DECEMBER 2010

Providing sustainable environmental strategies, management and monitoring solutions to industry and government.

ecologia ENVIRONMENT

SINOSTEEL MIDWEST CORPORTATION

BLUE HILLS

SHORT-RANGE ENDEMIC INVERTEBRATE SURVEY

This page has been left blank intentionally

SINOSTEEL MIDWEST CORPORTATION

BLUE HILLS

SHORT-RANGE ENDEMIC INVERTEBRATE SURVEY

SINOSTEEL 中钢澳洲中西矿业公司

SINOSTEEL MIDWEST CORPORATION LIMITED

Document Status						
Rev	**Author**	**Reviewer/s**	**Date**	**Approved for Issue**		
				Name	**Distributed To**	**Date**
A	C. Hall	L.. Roque-Albelo	31/08/10			
B	C. Hall	L.. Roque-Albelo	08/11/10			
C	N. Thompson	L. Roque-Albelo	12/11/10			
D	C. Hall	L. Roque-Albelo	15/11/10	L. Roque-Albelo	Wayne Ennor Steve Neill	17/11/10

ecologia Environment
1025 Wellington Street
WEST PERTH WA 6005
Phone: 08 9322 1944
Fax: 08 9322 1599
Email: admin@ecologia.com.au

TABLE OF CONTENTS

TABLES

FIGURES

APPENDICES

ACRONYMS

BOM	Bureau of Meteorology
DEC	Department of Environment and Conservation
DSEWPC	Department of the Sustainability, Environment, Water, Population and Communities
EPA	Environmental Protection Authority
EP Act	*Environmental Protection Act 1986*
EPBC Act	*Environment Protection and Biodiversity Conservation Act 1999*
IBRA	Interim Biogeographic Regionalisation for Australia
SAC	Species Accumulation Curve
SRE	Short-Range Endemic
WC Act	*Wildlife Conservation Act 1950*

EXECUTIVE SUMMARY

Sinosteel Midwest Corporation's (SMC) Koolanooka / Blue Hills (Mungada) Direct Shipping Iron Ore (DSO) Project commenced operations in early 2010. The project involves the mining, crushing, screening and transport of iron ore from three existing pits in the Koolanooka and Blue Hills region, to the Geraldton Port.

As part of the approvals process in 2006, *ecologia* Environment conducted a base-line short-range endemic invertebrate survey, which yielded several SRE species including one mygalomorph spider species from the family Barychelidae, a snail species of the genus *Bothriembryon* and a pseudoscorpion from the genus *Synsphronus*. In addition, two protected species *Idiosoma nigrum* and *Aganippe castellum* have been recorded from nearby areas. Consequently, a more extensive follow-up survey of SRE invertebrates, both inside and outside the proposed impact areas, was requested by the Environmental Protection Authority and is detailed in this report.

The methodology used was based on the principles outlined in EPA Guidance statement 20: *Sampling of Short Range Endemic Invertebrate Fauna for Environmental Impact Assessment in Western Australia* (EPA 2009). A total of 24 foraging sites and eight dry-pitfall trap sites were sampled during the survey spread throughout Mungada East and West and also outside the impact area. Specimens collected were sent to the Western Australian Museum for formal identification.

A total of 74 invertebrate specimens were collected during the survey representing two mygalomorph spider species (*Idiosoma* 'MYG018' and *Missulena* 'MYG045'), a scorpion species (*Lychas* 'splendens'), five pseudoscorpions (*Tryannochthonius* 'sp.nov.Blue Hills', *Synsphyronus mimulus*, *Beierolpium* 'sp.8/4', *Austrohorus* sp. and *Indolpium* sp.), two isopod species (*Buddelundia* sp. and *Spherillo* sp.) and four snail species (*Sinumelon vagente*, *Pupoides adelaidae*, *Gastrocopta bannertonensis* and *Westralaoma expita*). In addition *Idiosoma* burrows were found at 14 sites both inside and outside the impact areas.

Of the specimens recorded, the spider *Idiosoma* 'MYG018' was a confirmed SRE and three pseudoscorpions were potential SREs (*Tyrannochthonius, Beierolpium* and *Austrhorus*). The spider *Idiosoma* was tentatively described as *Idiosoma* 'MYG018' and not *Idiosoma nigrum* which is a schedule 1 listed species.

None of the potential SRE species collected during the 2006 survey were collected during this survey however, the Barychelid spider and *Bothriembryon* snail were previously collected outside of the impact area where they will not be directly at threat from mining activities. The *Synsphronus* pseudoscorpion was previously collected inside the Project Area and is therefore considered at medium risk from impacts.

The schedule 1 listed trapdoor spider *Aganippe castellum* was not recorded in the Project area during either surveys.

The pseudoscorpions *Tyrannochthonius* 'sp.nov. Blue Hills' and *Austrohorus* sp. are potential SREs however, they were only recorded from outside the proposed impact area. They will therefore not be directly impacted by the Project however, both sites F21 and F23 are located in relatively close proximity to the pit outline and so the species may still be affected by indirect impacts such as dust from vehicles, or vegetation clearing. Management recommendations should be put in place to reduce any indirect impacts.

Both the spider *Idiosoma* 'MYG018' and the pseudoscorpion *Beierolpium* were recorded from sites both inside and outside the proposed impact areas and as such these species will be partially impacted by the Project. Neither species appear to be restricted to a particular habitat and both appear to be widespread across the tenement. Management recommendations should be put in place to reduce the direct impacts to inside populations and indirect impacts to outside populations.

In summary, a total of seven SRE or potential SRE species have been recorded from the Blue Hills Project Area. The impact is considered medium for the *Synsphronus* sp. collected during 2006 as it has only been found within the Project Area, however the vegetation community where it was found is expected to be impacted less than 10 %. The impact of the development is considered low for all of the other species.

1 INTRODUCTION

1.1 PROJECT OVERVIEW

Sinosteel Midwest Corporation's (SMC) Koolanooka / Blue Hills (Mungada) Direct Shipping Iron Ore (DSO) Project commenced operations in early 2010. The project involves the mining, crushing, screening and transport of iron ore from three existing pits in the Koolanooka and Blue Hills region, to the Geraldton Port.

The Koolanooka mine site is located approximately 160 km south east of Geraldton and 20 km east of Morawa, and the Mungada East and Mungada West mine sites are located 60 km to the east of Koolanooka.

As part of the approvals process in 2006, *ecologia* Environment (*ecologia)* conducted a base-line short-range endemic (SRE) invertebrate survey, which yielded several SRE species. Consequently, a more extensive follow-up survey of SRE invertebrates, both inside and outside the proposed project areas, was requested by the Environmental Protection Authority (Minister for Environment 2009). This report details the follow-up survey carried out at Blue Hills, both within the Mungada East and West impact areas and outside the proposed areas of impact.

1.2 SURVEY OBJECTIVES

The primary objective of the SRE survey is to provide the EPA with more accurate reference data on the diversity of invertebrate communities and their habitats both inside and outside the proposed impact area, complementing the 2006 survey work.

The Environmental Protection Authority's (EPA) objectives with regards to fauna management are to:

- maintain the abundance, species diversity and geographical distribution of terrestrial invertebrate fauna; and
- protect Specially Protected (Threatened) fauna, consistent with the provisions of the *Wildlife Conservation Act 1950* (WC Act).

Hence, the primary objective of this study was to provide sufficient information for the EPA to assess the impact of the Project on the invertebrate fauna of the area, thereby informing assessment against these objectives.

Specifically, the objectives were to undertake a survey that satisfies the requirements documented in EPA's Guidance Statement 20 (EPA 2009), thus providing:

- a review of background information (including literature and database searches);
- an inventory of SRE fauna species occurring in the project area, incorporating recent published and unpublished records;
- an inventory of species of biological and conservation significance recorded or likely to occur within the project area and surrounds; and
- an assessment of likely habitats that could support SREs

- targeted foraging for listed species, *Idiosoma nigrum* (Shield-backed Trapdoor Spider) and *Aganippe castellum* (Tree-stem Trapdoor Spider)

1.3 LEGISLATIVE FRAMEWORK

Federal and State legislation applicable to the conservation of native fauna include, but are not limited to, the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act), the WC Act, and the *Environmental Protection Act 1986* (EP Act). Section 4a of the Environmental Protection Act 1986 requires that developments take into account the following principles applicable to native fauna:

- The Precautionary Principle

Where there are threats of serious or irreversible damage, a lack of full scientific certainty should not be used as a reason for postponing measures to prevent environmental degradation.

- The Principles of Intergenerational Equity

The present generation should ensure that the health, diversity and productivity of the environment is maintained or enhanced for the benefit of future generations.

- The Principle of the Conservation of Biological Diversity and Ecological Integrity

Conservation of biological diversity and ecological integrity should be a fundamental consideration.

The document was constructed with a view to satisfy the requirements of EPA Guidance Statement *No. 56: Terrestrial Fauna Surveys for Environmental Impact Assessment in Western Australia* (EPA 2004). In relation to SRE fauna, the guidance statement states that:

> *"Comprehensive systematic reviews of different faunal groups often reveal the presence of short-range endemic* species *(Harvey 2002). Among the terrestrial fauna there are numerous regions that possess short-range endemics. Mountainous terrains and freshwater habitats often harbour short-range endemics, but the widespread aridification and forest contraction that have occurred since the Miocene has resulted in the fragmentation of populations and the evolution of many new species. Particular attention should be given to these types of species in environmental impact assessment because habitat loss and degradation will further decrease their prospects for long-term survival."*

Harvey (2002) considered that although there were occasional SREs among the vertebrates and insects, there were much higher numbers among the molluscs, earthworms, some spider groups (especially the mygalomorphae), millipedes and some groups of crustaceans. SREs generally possessed similar ecological and life history characteristics, especially poor powers of dispersal, confinement to discontinuous habitats, slow growth, and low fecundity.

Some better known SRE species have been listed as threatened or endangered under State or Commonwealth legislation in the *WC Act* and/or *EPBC Act*, but the majority have not. Often the lack of knowledge about these species precludes their consideration for listing as threatened or endangered. Listing under legislation should therefore not be the only conservation consideration in environmental impact assessment.

The State is committed to the principles and objectives for the protection of biodiversity as outlined in *The National Strategy for the Conservation of Australia's Biological Diversity* (Commonwealth

Government 1996). The EPA expects that environmental impact assessment will consider impacts on conservation of SREs (EPA 2004).

This document also satisfies the requirements of the later released Guidance Statement No. 20: *Sampling of Short-range Endemic Invertebrate Fauna for Environmental Impact Assessment in Western Australia* (EPA 2009) and specifically the requirements of the Ministerial Statement 811 (Minister for Environment 2009).

1.4 CONSERVATION SIGNIFICANT FAUNA

Fauna species that have been formally recognised as rare, threatened with extinction, or as having high conservation value are protected by law under Commonwealth and State legislation. At the national level, fauna are protected under the *Environment Protection and Biodiversity Conservation Act* 1999 (EPBC Act). Within Western Australia (WA), rare fauna are listed under the *WC Act: Wildlife Conservation (Specially Protected Fauna) Notice 2010*.

Schedule 1 of the Commonwealth *EPBC Act* 1999 contains a list of species that are considered Critically Endangered, Endangered, Vulnerable, Extinct, Extinct in the wild and Conservation Dependent. Definitions of categories relevant to fauna occurring or potentially occurring in the project area are provided in Table 1-1.

Table 1-1 – EPBC Act Categories

Category	Definition	Taxa reported from the Midwest and Wheatbelt
Critically Endangered	The species is considered to be facing an extremely high risk of extinction in the wild.	*Ogyris subterrestris petrina* (butterfly) *Kwonkan eboracum* (trapdoor spider) *Teyl* sp. (trapdoor spider)
Endangered	The species is likely to become extinct unless the circumstances and factors threatening its abundance, survival or evolutionary development cease to operate; or its numbers have been reduced to such a critical level, or its habitats have been so drastically reduced, that it is in immediate danger of extinction.	*Neopasiphe simplicolor* (bee) *Aganippe castellum* (trapdoor spider)
Vulnerable	Within the next 25 years, the species is likely to become endangered unless the circumstances and factors threatening its abundance, survival or evolutionary development cease to operate.	*Idiosoma nigrum*

Classification of rare and endangered fauna under the *WA Wildlife Conservation (Specially Protected Fauna) Notice 2010* of the WC Act recognises four distinct schedules, as listed in Table 1.2 below. In addition, Department of Environment and Conservation (DEC) maintains a Priority Fauna list which includes those removed from the WC Act and other species known from only a few populations or, are in need of monitoring. Five Priority Codes are recognised, as detailed in Table 1.3.

