MAY 2010

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

ecologia ENVIRONMENT

OAKAJEE PORT AND RAIL

PORT TERRESTRIAL DEVELOPMENT SHORT RANGE ENDEMIC INVERTEBRATE SURVEY PART 2 - REGIONAL

This page has been left blank intentionally

OAKAJEE PORT AND RAIL
PORT TERRESTRIAL DEVELOPMENT
SHORT RANGE ENDEMIC VERTEBRATE SURVEY
PART 2 - REGIONAL

Document Status						
Rev.	**Author**	**Reviewer/s**	**Date**	**Approved for Issue**		
				Name	**Distributed To**	**Date**
A	C. Taylor	N. Dight	20/11/09			
1	N. Dight	M. Davis	7/12/09	M. Davis	C. Miller	9/12/09
2		M. Davis	13/1/10	M. Davis	C. Miller	19/1/10
3		L.. Roque-Albelo	14/5/10	L. Roque-Albelo	D. McAllinden	17/5/10

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

ACRONYMS ..... **V**

GLOSSARY ..... **VI**

EXECUTIVE SUMMARY ..... **VII**

1 INTRODUCTION **1**

1.1 PROJECT BACKGROUND 1

1.2 OBJECTIVES 1

2 PROJECT AREA **3**

2.1 BIOGEOGRAPHY 3

2.2 CLIMATE 3

2.3 LEGISLATIVE FRAMEWORK 4

3 SHORT RANGE ENDEMIC FAUNA: A REVIEW **7**

3.1 THREATS TO SHORT RANGE ENDEMICS 7

3.2 CONSERVATION OF SHORT RANGE ENDEMICS 8

3.3 SHORT RANGE ENDEMISM ON GERALDTON SANDPLAINS 8

4 METHODS **11**

4.1 HAND FORAGING 11

4.2 LITTER SIFTING 11

4.3 LEAF LITTER COLLECTION 11

4.4 SITE SELECTION 11

4.5 SURVEY TIMING 11

4.6 LABORATORY METHODS 11

4.7 SURVEY ADEQUACY 12

4.8 CURATION AND SPECIES IDENTIFICATION 15

5 RESULTS AND DISCUSSION **17**

5.1 SURVEY ADEQUACY 17

5.2 ARACHNIDA (MYGALOMORPHAE) 17

5.3 ARACHNIDA (SCORPIONES) 18
5.4 ARACHNIDA (PSEUDOSCORPIONES) 18
5.5 MALACOSTRACA (ISOPODA) 19
5.6 STYLOMMATOPHORA (SNAILS) 20
5.7 DIPLOPODA (SPIROSTREPTIDA) 20
5.8 DIPLOPODA (POLYDESMIDA) 21
5.9 CHILOPODA (MYRIAPODA) 22

6 CONCLUSIONS 25

7 STUDY TEAM 27

8 REFERENCES 29

TABLES

Table 4.1 – Location of survey sites. Datum is GDA 94, MGA zone 50J. 14
Table 4.2 – The List of Experts Used to Identify Potential SRE Taxa Found During the Survey....15
Table 5.1 – Specimens collected. 23

FIGURES

Figure 2.1 – Average Monthly GeraldtonRainfall. 3
Figure 2.2 – Average Monthly Geraldton Temperatures. 4
Figure 4.1 – Map of Survey Sites 13
Figure 5.1 – Species Accumulation Curve....17

ACRONYMS

BOM	Bureau of Meteorology
CAMBA	China – Australia Migratory Bird Agreement
DEC	Department of Environmental Conservation
DEWHA	Department of the Environment, Water, Heritage and the Arts
EIA	Environmental Impact Assessment
EPA	Environmental Protection Authority
EPBC Act	*Environment Protection and Biodiversity Conservation Act 1950*
IBRA	Interim Biogeographic Regionalisation for Australia
JAMBA	Japan-Australia Migratory Bird Agreement
OPR	Oakajee Port and Rail
SAC	Species Accumulation Curve
WCA, WC Act	*Wildlife Conservation Act 1950*

GLOSSARY

Approved Port The deepwater port facility at Oakajee for which the Department of State Development is the proponent. This Project was approved by the WA Government in 1998, with the release of Ministerial Statement 469 (Approved Port), and more recently updated with an approved Section

Conservation Significant This term is applied to species which are protected under the *Environment Protection and Biodiversity Conservation Act 1999*, the *Wildlife Conservation Act 1950*, or are listed by the Department of Environment and Conservation as priority fauna.

Oakajee Port and Rail Development The larger OPR project comprising the marine port, terrestrial port and rail components, each the subject of a separate approvals process.

The Project The Project refers to the footprint of this development as outlined in the PER.

Study Area An area larger than the Project, surveyed for the purpose of biological studies. The area may generally be described as extending approximately 12 km along the coast (between the Oakajee and Buller Rivers) and approximately 7 km inland at its widest point.

EXECUTIVE SUMMARY

Oakajee Port and Rail Pty Ltd (OPR) proposes to construct a deepwater port and terrestrial iron-ore handling facilities at Oakajee. The site is located 24 kilometres north of Geraldton, within the proposed Oakajee Industrial Estate, between the Oakajee and Buller Rivers (Study Area).

In order to provide regional context for SRE's invertebrates, 18 sites were surveyed in regional areas surrounding the proposed development (Regional Areas). Sites were selected within potential SRE habitat types based on aerial photography. A variety of methodology was used at all sites including litter sifting, litter sorting, hand foraging and litter collection and subsequent extraction in Tullgren funnels. The adequacy of sampling was measured by extrapolating species accumulation curves, fitting parametric models of relative abundance and using non parametric estimators.

The survey sampling and effort was deemed adequate by the species accumulation curve, although it is important to note that the methodology had its limitations for collecting cryptic mygalomorph spiders (the most effective method for this group is wet pitfall trapping). Twenty species of significance were collected, including mygalomorph spiders, scorpions, pseudoscorpions, isopods, snails and millipedes. Some of the previously known species were re-named by experts in light of the new regional reference material.

Three millipede species, previously collected within the Oakajee Study Area, were identified - *Antichiropus* 'Geraldton 1' (previously *Antichiropus* 'Geraldton'), *Podykipus* 'Geraldton 3' and *Podykipus* 'Geraldton 5' (previously *Podykipus* sp. 1 and *Podykipus* 'sp. 2, respectively). One snail, *Bothriembryon* sp, was also identified outside the Oakajee Study Area. Two species (the isopod *Hanoniscus tuberculatus* and the mygalomorph spider *Aname* sp. 1) were not collected in the regional survey and thus remain to be known only from within the Study Area, where their distribution will be partially impacted by the Terrestrial Port Development. In addition, the mygalomorph spider *Aname* sp. 2 remains to be known only from within the Oakajee River banks on the northern boundary of the Study area. However, this area is not expected to be impacted by the development. The remainder of the species identified were SREs that were not impacted by the proposed development, species whose SRE status could not be commented upon or species that were not SREs.

In conclusion, none of the confirmed or potential SRE species identified within the Study Area will be fully impacted by the Terrestrial Port Development.

