichiropus</i> `Eneabba 2`	GES02, Bassendean, 1030; few records	R1	WAM records	Very likely	Low woodland; <i>Banksia attenuata</i> & <i>B. menziesii</i>
	<i>Antichiropus</i> `GI/UBS1`	SWA02, Guilderton, 1026; few records	R1	WAM records	Likely	Shrublands/heath
	<i>Antichiropus</i> `hamatus`	GES02, Marchagee, 551; few records	R1	WAM records	Possible	Shrublands; <i>A. campestris</i> thicket
Spirostreptida						
Iulomorphidae	<i>Podykipus</i> sp.	In the vicinity of the Proposal	R1	Bamford 2010	Very likely	Low <i>Banksia</i> woodland
Gastropoda						
Stylommatophora						
Bothriembryontidae	<i>Bothriembryon perobesus</i>	GES02, Gairdner, 4, Le Sueur, 1031; SWA01, Bassendean, 1035; SWA02, Guilderton, 129 & 1026, Jurien, 1029, Bassendean, 1030	SRE	Iredale 1939	Very likely	Stabilised sand dunes; Low <i>Banksia</i> woodland; <i>Hakea</i> shrublands/dryandra heath
	<i>Bothriembryon</i> sp. nov. 'North Wheatbelt'	Guilderton, 1026; Victoria Plains, 694; Probably undescribed species; 65 km NE. of Proposal	R1	WAM data	Possible	Medium woodland (York gum & salmon gum); shrublands/heath
Insecta						
Orthoptera						
Tettigoniidae	<i>Throscodectes xederoides</i>	JAF01, Mogumber, 4	R1	Michener 1965	Unlikely	Medium woodland; marri & wandoo

Appendix 4. Survey Photos
Pilot-scale survey





Targeted Survey



Appendix 5. Invertebrate Results of Pilot Survey

Classification	Species	No. Animals	Site(s) Impact	Reference	Specimen Sex(s)	Range (linear/notes)	Habitat Landform	Vegetation	SRE Status	Lodgement Reference
Arachnida										
Araneae										
Barychelidae	<i>Synothele</i> cf. <i>butleri</i>	1	03		♂	-	SS	wh	No	
	<i>Synothele</i> 'sp.'	2		19	J	-	DF	h	Unknown	
Nemesiidae	<i>Aname</i> cf. <i>mainae</i>	1	05		♀	-	SS	wh	No	
	<i>Aname</i> 'sp.'	2		09,10	J	-	SS	wh	Unknown	
	<i>Aname</i> sp. B01	3	03,05		♂	2.4 km	SS	wh	No	
Pseudoscorpionida										
Atemnidae	Atemnidae sp. B05	1		07	J	-	SS;DF	wh;t	No	
Chernetidae	Chernetidae sp. B05	20	03	09,10	♂ ♀ J	22 km	SS	wh	No	
	Chernetidae sp. B06	9	25	01,17	J	13 km	SS;DF	fwh;fs	No	
Chthoniidae	<i>Austrochthonius</i> sp. B05	4	02,03	08	♀ J	25 km	SS;DF	fwh;ts	No	
Olpiidae	<i>Beierolpium</i> 'sp. 8/4'	3	02	01,06	♂ ♀ J	4 km	SS;DF	fwh;t	Unknown	
	<i>Euryolpium</i> 'sp.'	2		08	♂	-	DF	ts	Unknown	
	<i>Indolpium</i> 'sp.'	1		10	J	-	SS	wh	Unlikely	
	Olpiidae sp.	5		07,08,10	J	-	SS;DF	wht;ts	Unknown	
Scorpionida										
Buthidae	<i>Lychas</i> sp.	4	02,05	10		-	SS	fwh	No	
Chilopoda										
Geophilomorpha										
Chilenophilidae	<i>Sepedonophilus</i> sp. B03	7	02,03	01,09		13 km	SS	fwh	No	
Mecistocephalidae	<i>Mecistocephalus</i> sp. B07	1		14		-	DF	fg	R1	
Oryidae	<i>Orphnaeus brevilabiatus</i>	1		13		Widespread	DF	t	No	
Schendylidae	<i>Australoschendyla</i> sp. B09	1		10		-	SS	wh	Unknown	
Lithobiomorpha	Lithobiomorpha sp.	6		07		Not SRE	-	-	No	
Scolopendromorpha	Scolopendromorpha spp.	18	03,04,05	01,07,09,10,17,18		Not SRE	-	-	No	
Scutigermorpha	Scutigermorpha sp.	4	04,05	07,09		Not SRE	-	-	No	
Crustacea										
Amphipoda										
Chiltoniidae	<i>Austrochiltonia subtenuis</i>	5		06,08		Widespread	DF	ts	No	
Isopoda										
Armadillidae	<i>Acanthodillo</i> sp. B08	9		09,13		11 km	SS;DF	wh;t	No	52378
	<i>Acanthodillo</i> sp. B09	2		13		-	DF	t	R1	52379
	<i>Buddelundia</i> sp. B38	15	05	01,07,09		33 km	SS;DF	wh;t	No	52380
	<i>Buddelundia</i> sp. B39	36	05	11,13,14,17,18		34 km	SS;DS;DF	wh;h;ftsg	No	52381
Oniscidae	<i>Hanoniscus</i> sp. B08	12		06,14		17 km	DF	fgt	Unlikely	52382
	<i>Hanoniscus</i> sp. B09	4	05	10		28 km	SS	wh	No	52383
Philosciidae	Philosciidae sp.	2	05	08		NA	SS;DF	wh;ts	Unknown	
	Philosciidae sp. B23	174	02,03,04,05	01,06-12,14,17,18		48 km	SS;DS;DF	fwh;h;fsgt	No	52384
	Philosciidae sp. B24	42	03,04,05	01,06,09		15 km	SS;DF	wh;t	No	52385
	Philosciidae sp. B25	5	03			-	SS	wh	No	52386
Platyarthridae	<i>Trichorhina</i> sp. B14	4		13		-	DF	t	R1	52387
Diplopoda										
Polydesmida										
Paradoxosomatidae	<i>Antichiropus whistleri</i>	20	02,05	01,06,07,09,10,18	♀ J D	Widespread	SS;DF	fwh;fgt	No	129693-98

