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# FORTESCUE METALS GROUP

# CLOUDBREAK SHORT-RANGE ENDEMIC DESKTOP ASSESSMENT

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# CLOUDBREAK

# SHORT-RANGE ENDEMIC DESKTOP ASSESSMENT

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

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## ACRONYMS

List all acronyms used in the report here. Format alphabetically as follows:

**DEC** Department of Environment and Conservation

**EPA** Environmental Protection Authority

**EPBC** *Environment Protection and Biodiversity Conservation Act 1950*

**SRE** Short-Range Endemic

**WAM** Western Australian Museum

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# EXECUTIVE SUMMARY

The study area is located in the Pilbara, approximately 120 km north-west of Newman along the northern margin of Fortescue Marsh. Included in this project area is the Cloudbreak mine, which is part of Fortescue Metal Group's Chichester Operations.

Fortescue Metal Group commissioned *ecologia* Environment to undertake a baseline biological desktop study of the Short Range Endemic (SRE) invertebrate fauna of the Cloudbreak project area as part of the environmental approval process. The primary objective of this study was to provide sufficient information with which to assess previous surveys undertaken at the area and to guide further survey work at Cloudbreak.

The paucity of knowledge and lack of extensive invertebrate survey work in the area of Cloudbreak prompted database searches of the eastern Pilbara region between: 21°55'08" S to 22°54'32"S, and 118°48'40"E to 120°02'52"E. Families and genera known to contain SRE species were targeted from this area in searches of the Malacology and Terrestrial Invertebrate Databases of the Western Australian Museum.

Three species of conservation significance listed by DEC are potentially occurring on the Project Area. Search results and literature records from projects undertaken around the Project Area identified 38 species considered potential SRE invertebrates including Trapdoor spiders, Opilionids, Pseudoscorpions, Scorpions, Millipedes, Centipedes, Isopods and Snails.

Very few SRE invertebrate groups have been recognised in previous surveys at the Project Area. Two possible explanations for this are identified: Insufficient sampling and environmental degradation, which independently, or in conjunction would explain the absence of short-range endemic groups.

Additional surveys are recommended to augment the survey work previously undertaken and collect information about the distribution and habitat associations of the SRE invertebrates.

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# 1 INTRODUCTION

## 1.1 PROJECT BACKGROUND

Fortescue Metals Group (FMG) holds a number of mining tenements that cover iron ore resources in the Pilbara region of Western Australia and has commenced operation of the Pilbara Iron Ore and Infrastructure Project. Included in this project is the Cloudbreak mine, which is part of Fortescue's Chichester Operations, and is located approximately 120 km north-west of Newman along the northern margin of the Fortescue Marsh (Figure 1.1).

As part of the environmental approvals process, this document provides a desktop Short-Range Endemic (SRE) invertebrate fauna assessment of the Cloudbreak Project Area.

## 1.2 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 *Wildlife Conservation Act 1950* (WC Act), and the *Environmental Protection Act 1986* (EP Act).

Section 4a of the *Environmental Protection Act 1986* (EP Act) requires that development proposals 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

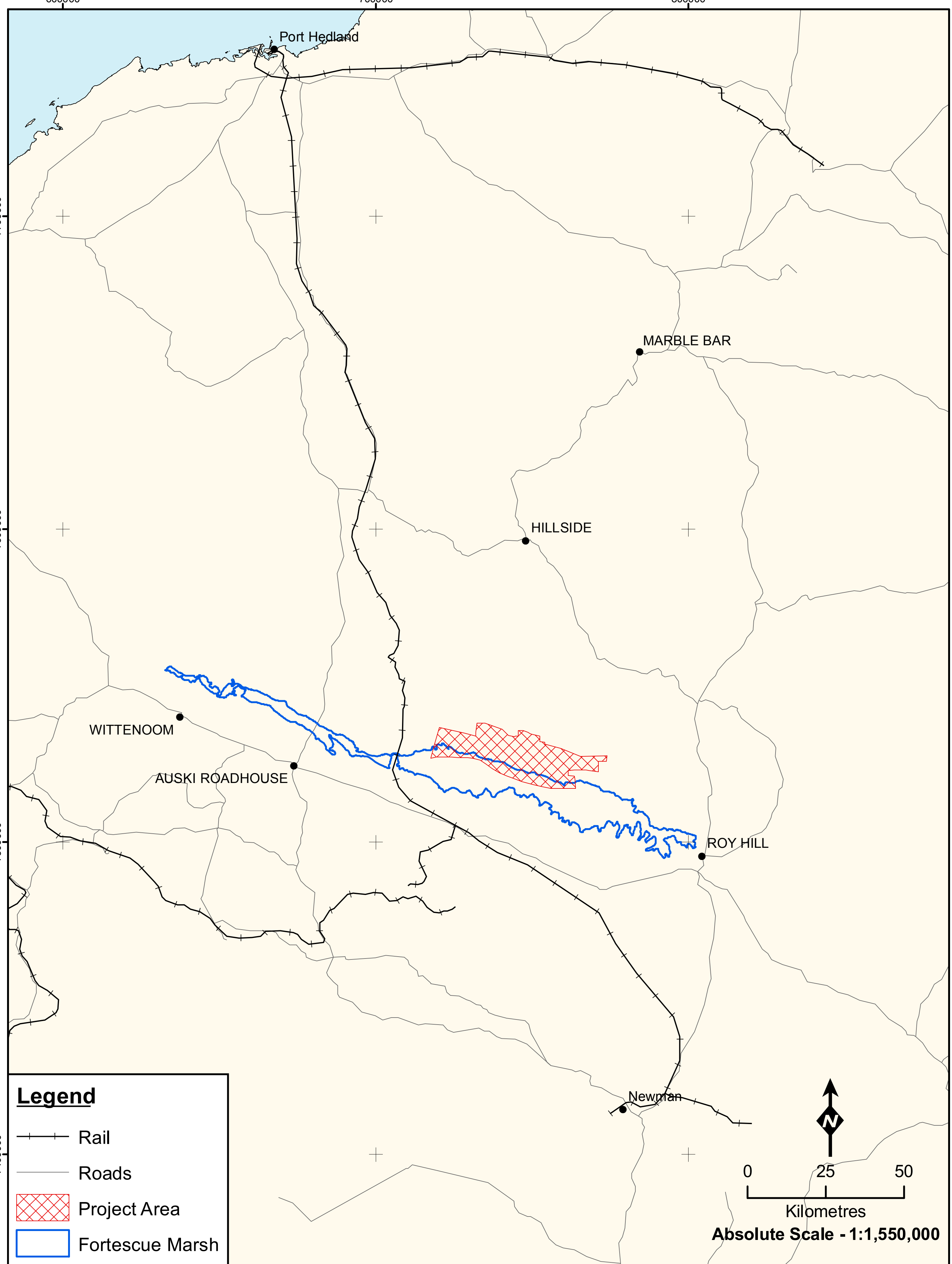
  The present generation should ensure that the health, diversity and productivity of the environment is maintained or enhanced for the benefit of future generations.

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

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

This document was constructed with a view to satisfy the requirements of Environmental Protection Authority (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."*

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**Location of the Cloudbreak Project Area**

**Figure: 1.1**
**Project ID: 1276**

**Drawn: AH**
**Date: 25/10/10**

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

Unique Map ID: A249

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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 SRE 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 satisfies the requirements of Guidance Statement No. 20: *Sampling of Short-range Endemic Invertebrate Fauna for Environmental Impact Assessment in Western Australia* (EPA 2009).

### 1.3 STUDY OBJECTIVES

FMG commissioned *ecologia* Environment (*ecologia*) to undertake a desktop SRE assessment of the invertebrate fauna of the Cloudbreak Project Area as part of the environmental approval process.

The EPA's objectives with regards to SRE 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 WC Act.

Hence, the primary objective of this assessment was to provide sufficient information with which to assess previous surveys undertaken at Cloudbreak (including Harvey 2006) and to guide further survey work at the Project Area.

Specifically, the objectives were to undertake an assessment that satisfied the requirements documented in EPA's Guidance Statement 20, 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 SRE species of biological and conservation significance recorded or likely to occur within the Project Area and local area; and
- an assessment of likely habitats that may potentially support SREs based on vegetation mapping data provided by FMG as well as bioregion and land system information.

## 1.4 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 is on SREs, and 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 because 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.

### 1.4.1 Processes promoting short range endemism

Short-range endemism is influenced by numerous processes, which generally contribute to the isolation of 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 generally low dispersal powers typical of most SRE.

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# 2 PROJECT AREA

## 2.1 CLIMATE

The Project Area is situated in the Pilbara region of Western Australia and experiences an arid-tropical climate with two distinct seasons; a hot summer from October to April and a mild winter from May to September (BOM 2010). Annual evaporation exceeds rainfall by as much as 500 mm per year. Seasonally low but unreliable rainfall, together with high temperatures and high diurnal temperature variations are also characteristic of the region (BOM 2010). In the past the region has received zero rainfall during some years, which is typical of a desert climate (Beard 1975).

Meteorological data has been recorded at the Newman Aero BoM weather station since 1971. This weather station is the closest to the Project Area, being located approximately 120 km to the south. Newman Aero was selected to provide an indication of the local climatic conditions experienced within the project area. Average climatic results for Newman Aero are presented in Figure 2.1.

Within the Pilbara, the temperature range is large and maxima are high. Summer temperatures may reach as high as 46°C, with an annual mean maximum of 31.4°C, while the winter mean maximum is 25°C (ranging from 22–29°C) (BOM 2010). Light frosts occasionally occur during July and August (BOM 2010). The climate experienced throughout the year is usually very dry since high temperatures and humidity seldom occur simultaneously (Beard 1975).

Rainfall in the Pilbara is highly unpredictable and recordings are highest at stations around the Hamersley Range which reach altitudes of up to 900 m. The majority of the Pilbara has a bimodal rainfall distribution, resulting in two rainfall maxima per year. From January to March rains result from tropical storms producing sporadic and drenching thunderstorms. Tropical cyclones moving south from northern Australian waters also bring sporadic heavy rains. From May to June extensive cold fronts move easterly across the state and occasionally reach the Pilbara. These fronts produce only light winter rains that are ineffective for the growth of plants other than herbs and grasses. Larger perennial species generally require heavier rainfall that is associated with the intense and prolonged storms of summer. Surface water can be found in some pools and springs in the Pilbara all year round, although watercourses only flow briefly due to the short wet season (Beard 1975).

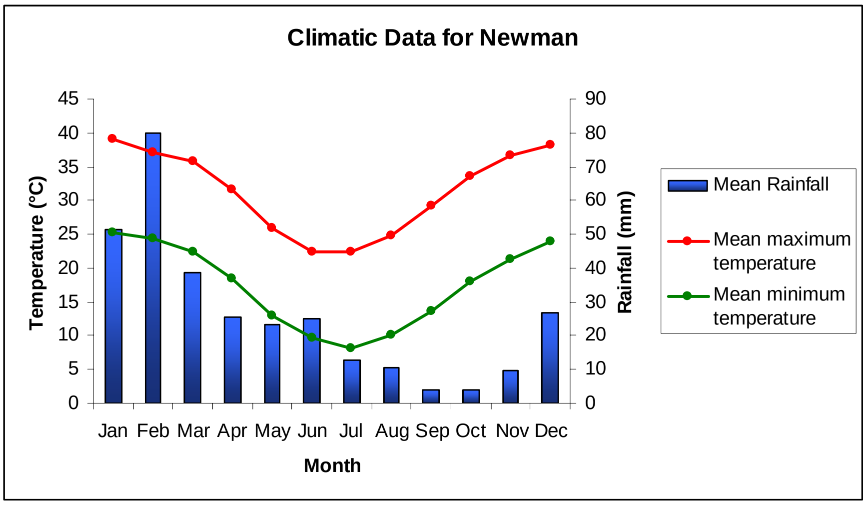


**Figure 2.1 – Climatic Summary Data (Newman Airport) (BOM 2010)**

## 2.2 VEGETATION

The Project Area lies in the Fortescue Botanical District of the Pilbara (Beard 1975). Four vegetation communities occur within the Cloudbreak Project Area (Table 2.1). They consist of Samphire steppe within the Fortescue Marsh ($k_3Ci$), open Mulga woodland on the flats surrounding the marsh ($a_1Lp$), and scattered Snappy Gums (*Eucalyptus leucophloia*) over Spinifex grassland in the hills and foot slopes of the Chichester Ranges mixed with open Mulga woodland, typically along creek lines and in low lying areas ($a_1Li/e_{16}Lrt_3Hi$) and hummock grasslands with scattered Eucalypt trees and Acacia shrubs (a2Sr t1,3Hi).

Open Mulga woodland ($a_1Lp$) is an extensive vegetation type found in Western Australia. Along with the Samphire steppe ($k_3Ci$), these areas are well represented outside the survey area (Table 2.1 Figure 2.2). Less well represented is the mixed Spinifex grassland and open Mulga woodland found in the survey area, with 12.64% of this vegetation type in the Pilbara occurring within the Project area. However, individually each vegetation type is well represented.

**Table 2.1 – Beard Vegetation Types of Cloudbreak Survey Area**

| Beard Vegetation Code | Vegetation Type | Total Area in Western Australia ($km^2$) | Extent in Project Area ($km^2$) | Percent of Total Vegetation Type in Project Area (%) |
|---|---|---|---|---|
| $k_3Ci$ | Unwooded Samphire steppe | 20,789 | 133 | 0.64 |
| $a_1Lp$ | Low woodland with Mulga in patches | 79,145 | 344 | 0.44 |
| $a_1Li/e_{16}Lrt_3Hi$ | Low Mulga woodland/Tree steppe with scattered Snappy Gum over Spinifex hummock grassland | 1,036 | 120 | 11.59 |
| a 2Srt1,3Hi | *Eucalyptus dichromophloia* trees over mixed Acacia hummock grassland, shrub steppe; kanji over soft Spinifex and *Triodia wiseana* on basalt | 17,553 | 0.075 | 0.00042 |

## 2.3 LAND SYSTEMS

An inventory of the land systems occurring in the Pilbara was completed by van Vreeswyk *et al.* (2004). The inventory aimed to provide a comprehensive description and mapping of the biophysical resources of the region, as well as an evaluation of the condition of soils and vegetation. Each land system is classified into a particular land type defined by the landforms and vegetation it contains.