This page has been left blank intentionally

1 INTRODUCTION

1.1 PROJECT BACKGROUND

Oakajee Port and Rail Pty Ltd (OPR) proposes to construct a deepwater port and terrestrial iron-ore handling facilities at Oakajee. The site is located 24 kilometres north of Geraldton, within the proposed Oakajee Industrial Estate, between the Oakajee and Buller Rivers. The terrestrial facilities proposed that are of interest to this study include the port rail system, access and service corridors, a car dumper, stockpiles, ore in-loading and out-loading infrastructure, and supporting facilities.

A short range endemic invertebrate survey was previously completed within an area of the Oakajee Terrestrial Port Development (Study Area) by *ecologia* Environment, identifying four SRE species in need of further investigation (ecologia in prep.). These included three new millipede species (*Antichiropus* 'Geraldton', *Podykipus* sp. 1 and sp.2) and isopod (*Hanoniscus tuberculatus*). Three potential SRE species were also identified within the Study area - a *Bothriembryon* snail and two species of mygalomorph spiders (*Aname* sp. 1 and sp. 2)(ecologia in prep.). The survey in regional areas outside the Study Area described in this report (Regional Areas henceforth) was undertaken in order to identify locations of these species outside of the proposed Terrestrial Port Development. In addition, details on findings of species whose SRE status could not be determined in ecologia (in prep.) and additional species found in the Regional Areas are also given.

1.2 OBJECTIVES

The objectives of the survey were to provide:

(a) an inventory of potential Short Range Endemic (SRE) invertebrate fauna species occurring in regional areas surrounding the proposed Oakajee Terrestrial Port Development; and

(b) locations of known SRE species outside the Oakajee Terrestrial Port Development.

This page has been left blank intentionally

2 PROJECT AREA

2.1 BIOGEOGRAPHY

The area is part of the Geraldton Sandplains bioregion (Thackway and Cresswell 1995) characterised by proteaceous scrub-heaths on an undulating lateritic sand plain, mantling Permian to Cretaceous strata. The climate is warm semi-arid to Mediterranean, with 400 – 500 mm of annual rainfall (CALM 2002). The site is considered to be part of the Greenough System within the Irwin District of the Southwestern Botanical Province (Beard 1976, 1980, 1990), associated with a coastal limestone belt of varying width and elevation. This belt includes abrupt rocky ridges, more gentle soil-covered areas, alluvial flats and, in some places, lagoons. The seaward side of the limestone belt is covered with recent, poorly consolidated or still mobile dune sands (Beard and Burns 1976). The vegetation is dominated by *Acacia rostellifera* and *Melaleuca cardiophylla* thickets on rocky ridges, *Acacia-Banksia* scrub on sand-covered limestone, *A. rostellifera* low forest on the alluvial flats and *Acacia ligulata* open scrub on the recent dunes (Dames and Moore 1993).

2.2 CLIMATE

The closest Bureau of Meteorology (BOM) weather station is situated at Geraldton, approximately 20 km south of the proposed Oakajee Terrestrial Port Development. The Geraldton Town weather station has been operational since 1877 and data collection is ongoing (BOM 2009).

The project area experiences a warm semi-arid to Mediterranean climate, characterised by hot dry summers and mild wet winters. The area receives an average annual rainfall of 448 mm, the majority of which falls between May and August (Figure 2.1). January and February are the hottest months of the year, with a mean maximum temperature of 32°C experienced in February (Figure 2.2). The coldest month is August, with an average minimum temperature of 9°C. June is the wettest month, receiving on average 114 mm of rainfall (BOM 2009).

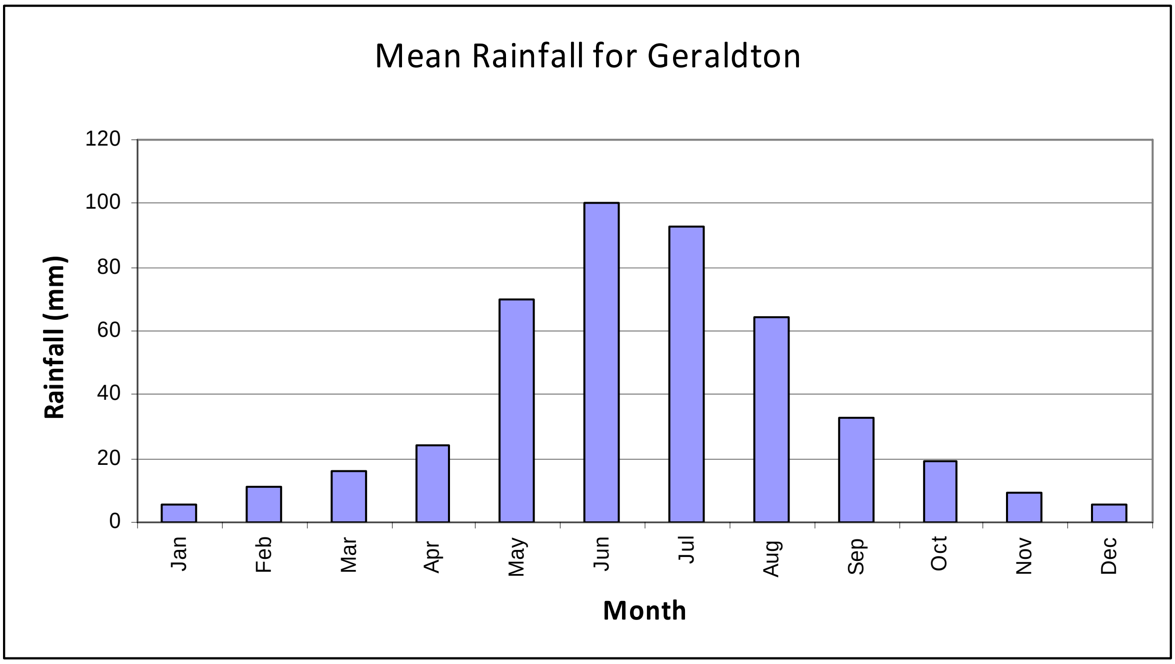

Figure 2.1 – Average Monthly GeraldtonRainfall.