Table 1-2 – WA *Wildlife Conservation Act 1950* (Specially Protected Fauna) Notice 2010

Code	Definition	Taxa reported from the Midwest and Wheatbelt
Schedule 1	Fauna that is rare or likely to become extinct are declared to be fauna that is in need of special protection.	*Aganippe castellum* (trapdoor spider) *Kwonkan eboracum* (trapdoor spider) *Idiosoma nigrum* (trapdoor spider) *Teyl* sp. (trapdoor spider) *Neopasiphe simplicolor* (bee) *Ogyris subterrestris petrina* (butterfly)
Schedule 2	Fauna that is presumed to be extinct are declared to be fauna that is in need of special protection.	none
Schedule 3	Birds that are subject to an agreement between the governments of Australia and Japan relating to the protection of migratory birds and birds in danger of extinction are declared to be fauna that is in need of special protection.	Not relevant for terrestrial invertebrates
Schedule 4	Declared to be fauna that is in need of special protection, otherwise than for the reasons mentioned in those listed above.	none

Table 1-3 – DEC Priority Fauna Categories

Priority Category	Definition	Taxa reported from the Midwest and Wheatbelt
Priority One Taxa with few, poorly known populations on threatened lands.	Taxa which are known from few specimens or sight records from one or a few localities, on lands not managed for conservation, e.g. agricultural or pastoral lands, urban areas, active mineral leases. The taxon needs urgent survey and evaluation of conservation status before consideration can be given to declaration as threatened fauna.	*Psacadonotus seriatus* (cricket) *Ixalodectes flectocerus* (cricket) *Branchinella wellardi* (Crustacean) *Parartemia contracta* (Crustacean) *Daphnia jollyi* (Crustacean) *Bothriembryon perobesus* (snail) *Bothriembryon bradshawi* (snail)
Priority Two Taxa with few, poorly known populations on conservation lands.	Taxa which are known from few specimens or sight records from one or a few localities, on lands not under immediate threat of habitat destruction or degradation, e.g. national parks, conservation parks, nature reserves, State forest, vacant crown land, water reserves, etc. The taxon needs urgent survey and evaluation of conservation status before consideration can be given to declaration as threatened fauna.	*Phasmodes jeeba* (cricket) *Austromerope poultoni* (scorpionfly)
Priority Three Taxa with several, poorly known populations, some on conservation lands.	Taxa which are known from few specimens or sight records from several localities, some of which are on lands not under immediate threat of habitat destruction or degradation. The taxon needs urgent survey and evaluation of conservation status before consideration can be given to declaration as threatened fauna.	*Austrosaga spinifer* (cricket) *Hemisaga vepreculae* (cricket) *Throscodectes xederoides* (cricket) *Hylaeus globuliferus* (bee)
Priority Four Taxa in need of monitoring	Taxa which are considered to have been adequately surveyed, or for which sufficient knowledge is available, and which are considered not currently threatened or in need of special protection, but could be if present circumstances change. These taxa are usually represented on conservation lands.	*Westralunio carteri* (bivalve)
Priority Five Taxa in need of monitoring	Taxa which are not considered threatened but are subject to a specific conservation program, the cessation of which would result in the species becoming threatened within five years.	none

1.5 SHORT RANGE ENDEMIC FAUNA: A REVIEW

The decline in biodiversity of terrestrial communities has already been observed both nationally and state-wide (CALM 2004). There is also an increasing shift in environmental protection from species based conservation to biodiversity based conservation (Chessman 1995; Burbidge *et al.* 2000; McKenzie *et al.* 2000) and one of the important considerations involved in this is the presence of endemic species.

Endemism refers to the restriction of species to a particular area, whether it is at the continental, national or local level (Allen *et al.* 2002). This review focuses on SREs, outlines the major paths to short-range endemism, the current knowledge of short-range endemism in Australia and the conservation significance of such species. It is important to note that the individual taxa and broader groups discussed are not an exhaustive list of all SRE. This is due to the fact that SRE are dominated by invertebrate species, which are historically understudied and in many cases lack formal descriptions. An extensive, reliable taxonomic evaluation of these species has begun only relatively recently and thus the availability of literature relevant to SREs is relatively scarce.

1.5.1 Processes Promoting Short Range Endemism

Short-range endemism is influenced by numerous processes, which generally contribute to the isolation of a species. A number of factors, including the ability and opportunity to disperse, life history, physiology, habitat requirements, habitat availability, biotic and abiotic interactions, and historical conditions, influence not only the distribution of a taxon, but also the tendency for differentiation and speciation (Ponder and Colgan 2002).

Isolated populations of plants and animals tend to differentiate both morphologically and genetically as they are influenced by different selective pressures over time. Additionally, a combination of novel mutations and genetic drift promote the accumulation of genetic differences between isolated populations. Conversely, the maintenance of genetic similarity is promoted by a lack of isolation through migration between the populations, repeated mutation and balancing selection (Wright 1943). The level of differentiation and speciation between populations is determined by the relative magnitude of these factors, with the extent of migration generally being the strongest determinant. Migration is hindered by the poor dispersal ability of the taxon as well as geographical barriers to impede dispersal. Thus, in summary, those taxa that exhibit short-range endemism are generally characterised by poor dispersal, low growth rates, low fecundity and reliance on habitat types that are discontinuous (Harvey 2002).

The historical connections between habitats are also important in determining species distributions and often explain patterns that are otherwise inexplicable by current conditions. Many SREs are considered to be relictual taxa (remnants of species that have become extinct elsewhere) and are confined to certain habitats, and in some cases, single geographic areas (Main 1996). Relictual taxa include extremely old species that can be traced back to the Gondwanan periods (180-65 million years ago) and have a very restrictive biology (Harvey 2002).

In Western Australia, relictual taxa generally occur in fragmented populations, from lineages reaching back to historically wetter periods. For example, during the Miocene period (from 25 million to 13 million years ago), the aridification of Australia resulted in the contraction of many areas of moist habitat and the fragmentation of populations of fauna occurring in these areas (Hill 1994). With the onset of progressively dryer and more seasonal climatic conditions since this time, suitable habitats have become increasingly fragmented. Relictual species now generally persist in habitats characterised by permanent moisture and shade, maintained by high rainfall and/or prevalence of fog. This may be induced by topography or coastal proximity, or areas associated with freshwater courses (e.g. swamps or swampy headwater of river systems), caves, or microhabitats associated with southern slopes of hills and ranges, rocky outcrops, deep litter beds, or various combinations of these features (Main 1996; Main 1999). As a result, these habitats support only small, spatially isolated populations, which are further restricted by their low dispersal powers typical for all SRE species.

1.5.2 Taxonomic Groups Likely to Support Short-Range Endemism

1.5.2.1 Arachnids (Phylum: Arthropoda, Sub Class: Arachnida)

Four orders of arachnids can exhibit short range endemism: Pseudoscorpiones (false scorpions), Scorpiones (true scorpions), Schizomida (short-tailed whip spiders) and Araneae (i.e. Infraorder: Mygalomorphae or trap-door spiders). Many mygalomorph trap-door spider species are vulnerable to disturbance and exhibit short range endemism due to their limited ability to disperse. These spiders also have extreme longevity and the long-term persistence of females in a single burrow (Raven 1982). Mygalomorph spiders are largely considered 'old world' spiders and, as such, are generally adapted to past climatic regimes making them vulnerable to desiccation in arid environments. They use a variety of behavioral techniques to avoid desiccation, the most obvious of which is their burrow, which may reach up to 70 cm in depth (Main 1982). Mygalomorph groups are thus capable of surviving on the periphery of the great central desert region and minor habitats within the general arid regions of the continent.

Another member of the arachnid class, the Schizomida, is comprised entirely of SREs, with most recorded from single localities (Harvey 2002). Forty-six schizomid species have been described in northern Australia. Most are known to occur in the entrances to and inside caves, while the remainder occur in nearby habitats (Harvey 2002). None are known to occur in the Midwest region of Western Australia.

Scorpions (Scorpionida: *Urodacus* sp.) and pseudoscorpions (Pseudoscorpiones) also exhibit high degrees of endemism (Koch 1981; Harvey 1996). Scorpions are popularly thought of as desert animals although they can be found in most of Australia's climatic zones.

1.5.2.2 Millipedes and Centipedes (Phylum Arthropoda, Class Myriapoda)

Despite millipedes being highly abundant in soil and leaf litter, and highly diverse at the order level, they are inadequately studied and relatively little is known of their biogeography (Harvey 2002).

Centipedes (Chilopoda) are not listed by Harvey (2002) as SRE species; however they have been shown to be endemic to small areas on the east coast (Edgecombe *et al.* 2002). Examination of the distributions of species featured in the CSIRO centipede webpage also reveals disjunct and isolated occurrences of many species. A number of genera have Pangaean and Gondwanan affinities (Edgecombe *et al.* 2002). In general, these animals have a relatively cryptic biology, preferring moist habitats in deep litter accumulations, under rocks and in rotting logs, and they have relatively poor dispersal abilities (Lewis 1981). This suggests that they are potential candidates for designation as SREs.

1.5.2.3 Molluscs (Phylum: Mollusca)

Numerous species of freshwater and terrestrial molluscs belonging to many genera have been identified in Australia, with most being SREs (Harvey 2002). Restricted ranges of the terrestrial molluscs of the drier northern and Western Australia were noted for a vast number of species (Solem 1997). Among these were seven endemic species of *Rhagada* from the Dampier Archipelago, five of which were found to occur sympatrically on one island. However, in a recent genetic study conducted on *Rhagada* (Johnson et al. 2004), allozyme analysis revealed little variation between taxa. Such a finding could indicate that there is merely high morphological diversity within one or a few species. It is also possible however, that there is a number of highly endemic species and that morphological diversity has taken place rapidly with little genetic change (Johnson *et al.* 2004).

1.5.2.4 Worms (Phylum: Annelida & Onychophora)

The taxonomic status of the earthworm family, Megascolecidae, in Western Australia was revised by Jamieson in 1971. As a result of this study, it was concluded that most of the earthworm genera are made up almost entirely of short-range endemics (Harvey 2002). This is also the case with the velvet worms (Onychophorans). Due to several taxonomic revisions that have been conducted (see references within Harvey, 2002), the number of onychophoran species has expanded from six to over 70 species, and a number of species still remain undescribed (Harvey 2002). Very few of these species exceed ranges of 200 km^2 and some are restricted to single localities and have high genetic differentiation, indicating very little mobility and dependence on their permanently moist habitats (Harvey 2002).

1.5.3 Current Knowledge of Short Range Endemic Species in the Blue Hills Area

SREs are common among the invertebrates. Many species are confined to topographically or geographically restricted areas and specialised microhabitats because of their small size and often specialised behaviour, typical for relict species. These microhabitats provide areas of short-range endemism and are vulnerable to artificial disturbances imposed by agriculture and other rural and urban disruptions to the landscape, for instance roads and other human constructions (Main 1996).

The previous survey at Koolanooka and Blue Hills completed in 2006 found several species that had the potential to be SREs including one species from the mygalomorph spider family Barychellidae, a snail species of the genus *Bothriembryon* and a pseudoscorpion from the genus *Synsphronus* (Table 1.4). These specimens could not be identified to species level however; other species from these groups are SRE species.

Table 1-4 – Species Previously Collected from the Blue Hills Area

Class (Order)	Family	Genus	Species
Arachnida (Aranae)			
	Barychelidae	unknown	sp.B
Arachnida (Pseudoscorpiones)			
	Garypidae	*Synsphronus*	sp.
Gastropda			
	Bulimulidae	*Bothriembryon*	sp.

A search of the Western Australian Museum (WAM) arachnid and mollusc databases showed records of several potential SRE species occurring nearby including mygalomorph spiders and millipedes (Table 1.5).

In addition, two mygalomorph spiders (*Idiosoma nigrum* and *Aganippe castellum*) were both listed under state and Commonwealth legislation and have been recorded near the Project area.

Table 1-5 – Potential SRE Species Recorded in the WAM Database from around the Blue Hills Area

Class (Order)	Family	Genus	Species	Location
Arachnida (Aranae)				
	Barychelidae	*Synothele*	sp.	Mt Gibson
	Nemesiidae	*Aname*	sp.	Blue Hills, Weelhamby Lake
		Kwonkan	sp.	Weelhamby Lake
		Yilgarnia	sp.	Weelhamby Lake
		Teyl	sp.	Lochada
	Idiopidae	*Euoplos*	sp.	Lochada
		Idiosoma	*nigrum*	Karara
	Dipluridae	*Cethegus*	sp.	Karara
Diplopoda				
	Paradoxosomatidae	*Antichirpous*	karara'	Karara, Blue Hills

This page has been left blank intentionally

2 BIOGEOGRAPHY AND CLIMATE

2.1 BIOGEOGRAPHY

The Interim Biogeographic Regionalisation for Australia (IBRA) classifies the Australian continent into regions (bioregions) of similar geology, landform, vegetation, fauna and climate characteristics (Department of the Environment, Water, Heritage and the Arts (DEWHA, 2010). According to IBRA (Version 6.1) the Study Area is located in the Yalgoo (YAL) bioregion which is further divided into subregions as described below and mapped in Figure 2-1.

The Yalgoo (YAL) bioregion is an interzone between the south-western bioregions and the Murchison bioregion (Desmond and Chant 2001). The Yalgoo bioregion represents the westernmost section of the pastoral land area.