The survey area contains seven land systems: Newman, McKay, Jamindie, Turee, Cowra, Christmas, and Marsh (Figure 2.3). These land systems are described in detail in Table 2.2. The Newman, McKay, Jamindie, Turee and Christmas land systems are well represented in the region with less than 3% of their total Pilbara bioregion extent occurring within the Project Area. Exceptions are the Cowra and Marsh land systems with 14% and 34% of their total distribution in the Pilbara bioregion occurring within the Project Area. The Cowra land system fringes the Marsh land system that occurs within the Fortescue Marsh. It consists of alluvial plains supporting Snakewood (*Acacia xiphophylla*) and Mulga shrublands with some halophytic vegetation. The Marsh land system consists of irregularly inundated lake beds and floodplains and surrounding halophytic shrub lands.

**Table 2.2 – Land Systems of the Project Area.**

| Land System | Description | Total Area in WA ($km^2$) | Extent in Project Area ($km^2$) | Percent of Total Land System in Project area (%) |
|---|---|---|---|---|
| *Land Type 1* | *Hills and ranges with Spinifex grasslands* | | | |
| Newman | Rugged jaspilite plateaux, ridges and mountains supporting hard Spinifex grasslands | 19,998 | 108 | 0.54 |
| McKay | Hills, ridges, plateau remnants and breakaways of meta sedimentary and sedimentary rocks supporting hard Spinifex grasslands | 4,274 | 21 | 0.5 |
| *Land Type 12* | Wash plains on hardpan with groved Mulga shrublands (sometimes with Spinifex understorey) | | | |
| Jamindie | Stony hardpan plains and rises supporting groved Mulga shrublands, occasionally with Spinifex understorey | 11,883 | 230 | 1.9 |
| *Land Type 14* | Alluvial plains with tussock grasslands or grassy shrublands | | | |
| Turee | Stony alluvial plains with gilgaied and non-gilgaied surfaces supporting tussock grasslands and grassy shrublands | 927 | 28 | 3.1 |
| *Land Type 15* | *Alluvial plains with Snakewood shrublands* | | | |
| Cowra | Plains fringing the Marsh land system and supporting Snakewood and Mulga shrublands with some halophytic undershrubs | 203 | 69 | 34.0 |
| Christmas | Stony alluvial plains supporting Snakewood and mulga shrublands with sparse tussock grasses | 232 | 3 | 1.5 |
| *Land Type 20* | Salt lakes and fringing alluvial plains with halophytic shrublands | | | |
| Marsh | Lakebeds and floodplains subject to regular inundation, supporting samphire shrubland, salt water couch grasslands and halophytic shrubland | 977 | 136 | 13.9 |

## 2.4 BIOGEOGRAPHY

The Interim Biogeographic Regionalisation for Australia (IBRA) classifies the Australian continent into regions (bioregions) of similar geology, landform, vegetation, fauna and climate characteristics (DSEWPC 2010). According to IBRA (Version 6.1) the Project area is located in the Fortescue Plains subregion of the Pilbara bioregion and runs parallel to the southern edge of the Chichester subregion

The Fortescue Plains subregion covers approximately 11% of the Pilbara region. Characteristic features are alluvial plains and river frontages with salt-marsh, Mulga-bunch grass and short grass communities on alluvial plains. River Gum (*Eucalyptus camaldulensis*) woodlands fringe the drainage lines. An extensive calcrete aquifer feeds numerous permanent springs in the central Fortescue, supporting large permanent wetlands with extensive stands of River Gum and Cadjeput (*Melaleuca argentea*) woodlands (DEC 2003). The Fortescue Plains subregion occupies an area of approximately 20,000 $km^2$ with the dominant uses being grazing native pastures, unallocated Crown land and Crown reserves, conservation and Aboriginal land.

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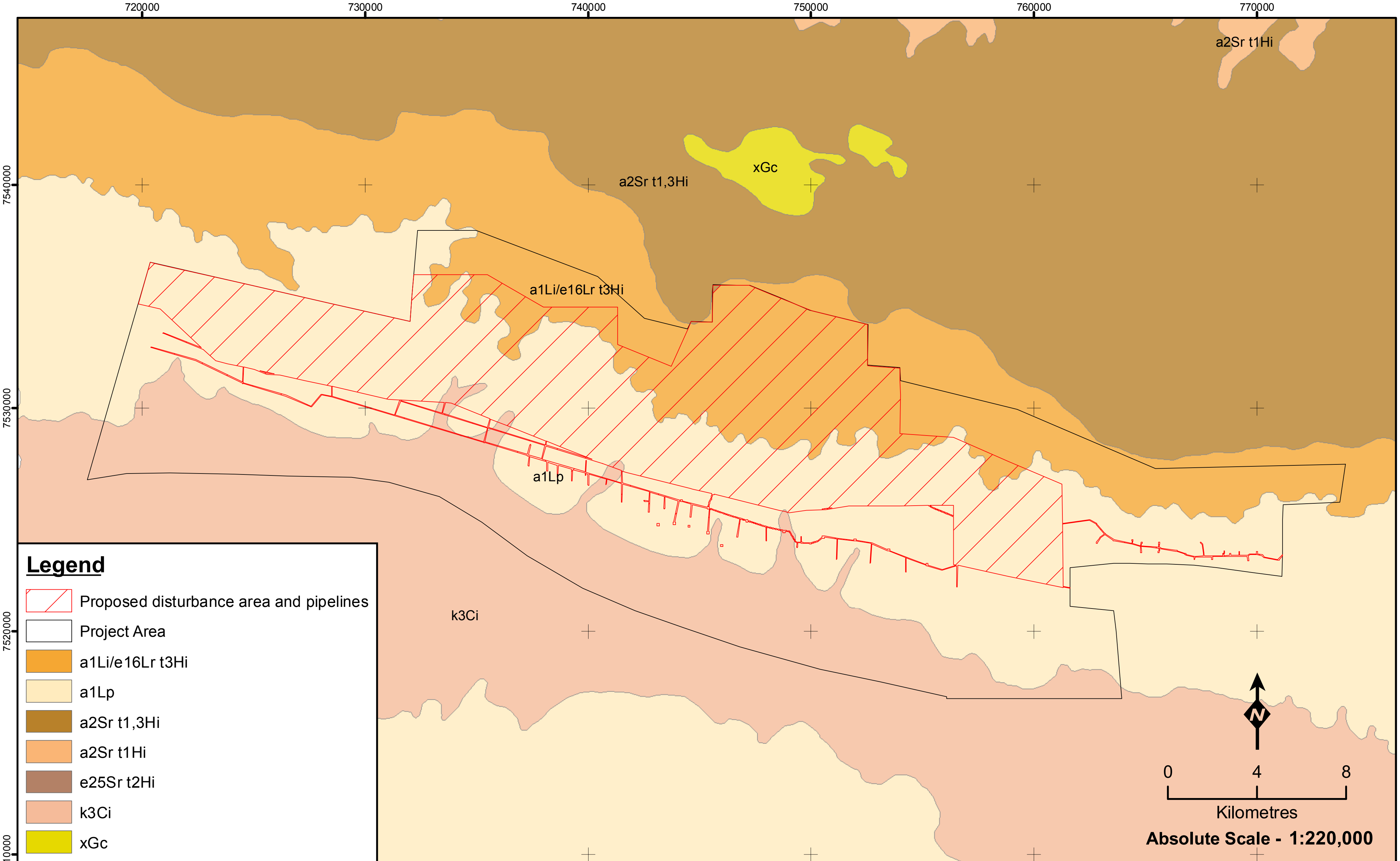


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**Beard vegetation of the Cloudbreak Project Area**

**Figure: 2.2**
**Project ID: 1276**

**Drawn: AH**
**Date: 25/10/10**

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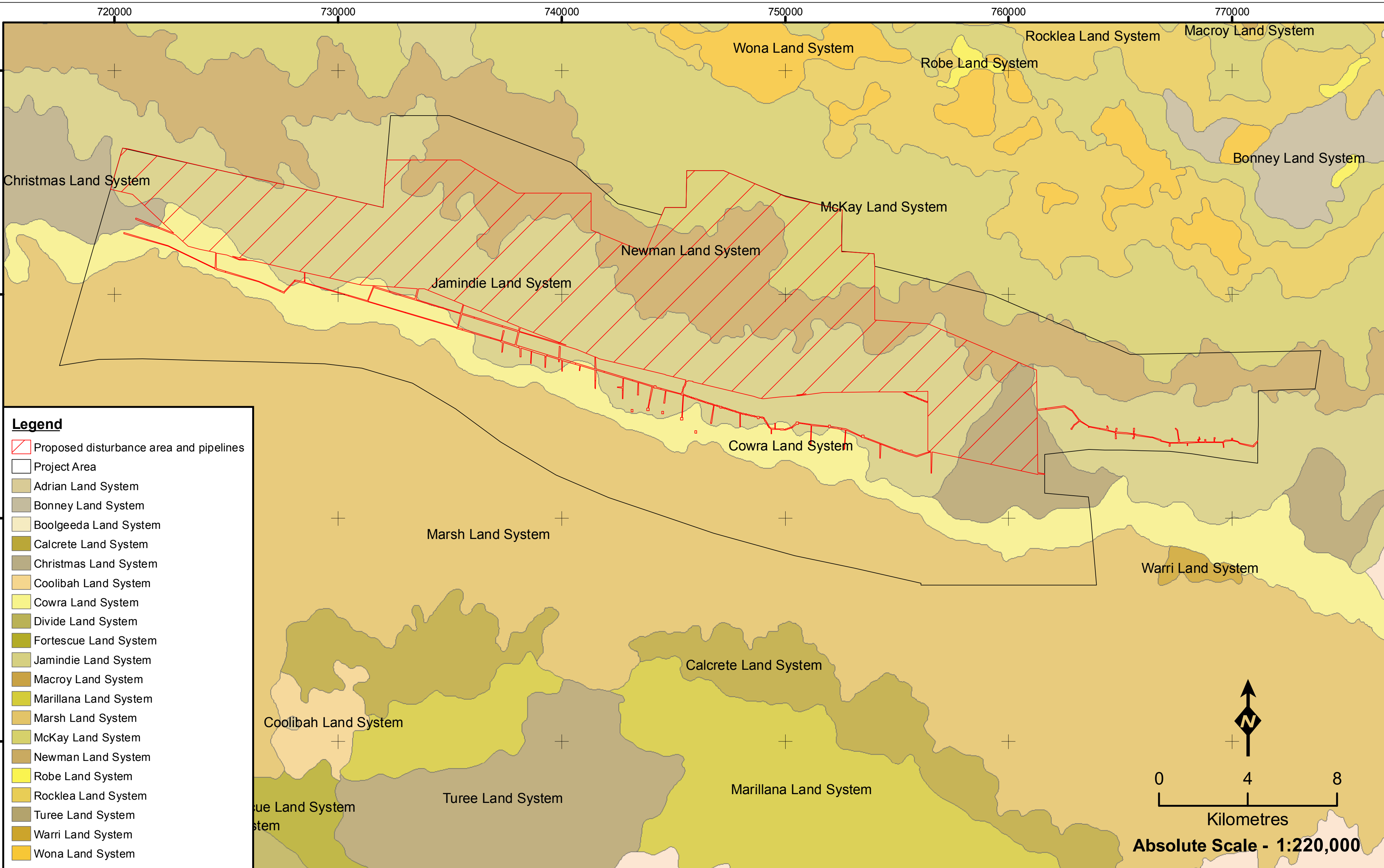


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**Landsystems of the Cloudbreak Project Area**