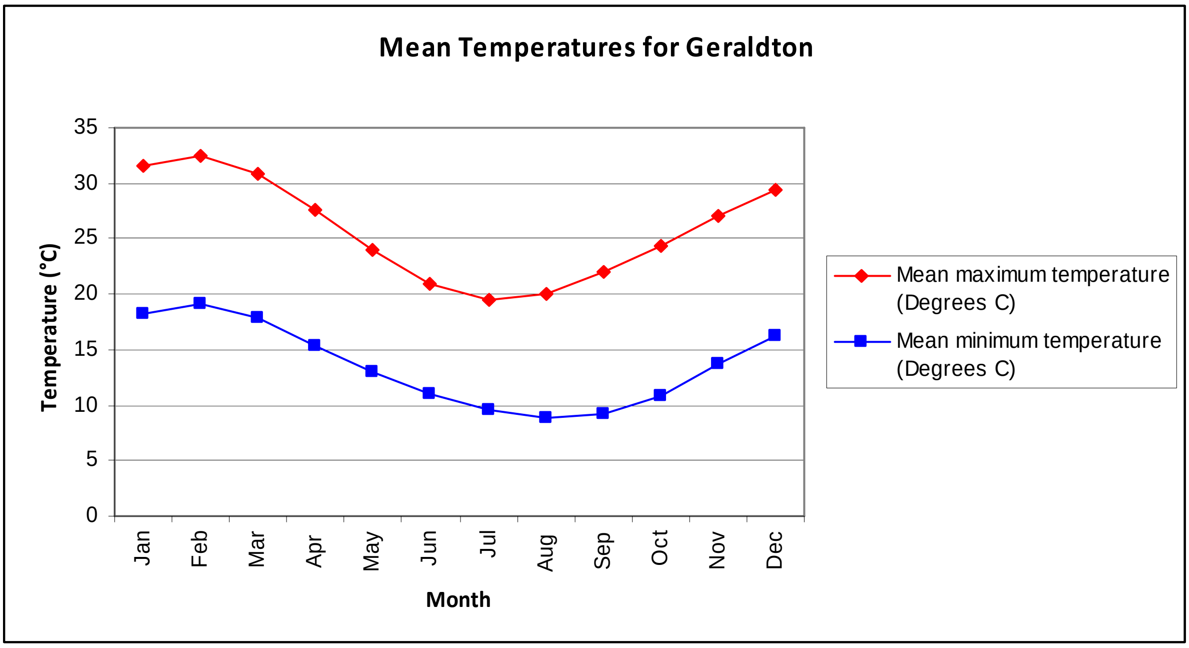

Figure 2.2 – Average Monthly Geraldton Temperatures.

2.3 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, the Wildlife Conservation Act 1950, and the Environmental Protection Act 1986. 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 has 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.

This document also satisfies the requirements of the later released Guidance statement 20: Sampling of Short Range Endemic Invertebrate Fauna for Environmental Impact Assessment in Western Australia (EPA 2009),

Harvey (2002) considered that although there were occasional short range endemics among the vertebrates and insects, there were much higher numbers among the molluscs, earthworms, some spider groups (especially the mygalomorphs), millipedes, and some groups of crustaceans. Short range endemics 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 short range endemic species have been listed as threatened or endangered under State or Commonwealth legislation in the Wildlife Conservation Act of WA 1950 and/or Environmental Protection and Biodiversity Conservation Act (EPBC) 1999, 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 of Australia 1996). The EPA expects that environmental impact assessment will consider impacts on conservation of short range endemics in accordance with these principles and objectives" (EPA 2004).

This page has been left blank intentionally

3 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 short range endemics (SRE), those species that exhibit tight local range restrictions. It outlines the major paths to short range endemism, the current knowledge of short range endemism in Australia (with an emphasis on Geraldton Sandplains bioregion), 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 SRE's is relatively scarce.

3.1 THREATS TO SHORT RANGE ENDEMICS

Short range endemism is influenced by numerous processes generally contributing to the isolation of a fauna species. A number of factors including life history, physiology, habitat requirements, habitat availability, the ability and opportunity to disperse, 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 both 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 mutation 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 amount of differentiation and speciation between populations will be determined by the relative magnitude of these factors, with the amount of migration generally being the strongest determinant. Migration is hindered by poor dispersal ability of the taxon as well as geographical barriers to dispersal. Thus, those taxa that exhibit short range endemism are generally characterised by poor dispersal, reliance on habitat types that are discontinuous, low growth rates and low fecundity (Harvey 2002).

A number of habitats in Australia contain SRE's because they are surrounded by geographic barriers. Islands are a classic example where terrestrial fauna are surrounded by a marine environment which impedes migration and thus genetic flow. Similarly, isolated habitats such as mountains, aquifers, lakes, and caves are essentially islands of differing environmental conditions amongst the surrounding landscape. Within Western Australia, caves and other subterranean habitats are examples of areas where short range endemics are common (Harvey 2002).

Historical connections of habitats are also important in determining species distributions and often explain patterns that are otherwise inexplicable by current conditions. Many SRE's are those from relict taxa (organisms surviving as a remnant of an otherwise extinct species) and are confined to certain habitats and in some cases geographic areas (Main 1996). Relict taxa include species dating back to Gondwanan periods that have very restricted natures.

In Western Australia, relict taxa are generally fragmented populations from lineages reaching back to historically wetter periods. 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 progressively dryer and more seasonal climatic conditions since this time, the most favourable habitats have now become increasingly fragmented and such fauna are now restricted to specialised moist microhabitats which simulate, on a small scale, an earlier, more widespread habitat (Main 1996). Many of the current species have restricted distributions as a result of these processes.

Relict species now generally persist in habitats characterised by permanent moisture and shade, with conditions provided by high rainfall (Main 1996). Such conditions can be seen at sites adjacent to granite outcrops (which benefit from rainwater runoff), mountain summits, swampy headwaters of river systems and caves (Main 1996). Topography, proximity to the coast and directional orientation are also influential in determining relict habitats. Due to the isolation of populations, many relict species of cave fauna have very disjunct populations, indicating that their dispersal is limited (Clarke and Spier-Ashcroft 2003).

3.2 CONSERVATION OF SHORT RANGE ENDEMICS

Specific characteristics of sites in south-west Australia in which relict SRE species might be found were proposed by Main (1996, 1997) , following Main and Main (1991), and include areas:

- unaffected by salinisation;
- of high rainfall with short summer drought;
- topographically high along the coast and subject to frequent mists, cloud and drizzle;
- adjacent to rocks from which water is shed;
- of impeded groundwater flow so producing winter wet swamps;
- of streams with extensive fresh headwater swamps and year round flow;
- where vegetation can harvest water from fog or cloud drip from leaves and stem flow e.g. tingle forest and south coast dunes and heath;
- with southern or south-west aspects which are thus sheltered from summer insolation e.g. valley slopes and wet valley floors; and
- of intact forest canopy under which the characteristics under storey shrubs and herbs occur.

To these, Horwitz and Rogan (2003) added:

- Springs and caves streams or other expressions of interstitial or groundwater.

3.3 SHORT RANGE ENDEMISM ON GERALDTON SANDPLAINS

Short range endemics 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).

Widespread and uniform short range endemism is found in both terrestrial and freshwater molluscs, onychophorans, millipedes, some arachnids and some crustaceans. Short range endemism also occurs in other groups but is not uniform throughout (Harvey 2002).

Many taxa that appear to be rare are often poorly documented and could prove to be more widespread than originally thought. Nevertheless, recent taxonomic and survey work has revealed that SRE species are common in Australia, and that (although rare) some taxonomic groups such as Megascolecidae are composed entirely of SRE species (Harvey 2002).

There is little published evidence of SRE fauna to date from the Geraldton Sandplains. This is most likely due to the historical lack of invertebrate research, as common in most areas of Australia. Geraldton Sandplains have a potential to provide refuges for SRE species where moist conditions have persisted during the continent's increasing aridity, as is the case for numerous relict invertebrate taxa in the south-west region of Western Australia (Abbott 1994; Horwitz and Rogan 2003). Due to the history of pastoral land use in the area, suitable remnant vegetation associations on the sand plain plateau as well as on the coastal limestone ridge, the river margins, the southern valley slopes and the stable dunes on the western slope of the Oakajee Study Area may function as refugia for invertebrates with restricted distributions and thus be important for their long-term survival.