The vegetation of the Yalgoo (YAL) bioregion is characterised by red sandy plains, supporting low to open woodlands of Eucalyptus, Acacia and Callitris species (Desmond and Chant 2001). The vegetation of the earth to sandy-earth plains is *Acacia aneura, Callitris-Eucalyptus salubris* and *Acacia ramulosa* var. *ramulosa* and *Acacia ramulosa* var. *linophylla* open woodlands and scrubs. Ephemeral species are particularly abundant in this bioregion.

The Blue Hills project is situated in the Tallering subregion (YAL2) and is dominated by red sandy plains and sandy earth plains of the western Yilgarn Craton. The predominant land use in the Tallering subregion is grazing on native pastures (approx 77%) (Payne *et al.* 1998).

2.2 LAND SYSTEMS

Land systems are described using the biophysical characteristics of geology, landforms, vegetation and soils (Curry *et al.* 1994; Payne *et al.* 1998). The Project Area covers two land systems the Tallering land system and the Yowie land system and are shown in Figure 2.2.

The Tallering land system is characterised by prominent ridges of banded ironstone, dolerite and sedimentary rocks supporting Bowgada and other *Acacia* shrublands. This land system covers almost 33,000 ha of land of which 0.11% is expected to be impacted by the Project.

The Yowie land system consists of loamy plains supporting shrublands of mulga and bowgada with patchy wanderrie grasses. This land system covers over 1,600,000 ha of land of which 0.001% is expected to be impacted by the Project

2.3 VEGETATION COMMUNITIES

A total of eight vegetation communities are described from within the Project Area in the flora and vegetation survey undertaken in 2007 (*ecologia* 2008) and are shown in Figure 2.3. Each of the vegetation communities is described in further detail in Table 2.1.

2.4 CLIMATE

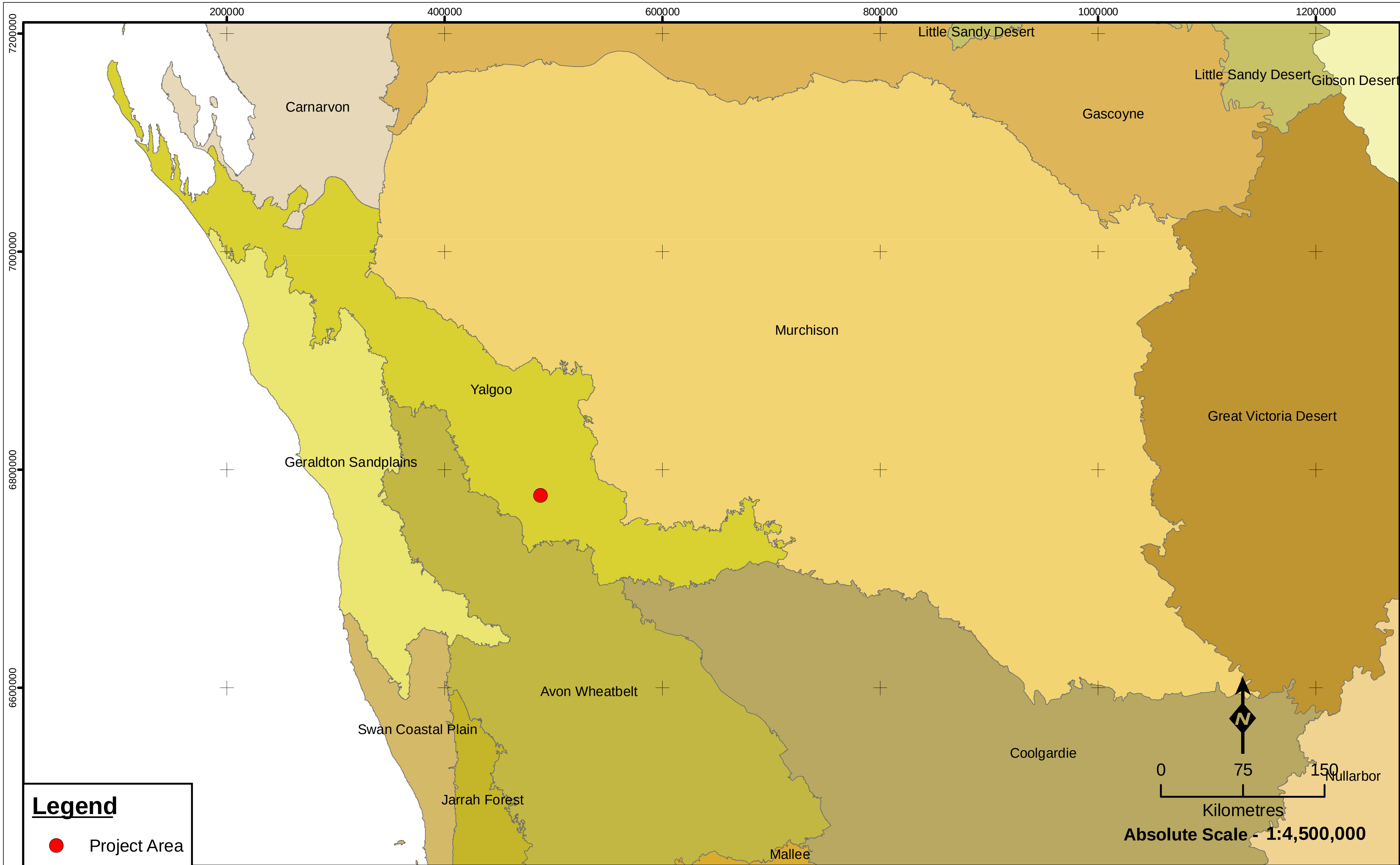
The closest Bureau of Meteorology (BOM) weather station is situated at the Morawa airport, approximately 80 km west of the Project. The Morawa airport weather station has been operational since 1997 and data collection is ongoing (BOM 2010).

The project area experiences a warm semi-arid to Mediterranean climate, characterised by hot dry summers and mild wet winters (Figure 2.4). December to February are the hottest months of the year, with a mean maximum temperature of 37°C experienced in January. The coldest month is August, with an average minimum temperature of 6°C.

The rainfall experienced at the project area was slightly bimodal with the majority of rainfall falling between May and September, and a second lower peak in January caused by cyclonic activities further north. The area receives an average annual rainfall of 276 mm, the majority of which falls between May and September. July is the wettest month, receiving on average 45 mm of rainfall.

Table 2-1 – Vegetation Communities within the Project Area

Vegetation Unit	Vegetation Description
Arr	Tall shrubland of *Acacia* species typically dominated by *Acacia ramulosa* subsp. *ramulosa* over a low open shrubland dominated by *Philotheca sericea* over an open herbland of annual daisies and/or bare ground
Aan	Tall open scrub of mixed Acacia species including *Acacia aneura* over a low open shrubland dominated by *Philotheca saricea* and a herbland with large areas of bare ground
ApCp	Tall open scrub of mixed species typically *Allocasuarina acutivalvis* subsp. *prinsepiana*, *Calycopeplus paucifiorus*, *Melaleuca nematophylla* and *Acacia* species over a very open herbland/grassland or BIF rocks
AaPo	Tall open scrubland of mixed species typically *Acacia assimilis* var. *assimilis* and *Melaleuca nematophylla* over a low open shrubland to open low heath of *Ptilotus obovatus* var. *obovatus* over a herbland of annual daisies
Deg	Degraded areas, mined previously
El	Tall shrubland of *Acacia ramulosa*, *Acacia burkittii*, *Melaleuca leiocarpa* and *Melaleuca uncinata* over a herbland of annual daisies and/or bare ground
Ew	Open shrub mallee of *Eucalyptus ewartiana* over a tall open scrub of *Acacia ramulosa* subsp. *ramulosa* over an open herbland of annual daisies and/or bare ground
Mu	Tall shrubland of *Acacia ramulosa*, *Acacia burkitii*, *Melaleuca leicarps* and *Melaleuca uncinata* over an open herbland of annual daisies, leaf litter and bare rocks



ecologia ENVIRONMENT

中钢澳洲中西矿业公司 SINOSTEEL SINOSTEEL MIDWEST CORPORATION LIMITED

Project Location

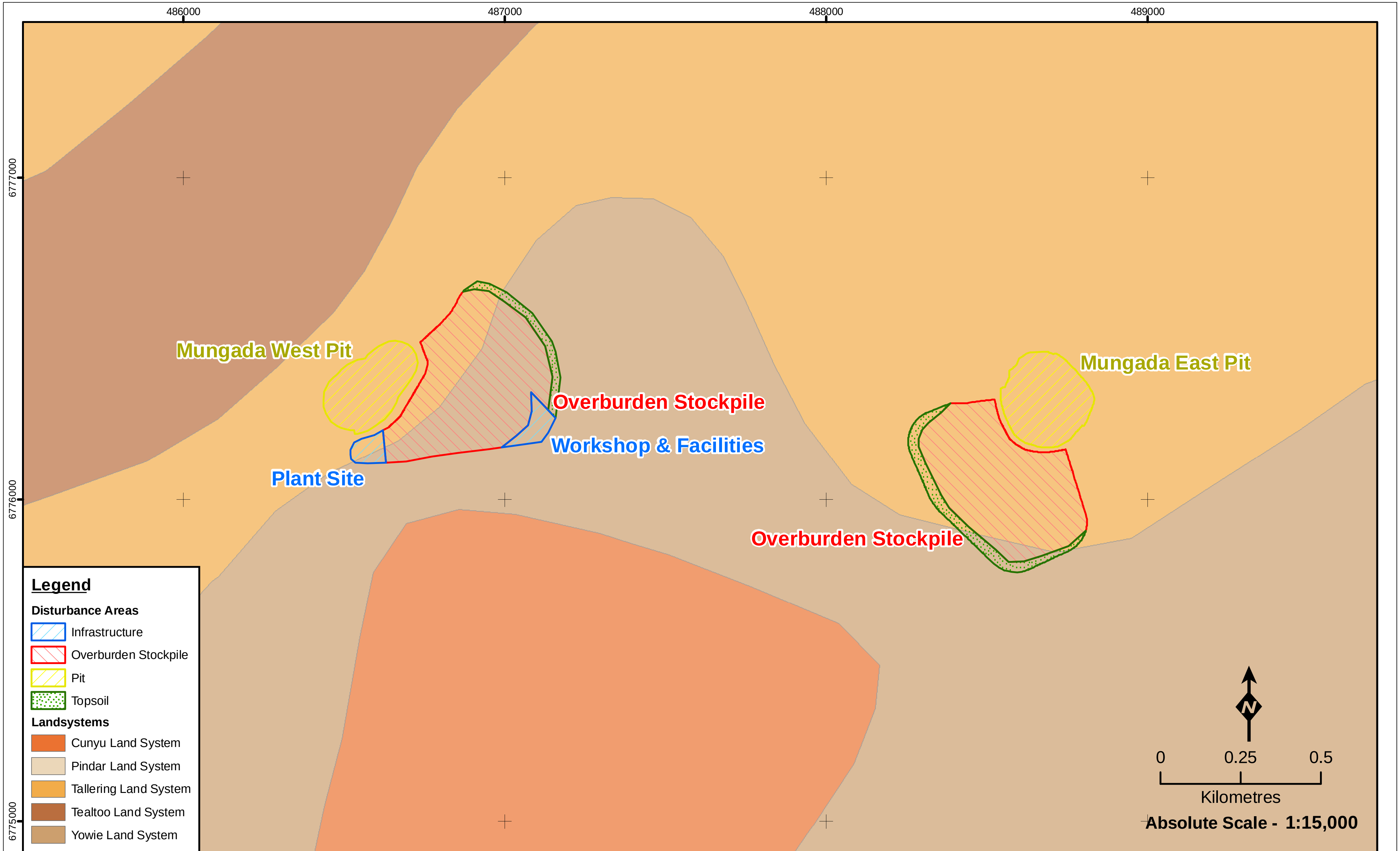
Figure: 2.1
Project ID: 1233

Drawn: AH
Date: 31/08/10

Coordinate System
Name: GDA 1994 MGA Zone 50
Projection: Transverse Mercator
Datum: GDA 1994