Polyxenida	Polyxenida spp.	6	02,04,21	10		Unknown	SS;DF	fwh;fgts	No	
Gastropoda	Gastropoda spp.	28	02	07,08,10,18		Cosmopolitan slugs, aquatic and Pupilloid snails (all widespread)	SS;DF	fwh;fgts	No	
Sigmurethra										
Orthalicidae	<i>Bothriembryon perobesus</i>	1	03		D	>100 km	SS	fwh	SRE	83994
	<i>Bothriembryon</i> sp. nov. 'Gingin Brook'	27	02,05	01,07,10	D	>150 km	SS;DF	fwh;t	No	83993
Insecta										
Coleoptera	Coleoptera sp.	2525	02-05,20,21	01,06-10,15,16,22		Not target	-	-	No listed	
Diptera	Diptera sp.	695	02-05,20,21	01,06-10,15,16,22		Not target	-	-	No listed	
Hymenoptera	Hymenoptera sp.	150	02-05,20,21,23	01,06,07,09,10,15,16,22,24		Not target	-	-	No listed	
Lepidoptera	Lepidoptera sp.	2472	02,04,05,20,21	01,06-10,16,22		Not target	-	-	No listed	
Mecoptera	Mecoptera sp.	5	21	22		Not target	-	-	No listed	
Orthoptera	Orthoptera sp.	452	02-05,20	01,06,07,09,10,13-15		Not target	-	-	No listed	
Oligochaeta	Oligochaeta sp.	1		14		-	DF	fg	R1	

Appendix 6. Habitat data

Table A. Floristics – species cover per site.