Short range endemic members of groups such as millipedes (Diplopoda), centipedes (Chilopoda), land snails (Mollusca), native earthworms (Megascolecidae) and trapdoor spiders (Mygalomorphae) have been recorded (Abbott 1994; Harvey *et al.* 2000) or are considered likely to exist on the Geraldton Sandplains (Mark Harvey pers. comm., October 2006).

Within the larger context of coastal regions of south-western Australia, there is more evidence of the presence of SRE fauna. The southern Carnarvon Basin, for example, which neighbours Geraldton Sandplains immediately to the north, is known to harbour several invertebrate SRE species (Harvey *et al.* 2000; Volschenk *et al.* 2000). To the south, the Southern Jarrah Forests region contains numerous SRE aquatic and terrestrial invertebrates taxa (Trayler *et al.* 1996), including unique relict taxa (characteristic of a wetter, milder era) with groups and species of invertebrates normally associated with the rainforests, forests and wetlands of south-east Australia. The Fitzgerald subregion, too, contains significant and endemic fauna species including relict taxa occurring in the Stirling Ranges and Mount Manypeaks (Comer *et al.* 2002).

3.3.1 Local Endemism

Confirmed short range endemic species of an isopod (*Hanoniscus tuberculatus*) and three millipedes (*Antichiropus* 'Geraldton', *Podykipus* sp. 1 and sp.2) have been collected at the Study Area (ecologia in prep.). In addition, three potential short-range endemic species, a *Bothriembryon* snail and two trapdoor spiders (*Aname* sp. 1 and sp.2)were also collected at tye Study Area (ecologia in prep.).

This page has been left blank intentionally

4 METHODS

The methodology for the fauna survey was developed based on the principles outlined in the EPA Guidance Statement 20: *Sampling of Short Range Endemic Invertebrate Fauna for Environmental Impact Assessment in Western* (EPA 2009). Several foraging techniques were used to collect specimens from a wide range of taxa.

4.1 HAND FORAGING

Each team member spent one hour hand foraging for a total of two man hours per site. During hand foraging the ground surface and the underside of logs and rocks were investigated for mygalomorph and scorpion burrows, snails, centipedes, millipedes, and centipedes.

4.2 LITTER SIFTING

At each site three litter sifts were completed by each team member for a total of six sifts per site. Litter sifting focuses on pseudoscorpions, snails, millipedes, centipedes, scorpions, isopods and worms.

4.3 LEAF LITTER COLLECTION

From each site three 1 m^2 quadrats of leaf litter were collected and placed on a sheet. Litter was then sorted through and invertebrate specimens were collected. Following sorting all litter was placed into plastic zip-lock bags. These bags were transported back to *ecologia's* Perth laboratory where they were dried under Tullgren funnels to extract the invertebrates (Brady 1969; Upton 1991). This process involves placing the sample in a funnel beneath a source of light and heat (i.e. 40 W light bulb) which encourages live specimens move downward through the funnel as the leaf litter in the sample dries. At the base of the funnel, the invertebrates fall into a vial of 70% ethanol which preserves them until they can be identified.

4.4 SITE SELECTION

Eighteen survey sites were selected from aerial photography of the area. Areas of geographical interest (hills and rocky outcrops etc.) and dense vegetation were primarily selected as these features typically promote short range endemism. The actual locations of sampling were refined once on site. Site locations are given in Figure 4.1 and Table 4.1

4.5 SURVEY TIMING

Sampling was conducted during two sampling rounds, from 9 - 14 July and 12 - 15 August 2009. Both these rounds followed the mean peak rainfall periods for Geraldton (Figure 2.1) as recommended in the EPA guidance statement 20 (EPA 2009).

4.6 LABORATORY METHODS

Samples were processed under a Leica S6 microscope with each taxon being placed into a separate vial containing 70% ethanol and assigned a unique identification code for tracking. All vials were labelled with the date, site, GPS coordinates and the name of the collector(s).

4.7 SURVEY ADEQUACY

There are three general methods of estimating species richness from sample data: extrapolating species-accumulation curves, 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) and two nonparametric estimators Chao 2 and Incidence based Coverage Estimator (ICE). SACs is a plot of accumulated number of species found with respect to the number of units of effort expected. The curve as a function of effort monotonically increases and typically approaches an asymptote, which is the total number of species.

Chao 2 is based on the concept that rare species carry most information about the number of missing ones. This estimator uses just singletons and doubletons to estimate the number of missing species. ICE works with similar principle based on the recognition that species that are widespread or abundant are likely to be included in any sample and thus contain very little information about the overall size of the assemblage (Magurran 2004). In contrast, it is the rare species that are most useful in deducting overall richness. The ICE focuses on species found in ≤ 10 sampling units. This analysis allowed test the survey adequacy and effectiveness comparing the number of species recorded with the number predicted.

SACs were randomised $1x10^4$ times using EstimateS (version 8, Colwell 2009).

The methods used in this study (foraging, leaf litter sifting and litter extraction) are the most effective for collecting soil and leaf-litter dwelling invertebrates (i.e. millipedes, centipedes, isopods, pseudoscorpions, scorpions, snails, araneomorph spiders), which were being targeted in this survey. It is important to note, however, that the methodology has its limitations for collecting cryptic mygalomorph spiders (the most effective method for this group being wet pitfall trapping). Nevertheless, the burrows of the mygalomorph spiders targeted in this Regional Study (*Aname* sp. 1 and sp. 2) were large (not considered cryptic) and therefore not expected to be limited by the methodology. Such approach was consistent with the new Guidance statement no. 20 (EPA 2009), which does not recommend the use of wet pitfall traps.

Figure 4.1 – Map of Survey Sites

Table 4.1 – Location of survey sites. Datum is GDA 94, MGA zone 50J.

Site	North	East
Buller 1	6829195	267461
Buller 2	6829375	266853
Buller 3	6829765	266413
Buller 4	6830267	266052
Buller 5	6830594	266023
Site 6	6830862	272017
Site 7	6828902	271666
Site 8	6839324	262652
Site 9	6843529	262080
Site 10	6842930	260166
Site 11	6823927	267428
Site 12	6806036	268856
Site 13	6807306	269573
CUT	6816966	276930
OKA A	6837316	270476
OKA B	6836831	270612
OKA C	6837427	269715
WOK B	6829593	271517

4.8 CURATION AND SPECIES IDENTIFICATION

The level of specimen identification achievable is dependent on the level of taxonomic knowledge and expertise currently available. Taxa belonging to groups known to include short range endemics were identified to genus or species level by relevant experts. Table 4.2 provides the list of experts used for identification.

Table 4.2 – The List of Experts Used to Identify Potential SRE Taxa Found During the Survey

Organism	Person	Institution
Mygalomorph spiders	V. Framenau	WAM
Scorpions	E. Volschenk	Subterranean Ecology
Millipedes	M. Harvey / V Framenau	WAM
Snails	S. Slack-Smith	WAM
Isopods	S. Judd	ECU

This page has been left blank intentionally

5 RESULTS AND DISCUSSION

The survey yielded a large number of specimens covering seven orders which are made up of at least 13 familles (Table 5.1).