Unique Map ID: A225

A4



ecologia ENVIRONMENT

中钢澳洲中西矿业公司
SINOSTEEL MIDWEST CORPORATION LIMITED

Land Systems of the Project Area

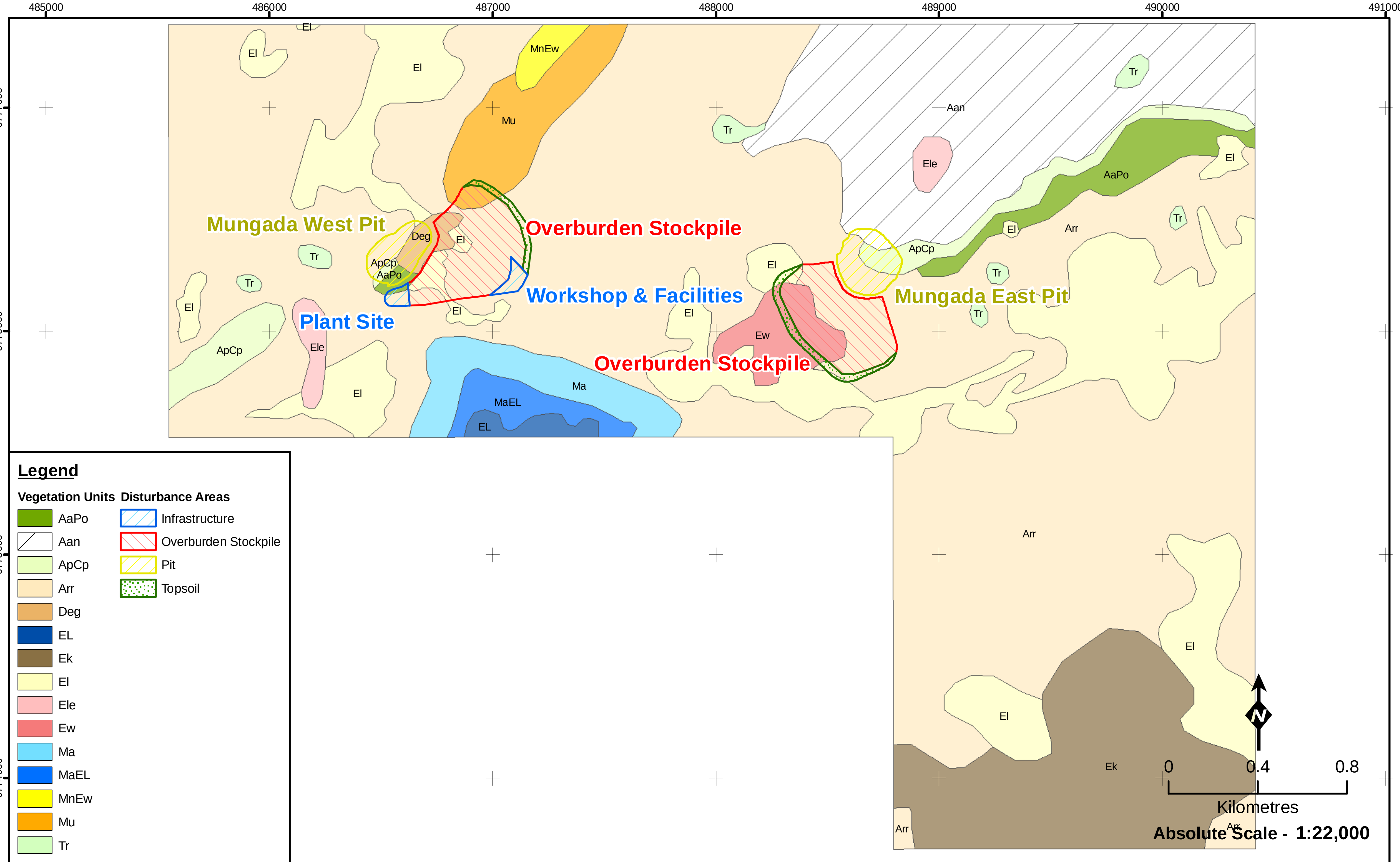
Figure: 2.2
Project ID: 1233

Drawn: AH
Date: 15/11/10

Coordinate System
Name: GDA 1994 MGA Zone 50
Projection: Transverse Mercator
Datum: GDA 1994

Unique Map ID: AH294

A4



ecologia ENVIRONMENT

中钢澳洲中西矿业公司 SINOSTEEL MIDWEST CORPORATION LIMITED

Vegetation of the Project Area

Figure: 2.3
Project ID: 1233

Drawn: AH
Date: 15/11/10

Coordinate System
Name: GDA 1994 MGA Zone 50
Projection: Transverse Mercator
Datum: GDA 1994

Unique Map ID: AH293

A4

This page has been left blank intentionally

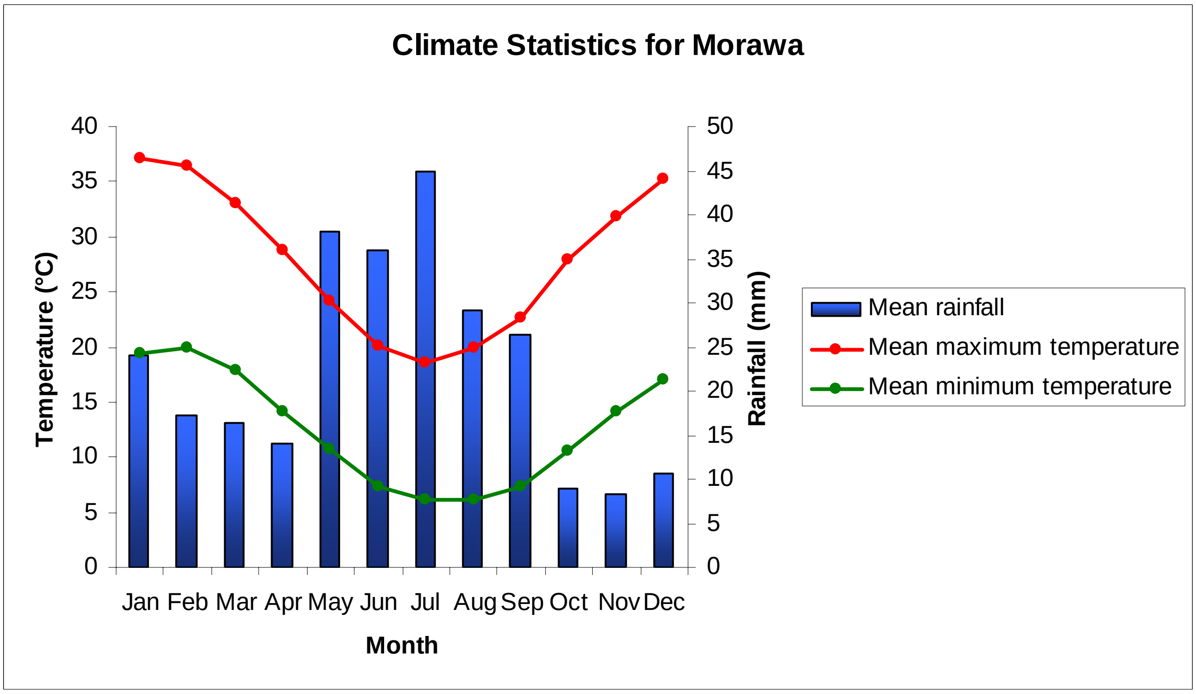


Figure 2-4 – Climate Statistics for Morawa (BOM 2010)

This page has been left blank intentionally

3 METHODS

The methodology used was based on the principles outlined in EPA Guidance statement 20: *Sampling of Short Range Endemic Invertebrate Fauna for Environmental Impact Assessment in Western Australia* (EPA 2009). The methodology developed for the survey is compliant with these requirements and in accordance with the guidance received from the DEC throughout the survey period.

The likelihood of invertebrate species to be considered SREs was determined by WAM taxonomists based on the current knowledge of the distribution and biology of each species.

3.1 SITE SELECTION, SURVEY INTENSITY AND ADEQUACY

Survey site locations were selected primarily based on those habitats with vegetation communities likely to support SRE invertebrates. Micro habitats likely to maintain higher moisture levels and 'island' habitats were targeted. A total of 24 foraging sites and eight dry-pitfall trap sites were sampled during the survey and are shown in Figure 3-3. The sites were spread throughout Mungada East and West with seven sites at Mungada East and 11 sites at Mungada West (Appendix A). Fourteen sites were sampled outside the impact area (Appendix A). Vegetation and habitat descriptions for each site can be found in Appendix B.

There are three general methods of estimating species richness from sample data: extrapolating species-accumulation curves (SAC), fitting parametric models of relative abundance, and using non-parametric estimators (Bunge and Fitzpatrick 1993; Colwell and Coddington 1994; Gaston 1996). In this report, the level of survey adequacy was estimated using species accumulation curves (SACs) as computed by Mao Tao. A SAC is a plot of the accumulated number of species found during the leaf-litter collection with respect to the number of units of effort. The curve, as a function of effort, monotonically increases and typically approaches an asymptote, which is the total number of species. In addition, a Michaelis-Menten enzyme kinetic curve was calculated and used as a stopping rule technique.

SRE species diversity was estimated with two nonparametric estimators: Chao 1 and Abundance Coverage Estimator (ACE). To eliminate features caused by random or periodic temporal variation, the sample order was randomised 100 times. All estimators applied to the data set were performed using EstimateS (version 8, Colwell 2009).

3.2 DRY PITFALL TRAPPING

A battery of five dry-pitfall traps was deployed at the eight dry-pitfall trap sites. Each battery consisted of five traps arranged with one trap in the centre and the other four traps 10 m from each 'corner' of the centre trap (Figure 3-1). The traps consisted of containers that were dug into the ground so that the edge of the container was flush with the soil surface.

The traps were left out for five consecutive nights for the duration of the survey, at the end of which they were removed. The traps were serviced each morning and any potential SRE specimens were collected and placed in individual vials containing absolute ethanol. Any other collected specimens were released.

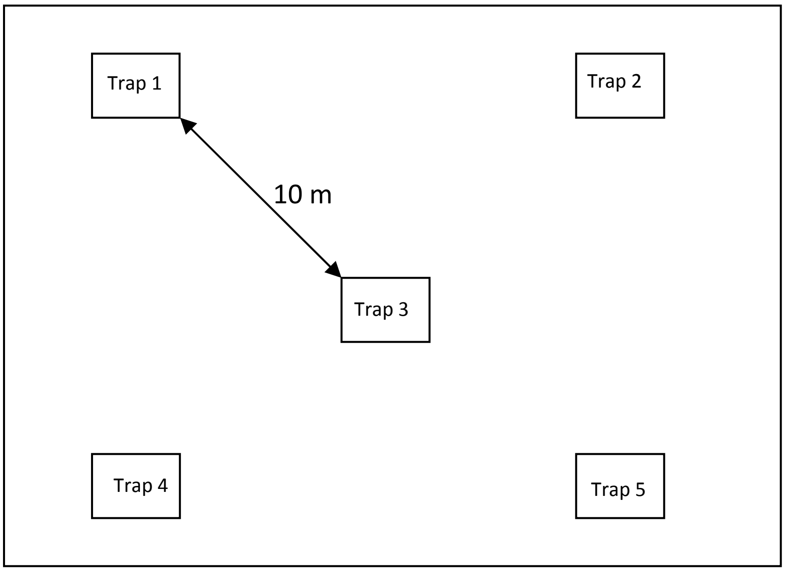


Figure 3-1 – Arrangement of Pitfall Traps at Each Site

3.3 FORAGING

Foraging consisted of searching the ground for spider burrows as well as raking leaf-litter and turning over rocks and logs in order to collect additional specimens and especially snail shells. Each foraging site was foraged for one person hour. Any specimens collected were preserved in absolute ethanol and sent back to *ecologia*'s Perth laboratory for further sorting and identification.

3.4 LEAF-LITTER COLLECTION

At each site three samples of leaf-litter were collected from under trees with dense leaf-litter. Each sample consisted of 1 m^2 of leaf-litter that was raked and placed in a leaf-litter reducer. The leaf-litter reducer (Figure 3-2) consists of a large canvas funnel with a large opening at the top and a smaller opening at the bottom that can be tied shut. A metal sieve rests inside the reducer about halfway down. The reducer was shaken vigorously to separate the coarse and fine leaf-litter and force any animals to the bottom. The coarse leaf-litter above the sieve was emptied onto the ground and the finer material containing any animals is placed in a plastic zip-lock bag, labelled and stored in an esky to be kept cool and moist. The samples are then transported back to *ecologia*'s laboratory. Once in Perth, the samples are placed in Tullgren funnels to extract any invertebrates.


Figure 3-2 – Example of the Leaf-Litter Reducer and Tullgren Funnels

3.5 EXTRACTION METHODS

Tullgren funnels were used to extract any animals from the collected leaf litter samples (Figure 3-2). The general principle of Tullgren funnels is that a sample of leaf litter gathered is suspended above a vessel containing ethanol. Animals inhabiting the sample are forced downwards by the progressive drying of the sample and ultimately fall into the collecting vessel containing ethanol. Typically, drying is enhanced by placing an incandescent lamp or heat source above the sample.

3.6 LABORATORY SORTING AND SPECIMEN IDENTIFICATION

Once in Perth, all samples collected in the field and from the leaf-litter were sorted under a compound Leica microscope by *ecologia* staff and any potential SRE species were collected and labelled. In addition, the dried leaf-litter samples were sorted under a magnifier in order to collect snail shells and any specimens that may have died before they could fall into the vial.