**Figure: 2.3**
**Project ID: 1276**

**Drawn: AH**
**Date: 25/10/10**

*Coordinate System*
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Projection: Transverse Mercator
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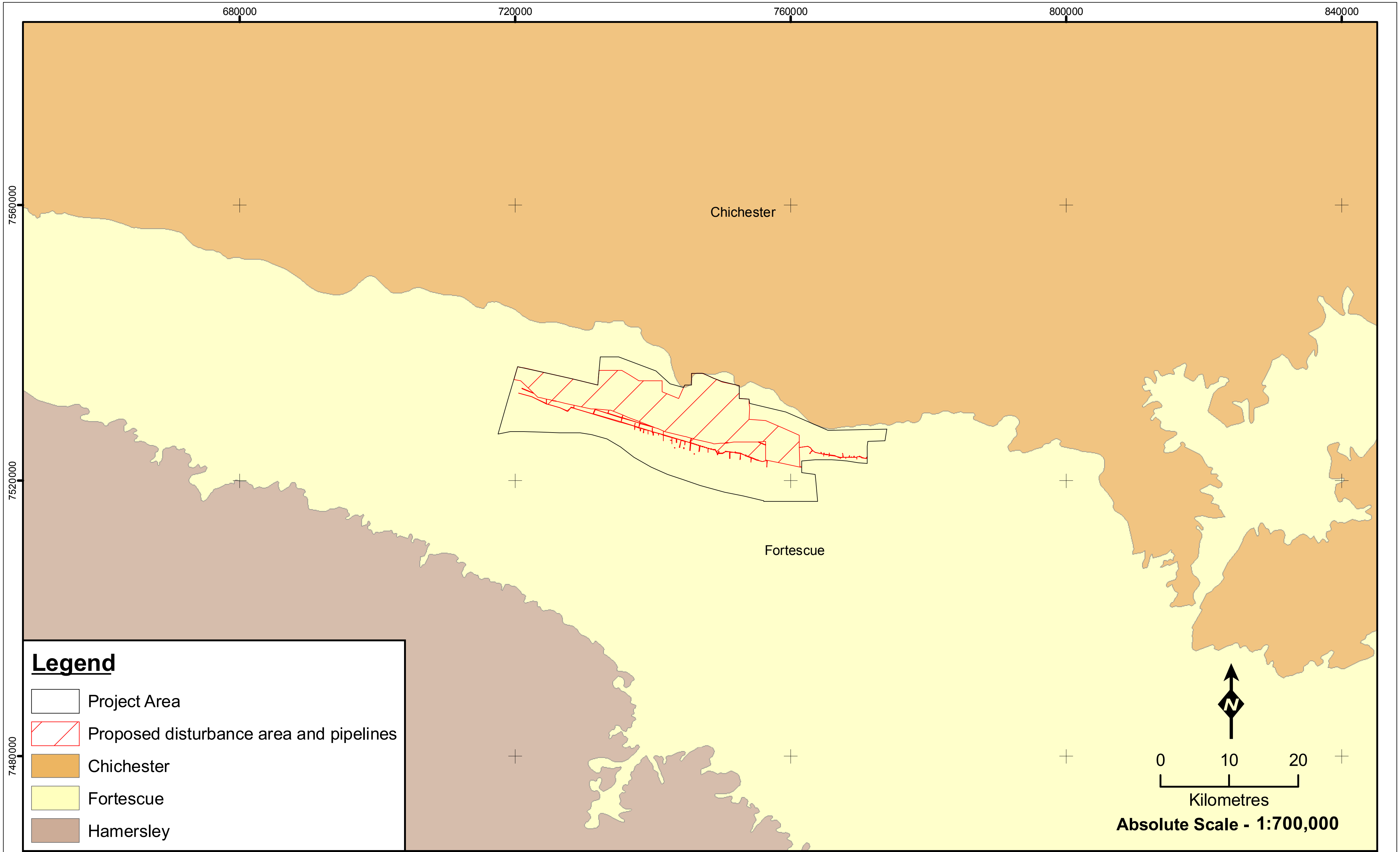


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**Biogeographic Regions of the Cloudbreak Project Area**

**Figure: 2.4**
**Project ID: 1276**

**Drawn: AH**
**Date: 25/10/10**

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

Unique Map ID: A250

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# 3 METHODS

This desktop assessment involved a search of the NatureMap DEC database and as many SRE species are not formally recognised under Commonwealth and state legislation due to limited knowledge of the species, searches were also undertaken of the Western Australian Museum (WAM) database and previous nearby surveys.

## 3.1 SRE STATUS

The likelihood of the invertebrate species to be considered a SRE or not a SRE was determined by expert taxonomists (Volker Framenau and Mark Harvey, Department of Terrestrial Invertebrates, WAM; Shirley Slack-Smith and Corey Whisson, Department of Malacology; Erich Volschenk, private consultant) based on the current knowledge of the distribution and biology of each species, as follows:

- No – Not considered a SRE
- Yes - Current knowledge confirms that this species is a SRE
- Likely – Current knowledge suggests this species is probably a SRE. However, further research is required to confirm status.
- Potential – Current knowledge of this species or group is very limited however, there is the potential for this species to represent a SRE. Further research is required to confirm status.

## 3.2 WAM DATABASE SEARCH

Ideally, a database search for SRE would be undertaken of the Project Area and immediate surrounding local area. However, as knowledge of invertebrate diversity throughout the Pilbara is very limited, a regional approach was taken. Taxa (Orders) known to contain SREs were searched within the Malacology and Terrestrial Invertebrate electronic databases of the WAM, between 21°55’08” S to 22°54’32”S and 118°48’40” E to 120°02’52”E (50 km radius around Project Area). The list of species obtained represents possible SRE with the potential to be present in the area. None of these species are currently listed under the WC Act; however, this is largely due to inadequate knowledge of their taxonomy, distribution and ecology.

## 3.3 NATUREMAP DATABASE SEARCH

A DEC NatureMap database search was undertaken in order to determine if any species listed by the EPBC Act or the WC Act have the potential to occur in the Project Area.

## 3.4 PREVIOUS SRE SURVEYS

Reports from previous invertebrate surveys conducted near the Project Area were examined for SRE that have the potential to occur. Data were collected from five projects including:

- HPPL Roy Hill (*ecologia* 2006);
- Hope Downs Stage 4 (Ninox 2009);
- BHP Billiton Rapid Growth Project 5 rail corridor (*ecologia* 2008);

- FMG Stage B (Biota 2003); and
- Cloudbreak (Harvey 2006).

### 3.5 SRE HABITATS DETERMINATION

SRE habitat was primarily determined based on vegetation communities and geographical features such as southern facing slopes, creek lines, breakaways and micro habitats likely to maintain higher moisture levels and 'island' habitats. Vegetation map of the Project Area and aerial photographs were studied to determine the vegetation communities in which the SREs are likely to occur within the Project Area. Aerial photography and vegetation mapping was not available for all areas of the Project area. Therefore ground truthing would be required to confirm predicted SRE habitats in these areas.

# 4 RESULTS

The results from the DEC and WAM database searches and review of previous nearby survey reports are provided in detailed in the following pages. A map of the SRE or potential SRE species that have been recorded within the Project Area are shown in Figure 4.1.

## 4.1 CONSERVATION SIGNIFICANT SRE FAUNA

The results of the database search for SRE are presented in Table 4.1. No terrestrial invertebrate taxa from the Pilbara were reported from the DEC Declared Threatened Fauna list or the WC Act (Specially Protected Fauna) Notice 2010.

Three SREs were listed as Priority 2 by the DEC. These were *Antipodogomphus hodgkini* (Dragonfly), *Nosostica pilbara* (Dragonfly) and *Dupucharopa millestriata* (Snail). These species are known from areas not under immediate threat of habitat destruction or degradation. The Fortescue Marsh and surounding areas can provide suitable habitats for these three species.

**Table 4.1 – DEC Priority Fauna Categories**

| Priority Category | Definition | Taxa Reported from the Pilbara |
|---|---|---|
| **Priority One**<br><br>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. | none |
| **Priority Two**<br><br>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. | *Antipodogomphus hodgkini* (Dragonfly)<br><br>*Nososticta pilbara* (Dragonfly)<br><br>*Dupucharopa millestriata* (Mollusc) |
| **Priority Three**<br><br>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. | none |
| **Priority Four**<br><br>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. | none |
| **Priority Five**<br><br>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 |

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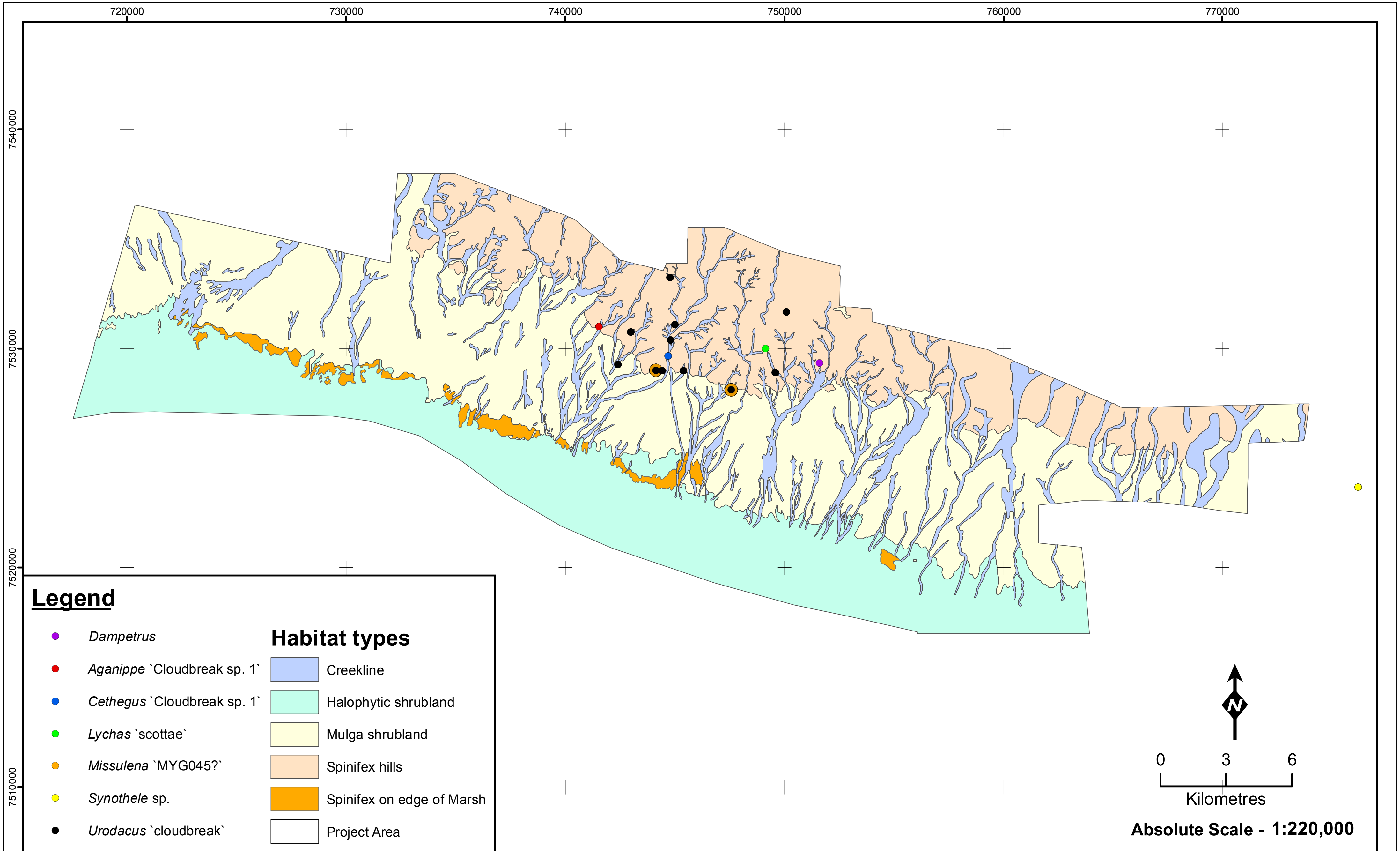


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**SRE or Potential SRE Species That Have Been Recorded Within the Project Area**

**Figure:** 4.1
**Project ID:** 1276

**Drawn:** SG
**Date:** 16/08/10

*Coordinate System*
Name: GDA 1994 MGA Zone 50
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Datum: GDA 1994

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## 4.2 WAM DATABASE SEARCH

The results of the WAM database search are presented in Table 4.2. The search identified a total 25 species that are potentially SREs. Thirteen of these species are Mygalomorph spiders with 13 possible SRE species recorded. Five scorpions and five snail species were also recorded as SREs or potential SREs. In addition, one pseudoscorpion species and one millipede species belonging to the genus *Antichiropus* are considered SREs.

**Table 4.2 – Results from WAM Database Search**

| Class (Order) | Family | Genus | Species | SRE |
|---|---|---|---|---|
| **Arachnida (Aranae: Mygalomophae)** | | | | |
| | Nemesiidae | *Aname* | 'MYG001' | Potential |
| | | *Aname* | *mainae*? | Potential |
| | | *Aname* | 'Biota sp. A' | Potential |
| | | *Aname* | sp. | Potential |
| | Idiopidae | *Aganippe* | 'MYG086' | Potential |
| | | *Aganippe* | 'MYG126' | Potential |
| | | *Aganippe* | *occidentalis*? | Potential |
| | | *Aganippe* | 'Cloudbreak sp.1' | Potential |
| | | *Aganippe* | sp. | Potential |
| | Actinopodidae | *Missulena* | 'MYG045?' | Potential |
| | | *Missulena* | sp. | No |
| | Dipluridae | *Cethegus* | 'Cloudbreak sp.1' | Potential |
| | Barychelidae | *Aurecocrypta* | *katersi* | Potential |
| | | *Synothele* | 'MYG127' | Potential |
| | | *Synothele* | sp. | No |
| | | *Idiommata* | sp. | No |
| **Arachnida (Scorpiones)** | | | | |
| | Buthidae | *Lychas* | 'gracilimanus' | Potential |
| | | *Lychas* | 'scottae' or 'mjobergi' | Potential |
| | | *Lychas* | 'prendinii' | Potential |
| | | *Lychas* | 'sp. 1' | No |
| | | *Lychas* | 'sp. 2' | No |
| | Urodacidae | *Urodacus* | 'linnaei' | Potential |
| | | *Urodacus* | 'cloudbreak' | Potential |
| **Arachnida (Pseudoscorpiones)** | | | | |
| | Garypidae | *Synsphyronus* | *heptatrichus* | No |
| | | *Synsphyronus* | *gracilis* | Yes |
| **Gastrapoda (Pulmonata)** | | | | |
| | Bulimulidae | *Bothriembryon* | sp. | Likely |
| | Camaenidae | *Quistrachia* | sp. | Likely |
| | Camaenidae | *Rhagada* | *richardsonii* | Potential |
| | Helicodiscidae | *Stenopylis* | *coarctata* | No |

| Class (Order) | Family | Genus | Species | SRE |
|---|---|---|---|---|
| | Punctidae | *Paralaoma* | sp. | Potential |
| | Pupillidae | *Gastracopta* | cf. *larapinta* | No |
| | | *Gastracopta* | *mussoni* | No |
| | | *Pupoides* | cf. *beltanius* | No |
| | | *Pupoides* | *pacificus* | No |
| | Sublinidae | *Eremopeas* | *interioris* | No |
| | Succineidae | *Succinea* | sp. | Potential |
| | Planorbidae | *Gyraulus* | sp. | No |
| | | *Leichhardtia* | sp. | No |
| **Diplopoda (Polydesmida)** | | | | |
| | Paradoxosomatidae | *Antichiropus* | sp. | Yes |

## 4.3 PREVIOUS SURVEYS

Previous SRE surveys conducted near the Project Area are shown in Table 4.3. At least 62 different species were recorded during the surveys. Of these, 13 species are from 12 genera, 11 families and five orders were considered to potentially represent SRE species.