5.1 SURVEY ADEQUACY

As a result of estimating the species richness, the adequacy of the sampling methodology and sample size used in this survey is demonstrated by the plateau of the species accumulation curve in Figure 5.1. The methods used in this study (foraging, leaf litter sifting and litter extraction) were the most effective for collecting soil and leaf-litter dwelling invertebrates (i.e. millipedes, isopods, snails) targeted in this survey. The limitations of the methodology for collecting cryptic mygalomorph spiders did not affect the results as the burrows of the mygalomorph spiders *Aname* sp. 1 and sp. 2 targeted in this Regional Study are large and therefore not subject to limitation by the methodology.

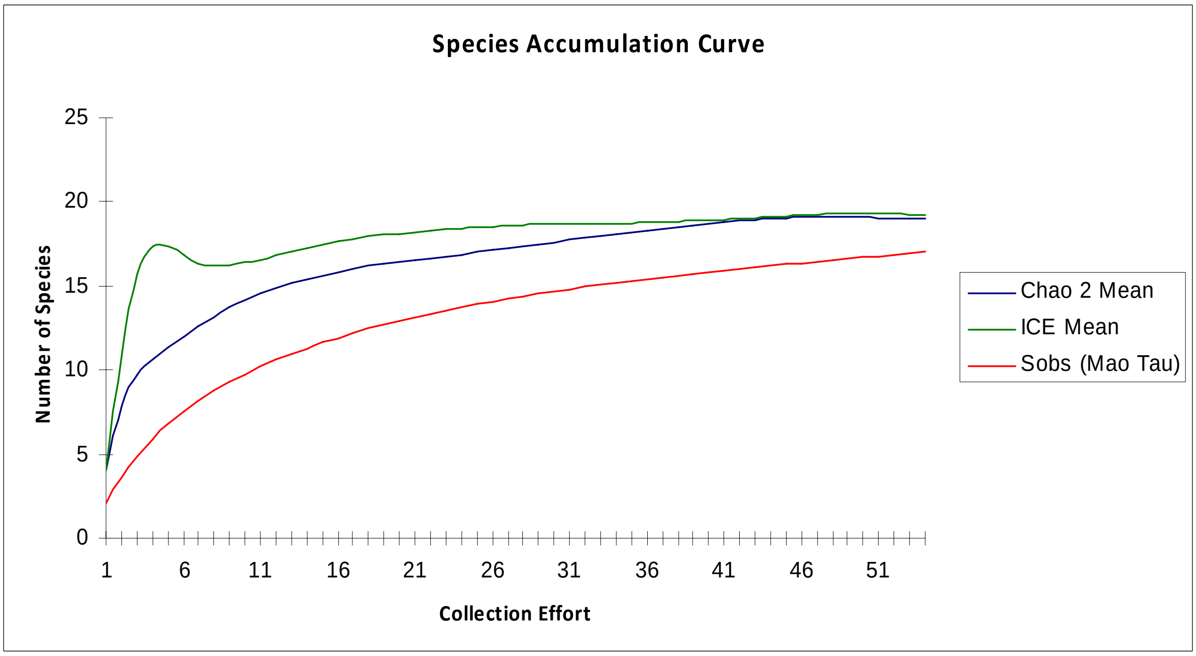

Figure 5.1 – Species Accumulation Curve

5.2 ARACHNIDA (MYGALOMORPHAE)

5.2.1 *Eucyrtops* 'MYG132' (family Idiopidae)

A single specimen was identified as *Eucyrtops* 'MYG132'. *Eucyrtops* currently consists of three named species, all from Western Australia. Many more undescribed species are known from collections, therefore taxonomic work on the genus is ongoing. The specimen is closely related to another species, *Eucyrtops* 'MYG149' found in the Mount Gibson area, however they differ enough to be considered unique species. Both of these species are only known from single specimens. Based on current knowledge *E.* 'MYG132' is considered to be a SRE species (Framenau and Harvey 2009).

5.3 ARACHNIDA (SCORPIONES)

5.3.1 *Cercophonius* sp. (family Bothriuridae)

Three specimens were collected and identified as belonging to the genus *Cercophonius*. All three specimens were sub adult and therefore identification below genus level could not be completed. However, based on current knowledge of *Cercophonius*, it is unlikely that these represent SRE species.

5.3.2 *Lychas* 'splendens' (family Buthidae)

A single specimen collected was identified as *Lychas* 'splendens'. Based on current knowledge of the genus *Lychas*, it is unlikely that this specimen represents a SRE species.

5.4 ARACHNIDA (PSEUDOSCORPIONES)

5.4.1 *Oratemnus* sp. (family Atemnidae)

Fifty six specimens were collected which belong to the genus *Oratemnus*. The systematics of Atemnidae is currently uncertain. However, current data suggest that most species will eventually be found to be widespread in Western Australia and as such this species is not considered to be a SRE.

5.4.2 *Nesidiochernes* sp. (family Chernetidae)

Of all pseudoscorpion families, Chernetidae is the most diverse. Twenty specimens of the genus *Nesidiochernes* were collected. *Nesidiochernes* is found throughout Australasia and the Pacific (Harvey 2009). The species the collected specimens belong to have a wide distribution throughout southern Australia, as such they are not considered to be SRE species.

5.4.3 *Austrochthonius* sp. (family Chernetidae)

There are species of *Austrochthonius* throughout Western Australia. Although the taxonomy of the genus is still to be resolved, clear distinct species do exist. Two specimens collected matched species represented in wider distributions. This specimen collected does not appear to represent a SRE species.

5.4.4 *Tyannochthonius* sp. (family Chthoniidae)

The genus *Tyannochthonius* is represented throughout tropical regions of the world (Harvey 2009). Australia maintains several epigean and troglobitic species, of which five are described from Western Australia (Harvey 1991; Edward and Harvey 2008). A single specimen collected belongs to this genus and is likely to represent a new species, however, it is unlikely to be a SRE species.

5.4.5 *Synsphyronus mimulus* (family Garypidae)

Many species of the genus *Synsphyronus* have the potential to be short range endemic species (Harvey 1987). Seven specimens collected represented *Synsphyronus mimulus.* However, *S. mimulus* has a widespread distribution throughout mainland Australia (Harvey 1987) and is not a SRE species.

5.4.6 *Amblyolpium* sp. (family Garypidae)

The genus *Amblyolpium* has a worldwide distribution (Harvey 2009). Ten specimens of *Amblyolpium* sp. were collected which are conspecific to a species known from other areas of Western Australia. It is therefore not a SRE.

5.4.7 *Austrohorus* sp. (family Olpiidae)

A single specimen belonging to the genus *Austrohorus* was collected. Little is known about this genus and therefore the SRE status cannot be confirmed.

5.4.8 *Beierolpium* sp. (family Olpiidae)

A total of fifteen specimens of the genus *Beirolpium* were collected. The taxonomy *Beierolpium* has not been completely assessed. As such specimens cannot be confidently identified. It is possible these specimens may represent SREs but without a full taxonomic revision their status cannot be confirmed.

5.4.9 *Beierolpium* 'sp. 8/4' (family Olpiidae)

A single specimen was identified as *Beierolpium* 'sp. 8/4'. As the taxonomy of the genus requires revision, the SRE status of this species is uncertain.