Species\Site	01	02	03	04	05	06	07	08	09	10
<i>Acacia lasiocarpa</i>	1	0.5	1	0	1	1	5	0	1	0.5
<i>Acacia sessilis</i>	0	0.5	0	0	0	10	2	1	0.5	0
<i>Acacia spathulifolia</i>	0	0	0	0	0	0	5	0	0	0
<i>Adenanthos cygnorum</i> subsp. <i>cygnorum</i>	2	0	5	0	5	0	1	0	0	5
<i>Allocasuarina humilis</i>	5	5	5	0	1	0	0	0	5	0
<i>Anigozanthus humilis</i> subsp. <i>humilis</i>	0.5	0.5	0.5	0	0.5	0	0.5	0	0.5	0.5
<i>Banksia attenuata/menziesii/prionotes</i>	15	25	25	0	25	0	40	0	10	15
<i>Banksia dallanneyi?</i>	0.5	0	0	0	0.5	0.5	0.5	0	0.5	0.5
<i>Banksia</i> sp. (<1m)	0	0	0	40	0	0.5	0	5	2	0
<i>Callitris pyramidalis</i>	0	0	0	0	0	0	10	0	0	0
<i>Calothamnus sanguineus</i>	0	0	0	20	0	0	0	0	0	0
<i>Chamelaucium uncinatum</i>	0.5	1	0	0	0	0	0	0	0.5	0
<i>Conospermum stoechadis</i>	5	0.5	2	1	5	0.5	0	0	3	0.5
<i>Conospermum triplinervium</i>	0	0	0	0	0	0	2	0	0	0
<i>Conostylis aculeata</i>	0.5	1	1	0	1	0.5	0.5	0	0.5	0.5
<i>Daviesia divaricata</i> subsp. <i>divaricata</i>	5	0	0.5	0	0.5	0.5	0	0	1	0.5
<i>Daviesia incrassata</i> subsp. <i>incrassata</i>	5	0	0.5	0	0.5	0.5	0	0	1	0.5
<i>Eucalyptus decipiens</i> & <i>E. todtiana</i>	15	0.5	5	0	10	0	0	0	10	5
<i>Goodenia</i> sp.	1	0.5	0.5	0	0.5	0.5	0.5	0	0.5	0.5
<i>Haemodorum spicatum</i>	0.5	0.5	0.5	0.5	1	0.5	0.5	0.5	1	0.5
<i>Hibbertia</i> sp.	5	5	5	0.5	5	0.5	0.5	0	1	1
<i>Isopogon linearis</i>	1	0.5	1	0	1	0.5	0	0	1	0.5
<i>Lepidosperma gladiatum</i>	0	2	1	0	0	0	1	0	1	0
<i>Lepidosperma longitudinale</i>	0	5	1	0.5	5	5	5	5	1	0.5
<i>Malleostemon</i> sp.	0	0	0	0	0	0	5	0	0.5	0
<i>Melaleuca</i> sp. (<3m)	0	0	0	0	0	60	1	0	0.5	0
<i>Melaleuca preissiana</i>	0	10	0	0	0	0	0	10	1	0
<i>Melaleuca seriata</i>	1	3	5	5	5	0.5	1	0	5	5
<i>Nuytsia floribunda</i>	1	0	0	5	1	0.5	0	0	1	0
<i>Patersonia occidentalis</i>	1	1	1	0	1	0.5	0.5	0	1	0.5
Poaceae sp.	1	0	1	0	1	0.5	0.5	0	1	0.5
<i>Westringia?</i> sp.	0	0	0	0	0	0	1	0	0	0
<i>Tecticornia disarticulata</i>	0	0	0	0	0	0	0	10	0	0
<i>Typha domingensis</i>	0	0	0	0	0	0	0	5	0	0
<i>Verticordia densiflora</i> var. <i>cespitosa</i>	0	0	0	2	0	5	0	0	0	0
<i>Xanthorrea preisii</i>	5	0.5	1	0.5	1	0.5	0	0	5	1

Table B. Litter depth and cover per site.

Site	< 1 cm	1 to 5 cm	5 + cm	Litter Index	Dominant species
01	89.5	10	0.5	43.0	<i>Eucalyptus, Banksia</i> , shrubs
02	84	15	1	61.4	<i>Melaleuca</i>
03	94.5	5	0.5	28.5	<i>Banksia</i>
04	99	1	0	12.9	-
05	84.5	15	0.5	57.5	<i>Eucalyptus, Banksia</i> , shrubs
06	90	10	0	39.0	<i>Melaleuca</i>
07	68	30	2	112.8	<i>Banksia</i>
08	95	5	0	24.5	-
09	79.5	20	0.5	72.0	<i>Eucalyptus</i>
10	89.5	10	0.5	43.0	<i>Banksia</i>