The infraorder Mygalomorphae contained the most potential SRE species with seven species from five families being found from three of the projects. Some species of Opilionids, Snails, Millipedes and Isopods also had the potential to represent SRE species.

**Table 4.3 – Results from Previous Surveys Within and Around the Project Area**

| Class (Order) | Family | Genus | Species | SRE | Project |
|---|---|---|---|---|---|
| **Arachnida (Aranae: Mygalomophae)** | | | | | |
| | Actinopodidae | *Missulena* | *occatoria* | No | FMG Stage B |
| | | *Missulena* | sp. | Potential | Roy Hill |
| | Idiopidae | *Aganippe* | sp. | Potential | FMG Stage B |
| | | *Anidiops* | sp. | No | Hope Downs Stage 4 |
| | | *Gaius* | sp. | No | Hope Downs Stage 4 |
| | Barychelidae | *Aurecocrypta* | 'Chichester' | No | RGP5 Rail |
| | | *Synothele* | 'MYG127' | Potential | Roy Hill |
| | | *Synothele* | 'near karara' | no | Hope Downs Stage 4 |
| | | *Synothele* | sp. | Potential | FMG Stage B |
| | Ctenizidae | *Conothele* | sp. | Potential | Roy Hill |
| | Dipluridae | *Cethegus* | sp. | No | Hope Downs Stage 4 |
| | Nemesiidae | *Aname* | 'MYG001' group | Potential | Roy Hill |
| | | *Aname* | sp. | No | Hope Downs Stage 4 |
| | | *Kwonkan* | 'MYG101' | No | Roy Hill |
| | | *Yilgarnia* | 'MYG033' | Potential | Roy Hill |
| **Arachnida (Aranae: Araneomorphae)** | | | | | |
| | Clubionidae | Unknown | | No | RGP5 Rail |
| | Gnaphosidae | Unknown | | No | RGP5 Rail<br>Hope Downs Stage 4 |
| | Lamponidae | Unknown | | No | RGP5 Rail |

| Class (Order) | Family | Genus | Species | SRE | Project |
|---|---|---|---|---|---|
| | Lycosidae | Unknown | | No | RGP5 Rail |
| | Miturgidae | Unknown | | No | RGP5 Rail |
| | Trochanteriidae | *Fissarena* | *castanea* | No | Hope Downs Stage 4 |
| **Arachnida (Scorpiones)** | | | | | |
| | Buthidae | *Lychas* | 'bituberculatus' | No | Roy Hill<br>RGP5 Rail<br>Hope Downs Stage 4 |
| | | *Lychas* | 'harveyi' | No | Roy Hill<br>Hope Downs Stage 4 |
| | | *Lychas* | 'hairy tail' | No | RGP5 Rail |
| | | *Lychas* | 'multipunctatus' | No | Hope Downs Stage 4 |
| | | *Lychas* | 'Pilbara sp. 1' | No | Hope Downs Stage 4 |
| | | *Lychas* | 'spiney hairy tail' | No | RGP5 Rail |
| | Urodacidae | *Urodacus* | sp. | No | Roy Hill<br>Hope Downs Stage 4 |
| **Arachnida (Opliones)** | | | | | |
| | Assamiidae | *Dampetrus* | 'Pilbara 1' | Potential | Cloudbreak |
| | Unknown | | | Potential | RGP5 Rail |
| **Arachnida (Pseudoscorpiones)** | | | | | |
| | Chernetidae | *Haplochernes* | sp. | No | Hope Downs Stage 4 |
| | Garypidae | *Synsphyronus* | sp. | No | Hope Downs Stage 4 |
| | Olpiidae | *Beierolpium* | sp. | No | RGP5 Rail<br>Hope Downs Stage 4 |
| | | *Eurolpium* | sp. | No | RGP5 Rail |
| | | *Indiolpium* | sp. | No | RGP5 Rail<br>Hope Downs Stage 4 |
| | | *Oratemnus* | sp. | No | Hope Downs Stage 4 |
| | | Unknown | | No | Roy Hill |
| | Sternophoridae | *Afrosternophorus* | sp. | No | Hope Downs Stage 4 |
| **Malacostraca (Isopoda)** | | | | | |
| | Armadillidae | Unknown | | No | Roy Hill<br>RGP5 Rail |
| | Philoscidae | *Laevophiloscia* | sp. | Potential | Roy Hill |
| **Gastropoda (Pulmonata)** | | | | | |
| | Camaenidae | unknown | | No | Roy Hill |
| | Bulimulidae | *Bothriembryon* | sp. | No | FMG Stage B |
| | | *Bothriembryon* | sp. | Potential | Hope Downs Stage 4 |
| | Lymnaeidae | *Austropeplea* | c.f. *lessoni* | No | Hope Downs Stage 4 |
| | Succineidae | *Succinea* | sp. | Potential | Roy Hill |
| | Planorbidae | *Leichhardtia?* | sp. | No | Hope Downs Stage 4 |
| | Pupilidae | *Pupoides* | *beltaianus* | No | FMG Stage B<br>Hope Downs Stage 4 |
| | | *Pupoides* | *pacificus* | No | Hope Downs Stage 4 |
| | | *Pupoides* | cf. *lepidulus* | No | Hope Downs Stage 4 |
| | | *Gastrocopta* | cf. *mussoni* | No | Hope Downs Stage 4 |
| | | *Gastrocopta* | *larapinta?* | No | Hope Downs Stage 4 |

| Class (Order) | Family | Genus | Species | SRE | Project |
|---|---|---|---|---|---|
| | | Unknown | | No | Roy Hill |
| | Subulinidae | *Eremopeas* | *interioris* | No | Hope Downs Stage 4 |
| **Chilopoda (Geophilida)** | | | | | |
| | Unknown | | | No | Roy Hill |
| **Chilopoda (Scolopendromorpha)** | | | | | |
| | Cryptopidae | *Cryptops* | 'spinipes' | No | Roy Hill |
| | Scolopendridae | *Cormocephalus* | sp. | No | RGP5 Rail |
| | | *Scolopendra* | *mortisans* | No | RGP5 Rail |
| | | *Scolopendra* | sp. | No | RGP5 Rail |
| | Scutigeridae | Unknown | | No | Hope Downs Stage 4 |
| **Diplopoda (Polyxenida)** | | | | | |
| | Polyxenidae | Unknown | | No | Roy Hill<br>Hope Downs Stage 4 |
| **Diplopoda (Polydesmida)** | | | | | |
| | Paradoxosomatidae | *Antichiropus* | sp. | Yes | Hope Downs Stage 4 |
| **Diplopoda (Spirobolida)** | | | | | |
| | Pachybolidae | *Austrostrophus* | sp. | No | Hope Downs Stage 4 |

## 4.4 POTENTIAL SRE

### 4.4.1 CLASS ARACHNIDA: ARACHNIDS

#### 4.4.1.1 ORDER ARANEAE: INFRAORDER MYGALOMORPHAE: TRAP-DOOR SPIDERS

Mygalomorph (Trapdoor Spiders) are moderate to large sized burrowing spiders (Brusca and Brusca 1990). The taxonomy of many Mygalomorphae families and genera are incompletely known, making it impossible to make definitive comment on the conservation status of these groups. Representatives of the families Barychelidae, Ctenizidae, Dipluridae, Idiopidae, and Nemesiidae are known from the eastern Pilbara region and are likely to contain SRE. Four species of Mygalomorphae spiders were collected at Cloudbreak (Harvey 2006). In addition, potential SRE representatives of the genera *Aname*, *Aganippe*, *Cethegus*, *Missulena*, *Synothele* and *Yilgarnia* have been recorded occurring near to the Project Area during surveys for Roy Hill and FMG Stage B and from within the WAM search area (Table 4.2 and Table 4.3). Most of the Mygalomorphae identified from the eastern Pilbara are undescribed.

#### 4.4.1.2 ORDER ARANEAE: OPILIONES: HARVESTMAN

One undescribed and potential SRE species belonging to the genus *Dampetrus* was reported by Harvey (2006). The species was found abundantly at two sites, one on the Cloudbreak tenement and one site just to the north of the tenement. Opilionids are most commonly found throughout the damper regions of Australia although some species of Opilionids have adapted to life in arid regions. Most live in moist leaf litter but they can also be found living under rocks and logs, or under the bark of trees. Six species of *Dampetrus* occurr in Australia however, only one is known from Western Australia, this being *D. isolatus* (Shear 2001) which is found in caves at Cape Range near Exmouth.

#### 4.4.1.3 ORDER SCORPIONES: SCORPIONS

Five potential SRE species, including two collected at Cloudbreak (Harvey 2006), from each of the genera *Lychas*, and *Urodacus*, were identified in the WAM database search. These five species are only known from very small or patchy samples from the Pilbara region (E. Volschenk Pers. com.). Their conservation status is hampered by lack of biological and geographical knowledge.

#### 4.4.1.4 ORDER PSEUDOSCORPIONES: PSEUDOSCORPIONS

One species, *Synsphyronus gracilis,* was recorded from the near the Project Area and represents a SRE species (Harvey 2006). This species was described from a single specimen collected in 1924 from Marillana Station-Roy Hill (Harvey 1987). Since this time more specimens have been collected from across the Hamersley Ranges on the Firetail tenement (*ecologia* 2010). All have been taken under rocks at breakaways.

### 4.4.2 CLASS MALACOSTRACA: CRUSTACEANS

#### 4.4.2.1 ORDER ISOPODA; SUPERFAMILY ONISCOIDEA: SLATERS AND WOODLICE

All terrestrial Isopods belong to the suborder Onscoidea (Brusca and Brusca 1990). *ecologia* (2006) reported one undescribed SRE species of *Laevophiloscia* (family Philosciidae) from Roy Hill, 35 km from the Project Area. Relatively little is known about the isopod's distribution in the Pilbara and more SRE isopod species are expected to occur in the region. In addition, specimens of an undetermined isopod species were collected at Cloudbreak but it was not determined whether these species may be SREs (Harvey 2006).

### 4.4.3 CLASS CHILOPODA: CENTIPEDES

A few Centipedes are considered to be SREs with the main SRE recognised from the family Cryptopidae and the Order Geophilomorpha. The taxonomic status of both of these groups is unresolved and problematic, and presently not being researched in Australia. One species of Geophilomorpha was reported to occur at the Cloudbreak Project Area, but the SRE status was undetermined (Harvey 2006).

### 4.4.4 CLASS DIPLOPODA: DIPLOPODS

Diplopods of the order Polydesmida contain numerous SRE species in Western Australia. The genus *Antichiropus* presently contains more than 150 morpho-species, of which only one is not a SRE: *Antichiropus variabilis*. The WAM has records of one putative species of *Antichiropus* from the near the Project Area (within the WAM search area) and another species was collected at Hope Downs Stage 4 project (Ninox, 2009).

### 4.4.5 CLASS GASTROPODA: MOLLUSCS

### 4.4.6 Families Camaenidae, Bulimulidae, Punctidae and Succineidae

In the eastern Pilbara, two families of terrestrial Snails are recognised as having species that are characterized by short-range endemism. These are Camaenidae and Bulimulidae. Short range endemism has also been reported for species of the families Puctidae and Succineidae.

Camaenidae is Australia's most diverse terrestrial Snail family with more than 400 described species (Ponder 1997; Solem 1997; Johnson *et al.* 2004). The camaenid genera *Rhagada* and *Quistrachia*, are present within the eastern Pilbara, and two species have been recorded within the WAM search area the Project Area: *Quistrachia* sp. and *Rhagada richardsonii*, which are considered to be SREs (WAM database).

Bulimulidae is also a diverse family with all Australian species belonging to the genus *Bothriembryon*. Undescribed species of *Bothriembryon* were recorded from three different localities: FMG Stage B, Hope Downs Stage 4 and from within the WAM search area (WAM database, Biota 2005, Ninox 2009).

Punctidae is a family characterized by species with small size shells, irregular ribbing and sculpture. Punctidae species are usually found in fairly dry conditions in the micro-shelter habitats in litter and under stones, logs and other ground cover. Australian Punctidae fauna comprise 18 genera and 42 species (Stanisic 1998). One potential SRE species, *Paralaoma* sp. was collected near of the Project Area within the WAM search area(WAM database).

One species of the genus *Succinnea* was collected near to the Project Area at Roy Hill (*ecologia* 2006). The species should represent a SRE. In Australia members of this family are found in widely differing habitats throughout the country. No detailed taxonomic study has been carried out on this family and many undescribed species may exist (Solem 1998).

## 4.5 SRE INVERTEBRATE HABITATS

Based on a review of aerial photography and vegetation surveys previously conducted in the Project Area (Biota 2004; Mattiske Consulting 2005, 2007), there are five broad habitats present within the Project Area (Figure 4.1):

- Low halophytic shrubland.
- Hummock grassland on fringe of Fortescue Marsh.
- Low Mulga and other *Acacia* species woodland.
- Spinifex-covered hills and ranges.
- Creeklines with *Acacia* shrubland and/or Eucalypt open woodland.