5.4.10 *Indolpium* sp. (family Olpiidae)

A single specimen of the genus *Indolpium* was collected. The species resembles others recorded from other regions in Australia. Based on current knowledge this species does not represent a SRE.

5.5 MALACOSTRACA (ISOPODA)

5.5.1 *Buddelundia* sp. (family Armadillidae)

A total of 17 specimens of *Buddelundia* sp. were collected. These specimens belong to an undescribed species, however the species is common throughout drier areas of Australia and thus is not a SRE.

5.5.2 *Buddelundia* sp. nov. (family Armadillidae)

Nine specimens of *Buddelundia* sp. nov. were collected. This species has only been seen in a few records and distributional data is lacking, however it is unlikely to be a SRE species.

5.5.3 *Spherillo* sp. (family Armadillidae)

Two specimens of an undescribed species of *Spherillo* were collected. There are currently no described species of *Spherillo* from Western Australia, however the genus is widespread and the species is not expected to be a SRE.

5.5.4 *Laevophiloscia* sp. (family Philosciidae)

Three specimens collected are likely to be *Laevophiloscia yalgoonensis,* which is common and widespread, however this cannot be confirmed without a review of the genus. The genus *Laevophiloscia* itself is widespread in Western Australia and therefore not a SRE.

5.6 STYLOMMATOPHORA (SNAILS)

5.6.1 *Bothriembryon* sp. (family Bulimulidae)

A total of five specimens were collected on the sites 6, OKA A and WOK B. The species is delicately sculptured and fragile and is similar to the species collected previously within the Oakajee Study Area (ecologia in prep.).

5.7 DIPLOPODA (SPIROSTREPTIDA)

The survey yielded 340 specimens of the genus *Podykipus*. There are currently three described species of *Podykipus* in Western Australia, all from the greater Perth region only. Two undescribed species exist along the south western coast of Western Australia (Framenau *et al.* 2008).

Five morphospecies were identified from the 340 specimens collected. These can be categorised into two distinct morphological groups. One group comprises of *Podykipus* 'Geraldton 1', *Podykipus* 'Geraldton 2' and *Podykipus* 'Geraldton 3', the other of *Podykipus* 'Geraldton 4' and *Podykipus* 'Geraldton 5'.

5.7.1 *Podykipus* sp. (family Iulomorphidae)

A total of 111 specimens collected could only be identified as belonging to the genus *Podykipus*. These could not be identified to species as they were either juvenile or female specimens (adult male specimens are required for species level identification). These specimens are expected to belong to one of the species listed below.

5.7.2 *Podykipus* 'Geraldton 1' - *Podykipus* 'Geraldton 3' (family Iulomorphidae)

Sixteen specimens were identified as *Podykipus* 'Geraldton 1', ten specimens as *Podykipus* 'Geraldton 2' and a total of 185 specimens as *Podykipus* 'Geraldton 3'. These species can be grouped morphologically as they are comparatively larger species with males displaying reduced first legs as is typical of *Podykipus (Attems 1911)*. The *Podykipus* 'Geraldton 3' is synonymous with *Podykipus* sp. 1 in (ecologia in prep.) (V. Framenau, WAM, pers.comm. December 2009). Based on current information regarding the distribution of *Podykipus* it is likely that all three species represent SREs (Framenau and Harvey 2009).

5.7.3 *Podykipus* 'Geraldton 4' and *Podykipus* 'Geraldton 5' (family Iulomorphidae)

Five specimens were identified as *Podykipus* 'Geraldton 4' and a total of 13 were identified as *Podykipus* 'Geraldton 5'. These two species can also be morphologically grouped as they are comparatively smaller species with fully developed first legs, an unusual characteristic of *Podykipus*, however, the gonopod morphology is similar to that of the other three species. *Podykipus* 'Geraldton 4' is also synonymous with *Podykipus* sp. 1 in (ecologia in prep.) and *Podykipus* 'Geraldton 5' is synonymous with *Podykipus* sp. 2 in (ecologia in prep.) (V. Framenau, WAM, pers. comm. December

2009). Based on current information regarding the distribution of *Podykipus*, it is likely that both species represent SREs (Framenau and Harvey 2009).

5.8 DIPLOPODA (POLYDESMIDA)

A number of specimens collected were identified as belonging to the genus *Antichiropus*. They are the most abundant and diverse group of Western Australian millipedes. Recent field work has yielded many specimens from across Western Australia, and as a result *Antichiopus* currently consists of over 110 species and it is found from the Pilbara to the Nullarbor Plain and Eyre Peninsula in South Australia.

With the exception of two known species, *Anitchiropus variabilis* (found in the jarrah forests of south western WA) and *Antichiropus* 'PM1' (from northern areas of the Wheatbelt and sand plains of Geraldton) all species are known to be SREs.

5.8.1 *Antichiropus* sp.

A total of 134 specimens collected could not be identified beyond the genus *Antichiropus* as specimens were either juvenile or female. These specimens are expected to belong to one of the species listed below.

5.8.2 *Antichiropus* 'Geraldton 1' (family Paradoxosomatidae)

A total of 79 specimens of *Antichiropus* 'Geraldton 1' were collected. *Antichiropus* 'Geraldton 1' is known from a small number of areas around Geraldton and it is synonymous with *Antichiropus* 'Geraldton' in (ecologia in prep.)(V. Framenau, WAM, pers. comm. December 2009). *Antichiropus* 'Geraldton 1' is considered to be a SRE species.

5.8.3 *Antichiropus* 'Buller 1' (family Paradoxosomatidae)

The survey yielded two specimens of *Antichiropus* 'Buller 1'. This is a new morphospecies previously unknown and is considered a SRE (Framenau and Harvey 2009).

5.8.4 *Antichiropus* 'Buller 2' (family Paradoxosomatidae)

Nineteen specimens of *Antichiropus* 'Buller 2' were collected from the survey. *Antichiropus* 'Buller 2' is only known from these specimens and other material collected by ecologia Environment from the region and is considered to be a SRE (Framenau and Harvey 2009).

5.8.5 *Antichiropus* 'PM1' (family Paradoxosomatidae)

Seven specimens of *Antichiropus* 'PM1' were collected. The *Antichiropus* 'PM1' is not considered a SRE as it is known throughout the Geraldton Sandplains and northern Avon Wheatbelt areas (Framenau and Harvey 2009).

5.9 CHILOPODA (MYRIAPODA)

5.9.1 Order Geophilomorpha

Two specimens of centipedes were collected. These were members of the order Geophilomorpha. The taxonomy of this order is very poorly known, thus the status as a short range endemic is uncertain. It is possible that the order does contain SRE species but this cannot be determined at present as a major taxonomic revision of the order is required.

Table 5.1 – Specimens collected.