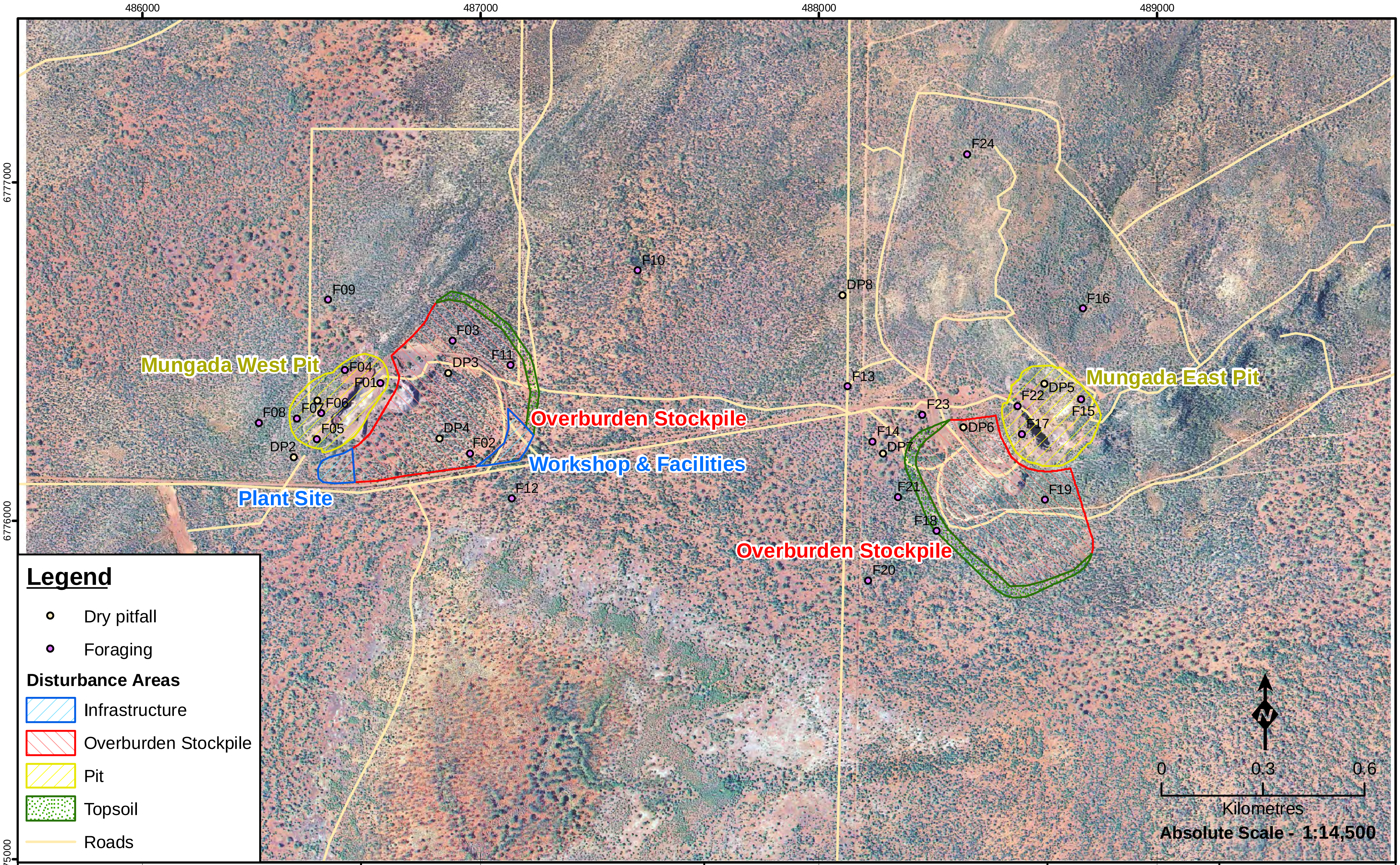
All specimens collected from potential SRE groups were then sent to the WAM or relevant taxonomic expert for identification. A list of the taxonomic experts used for identification is provided in Table 3-1 below.

Table 3-1 – Taxonomic Experts used to Identify Potential SRE Taxa Found During the Survey

Taxonomic Expert	Institution	Specialist Group
Mark Harvey	Western Australian Museum	Pseudoscorpions and Myriapods
Volker Framenau	Western Australian Museum	Mygalomorph spiders
Shirley Slack-Smith	Western Australian Museum	Molluscs
Corey Whisson	Western Australian Museum	Molluscs
Simon Judd	Private consultant	Isopods
Erich Volschenk	Subterranean Ecology	Scorpions

3.7 HABITAT ANALYSIS

An analysis of the preferred habitat of SRE and potential SRE species collected was made by mapping each species against the land systems of the area and vegetation communities as presented in the vegetation and flora survey of the area (*ecologia* 2008). The percentage of each land system and vegetation community that would be directly impacted by the proposed development was calculated to determine the potential impact on each species and the habitat connectivity was also examined.



ecologia ENVIRONMENT

中钢澳洲中西矿业公司
SINOSTEEL MIDWEST CORPORATION LIMITED

Location of Sample Sites across Blue Hills

Figure: 3.3
Project ID: 1233

Drawn: AH
Date: 31/08/10

Coordinate System
Name: GDA 1994 MGA Zone 50
Projection: Transverse Mercator
Datum: GDA 1994

Unique Map ID: A224

A4

This page has been left blank intentionally

4 RESULTS

4.1 SURVEY ADEQUACY

4.1.1 Species Accumulation Curves

Species Accumulation Curve through 100 randomisations of the sample sequence gave a smooth curve (Figure 4.1). New species were accumulated at mean rate of 0.29 species per sample during the first 25 samples, 0.12 species between the samples 25 to 50 and 0.08 species per sample during the final 22 samples. At 70 samples, the sample sufficiency was 82% confirming the confidence of the survey efficiency.

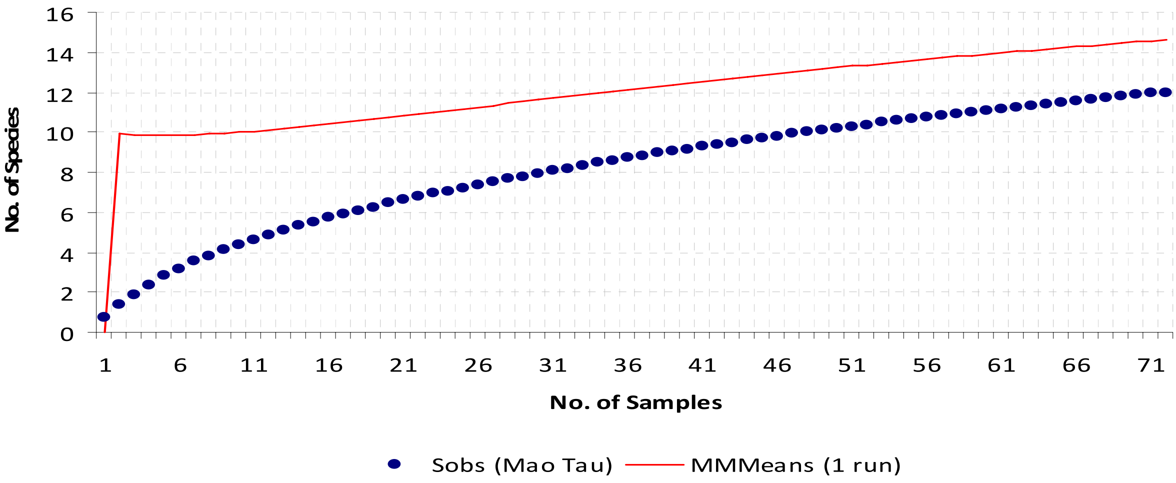


Figure 4-1 – Species Accumulation Curve (SAC) of the SRE Fauna Data from the Leaf-litter Collection Using the Observed Number of Species (Sobs Mao Tau)

4.2 SPECIES DIVERSITY AND ABUNDANCE

The estimator ACE produced the highest prediction of 18.2 species and Chao 1 gave a more conservative estimate of 14 species. These estimations show that 15 – 35% more species potentially occur in the SRE assemblage (Figure 4.2).

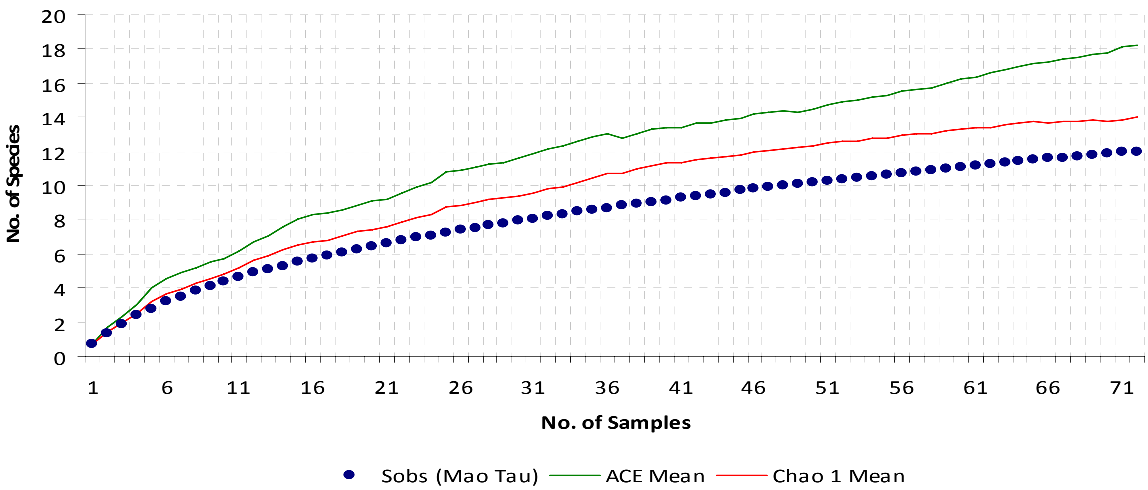


Figure 4.2 – Species Accummulation Curve (SAC) for Specimens Collected From Leaf-Litter Samples

4.3 SPECIMENS COLLECTED

A total of 74 invertebrate specimens were collected during the survey representing five orders, 10 families, 12 genera and 12 species and are presented in Table 4-1 and Table 4-2. Four SRE or potential SRE species were collected during the survey and the distribution of these specimens is shown in Figure 4-4. In addition trapdoor spider burrows from the genus *Idiosoma* were found at 14 sites.

4.4 ARACHNIDA

4.4.1 Trapdoor Spiders (Mygalomorphae)

Family Idiopidae

***Idiosoma* 'MYG018'**

Trap-door burrows belonging to the spider genus *Idiosoma* were found at sites F05, F06, F07, F08, F09, F11, F13, F14, F16, F18, F19, F20, F21 and F24 (Table 4.2). Burrows were found at sites in both Mungada East and West as well as outside the impact area.

The spider collected was a juvenile specimen and could not be identified to species level. It has tentatively been identified as *Idiosoma* 'MYG018' however, adult males are required for accurate identification (Framenau and Harvey 2010). *Idiosoma* 'MYG018', of which two males were previously collected at Glen Station (Framenau and Harvey 2009), has very close morphological affinities to *Idiosoma nigrum* (Figure 4-3) based on the rugosity of the abdomen. However, it differs significantly in male pedipalp morphology and must be considered a different species. Currently only one species from the genus *Idiosoma* (*I. nigrum*) is listed as Schedule 1 under the *WC Act* (Government Gazette 2010) however, all species of the genus *Idiosoma* are considered SREs.

Figure 4.3 – The Shield-backed Trapdoor Spider *Idiosoma nigrum*. A, Burrow with Open Lid; B, Adult Spider

Family Actinopodidae

***Missulena* 'MYG045'**

Spiders of the genus *Missulena* are commonly known as Mouse Spiders. Emergent juveniles of *Missulena* are known to disperse via ballooning, potentially allowing them to disperse large distances and thereby reducing the predisposition for short-range endemism (Framenau and Harvey 2010).

A single specimen of *Missulena* 'MYG045' was collected from site DP3. This species has been previously collected from Western Australia including the Avon Wheatbelt near Pintharuka, Mt Gibson, Mt Manning and Meka Station (Framenau and Harvey 2010). Although it appears to have a limited distribution, it is not considered to be an SRE (Framenau and Harvey 2010).

4.4.2 Scorpions (Scorpiones)

A single scorpion specimen was collected during the survey from site F01.

Family Buthidae

***Lychas* 'splendens'**

The scorpion specimen collected was an adult male of the species *Lychas* 'splendens' from the family Buthidae. This species is found widely throughout the semi-arid parts of the southwest of Western Australia and is not considered to represent an SRE (pers. comm. E. Volschenk).

4.4.3 Pseudoscorpions (Pseudoscorpiones)

Pseudoscorpions were the most abundant group found with a total of 43 specimens collected.

Family Chthoniidae

***Tyrannochthonius* sp.nov. 'Blue Hills'**

One male specimen of *Tyrannochthonius* was recorded from site F21 located just outside the impact area at Mungada East. This genus is distributed throughout tropical regions of the world where they occur in leaf litter and the upper soil layer (Framenau and Harvey 2010). The Australian fauna consists of several epigean species and several troglobitic species, of which five have been described from Western Australia: *L. basme*, *T. billhumphreysi*, *T. butleri*, *T. garthhumphreysi* and *T. souchomalus* (Harvey 1991; Edward and Harvey 2008).