These habitats are broadly reflected by both the land system and Beard vegetation mapping, in the Project area. They consist of halophytic shrubland within the boundary of the Fortescue Marsh, with areas of hummock grassland on the edge of the Marsh (Fortescue land system), moving into low Mulga woodland on alluvial flats (Jamindie land system), followed by the Spinifex-covered hills and ranges (Newman and McKay land systems). Running north-south into the Fortescue Marsh are creek and drainage lines supporting either *Acacia* shrubland or occasionally Eucalypt woodland.

### 4.5.1 Low Halophytic Shrubland

The Fortescue Marsh consists of areas of semi-permanent and ephemeral water bodies surrounded by a low halophytic scrubland. Fortescue Marsh is an important ecological area within the Pilbara, being classed as an Ecologically Sensitive Area (ESA) and Priority Ecological Community (PEC). After period of heavy rain, the entire Fortescue Marsh becomes inundated, providing suitable habitat for aquatic and semi-aquatic invertebrates such as Dragonflies, Tiger Beetles and others micro-invertebrates. Areas of dense vegetation are likely to provide suitable habitat for Isopods and Land

Snails. Invertebrates of conservation significance that have been observed in this type of habitat are the Dragonflies *Antipodogomphus hodgkini* and *Nososticta pilbara*. These species are listed as Priority 2 by the DEC (Table 4.1).

### 4.5.2 Hummock Grassland on Fringe of the Fortescue Marsh

Surrounding the halophytic shrubland of the Fortescue Marsh are pockets of hummock grassland consisting of *Triodia angusta* with patches of *Acacia* spp., *Eremophila* spp., and mixed chenopods. The Spinifex often forms large, dense hummocks that provide shelter and protection for a variety of species. Potential species occurring in this habitat are Trapdoors Spiders, Scorpions, Land Snails, and Diplopods. However, little is known about the habitat preferences of SREs in relation with this particular habitat. No invertebrate species of conservation significance have been associated with this habitat type, but temporal water bodies may provide suitable habitat for Dragonflies and Land Snails.

### 4.5.3 Mulga Woodland

Mulga woodland is the dominant habitat type mapped east-west across the centre of the Project Area. The Mulga woodland consists of open to moderate Mulga (*Acacia aneura*) low woodland over scattered *Eremophila*, *Senna*, and mixed *Acacia* shrubs. An understorey of Spinifex is also present in some areas. Several species are strongly associated with Mulga woodlands including Trapdoors Spiders, Scorpions, Pseudoscorpions and Geophilida. Within Mulga woodland, dead wood, stumps and peeling bark provided habitat for Isopods and Lands Snails.

Two SRE species have been recorded in this habitat type at the Project area, these are the Scorpion *Urodachus* "cloudbreak" and the Barychelid spider *Synothele* "MYG127" (Harvey 2006).

### 4.5.4 Spinifex Covered Hills and Ranges

This habitat consisted of scattered Eucalypts (e.g. Snappy Gum*)* and *Acacias* (Kanji, *Acacia pyrifolia*) over Spinifex grassland.

Four SRE species have been recorded occurring in this habitat type: the Trapdoors Spiders *Aganippe* sp and *Missulena* "MYG045", and the Scorpions *Lychas* "scottae" and *Urodachus* "cloudbreak" (Harvey 2006).

Along the top of some spinifex hills, small rocky ridges and breakaways can occur. The large rocks and crevices provides humid microhabitats for numerous species including Opilionids, Land Snails and Pseudoscorpions and several rocky range specialists can be found in this habitat type.

### 4.5.5 Creeklines and Water Sources

The Project Area contained numerous small to large sized creeklines, typically running north-south and draining into the Fortescue Marsh. All the creeklines dry up over the dry winter months, although some wells provide a permanent water source, e.g. Minga Well. The riverine vegetation consists primarily of tall Eucalypts bordering the sandy or gravel creek bed, with an understorey of *Acacia* shrubs and tussock grassland.

Accumulations of leaf litter below the Eucalypts and along the watercourses provide good habitat for SRE groups. This habitat type has been reported as the richest in term of species diversity and abundance of SREs. Harvey (2006) reported the occurrence of the potential SRE Trapdoor Spider,

*Missulena* "MYG045", the Curtain Web Spider, *Cethegus* "Cloudbreak sp 1" and the scorpion *Urodacus* "cloudbreak" in this habitat type. Many Trapdoor Spiders', Isopods, Lands Snails, Millipedes and Centipedes are also typically common in this habitat, possibly due to the high humidity and more abundance of a potential prey species.

# 5 DISCUSSION AND CONCLUSIONS

The searches of the WAM databases and literature records indicate the presence of several invertebrate families and genera known to contain SRE species from the near of the Project Area.

The five habitat types occurring in the Project Area are likely to represent SRE habitats with specific assemblage of species occurring on each one. The creek line habitat is likely to be the most diverse in term of SRE richness. However, all the habitats described in the Project area are very well distributed in the surrounding area then the likelihood of SREs being confined to the impact area is reduced.

Results from of a previous survey carried out at the Project Area showed the absence of some SRE groups (millipedes and land snails) and a low abundance of Pseudoscorpions, Isopods, and Mygalomorph spiders (Harvey 2006). This may be explained in three ways, independently or in combination:

1) Survey Limitations

- No pitfall trapping survey was done. Pitfall trapping is completed mainly to record the presence of Mygalomorph Spiders, males of which become active shortly after rains and commence searching for females.
- The survey was carried out in July 2006. According to the Guidance statement 20 the optimal timing for SREs in the Pilbara is during the cyclone season (Nov- Apr).
- The foraging methodology was limited to searches under rocks, debris, among the grasses and litter etc. Small invertebrates such as Pseudoscorpions and Micro-snails are better sampled using litter extraction techniques such as Tullgren funnels, Winkler sacs and litter sifting.

2) Environmental degradation

Mattiske (2005) assessed the habitat/ vegetation conditions on part of the Project Area, and reported damage from fire and cattle to vegetation. The impact of the fires was variable between the different plants communities, as a result of the fuel load in the different communities and the different structure and composition of the vegetation communities. The extent of impact from cattle was high in areas close to the bores. SREs are largely correlated with habitat type and the degree of environmental degradation of the habitats. For instance, persistent Trapdoor Spiders are likely to be isolated to small patches unaffected by the extreme grazing pressure and fires (Main 1987, 1995). Follow up surveys would need to identify and target areas less impacted on by cattle and fires.

In conclusion, Harvey (2006) recognised the presence of SRE groups in the Project Area, but no follow-up surveys were undertaken to gain information about the distribution and habitat relationship of these groups. Literature records and database searches indicate the potential for the occurrence of conservation significant invertebrates and a high potential for other SRE groups, however it is unlikely that these species would be restricted to the Project Area given the broad distribution of the habitat types represented. Subsequent surveys should aim to collect representatives of these taxa in order to get information of their distribution and habitat associations.

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# 6 STUDY TEAM

The FMG Cloudbreak SRE Invertebrate Desktop 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 |

Special Thanks:

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

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

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| **ACE** | Abundance-based Coverage Estimator |
| **ANOVA** | Analysis of Variance |
| **ANOSIM** | Analysis of Similarities |
| **DEC** | Department of Environment and Conservation |
| **EPA** | Environmental Protection Authority |
| **EPBC** | *Environment Protection and Biodiversity Conservation Act* 1999 |
| **SAC** | Species Accumulation Curve |
| **SRE** | Short-Range Endemic |
| **WAM** | Western Australian Museum |
| **WC Act** | *Wildlife Conservation Act 1950* |

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# EXECUTIVE SUMMARY

Fortescue Metals Group Limited (Fortescue) has commenced operation of the Pilbara Iron Ore and Infrastructure Project, consisting of several iron ore mines and associated infrastructure in the Pilbara region of Western Australia. The Cloudbreak mine is located in the Pilbara, approximately 120 km north- west of Newman along the northern margin of Fortescue Marsh.

A desktop survey of Cloudbreak indicated a high potential for SRE groups to be found in the area (*ecologia* 2010). Fortescue Metals Group commissioned *ecologia* Environment to undertake a baseline short-range endemic invertebrate fauna of the Cloudbreak Study Area as part of the environmental impact assessment for the project in order to determine whether any SRE species were restricted to the proposed development.

A survey was undertaken in November 2010 targeting SRE invertebrates. Survey methods consisted of wet-pitfall trapping, foraging and leaf-litter collection within different habitat types present at Cloudbreak.

The main conclusions of the survey were:

- The survey methods of the SRE survey were consistent with the EPA Guidance Statement 20 to sample for SRE fauna. Species accumulation curves were used to assess survey adequacy and these indicate that the survey was sufficient;
- Twenty six species were collected at Cloudbreak of which one is a confirmed SRE (*Antichiropus* 'Cloudbreak'), one is a likely SRE (*Linnaeolpium* sp.) and five are potential SREs (*Conothele* sp., *Aname* 'MYG001 group', *Urodacus* sp., *Austrohorus* sp. and *Beierolpium* 'sp. 8/2');
- *Linnaeolpium* sp., *Conothele* sp., *Aname* 'MYG001 group', *Austrohorus* sp. and *Beierolpium* 'sp. 8/2' have all been collected outside the impact area;
- *Antichiropus* 'Cloudbreak' and *Urodacus* sp. are known from single locations within the impact area;
- A habitat analysis showed no statistically significant difference between species diversity and habitat type. The invertebrate assemblage distribution depends on suitability of micro-habitats rather than broad scale habitat types; and
- All habitat types present within the impact area are likely to extend outside the impact area, so it is possible that *Antichiropus* 'Cloudbreak' and *Urodacus* sp. occur outside the impact area.

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# 1 INTRODUCTION

## 1.1 PROJECT BACKGROUND

Fortescue Metals Group Limited (Fortescue) has commenced operation of the Pilbara Iron Ore and Infrastructure Project, consisting of several iron ore mines and associated infrastructure in the Pilbara region of Western Australia. Two mine sites, located to the north of the Fortescue Marsh, are collectively known as the Chichester Operations: Cloudbreak and Christmas Creek. The Cloudbreak mine is located approximately 120 km north-west of Newman.

Cloudbreak represents the first mine site of Fortescue. Beginning in 2008, more than 28 million tonnes of iron ore was mined in the first year of production. The production has been increased to 100,000 tonnes of iron ore daily. The current mine site is going to be expanded towards the east and the west of the existing sites with developing pipelines leading south, east and west towards developed bore fields.

Fortescue Metals Group commissioned *ecologia* Environment (*ecologia*) to undertake a baseline short-range endemic (SRE) invertebrate fauna survey which incorporates the Cloudbreak tenements as well as part of the Fortescue Marsh (along the southern edge of the study area) (Figure 1.1). The total size of the study area is approximately 581.5 km$^2$.

## 1.2 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 *Wildlife Conservation Act 1950* (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 2009b).

### 1.3 SURVEY OBJECTIVES

FMG commissioned *ecologia* to undertake a baseline SRE invertebrate fauna survey of the Cloudbreak Study Area as part of the environmental approval process.

The EPA's objectives with regards to fauna management are to:

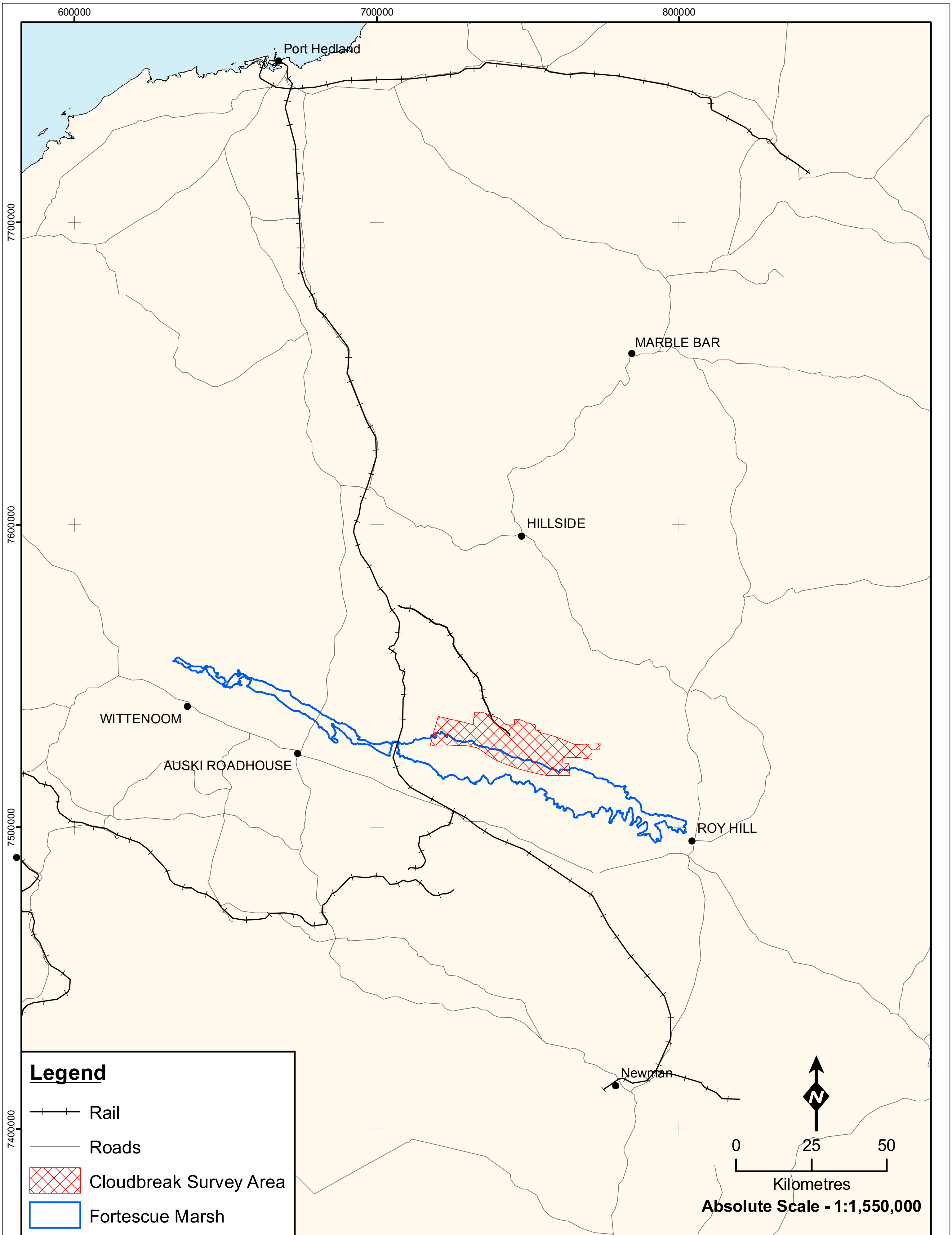
- maintain the abundance, species diversity and geographical distribution of terrestrial invertebrate fauna; and
- protect Specially Protected (Threatened) fauna, consistent with the provisions of the *Wildlife Conservation Act 1950* (WC Act).