Order	Family	Genus	Species	OKC	CUT	OKB	WOKB	OKA	B1	B2	B3	B4	B5	Site 6	Site 7	Site 8	Site 9	Site 10	Site 11	Site 12	Site 13
Mygalomorphae	Idiopidae	*Eucyrtops*	'MYG132'	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-
Scorpiones	Bothriuridae	*Cercophonius*	sp.	-	-	-	-	-	1	-	1	1	-	-	-	-	-	-	-	-	-
	Buthidae	*Lychas*	'splendens'	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-
Pseudoscorpionida	Atemnidae	*Oratemnus*	sp.	-	-	-	-	-	3	-	40	1	5	-	-	4	-	-	-	-	3
	Chernetidae	*Nesidiochernes*	sp.	-	-	-	-	-	7	-	-	-	3	6	-	2	-	-	-	-	2
		Austrochthonius	sp.	-	-	-	-	1	-	1	-	-	-	-	-	-	-	-	-	-	-
		Tyannochthonius	sp.	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-
	Garypidae	*Synsphyronus*	*mimulus*	-	-	-	-	-	-	-	-	-	-	-	-	-	7	-	-	-	-
		Amblyolpium	sp.	-	-	-	-	-	-	-	4	-	-	-	-	-	-	-	-	-	6
	Olpiidae	*Austrohorus*	sp.	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-
		Beierolpium	sp.	-	-	-	-	-	15	-	-	-	-	-	-	-	-	-	-	-	-
		Beierolpium	'sp. 8/4'	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		Indolpium	sp.	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Isopoda	Armadillidae	*Buddelundia*	sp.	-	-	-	17	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		Buddelundia	sp. nov.	-	-	9	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		Spherillo	sp.	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Philosciidae	*Laevophiloscia*	sp.	-	-	2	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-
Stylommatophora	-	-	-	-	-	-	-	-	2	253	674	52	110	-	-	-	-	-	1	-	-
Spirostreptida	Lulomorphidae	*Podykipus*	sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	111	-	-

Order	Family	Genus	Species	OKC	CUT	OKB	WOKB	OKA	B1	B2	B3	B4	B5	Site 6	Site 7	Site 8	Site 9	Site 10	Site 11	Site 12	Site 13
		Podykipus	'Geraldton 1'	-	-	-	-	-	-	2	2	-	-	-	-	-	-	-	12	-	-
		Podykipus	'Geraldton 2'	-	-	-	-	-	-	-	-	-	-	-	-	10	-	-	-	-	-
		Podykipus	'Geraldton 3'	-	-	-	-	-	-	-	25	-	-	-	-	-	30	-	130	-	-
		Podykipus	'Geraldton 4'	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5	-	-
		Podykipus	'Geraldton 5'	-	-	-	-	-	-	-	9	-	-	-	-	-	-	-	4	-	-
	Paradoxosomatidae	*Antichiropus*	sp.	55	29	13	8	22	1	1	-	-	-	-	-	2	-	-	-	-	3
		Antichiropus	'Geraldton 1'	-	-	-	-	14	4	23	4	-	-	33	-	-	1	-	-	-	-
		Antichiropus	'Buller 1'	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-
		Antichiropus	'Buller 2'	4	-	-	-	-	-	-	-	-	-	-	15	-	-	-	-	-	-
		Antichiropus	'PM1'	-	-	-	2	2	-	-	-	-	-	-	3	-	-	-	-	-	-
Geophilomorpha	-	-	-	1	1	-		-	-	-	-	-	-	-	-	-	-	-	-	-	-
Gastropoda	Bulimulidae	*Bothriembryon*	sp.				1	4						1							

6 CONCLUSIONS

A survey undertaken by *ecologia* at the Study Area (ecologia in prep.) identified four SRE species in need of further investigation (ecologia in prep.). These included three new millipede species (*Antichiropus* 'Geraldton', *Podykipus* sp. 1 and sp.2) and isopod (*Hanoniscus tuberculatus*). In addition, three potential SRE species were also identified within the Study area - a *Bothriembryon* snail and two species of mygalomorph spiders, *Aname* sp. 1 and sp. 2. The regional survey discussed within this report was undertaken in order to identify locations of these species in Regional Areas outside of the Study Area. Surveying was focused on regional areas where vegetation was dense and similar in content to areas within the Study Area.

The millipede species *Antichiropus* 'Geraldton 1', identified by experts as synonymous with *Antichiropus* 'Geraldton' (ecologia in prep.), was located at five sites of Regional Areas (Buller 1, Buller 2, Buller 3, Site 1, Site 6 and Site 9). Four of these sites were located south of the Study Area (Figure 4.1) while Site 9 was located north of the Study Area.

Similarly, *Podykipus* sp. 1 and *Podykipus* sp. 2 (Harvey 2006; ecologia in prep.), have been revised in context of the material collected during this regional survey. The species previously identified as *Podykipus* sp. 1 (ecologia in prep.) was found to comprise two species, named *Podykipus* 'Geraldton 3' and *Podykipus* 'Geraldton 4'. The *Podykipus* sp. 2 (ecologia in prep.) was re-named *Podykipus* 'Geraldton 5'. The specimens were collected from a range of regional sites (Buller 2, Buller 3, Site 8, Site 9 and Site 11, see Table 5.1).

Regarding the *Bothriembryon* snail, or any other species of snail, no conclusion could be made about their regional distribution as all snail specimens collected during the regional survey remain to be identified by the WAM experts. Nevertheless, is it possible that specimens of the *Bothreimbryon* sp. will be identified within the specimens from the Regional Areas as up to five different snail morphs were collected.

The isopod *Hanoniscus tuberculatus* from the family Oniscidea was not collected during the regional survey despite the fact that a number of isopod specimens were collected. As demonstrated by the species accumulation curve, the sampling effort of the regional survey was comprehensive and adequate, therefore the species were either;

- relatively rare, or
- subject to large seasonal variation in population dynamics, or
- restricted to the Study Area.

The latter option was viewed as unlikely by the isopod expert (S. Judd, ECU, pers. comm. 2006), therefore rarity and / or seasonal variability were expected to explain the lack of record during the regional survey. Unless further records from the area become available, the only known location of this species remains within the Study Area.

Similarly, the undescribed genus from the family Platyarthridae (SRE status could not be determined) (ecologia in prep.) was also not collected during the regional survey and remains known only from within the Study Area.

Specimens from genera *Buddelundia* and *Leavophiloscia* were identified from sites in the Regional Areas. The taxonomic knowledge of these genera is limited due to the poor understanding of these groups, and as such no conclusion could be made concerning their short range endemic status.

Members of the genus *Aname* (family Nemesiidae), of which two undescribed species were identified from the Study Area (ecologia in prep.), were not collected from Regional Areas. The two undescribed species, therefore, remain known only from within the Study Area. *Aname* sp. 2 is probably restricted to Oakajee River banks at the northern boundary of the Study Area.

Spiders from the family Nemesiidae belonging to the genera *Chenistonia*, *Teyl* and *Yilgarnia* (SRE status could not be determined) (*ecologia* in prep.) were not collected in Regional Areas either. This was largely due to the methodology used, specifically searching for SRE species by foraging. Typically, burrows of smaller nemesiid spiders are cryptic and can be difficult to identify, despite extensive foraging efforts. Pitfall trapping during correct season is generally the preferred method as mature males running around in search of females are required for taxonomic identification. Only singleton records exist from the Study Area (ecologia in prep.), with the location of *Yilgarnia* and *Teyl* found within the proposed Terrestrial Port Development footprint while the *Chenistonia* location is in the Oakajee River valley.