This species is potentially a short-range endemic, but it may also be more widespread in the Pilbara, similar to *T. aridus* (Framenau and Harvey 2010).

Family Garypidae

Synsphyronus mimulus

Specimens of *Synsphyronus mimulus* were recorded from sites F02, F10 and F12 both inside and outside the Project Area. Many species of *Synsphyronus* may represent short-range endemic species (Framenau and Harvey 2010), in particular in ground habitats such as under rocks. However, *S. mimulus* is a widespread species that occurs in all Australian mainland states (Harvey 1987) and does not represent an SRE (Framenau and Harvey 2010).

Family Olpiidae

***Austrohorus* sp.**

Two specimens of *Austrohorus* were recorded from site F23 located just outside the Project Area at Mungada East. The species collected appears to be very similar to other samples of *Austrohorus* collected elsewhere in Western Australia however, it is unknown whether this species represents and SRE (Framenau and Harvey 2010).

***Beierolpium* 'sp.8/4'**

Specimens from the genus *Beierolpium* were collected from foraging sites 03, 05, 10, 11, 12, 14, 15, 16, 17, 18, 21 and 22 which are spread across the tenement both inside and outside the Project Area at Mungada West and Mungada East. The systematic status of members of this genus has not been fully assessed and at present it is not possible to firmly establish the identity of these species until a complete systematic revision of the Western Australian member of *Beierolpium* is undertaken. It is possible that this species represents an SRE (Framenau and Harvey 2010).

***Indolpium* sp.**

Two specimens were recorded from sites F10 and F12 which are both located outside the Project Area. The specimens comprise a single species and extremely similar specimens have been collected from other regions of Western Australia, suggesting that only a single species is involved (Framenau and Harvey 2010). Based on current levels of knowledge, it is unlikely to represent a SRE (Framenau and Harvey 2010).

4.5 CRUSTACEA (MALACOSTRACA: ISOPODA)

A total of nine isopod specimens were collected during the survey representing two genera of the family Armadillidae.

Family Armadillidae

***Buddelundia* sp.**

Eight specimens from the genus *Buddelundia* were collected from sites F01, F02, F04 and F15. This species is a common form of *Buddelundia* found widespread throughout the Mid-west and Pilbara. This is similar to specimens both in the Pilbara and the coastal Geraldton area and is one of the most common encountered isopod in semi-arid areas and is therefore not considered to be an SRE (pers. comm. S. Judd, September 2010).

***Spherillo* sp.**

One species from the genus *Spherillo* was collected in a dry-pitfall trap at site DP7. No species of *Spherillo* are yet described from WA however; isopods of this genus are widespread, particularly in drier areas. The specimen collected is similar to specimens collected from the York area (pers. comm. S. Judd, September 2010). It is also found in the northern jarrah forest and has a wide distribution in a range of microhabitat types. It is found in seasonally-dry areas and not in the wetter parts of the south-west. This species is not considered to be an SRE (pers. comm. S. Judd, September 2010).

4.6 MOLLUSCA (SNAILS)

Nineteen snail specimens were collected from four sites and represent three families, four genera and four species. None of the species collected have a restricted geographic range and therefore do not represent SREs.

Family Camaenidae

Sinumelon vagente

A single specimen of *Sinumelon vagente* was collected from site F04 during the survey and was also collected during the 2006 survey (*ecologia* 2007). The known geographic range of this species extends from Bindoo Hill (east of Geraldton) in an ESE direction to the vicinity of Mt Jackson so this specimen lies well the known geographic distribution (Slack-Smith and Whisson 2010). Due to it's wide geographic range, this species is not considered to be an SRE (Slack-Smith and Whisson 2010).

Family Pupillidae

Pupoides adelaidae

A single specimen of *Pupoides adelaidae* was collected during the survey from site F11. This species has a wide geographic distribution that appears to extend from New South Wales and north-western Victoria, across southern South Australia into the wheatbelt areas of Western Australia and as far to the north-west as Morawa (Slack-Smith and Whisson 2010). Due to it's wide geographic range, this species is not considered to be an SRE (Slack-Smith and Whisson 2010).

Gastrocopta bannertonensis

Eleven specimens of *Gastrocopta bannertonensis* were collected at sites F21 and F21. This species has a wide geographic distribution in southern Australia, having been recorded from the southern regions of Western Australia, South Australia and New South Wales. There is also a single record of its presence in an area to the north-west of Alice Springs in the Northern Territory (Slack-Smith and Whisson 2010). Due to it's wide geographic range, this species is not considered to be an SRE (Slack-Smith and Whisson 2010).

Family Punctidae

Westralaoma expita

Six specimens of *Westralaoma epita* were collected at sites F21 and F21.

There is little positive evidence for an extension of the geographic range of the species *W. expicta* beyond the area of the type locality, Nangeenan in WA as very few similar specimens have been collected in good condition. However, the specimens collected from this survey are in good condition and are of considerable research value and have been preserved for genetic analysis (Slack-Smith and Whisson 2010).

There is a noticeable morphological consistency among recently collected specimens and so *W. expita* seems to have a considerable geographic range through the eastern wheat belt and is therefore not considered an SRE species (Slack-Smith and Whisson 2010).

This page has been left blank intentionally

Table 4-1 – Specimens Collected from the Dry-Pitfall Trap Sites

Class (Order)	Family	Genus	Species	SRE	Dry-Pitfall Trap Site Number DP1	DP2	DP3	DP4	DP5	DP6	DP7	DP8
Arachnida (Aranae)												
	Actinopodidae	*Missulena*	'MYG045'	No			1					
Malacostraca (Isopoda)												
	Armadillidae	*Spherillo*	sp.	No							1	

Table 4-2 – Specimens Collected from the Foraging Sites

Class (Order)	Family	Genus	Species	SRE	Foraging Site Number F01	F02	F03	F04	F05	F06	F07	F08	F09	F10	F11	F12	F13	F14	F15	F16	F17	F18	F19	F20	F21	F22	F23	F24
Arachnida (Aranae)																												
	Idiopidae	*Idiosoma*	MYG018'	Yes					1*	9*	8*	3*	6*		2*		2**	5*		8*		3*	1*	6*	2*			15*
Arachnida (Scorpiones)																												
	Buthidae	*Lychas*	splendens'	No	1																							
Arachnida (Pseudoscorpiones)																												
	Chthoniidae	*Tyrannochthonius*	sp.nov.Blue Hills	Potential																					**1**			
	Garypidae	*Synsphyronus*	*mimulus*	No		**4**								**6**		**1**												
	Olpiidae	*Austrohorus*	sp.	Potential																							**2**	
		Beierolpium	sp.8/4'	Potential			**4**		**3**					**1**	**2**	**1**		**9**	**1**	**1**	**1**	**2**			**1**	**1**		
		Indolpium	sp.	No										**1**		**1**												
Malacostraca (Isopoda)																												
	Armadillidae	*Buddelundia*	sp.	No	2	4		1											1									
Gastropoda																												
	Camaenidae	*Sinumelon*	cf. *vagente*	No				1																				
	Pupillidae	*Pupoides*	cf. *adelaidae*	No											1													
		Gastrocopta	cf. *bannertonensis*	No																					1	10		
	Punctidae	*Westralaoma*	cf. *expicta*	No																					2	4		

* Indicates number of burrows found
** Single specimen collected for identification

This page has been left blank intentionally

4.7 HABITAT ANALYSIS

Table 4.3 shows the percentage impact of the project in the land systems that are present within the project area. All of the SRE or potential SRE species collected during the survey were recorded in the Tallering land system however the total impact on this land system will be low with only 0.11% expected to be directly impacted by the development.

Table 4-3 – Percentage Impact on Land Systems within the Project Area

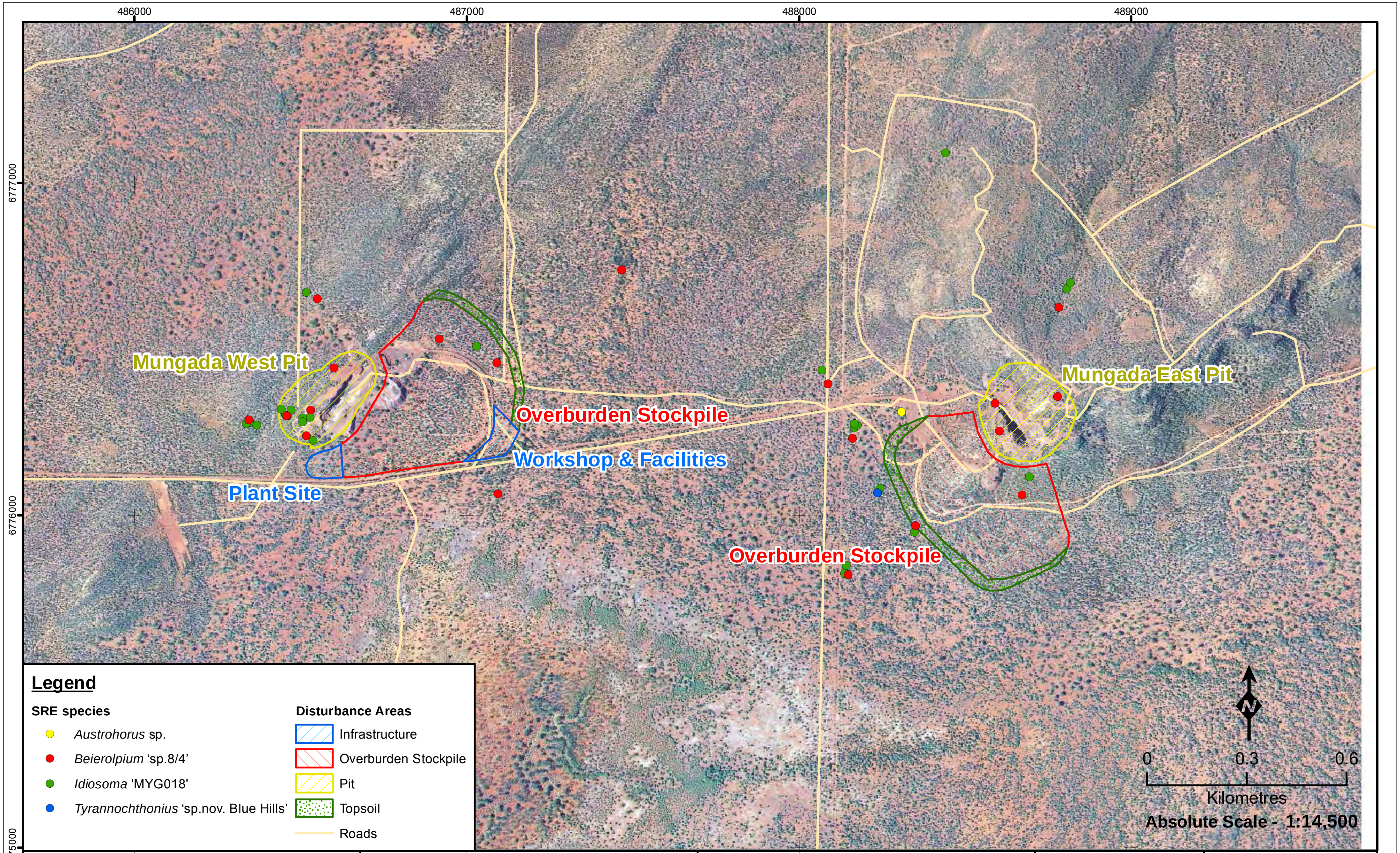
Land System	Area of Land System within Disturbance Area (ha)	Total Land System Area in W.A. (ha)	Percentage of Land System that will be Impacted %	SRE Species Present
Tallering	35.5	32948	0.11	*Idiosoma* 'MYG018' *Tyrannochthonius* 'sp. nov. Blue Hills' *Austrohorus* sp. *Beierolpium* 'sp. 8/4'
Yowie	16.1	1620859	0.001	*Idisoma* 'MYG018' *Beierolpium* 'sp. 8/4'

Eight vegetation communities are present within the Project Area and five of these contain SRE or potential SRE species including Arr, Aan, ApCp, El and Ew (Table 4.4). Of the vegetation communities that contain SRE or potential SRE species, Ew will be impacted the most with almost 42% of the vegetation community within the tenement expected to directly impacted. All of the vegetation communities occurring in the proposed impact areas have connectivity with outside areas.