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, thus providing:

- A review of background information (including literature and database searches).
- An inventory of invertebrate fauna species occurring in the Study Area, incorporating recent published and unpublished records;
- An inventory of species of biological and conservation significance recorded or likely to occur within the Study Area and surrounds.

- A description of the characteristics of the invertebrate fauna habitats occurring in the Study Area.
- A description of the characteristics of SRE assemblages occurring in the Study Area.
- A review of regional and biogeographical significance, including the conservation status of species recorded in the Study Area.

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**Location of the Cloudbreak Study Area**

**Figure: 1.1**
**Project ID: 1301**

**Drawn: AH**
**Date: 25/10/10**

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

Unique Map ID: A249

**A4**

## 1.4 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 SREs. 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.

### 1.4.1 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. 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 headwaters 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.

### 1.4.2 Taxonomic Groups Likely to Support Short-Range Endemism

#### 1.4.2.1 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 behavioural 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. Many mygalomorph spider species are known from the Pilbara region with representatives of the families Nemesiidae, Barychelidae, Actinopidae, Idiopidae, Dipluridae and Ctenizidae and over 20 potential SRE mygalomorph species known from nearby locations to the study area.

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). No epigean schizomids are known from the Pilbara region (Harvey *et al.* 2008).

Scorpions and pseudoscorpions 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. Several SRE scorpions and pseudoscorpions are known from the Pilbara region including species from the scorpion genera *Lychas* and *Urodacus* and the pseudoscorpion species *Synsphyronus gracilis*.

#### 1.4.2.2 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). SRE millipedes known to occur in the Pilbara include species from the genus *Antichiropus*. All species from this genus are known to be short-range endemics with the exception of two species *Antichiropis variabilis* and *Antichiropis* ‘PM1’, from the jarrah forests and northern Wheatbelt respectively. This genus extends from the Nullarbor Plain to the Pilbara region and has been collected close t the study area.

Centipedes 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.

#### 1.4.2.3 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).

Some species of the terrestrial snail genera *Rhagada* and *Bothriembryon* are known to be SREs. Species of these genera have been recorded within the Pilbara region with some occurring in areas close to the study area.

#### 1.4.2.4 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 SREs (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). No terrestrial SRE worms are known from the Pilbara region.

## 1.5 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 WA, rare fauna are listed under the *Western Australian Wildlife Conservation Act 1950: 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.

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

Table 1.1 shows a list of significant invertebrate terrestrial epigean fauna currently protected under Commonwealth and State legislation in the Pilbara region of Western Australia.

**Table 1.1 – Conservation Significant Invertebrate Terrestrial Epigean Fauna Occurring in the Pilbara Region**

| Taxa | Species | EPBC Act | WC Act | DEC |
|---|---|---|---|---|
| **Insects** | *Antipodogomphus hodgkini* (dragonfly) | | | P2 |
| | *Nososticta pilbara* (dragonfly) | | | P2 |
| | *Nocticola flabella* (cockroach) | | | P2 |
| **Molluscs** | *Dupucharopa millestriata* | | | P2 |

# 2 STUDY AREA

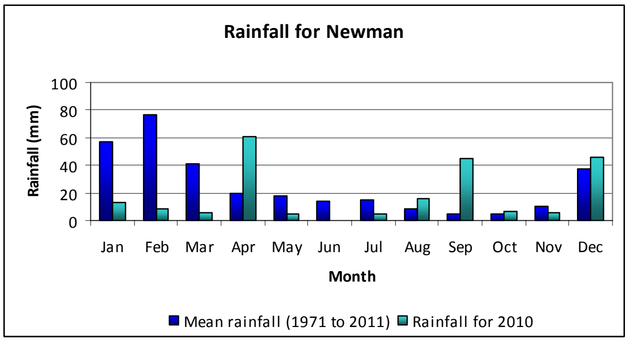
## 2.1 CLIMATE

The study area is situated in the Pilbara region of Western Australia and experiences an arid-tropical climate with two distinct seasons; a hot summer from October to April and a mild winter from May to September. Annual evaporation exceeds rainfall by as much as 500 mm per year. Seasonally low and unreliable rainfall together with high temperatures and high diurnal temperature variations are also characteristic of the region (Beard 1975).

Within the Pilbara, the temperature range is large and maxima are high. Summer temperatures may reach as high as 46 °C, with an annual mean maximum of 31.4 °C, while the winter mean maximum is 25 °C (BoM 2010). Light frosts occasionally occur during July and August. The climate experienced throughout the year is usually very dry with only a few months of rainfall potentially occurring (Beard 1975).

Rainfall in the Pilbara is highly unpredictable. The greatest rainfall in the Pilbara is recorded at stations around the Hamersley Range Average (annual rainfall approximately 400 mm). The majority of the Pilbara has a bimodal rainfall distribution, resulting in two rainfall maxima per year. Between January and March rainfall generally results from tropical storms producing sporadic and drenching thunderstorms. Tropical cyclones moving south from northern Australian waters also bring sporadic heavy rains. From May to June extensive cold fronts move easterly across the state and occasionally reach the Pilbara. These fronts produce only light winter rains that are ineffective for the growth of plants other than herbs and annual grasses. Larger perennial species require the intense and prolonged storms of summer. Surface water can be found in some pools and springs in the Pilbara all year round, although watercourses only flow briefly due to the short wet season (Beard 1975).

Meteorological data have been recorded by the Bureau of Meteorology (BoM) at Newman Airport since 1971. This weather station is the closest to the study area, being located approximately 120 km to the south. Newman airport was selected to provide an indication of the local climatic conditions experienced within the study area (Figure 2.1).



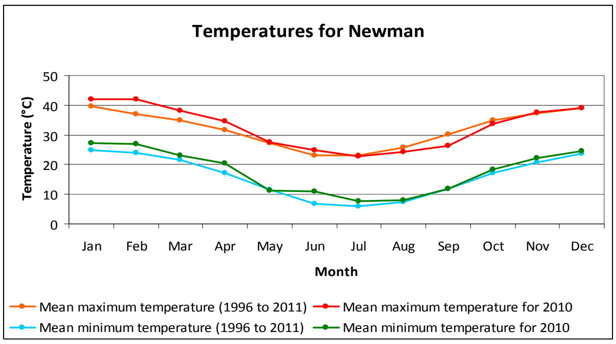




**Figure 2.1 – Temperature and Rainfall Recorded at Newman Airport (1996-2010, BoM 2010)**

## 2.2 VEGETATION

The study area is located within Fortescue Botanical District of the Pilbara (Beard 1975). The vegetation mapping of Beard and Hopkins throughout Western Australia was subsequently reinterpreted and updated to reflect the National Vegetation Information System (NVIS) standards (Shepherd *et al.* 2002), as described in Table 2.1 and mapped in Figure 2.2.

Four vegetation communities occur within the Cloudbreak study area (Table 2.1), lying in four main east-west oriented strips. From south to north they consist of Samphire steppe within the Fortescue Marsh (vegetation association 676), open Mulga (*Acacia aneura*) woodland on the flats surrounding the marsh (veg. assoc. 29), scattered Snappy Gums (*Eucalyptus leucophloia*) over spinifex grassland mixed with open Mulga woodland, typically along creeklines and in low lying areas (veg. assoc. 562) and hummock grasslands with scattered eucalypt trees and acacia shrubs (veg. assoc. 173).

Open Mulga woodland (veg. assoc. 29) is an extensive vegetation type found in Western Australia. Along with the Samphire steppe (veg. assoc. 676) and the hummock grassland with scattered eucalypt and acacia (veg. assoc. 173) these vegetation associations are well represented outside the study area (Table 2.1). Less well represented is the low Mulga woodland /Tree steppe with scattered *Eucalyptus leucophloia* over *Triodia wiseana* hummock grassland (veg. assoc. 562) with 11.65% of this vegetation type in the Pilbara occuring within the Cloudbreak study area.

**Table 2.1 – Vegetation Associations of the Cloudbreak Study Area (from Shepherd *et al.* 2002)**

| Vegetation Association | Vegetation Type | Total Area in Western Australia ($km^2$) | Area in Cloudbreak Study Area ($km^2$) | Percent of Total Vegetation Type (%) |
|---|---|---|---|---|
| 676 | Unwooded Samphire steppe | 20,879 | 133 | 0.64 |
| 29 | Low woodland with Mulga in patches | 77,822 | 316 | 0.40 |
| 562 | Low Mulga woodland/Tree steppe with scattered *Eucalyptus leucophloia* over *Triodia wiseana* hummock grassland | 1,124 | 131 | 11.65 |
| 173 | Eucalypt trees and acacia shrubs over Hummock grasslands of soft spinifex & *Triodia wiseana* on basalt | 18,567 | 0.07 | <0.01 |

## 2.3 LAND SYSTEMS

An inventory of the land systems occurring in the Pilbara was completed by van Vreeswyk *et al.* (2004). The survey aimed to provide a comprehensive description and mapping of the biophysical resources of the region, as well as an evaluation of the condition of soils and vegetation throughout. Each land system is classified into a particular land type defined by the landforms and vegetation it contains.

The study area contains seven land systems: Newman, McKay, Jamindie, Turee, Cowra, Christmas, and Marsh (Figure 2.3). These land systems are described in detail in Table 2.2. The majority of land systems (Newman, McKay, Jamindie, Turee and Christmas) are well represented in the region with less than 3% of their total area occurring within the study area. Exceptions are the Cowra and Marsh land systems with 33.7% and 14% of their total mapped extent in the Pilbara occurring within the study area. The Cowra land system fringes the Marsh land system that occurs within the Fortescue Marsh. It consists of alluvial plains supporting Snakewood (*Acacia xiphophylla*) and Mulga shrublands

with some halophytic vegetation. The Marsh land system consists of irregularly inundated lake beds and floodplains and surrounding halophytic shrublands.

**Table 2.2 – Land Systems of the Cloudbreak Study Area**

| Land System | Description | Total Area in WA ($km^2$) | Area in Cloudbreak study area ($km^2$) | Percent of Total Land System (%) |
|---|---|---|---|---|
| *Land Type 1* | *Hills and ranges with spinifex grasslands* | | | |
| Newman | Rugged jaspilite plateaux, ridges and mountains supporting hard spinifex grasslands | 19,998 | 110 | 0.6 |
| McKay | Hills, ridges, plateau remnants and breakaways of meta sedimentary and sedimentary rocks supporting hard spinifex grasslands | 4,274 | 30 | 0.7 |
| *Land Type 12* | *Wash plains on hardpan with groved Mulga shrublands (sometimes with spinifex understorey)* | | | |
| Jamindie | Stony hardpan plains and rises supporting groved Mulga shrublands, occasionally with spinifex understorey | 11,883 | 208 | 1.7 |
| *Land Type 14* | *Alluvial plains with tussock grasslands or grassy shrublands* | | | |
| Turee | Stony alluvial plains with gilgaied and non-gilgaied surfaces supporting tussock grasslands and grassy shrublands | 927 | 23 | 2.5 |
| *Land Type 15* | *Alluvial plains with Snakewood shrublands* | | | |
| Cowra | Plains fringing the Marsh land system and supporting Snakewood and Mulga shrublands with some halophytic undershrubs | 203 | 68 | 33.7 |
| Christmas | Stony alluvial plains supporting Snakewood and Mulga shrublands with sparse tussock grasses | 232 | 3 | 1.5 |
| *Land Type 20* | *Salt lakes and fringing alluvial plains with halophytic shrublands* | | | |
| Marsh | Lakebeds and floodplains subject to regular inundation, supporting Samphire shrubland, salt water couch grasslands and halophytic shrubland | 977 | 136 | 14.0 |

## 2.4 BIOGEOGRAPHY

The Interim Biogeographic Regionalisation for Australia (IBRA) classifies the Australian continent into regions (bioregions) of similar geology, landform, vegetation, fauna and climate characteristics (DEWHA 2004). According to IBRA (Version 6.1) the study area is located in the Fortescue Plains subregion of the Pilbara bioregion and runs parallel to the southern edge of the Chichester subregion (Figure 2.4).

The Fortescue Plains subregion covers approximately 11% of the Pilbara region. Characteristic features are alluvial plains and river frontages with salt-marsh, Mulga-bunch grass and short grass communities on alluvial plains. River Gum (*Eucalyptus camaldulensis*) woodlands fringe the drainage lines. An extensive calcrete aquifer feeds numerous permanent springs in the central Fortescue, supporting large permanent wetlands with extensive stands of River Gum and cadjeput woodlands (DEC 2003). The Fortescue Plains subregion occupies an area of 20,400 $km^2$, with the dominant uses being grazing native pastures, unallocated Crown land and Crown reserves, conservation and Aboriginal land.