It is possible that seasonal variation played its role, particularly in case of the SRE isopod, *Hanoniscus tuberculatus*. Most SRE species are highly seasonal and only active during cooler and/or wetter periods (Harvey 2002). For that reason, the EPA Guidance Statement 20 recommends that sampling in the mid-west region is conducted during winter (May – August) (EPA 2009). The regional survey complied with this recommendation. Nevertheless, little is known about population dynamics and dispersal abilities of terrestrial isopods (S. Judd, ECU, pers. com. 2006), and it is, therefore, possible that their seasonal patterns are more complex than anticipated.

7 STUDY TEAM

The Oakajee Terrestrial Port Development Short Range Endemic Invertebrate Survey described in this document was planned, coordinated, and executed by:

ecologia Environment

1025 Wellington Street

WEST PERTH WA 6005

Project Staff:

Magdalena Davis (nee Zofkova),	BSc, MSc, PhD, Invertebrate Zoologist
Lazaro Roque Albelo,	BSc, MSc, PhD, Invertebrate Zoologist
Laura Quinn	BSc, MSc, Invertebrate Zoologist
Sean White	BSc, Invertebrate Zoologist

Special Thanks:

Dr Mark Harvey and Dr Volker Framenau (WAM) for identifying the millipedes, pseudoscorpions and mygalomorph spiders, and Dr Simon Judd for identifying the isopods.

This page has been left blank intentionally

8 REFERENCES

Abbott, I. 1994. Distribution of the native earthworm fauna of Australia: a continent-wide perspective. Australian Journal of Soil Research. 32:117 - 126.

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

Attems, C. G. 1911. Myriopoda exkl. Scolopendridae. Die Fauna Südwest-Australiens. pp. 147-204 *in* Hartmeyer, W. M. a. R., ed. Gustav Fischer, Jena.

Beard, J. S. 1976. Vegetation survey of Western Australia - Murchison 1:1 000 000 vegetation series. University of Western Australia Press, Perth.

Beard, J. S. 1980. A new phytographic map for Western Australia. Western Australian Herbarium Research Notes. 3:37-58.

Beard, J. S. 1990. Plant life of Western Australia. Kangaroo Press, Kenthurst.

Beard, J. S. and Burns, A. C. 1976. The vegetation of the Geraldton area. Western Australia. Map

and explanatory memoir. 1: 250,000 Series. Vegmap Publications Perth.

BOM. 2009. Bureau of Meteorology. Accessed http://www.bom.gov.au.

Brady, J. 1969. Some Physical Gradients Set Up In Tullgren Funnels During The Extraction of Mites From Poultry Litter. The Journal of Applied Ecology. 6:391 - 402.

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.

Bureau of Meteorology. 2009. Accessed http://www.bom.gov.au.

CALM. 2002. A Biodiversity Audit of Western Australia's 53 Biogeographic Subregions. Department of Conservation and Land Management.

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.

Clarke, G. M. and Spier-Ashcroft, F. 2003. A Review of the Conservation Status of Selected Australian Non-Marine Invertebrates. Natural Heritage Trust: Commonwealth Government of Australia, Canberra.

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.

Comer, S., Gilfillan, S., Grant, M., Barrett, S., and L., A. 2002. Esperance 1 (ESP1 - Fitzgerald subregion). A Biodiversity Audit of Western Australia's 53 Biogeographical Subregions. The Department of Conservation and Land Management., Perth.

Dames and Moore. 1993. Flora and fauna assessment. Oakajee proposed industrial site. Unpuplished report to Landcorp.

Oakajee Port and Rail. in prep. Port Terrestrial Development, Short Range Endemic Invertebrate survey, Part 1 - Study Area.

Edward , K. L. and Harvey, M. S. 2008. Short-range endemism in hypogean environments: the pseudoscorpion genera Tyrannochthonius and Lagynochthonius (Pseudoscorpiones: Chthoniidae) in the semiarid zone of Western Australia. Invertebrate Systematics. 22:259-293.

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 Statement 20: Sampling of Short Range Endemic Invertebrate Fauna for Environmental Impact Assessment in Western Australia.

Western Autralian Museum. 2009. The Short-Range Endemic Invertebrate Fauna of regional Geraldton, Western Australia. Unpublished report to ecologia Environment.

Framenau, V. W., Moir, M. L., and Harvey, M. S. 2008. Terrestrial Invertebrates of the South Coast NRM Region of Western Australia: Short-range Endemics in Gondwanan Relictual Habitats. Report to South Coast NRM. Western Australian Museum. Welshpool, 184pp.

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

Harvey, M. S. 1987. A revision of the genus Synsphyronus Chamberlin (Garypidae: Pseudoscorpionida: Arachnida). Australian Journal of Zoology, Supplementary Series. 126:1-99.

Harvey, M. S. 1991. The cavernicolous pseudoscorpions (Chelicerata: Pseudoscorpionida) of Cape Range, Western Australia. Records of the Western Australian Museum. 15:487-502.

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

Harvey, M. S. 2006. Short range endemic invertebrates from the Oakajee site. Report Prepared for ecologia Environment. Western Australian Museum.

Harvey, M. S. 2009. Pseudoscorpions of the World, version 1.2, Western Australian Museum, Perth. Accessed 26 November 2009. http://www.museum.wa.gov.au/arachnids/pseudoscorpions/.

Harvey, M. S., Sampey, A., West, P. L. J., and Waldock, J. M. 2000. The Chilopoda and Diplopoda of the southern Carnarvon Basin, Western Australia. Records of the Western Australian Museum Supplement. 61:323-333.

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

Horwitz, P. and Rogan, R. 2003. Aquatic macroinvertebrates and non-flowing wetland values of the Yarragadee (outcropping and subcropping) groundwater dependent systems of south-western Australia. Centre for Ecosystem Management, Edith Cowan University., Perth, W.A.

Magurran, A. E. 2004. Measuring biological diversity. Blackwell.

Main, A. R. and Main, B. Y. 1991. Report on the Southern Forest Region of Western Australia. Report. Australian Heritage Commission,, Perth.

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. 1997. Granite outcrops: A collective ecosystem. Journal of the Royal Society of Western Australia. 80:113 - 122.

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.

Ponder, W. F. and Colgan, D. J. 2002. What makes a narrow-range taxon? Insights from Australian freshwater snails. Invertebrate Systematics. 16.

Thackway, R. and Cresswell, I. D. 1995. An Interim Biogeographic Regionalisation for Australia. Australian Nature Conservation Agency, Canberra.

Trayler, K. M., Davis, J. A., Horwitz, P., and Morgan, D. 1996. Aquatic fauna of the Warren bioregion, south-west Western Australia: Does reservation guarantee preservation? Journal of the Royal Society of Western Australia. 79:281 - 291.

Upton, M. S. 1991. Methods for Collecting, Preserving and Studying Insects and Allied Forms (4th Ed.). The Australian Entomological Society. Miscellaneous Publication No. 3. Brisbane Australia.

Volschenk, E. S., Smith, G. T., and Harvey, M. S. 2000. A new species of *Urodacus* from Western Australia, with additional descriptive notes for *Urodacus megamastigus* (Scorpiones). Records of the Western Australian Museum. 20:57-67.

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

This page has been left blank intentionally