Table 4-4 – Percentage Impact on Vegetation Communities within the Project Area

Vegetation Unit	Area of Vegetation Unit within Disturbance Area (ha)	Total Vegetation Unit Area within the Tenement (ha)	Percentage of Vegetation Unit that will be Impacted %	Habitat Connectivity	SRE Species Present
Arr	32.7	643.8	5.07	Yes	*Idiosoma* 'MYG018' *Beierolpium* 'sp. 8/4'
Aan	1	132.9	0.72	Yes	*Idiosoma* 'MYG018' *Beierolpium* 'sp. 8/4'
ApCp	2.4	24.5	9.6	Yes	*Idiosoma* 'MYG018' *Beierolpium* 'sp. 8/4'
AaPo	0.8	20.6	4.03	Yes	None
Deg	3.3	4.2	78.01	Yes	None
El	3.5	182.4	1.92	Yes	*Idiosoma* 'MYG018' *Austrohorus* sp. *Beierolpium* 'sp. 8/4'
Ew	6.2	15	41.64	Yes	*Idiosoma* 'MYG018' *Tyrannochthonius* 'sp. nov. Blue Hills' *Beierolpium* 'sp. 8/4'
Mu	1.8	26.3	6.66	Yes	None

This page has been left blank intentionally



ecologia ENVIRONMENT

中钢澳洲中西矿业公司 SINOSTEEL MIDWEST CORPORATION LIMITED

Locations of SRE Specimens Collected at Blue Hills

Figure: 4.4
Project ID: 1233

Drawn: AH
Date: 15/11/10

Coordinate System
Name: GDA 1994 MGA Zone 50
Projection: Transverse Mercator
Datum: GDA 1994

Unique Map ID: A206

A4

This page has been left blank intentionally

5 DISCUSSION AND CONCLUSION

A total of 14 species were collected during the survey including mygalomorph spiders, scorpions, pseudoscorpions, isopods and snails. Of these, the mygalomorph spider *Idiosoma* 'MYG018' and the pseudoscorpions *Austrohorus* sp., *Beierolpium* 'sp.8/4' and *Tyrannochthonius* 'sp.nov. Blue Hills' are SREs or potential SREs. All of the other species collected have a wide geographic distribution and were not considered to represent SRE species. A summary of the SREs collected, location and predicted percentage impact can be found in Table 5-1.

The species accumulation curves showed that over 80% of species have been collected from the Blue Hills area during this survey which is considered sufficient. However, the survey was limited by the methods used as shown by the estimators of species diversity and abundance which showed that only 65 – 85% of the species have been collected. This survey consisted only of foraging and dry-pitfall trapping which is effective for some SRE groups but not all. Wet-pitfall trapping, where the pitfall traps are left in the ground for one month and then collected, records higher numbers of species and species abundance. Wet-pitfall trapping is not the preferred method of the DEC as it can impact native vertebrate fauna and, when misused, can result in over-sampling consequently damaging the species' populations.

Several potential SRE species were collected during the 2006 survey at Blue Hills including one unidentified species from the mygalomorph spider family Barychellidae, a snail species of the genus *Bothriembryon* and a pseudoscorpion from the genus *Synsphronus*. The Barychelid spider and the *Bothriembryon* snail were not collected during this survey, and a different species of the pseudoscorpion *Synsphronus* was collected but is not considered a SRE. The Barychelid spider and the *Bothriembryon* snail were collected from outside the impact area during the 2006 survey and will therefore not be impacted by the proposed development. The *Synsphronus* pseudoscorpion was collected from inside the Project Area during 2006, however the habitat type where this species was collected will be less than 10% impacted and extends and is connected well beyond on the Project Area. This species is considered to have a medium risk of impact because it has not been collected outside the impact area (Table 5-1).

Previous database searches (*ecologia* 2007) suggested that the Schedule 1 listed trapdoor spider *Aganippe castellum* may be present in the Koolanooka / Blue Hills area. However, no specimens or spider burrows were recorded during the 2006 survey or current survey.

The pseudoscorpions *Tyrannochthonius* 'sp.nov. Blue Hills' and *Austrohorus* sp. are potential SREs however, they were only recorded from outside the proposed impact area. They will therefore not be directly impacted by the Project. *Tyrannochthonius* 'sp.nov. Blue Hills' was collected at site F21 located in relatively close proximity to the pit outline. This species may still be affected by indirect impacts such as dust from vehicles, or vegetation clearing. Management recommendations should be put in place to reduce any indirect impacts. As this species was collected outside the Project Area, it is considered at low risk of impact if indirect impacts are managed.

Austrohorus sp. was collected from site F23 which is outside the Project Area but also in close proximity to the pit outline. The vegetation community in this area (El) does not extend very far beyond the pit so management procedures should be put in place to reduce indirect impacts in this area.

Both the spider *Idiosoma* 'MYG018' and the pseudoscorpion *Beierolpium* were recorded from sites both inside and outside the proposed impact areas and as such these species will be partially impacted by the Project. Neither species appears to be restricted to a particular habitat, with both species occurring in both land systems and at least five of the eight vegetation communities present within the Project Area, and both appear to be widespread across the tenement. Management recommendations should be put in place to reduce the direct impacts to inside populations and indirect impacts to outside populations.

The majority of *Idiosoma* populations were recorded from outside the proposed impact areas however, several populations were recorded in Mungada West, inside the proposed pit area where they will be directly at threat from the Project. The species have been tentatively identified as *Idiosoma* 'MYG018' which is considered to be a SRE and environmental management procedures should be put in place to conserve current populations.

In summary, a total of seven SRE or potential SRE species have been recorded from the Blue Hills Project Area. The impact is considered medium for the *Synsphronus* sp. collected during 2006 as it has only been found within the Project Area, however the vegetation community where it was found is expected to be impacted less than 10 %. The impact of the development is considered low for all of the other species.

Table 5-1 – Summary of SRE Species Recorded, Survey Sites and Collection Methods

Species	Year	SRE Status	Assessment of Impact from Proposal	Significance of Impact
Barychellidae Unknown sp.B	2006	Yes	Will not be impacted. Only recorded from outside the Project Area	Low
Idiosoma 'MYG018'	2010	Yes	Partially impacted. Has been recorded both within and well outside proposed impact areas.	Low
Austrohorus sp.	2010	Potential	Indirectly impacted. Recorded from site close to the pit boundary	Low
Beierolpium 'sp.8/4'	2010	Potential	Partially impacted. Has been recorded both within and well outside proposed impact areas.	Low
Synsphronus sp.	2006	Potential	Partially impacted. Only recorded from inside the impact area, however vegetation community is connected and extends well beyond impact area	Med
Tyrannochthonius sp.	2010	Potential	Indirectly impacted. Recorded from site close to the pit boundary	Low
Bothriembryon sp.	2006	Potential	Will not be impacted. Only recorded from outside the Project Area	Low

6 ACKNOWLEDGEMENTS

The Blue Hills SRE invertebrate assessment described in this document was planned, coordinated, and executed by:

ecologia Environment

1025 Wellington Street

WEST PERTH WA 6005

Project Staff:

Lazaro Roque-Albelo	BSc, MSc, PhD, Senior Invertebrate Zoologist
Catherine Hall	BSc Hon, Invertebrate Zoologist
Nicki Thompson	BSc Hon, Invertebrate Zoologist
Laura Quinn	BSc, MSc, Invertebrate Zoologist
Sean White	BSc, Invertebrate Zoologist

Special Thanks:

Dr Mark Harvey and Dr Volker Framenau, Department of Terrestrial Invertebrates, Western Australian Museum; Ms Shirley Slack-Smith and Mr Corey Whisson, Department of Malacology, Western Australian Museum; Dr Erich Volschenk and Dr Simon Judd for database searches and species identification.

This page has been left blank intentionally

7 REFERENCES

Allen, G. R., Midgley, S. H., and Allen, M. 2002. Field Guide to the Freshwater Fishes of Australia. CSIRO Publishing, Melbourne, VIC.

BOM. 2010. Bureau of Meteorology. Accessed http://www.bom.gov.au.

Bunge, J. and Fitzpatrick, M. 1993. Estimating the number of species: A review. Journal of the American Statistical Association. 88:364-373.

Burbidge, A. H., Harvey, M. S., and McKenzie, N. L. 2000. Biodiversity in the southern Carnarvon Basin. Records of the Western Australian Museum. Supp. 61:1 - 595.

Department of Conservation and Land Management,. 2004. Towards a biodiversity conservation strategy for Western Australia - discussion paper.

Chessman, B. C. 1995. Rapid assessment of rivers using macroinvertebrates: A procedure based on habitat-specific sampling, family level identification and a biotic index. Australian Journal of Ecology. 20:122 - 129.

Colwell, R. K. 2009. EstimateS: Statistical estimation of species richness and shared species from samples. Version 8.

Colwell, R. K. and Coddington, J. A. 1994. Estimating terrestrial biodiversity through extrapolation. Philosophical Transactions of the Royal Society (Series B). 345:101-118.

Commonwealth Government. 1996. The Natural Strategy for the conservation of Australia's Biological Diversity. *in* Department of the Environment, S. a. T., ed. Commonweath of Australia, canberra.

Curry, P. J., Payne, A. L., Leighton, K. A., Hennig, P., and Blood, D. A. 1994. An inventory and condition survey of the Murchison River Catchment, Western Australia. Technical Bulletin No. 84. Department of Agriculture, Western Australia.

Desmond, A. and Chant, A. 2001. Yalgoo. A Biodiversity Audit of Western Australia's 53 Biogeographic Subregions 2002. CALM, Perth, WA.

ecologia Environment. 2007. Koolanooka/Blue Hills DSO Mining Project Short-Range Endemic Biological Assessment. Report Prepared for Midwest Corporation.

ecologia Environment. 2008. Koolanooka Hills / Blue Hills Flora and Vegetation Survey. Report Prepared for Midwest Corporation.

Edgecombe, G. D., Giribet, G., and Wheeler, W. C. 2002. Phylogeny of Henicopidae (Chilopoda: Lithobiomorpha): a combined analysis of morphology and five molecular loci. Systematic Entomology. 27:31-64.

Environmental Protection Authority. 2004. Guidance for the Assessment of Environmental Factors No. 56: Terrestrial Fauna Surveys for Environmental Impact Assessment in Western Australia. 28 June 2004

Environmental Protection Authority. 2009. Guidance for the Assessment of Environmental Factors, Statement No 20: Sampling of Short Range Endemic Invertebrate Fauna for Environmental Impact Assessment in Western Australia.

Framenau, V. W. and Harvey, M. S. 2010. The Short-Range Endemic Invertebrate Fauna of Blue Hills (Ecologia Project 1233) (Western Australia). Report Prepared for Ecologia Environment. Western Australian Museum.

Gaston, K. J. 1996. Species richness: measure and measurement. In: Biodiversity, a biology of number and difference. Blackwell Science, Cambridge.

Government Gazette. 2010. Wildlife Conservation (Specially Protected Fauna) Notice 2010. Government Gazette, WA; Wildlife Conservation Act 1950.

Harvey, M. S. 1996. The Biogeography of Gondwanan pseudoscorpions (Arachnida). Revue Suisse de Zoologie. 1:255 - 264.

Harvey, M. S. 2002. Short-range endemism among the Australian fauna: some examples from non-marine environments. Invertebrate Systematics. 16:555 - 570.

Hill, R. S. E. 1994. History of Australian Vegetation: Cretaceous to Recent. Cambridge University Press, Cambridge, UK.

Johnson, M. S., Hamilton, Z. R., Murphy, C. E., MacLeay, C. A., Roberts, B., and Kendrick, P. 2004. Evolutionary genetics of island and mainland species of Rhagada (Gastropoda: Pulmonata) in the Pilbara Region, Western Australia. Australian Journal of Zoology. 52:341 - 355.

Koch, L. E. 1981. The scorpions of Australia: aspects of their ecology and zoogeography. pp. 875-884 *in* A., K., ed. Ecological Biogeography of Australia. Monogr. Biol. 41 (2).

Lewis, J. G. E. 1981. The Biology of Centipedes. Cambridge University Press, Cambridge.

Main, B. Y. 1982. Adaptations to arid habitats by mygalomorph spiders *in* Barker, W. R., and Greenslade, P. J. M., eds. Evolution of the Flora and Fauna of Arid Australia. Peacock Publications.

Main, B. Y. 1996. Terrestrial invertebrates in south-west Australian forests: the role of relict species and habitats in reserve design. Journal of the Royal Society of Western Australia. 79:277 - 280.

Main, B. Y. 1999. Biological anachronisms among trapdoor spiders reflect Australias environmental changes since the Mesozoic *in* Ponder, W., and Lunney, D., eds. The Other 99%. Transactions of the Royal Zoological Society of New South Wales, Mosman 2088.

McKenzie, N. L., Halse, S. A., and Gibson, N. 2000. Some gaps in the reserve system of the southern Carnarvon Basin, Western Australia. Records of the Western Australian Museum. Supp. 61.

Minister for Environment. 2009. Statement that a proposal may be implemented (pursuant to the provisions of the *Environmental Protection Act* 1986). Koolanooka/Blue Hills Direct Shipping Ore Mining Project. Shires of Morowa and Perenjori. Statement No. 811.

Payne, A. L., Van Vreeswyk, A. M. E., Pringle, H. J. R., Leighton, K. A., and Hennig, P. 1998. An inventory and condition survey of the Sandstone-Yalgoo-Paynes Find area, Western Australia. Technical Bulletin No. 90. Agriculture Western Australia, Perth.