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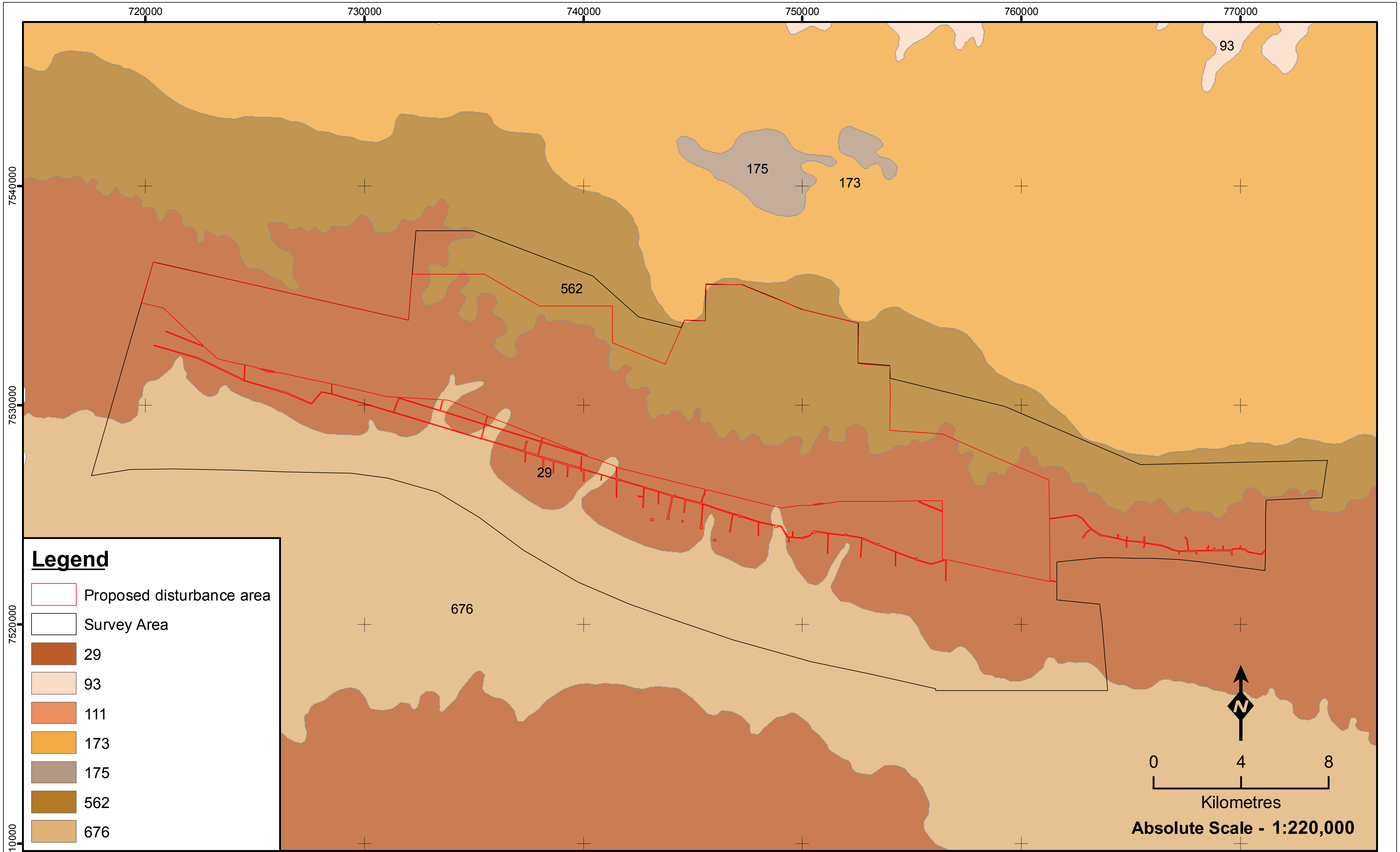


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**Vegetation of the Study Area (from Shepherd *et al.* 2002)**

**Figure: 2.2**
**Project ID: 1301**

**Drawn: EF**
**Date: 14/01/11**

*Coordinate System*
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Projection: Transverse Mercator
Datum: GDA 1994

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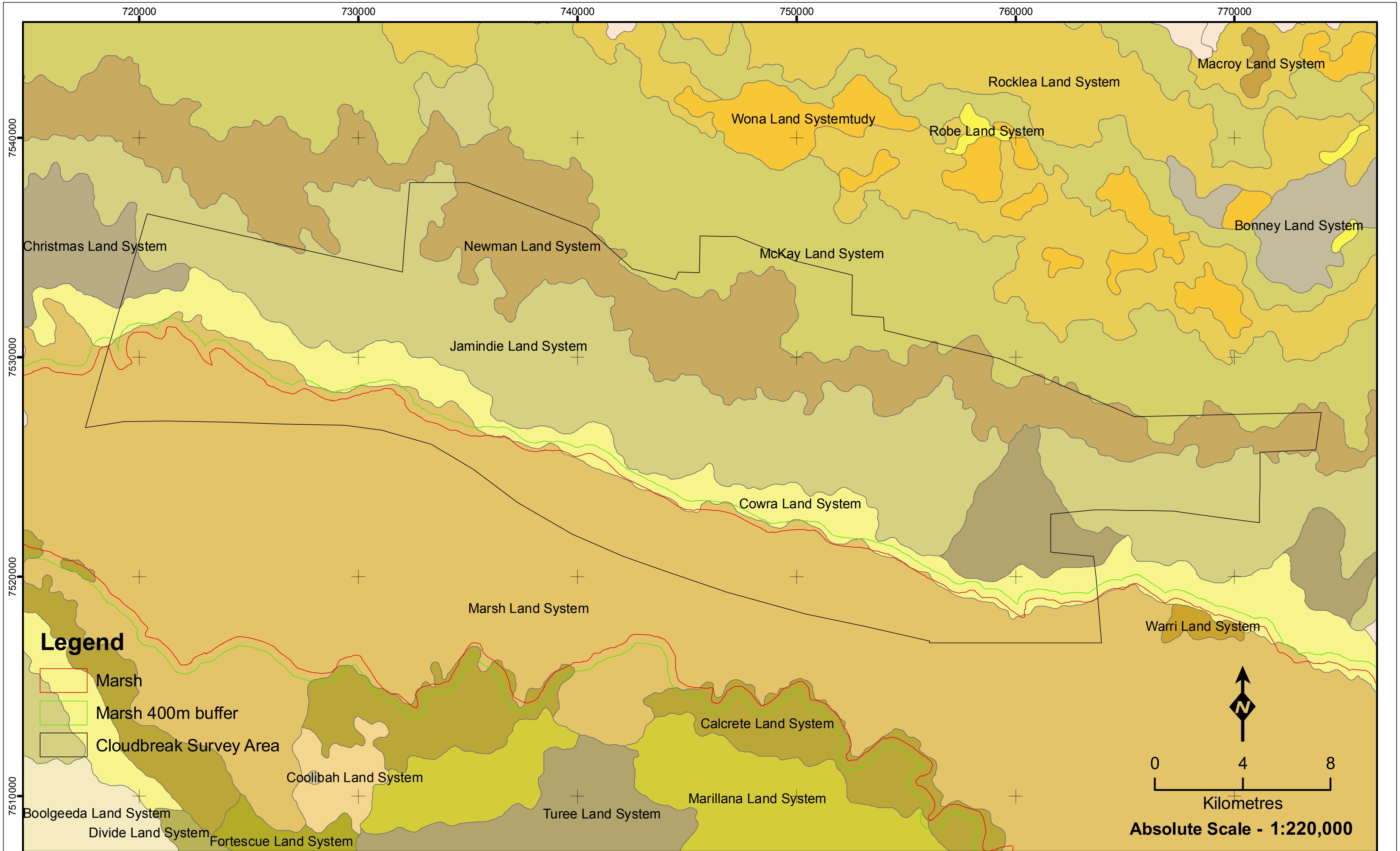


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FMG

**Landsystems of the Cloudbreak Study Area (from van Vreeswyk *et al.* 2002)**

**Figure: 2.3**
**Project ID: 1301**

**Drawn: EF**
**Date: 14/01/11**

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

Unique Map ID: EF010

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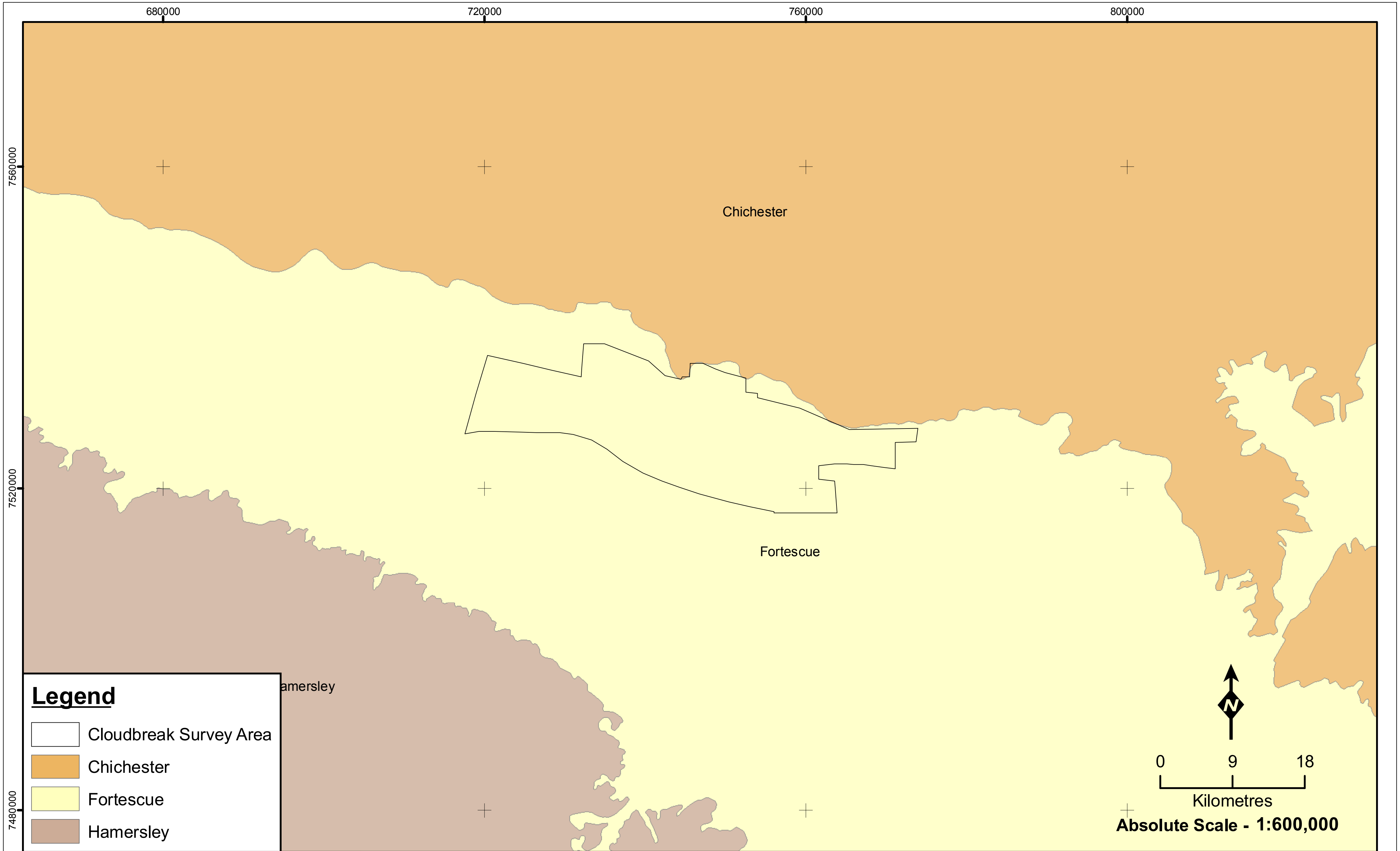


**Biogeographic Regions of the Cloudbreak Study Area (from DEWHA 2004)**

**Figure: 2.4**
**Project ID: 1301**

**Drawn: EF**
**Date: 14/01/11**

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

Unique Map ID: EF011

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# 3 METHODS

The survey methods adopted by *ecologia* are aligned with the EPA's Guidance Statement No. 20 (EPA 2009a) and Position Statement No. 3 (EPA 2002). Based on the level of disturbance, data from previous surveys and the results of a desktop study (*ecologia* 2010), a SRE field survey was recommended, incorporating a variety of SRE collecting techniques.

## 3.1 SRE STATUS

The likelihood of the invertebrate species to be considered a SRE or not a SRE was determined by expert taxonomists (Volker Framenau and Mark Harvey, Department of Terrestrial Invertebrates, WAM; Shirley Slack-Smith and Corey Whisson, Department of Malacology; Erich Volschenk, private consultant and Simon Judd, Private Consultant) based on the current knowledge of the distribution and biology of each species, as follows:

- No – Not considered a SRE
- Yes – Current knowledge confirms that this species is a SRE
- Likely – Current knowledge suggests this species is probably a SRE. However, further research is required to confirm status.
- Potential – Current knowledge of this species or group is very limited however, there is the potential for this species to represent a SRE. Further research is required to confirm status.

## 3.2 SURVEY TIMING

Sufficient rainfall is required for optimal SRE sampling, therefore the optimal sampling period in the Pilbara is during cyclone season, between November and April (EPA 2009a). The survey was completed during November 2010.