Raven, R. J. 1982. Systematics of the Australian mygalomorph spider genus *Ixamatus* Simon (Diplurinae: Dipluridae: Chelicerata). Australian Journal of Zoology. 30.

Slack-Smith, S. and Whisson, C. 2010. Land Snails from the area of the Blue Hills, Western Australia (Project 1233). Report Prepared for *ecologia* Environment. Western Australian Museum, Perth.

Solem, A. 1997. Camaenid land snails from Western and Central Ausrtalia (Mollusca: Pulmonata: Camaenidae). VII. Taxa from Dampierland through the Nullabor. Records of the Western Australian Museum, Supplement. 50.:1461 - 1906.

Wright, S. 1943. Isolation by distance. Genetics. 28:114 - 138.

This page has been left blank intentionally

APPENDIX A SRE SURVEY SITE CO-ORDINATES

Site Name	Location	Zone	Easting	Northing
Dry Pitfall Site 01	Mungada West Pit	50J	486520	6776355
Dry Pitfall Site 02	Outside	50J	486450	6776187
Dry Pitfall Site 03	Mungada West Waste Stockpile	50J	486906	6776436
Dry Pitfall Site 04	Mungada West Waste Stockpile	50J	486881	6776243
Dry Pitfall Site 05	Mungada East Pit	50J	488669	6776404
Dry Pitfall Site 06	Mungada East Waste Stockpile	50J	488431	6776276
Dry Pitfall Site 07	Outside	50J	488192	6776198
Dry Pitfall Site 08	Outside	50J	488073	6776666
Foraging Site 01	Mungada West Pit	50J	486707	6776406
Foraging Site 02	Mungada West Waste Stockpile	50J	486971	6776198
Foraging Site 03	Mungada West Waste Stockpile	50J	486919	6776532
Foraging Site 04	Mungada West Pit	50J	486602	6776444
Foraging Site 05	Mungada West Pit	50J	486518	6776241
Foraging Site 06	Mungada West Pit	50J	486531	6776317
Foraging Site 07	Mungada West Pit	50J	486459	6776302
Foraging Site 08	Outside	50J	486346	6776289
Foraging Site 09	Outside	50J	486552	6776652
Foraging Site 10	Outside	50J	487467	6776739
Foraging Site 11	Mungada West Waste Stockpile	50J	487091	6776459
Foraging Site 12	Outside	50J	487094	6776065
Foraging Site 13	Outside	50J	488088	6776396
Foraging Site 14	Outside	50J	488161	6776233
Foraging Site 15	Mungada East Pit	50J	488778	6776359
Foraging Site 16	Outside	50J	488783	6776627
Foraging Site 17	Mungada East Pit	50J	488604	6776255
Foraging Site 18	Mungada East Waste Stockpile	50J	488351	6775969
Foraging Site 19	Mungada East Waste Stockpile	50J	488671	6776061
Foraging Site 20	Outside	50J	488149	6775823
Foraging Site 21	Outside	50J	488236	6776069
Foraging Site 22	Mungada East Pit	50J	488590	6776338
Foraging Site 23	Outside	50J	488309	6776313
Foraging Site 24	Outside	50J	488442	6777082

APPENDIX B SITE DESCRIPTIONS

Dry Pitfall Site 01
Coordinates:
50 486520E 6776355N
Habitat: Mid-slope with mulga
Slope: Moderate, NE slope
Leaf-litter: <1 cm deep, concentrated under trees and shrubs
Surface: Coarse gravel and small stones, 50 - 90% cover
Soil Type: Red-brown sandy clay

Dry Pitfall Site 02
Coordinates:
50 486450E 6776187N
Habitat: Plain with mulga
Slope: Negligible
Leaf-litter: <1 cm deep, concentrated under trees and shrubs
Surface: Small stones, 50 – 90% cover
Soil Type: Red-brown sandy clay

Dry Pitfall Site 03
Coordinates:
50 486906E 6776436N
Habitat: Plain with mulga
Slope: Negligible
Leaf-litter: <1 cm deep, concentrated under trees and shrubs
Surface: Slight soil cracking and small stones, 30 – 50% cover
Soil Type: Red-brown sandy clay

Dry Pitfall Site 04
Coordinates:
50 486881E 6776243N
Habitat: Plain with mulga
Slope: Gentle, SE slope
Leaf-litter: <1 cm deep, concentrated under trees and shrubs
Surface: Small stones, 5 0 – 90% cover
Soil Type: Red-brown sandy clay

Dry Pitfall Site 05

Coordinates:

50 488669E 6776404N

Habitat: Mid-slope with mulga

Slope: Moderate

Leaf-litter: <1 cm deep, concentrated under trees and shrubs

Surface: Coarse gravel and small stones, 50 – 90% cover

Soil Type: Red-brown sandy clay

Dry Pitfall Site 06

Coordinates:

50 488431E 6776276N

Habitat: Foot-slope with mulga

Slope: Gentle, SE slope

Leaf-litter: <1 cm deep, concentrated under trees and shrubs

Surface: Coarse gravel and small stones, continuous cover

Soil Type: Red-brown sandy clay

Dry Pitfall Site 07

Coordinates:

50 488192E 6776198N

Habitat: Plain with *Eucalyptus* sp.

Slope: Negligible

Leaf-litter: <1 cm deep, concentrated under trees and shrubs

Surface: Small stones, 50 – 90% cover

Soil Type: Red-brown sandy clay

Dry Pitfall Site 08

Coordinates:

50 488073E 6776666N

Habitat: Plain with mulga

Slope: Negligible

Leaf-litter: <1 cm deep, concentrated under trees and shrubs

Surface: Fine gravel and small stones, 30 – 50% cover

Soil Type: Red-brown sandy clay

Foraging Site 01 Coordinates: 50 486789E 6776282N Habitat: Plain with *Acacia borkittii* Slope: Negligible Leaf-litter: <1 cm deep, concentrated under trees and shrubs Surface: Surface crust, fine gravel <10% cover Soil Type: Red-brown sandy clay	
Foraging Site 02 Coordinates: 50 486971E 6776198N Habitat: Plain with *Acacia borkittii* Slope: Negligible Leaf-litter: <1 cm deep, concentrated under trees and shrubs Surface: Surface crust, fine gravel <10% cover Soil Type: Red-brown sandy clay	
Foraging Site 03 Coordinates: 50 486919E 6776532N Habitat: Plain with *Calycopeplus paucifalivus* Slope: Negligible Leaf-litter: <1 cm deep, concentrated under trees and shrubs Surface: Small stones, 50 – 90% cover Soil Type: Red-brown sandy clay	
Foraging Site 04 Coordinates: 50 486602E 6776444N Habitat: Plain with *Acacia burlertii* Slope: Negligible Leaf-litter: <1 cm deep, concentrated under trees and shrubs Surface: Small stones, <10% cover Soil Type: Red-brown sandy clay	

Foraging Site 05 Coordinates: 50 486518E 6776241N Habitat: Mid-slope with *Acacia ramulosa* Slope: Moderate, SE slope Leaf-litter: <1 cm deep, concentrated under trees and shrubs Surface: Small – large stones, 50 – 90% cover Soil Type: Red-brown sandy clay	
Foraging Site 06 Coordinates: 50 486531E 6776317N Habitat: Hill top with *Acacia ramulosa* Slope: Negligible Leaf-litter: <1 cm deep, concentrated under trees and shrubs Surface: Large stone - boulders, 90 – 100% cover Soil Type: Red-brown sandy clay	
Foraging Site 07 Coordinates: 50 486459E 6776302N Habitat: Plain with *Melaleuca hamata* Slope: Negligible Leaf-litter: <1 cm deep, concentrated under trees and shrubs Surface: Small stones, 50 – 90% cover Soil Type: Red-brown sandy clay	
Foraging Site 08 Coordinates: 50 486346E 6776289N Habitat: Plain with *Acacia effusifolia* Slope: Negligible Leaf-litter: <1 cm deep, concentrated under trees and shrubs Surface: Small stones and coarse gravel, 90 – 100% cover Soil Type: Red-brown sandy clay	

Foraging Site 09 Coordinates: 50 486552E 6776652N Habitat: Plain with *Allocasuarina acutivalvis* Slope: Negligible Leaf-litter: <1 cm deep, concentrated under trees and shrubs Surface: Small stones and coarse gravel, 90 – 100% cover Soil Type: Red-brown sandy clay	
Foraging Site 10 Coordinates: 50 487467E 6776739N Habitat: Plain with *Acacia ramulosa* Slope: Negligible Leaf-litter: <1 cm deep, concentrated under trees and shrubs Surface: Fine gravel, <10% cover Soil Type: Red-brown sandy clay	
Foraging Site 11 Coordinates: 50 487018E 6776493N Habitat: Plain with *Acacia ramulosa* Slope: Negligible Leaf-litter: 1 - 5 cm deep, concentrated under trees and shrubs Surface: Surface crust Soil Type: Red-brown sandy clay	
Foraging Site 12 Coordinates: 50 487094E 6776065N Habitat: Plain with *Acacia burlertii* Slope: Negligible Leaf-litter: <1 cm deep, concentrated under trees and shrubs Surface: Surface crust Soil Type: Red-brown sandy clay	

Foraging Site 13

Coordinates:

50 488088E 6776396N

Habitat: Plain with *Acacia ramulosa*

Slope: Negligible

Leaf-litter: <1 cm deep, concentrated under trees and shrubs

Surface: Coarse gravel, 50 – 90% cover

Soil Type: Red-brown sandy clay

Foraging Site 14

Coordinates:

50 488161E 6776233N

Habitat: Plain with *Acacia ramulosa*

Slope: Negligible

Leaf-litter: <1 cm deep, concentrated under trees and shrubs

Surface: Small stones and fine gravel, 50 – 90% cover

Soil Type: Red-brown sandy clay

Foraging Site 15

Coordinates:

50 488778E 6776359N

Habitat: Mid-slope with *Acacia ramulosa*

Slope: Moderate, SE slope

Leaf-litter: <1 cm deep, concentrated under trees and shrubs

Surface: Small stones, 50 – 90% cover

Soil Type: Red-brown sandy clay

Foraging Site 16

Coordinates:

50 488783E 6776627N

Habitat: Foot-slope and minor channel with *Acacia sibiana*

Slope: Moderate, ESE slope

Leaf-litter: <1 cm deep, concentrated under trees and shrubs

Surface: Small stones, 50 – 90% cover

Soil Type: Red-brown sandy clay

Foraging Site 17 Coordinates: 50 488604E 6776255N Habitat: Mid-slope with *Acacia ramulosa* Slope: Steep, SE slope Leaf-litter: <1 cm deep, concentrated under trees and shrubs Surface: Coarse gravel and small stone - boulders, 90 – 100% cover Soil Type: Red-brown sandy clay	
Foraging Site 18 Coordinates: 50 488351E 6775969N Habitat: Plain with *Eucalyptus ewaitiana* Slope: Negligible Leaf-litter: 1 - 5 cm deep, concentrated under trees and shrubs Surface: Surface crust Soil Type: Red-brown sandy clay	
Foraging Site 19 Coordinates: 50 488671E 6776061N Habitat: Mid-slope with *Acacia sibiana* Slope: Moderate, SE slope Leaf-litter: <1 cm deep, concentrated under trees and shrubs Surface: Small stones, 50 – 90% cover Soil Type: Red-brown sandy clay	
Foraging Site 20 Coordinates: 50 488149E 6775823N Habitat: Plain with *Acacia ramulosa* Slope: Negligible Leaf-litter: 1 - 5 cm deep, concentrated under trees and shrubs Surface: Coarse gravel, 90 - 100% cover Soil Type: Red-brown sandy clay	

Foraging Site 21

Coordinates:

50 488236E 6776069N

Habitat: Plain with *Acacia ramulosa*

Slope: Negligible

Leaf-litter: <1 cm deep, concentrated under trees and shrubs

Surface: Coarse gravel, 90 – 100% cover

Soil Type: Red-brown sandy clay

Foraging Site 22

Coordinates:

50 488590E 6776338N

Habitat: Foot-slope with *Acacia ramulosa*

Slope: Gentle

Leaf-litter: <1 cm deep, concentrated under trees and shrubs

Surface: Coarse gravel, 90 – 100% cover

Soil Type: Red-brown sandy clay

Foraging Site 23

Coordinates:

50 488309E 6776313N

Habitat: Plain with *Acacia ramulosa*

Slope: Negligible

Leaf-litter: <1 cm deep, concentrated under trees and shrubs

Surface: Fine gravel, 50 – 90% cover

Soil Type: Red-brown sandy clay

Foraging Site 24

Coordinates:

50 488442E 6777082N

Habitat: Mid-slope with *Acacia ramulosa*

Slope: Moderate, SE slope

Leaf-litter: <1 cm deep, concentrated under trees and shrubs

Surface: Small stones, 90 – 100 % cover

Soil Type: Red-brown sandy clay