## 3.3 SITE SELECTION

Based on a review of aerial photography and vegetation surveys previously conducted in the Study Area (Biota 2004; Mattiske Consulting 2005, 2007), there are six broad habitats present within the Study Area:

- Spinifex-covered hills
- Rocky escarpments
- Snakewood and Mulga woodland
- Hummock grassland on fringe of Fortescue Marsh
- Low halophytic shrubland
- Creeklines with fringing acacia and eucalypts

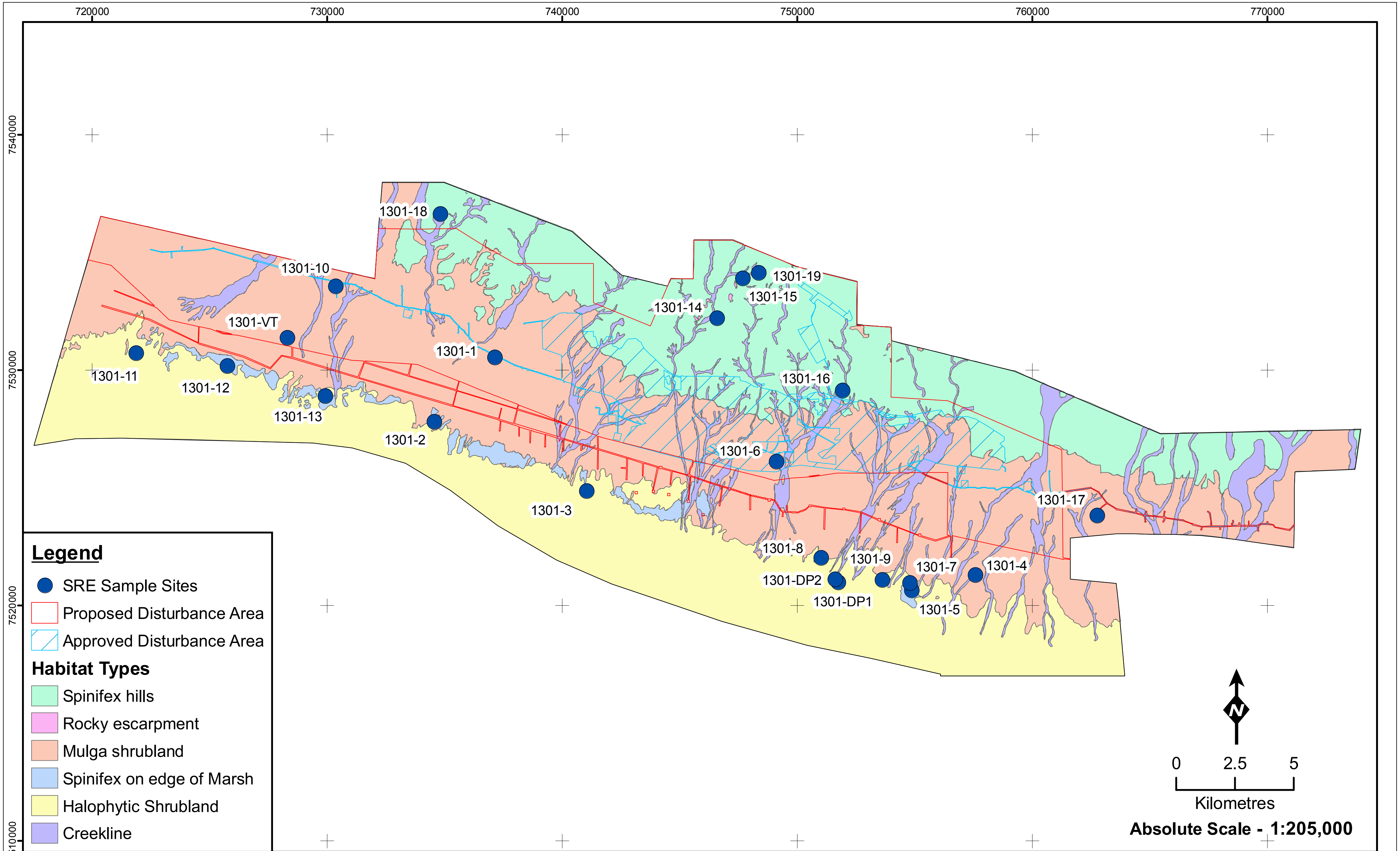
These habitats are broadly reflected by both the land system and vegetation mapping, occurring in three main east-west running strips. The halophytic shrubland occurs within the boundary of the

Fortescue Marsh, with areas of hummock grassland on the edge of the marsh (Marsh and Cowra land systems), which is flanked by mixed acacia woodland on alluvial flats (Jamindie and Turee land systems), and on higher relief spinifex-covered hills and rocky ranges of the Newman and the McKay land systems. Draining north-south from the Chichester Range into the Fortescue Marsh are small to large creeks and drainage lines supporting mixed acacia shrubs or eucalypt trees. In addition to the Fortescue Marsh, several wells are also present that provide permanent or semi-permanent water, including Minga Well, Moojarrie Well and Bruce's Bore. The extent of all habitat types within the study area is listed in Table 3.1.

**Table 3.1 – Extent of each Habitat Type within the Study Area**

| Habitat type | Extent within Study Area ($km^2$) |
|---|---|
| Spinifex covered hills | 125.2 |
| Rocky escarpments | 0.32 |
| Snakewood and Mulga woodland | 245.5 |
| Hummock grassland on fringe of Fortescue Marsh | 8.8 |
| Low halophytic shrubland | 151.5 |
| Creek lines with fringing acacia and eucalypt | 50.1 |

Survey site locations were selected based on the different habitat types present in the study area that were considered likely to support SRE invertebrates (Spinifex-covered hills, Snakewood and Mulga woodland, Hummock grassland on fringe of marsh, low halophytic shrubland and creeklines). Sites were selected prior to knowing the location of the proposed impact area and therefore sampled sites occur both inside and outside of the proposed impact area on the Cloudbreak tenement. Over 50 prospective SRE survey sites were selected near unique geological features promoting SRE communities such as south facing breakaways and drainage channels as well as in various other habitat types and vegetation communities from the five habitat types. A random number generator was then used to pick 19 sites to be sampled (Figure 3.1). The locations of sites are provided in Appendix 1 and site habitat descriptions are provided in Appendix 2.

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**SRE Survey Sites at Cloudbreak**

**Figure: 3.1**
**Project ID: 1301**

**Drawn: ND**
**Date: 24/01/11**

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

Unique Map ID: ND006

A4

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## 3.4 SAMPLING METHODS

### 3.4.1 Wet Pitfall Trapping

Wet pitfall traps (Figure 3.2) consisting of a PVC tube (25 cm long) were dug into the ground so that the surface was flush with the ground level. A receptacle (containing 700 ml of pitfall trapping solution – 30% ethylene glycol and 5% formaldehyde) and funnel (fitting flush to the inside of the pitfall trap) were deployed into each tube. A cover was then fitted 3 cm above the tube with steel fittings to exclude medium sized vertebrates and rain, and to deter attention of larger vertebrates.

Four wet-pitfall traps were installed at each site and left in the ground for four weeks before being removed and sent to *ecologia*'s Perth laboratory for further sorting and preliminary identification.


**Figure 3.2 – Wet Pitfall Traps**

### 3.4.2 Leaf Litter Collection

At each site, three quadrats ($3m^2$) of leaf litter were collected and placed into a leaf-litter reducer separately (Figure 3.3). The contents from each collection was placed into a paper bag inside a zip-lock bag and kept separate. A small amount of wet tissue paper was placed into each sample to keep humid. Samples were then transported back to Perth in a cool, dark container where they were placed on Tullgren funnels to extract any specimens.

**Figure 3.3 – Example of the Leaf Litter Reducer and Tullgren Funnels**

### 3.4.3 Extraction Methods

Tullgren funnels were used to extract any animals from the collected leaf litter samples (Figure 3.3). The general principle of Tullgren funnels is that a sample of leaf litter 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.

After the leaf litter samples were processed on the Tullgren funnels, each sample was then examined for dead snail shells, or any other dead animals that were not collected during Tullgren funnel extraction. Each sample was emptied into a tray and examined using a light magnifier. Any dead animals were collected and immediately placed into ethanol.

### 3.4.4 Laboratory Sorting and Specimen Identification

All samples, whether from foraging or pitfall traps, were examined under a Stereo microscope and sorted into related groups. These specimens were labelled with the project name, site number and coordinates, the trap number or leaf-litter sift number and the collectors and were sent to the relevant taxonomic expert for further identification. Table 3.2 shows the list of taxonomic specialists used for identification and experience of staff involved in the survey.

**Table 3.2 – Experinece and Qualifications of Taxonomic Experts and Field Staff Involved During the Survey**

| | Institution | Relevant Experience |
|---|---|---|
| Corey Whisson | Western Australian Museum | Taxonomic expert in molluscs |
| Dr Erich Volschenk | Private consultant | Taxonomic expert in scorpions |
| Dr Mark Harvey | Western Australian Museum | Taxonomic expert in pseudoscorpions and myriapods |
| Shirley Slack-Smith | Western Australian Museum | Taxonomic expert in molluscs |
| Simon Judd | Private consultant | Taxonomic expert in isopods |
| Dr Volker Framenau | Western Australian Museum | Taxonomic expert in mygalomorph spiders |
| Dr Lazaro Roque-Albelo | *ecologia* | >20 years experience with terrestrial invertebrates |
| Catherine Hall (BSc, Hons) | *ecologia* | >3 years experience with SRE invertebrates |
| Nicholas Dight (BSc) | *ecologia* | >3 years experience with SRE invertebrates |
| Sean White (BSc) | *ecologia* | >7 years experience with terrestrial invertebrates |

## 3.5 DATA ANALYSIS

### 3.5.1 Survey Adequacy

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 SACs as computed by Mao Tao. In addition, a Michaelis-Menten enzyme kinetic curve was calculated and used as a stopping rule technique. To eliminate features caused by random or periodic temporal variation, the sample order was randomised 50 times. The estimator applied to the data set was performed using EstimateS (version 8, Colwell 2009).

### 3.5.2 Habitat Assessment

Habitat type has been established in the literature as playing an important role in SRE invertebrate diversity. Variability of habitats has been strongly linked with invertebrate species richness and composition. The expectation of this study was to find a relationship between species richness and habitat type, with higher species richness in moister habitats and less in drier habitats.

Statistical analyses were carried out on the complete data set from the 19 sites sampled during the survey. The primary aim of the statistical analysis was to determine whether the invertebrates assemblages containing SRE invertebrates groups of the study area differ in terms of richness (number of taxa present) and structure (relative abundance of taxa).

Differences between habitat types and species richness were tested with a one-way ANOVAs. Prior to run the ANOVA a test of normality (Anderson –Darling) and Homogeneity (Barlett’s and Levene) were performed in order test if the data set complains with the ANOVA assumptions.

To analyse differences in species diversity between habitats, a Bray Curtis similarity index was calculated for each pairwise site comparison followed by a non-metric multidimensional scaling (MDS) of similarity matrix. Stress values below 0.20 were considered to indicate a good fit of the scaling to the matrix. The dimensions that reduced the majority of the “raw stress” were chosen for the final scaling. In addition, to test whether the differences in species diversity between habitat

types were significant, analyses of similarity (ANOSIM) (Clarke 1993) comparisons were made using the one-way ANOSIM function in the PAST software package (Hammer *et al.* 2001). ANOSIM was calculated using the Bray-Curtis Similarity Index with 999 permutations. Bray Curtis is a widely used and well-tested index for incidence data. The analysis was run without the inclusion of rare species, to avoid potential bias. “Rare” species were defined as those species found in only one sample, based on visual inspection of a histogram of species abundances.

# 4 RESULTS

## 4.1 SURVEY LIMITATIONS

The limitations of the survey are provided below in Table 4.1. The main limitation of the survey was the species identification resolution of some specimens due to the lack of knowledge of the species collected. This can make it difficult to determine the distribution of the species collected and therefore the level of management they require.

Seasonality is considered a potential limiting factor as no rainfall occurred before or during the survey even though it was conducted during the wet season. This may impact invertebrate activity and therefore limit the number of species collected.

**Table 4.1 – Limitations for the SRE Survey at Cloudbreak**

| Aspect | Limitation (Y/N) | Comment |
|---|---|---|
| Survey Adequacy | No | Test of survey adequacy estimated survey sufficiency as 93% which is adequate |
| Method Efficiency | No | Survey methods utilised were efficient at collecting a broad range of SRE groups |
| Seasonality | Possible | Survey occurred during the wet season which is consistent with the EPA Guidance Statement 20, however significant rainfall did not occur before or during the sampling period. However, the survey is still thought to have been adequate with 93% of likely species recorded. |
| Field Personal Experience | No | All field personnel had a minimum of three years experience working with terrestrial invertebrates. |
| Species Identification Resolution | Possible | Poor taxonomic knowledge (e.g. *Beierolpium* 'sp 8/2' and *Austrohorus* sp.)<br>Specimens could not be identified to species level due to poor taxonomic knowledge of these groups, however are considered potential SREs because of biology or knowledge of closely related species. |
| | | New species but unknown distribution (e.g. *Antichiropus* 'Cloudbreak').<br>The specimens were identified as a new species but distribution and SRE status is unknown. Considered a SRE because of biology and closely related species. |
| | | Specimens could not be identified to species level due to gender or immaturity (e.g. *Urodacus* sp.)<br>Unknown if they represent new or known species however, is considered a potential SRE as similar species have limited distribution |

## 4.2 SURVEY ADEQUACY

### 4.2.1 Species Accumulation Curves/ Number of Samples

A SAC through 50 randomisations of the sample sequence of the complete data set gave a smooth curve with little change in slope beyond approximately 24 samples (Figure 4.1). New species were accumulated at mean rates of 1.08 species per sample during the first ten samples, 0.40 species between the samples 10 to 20 where the curve brake point is; 0.21 species per sample between 20 and 38 samples, 0.14 species per sample between 38 and 66 samples and 0.13 species per sample during the final 10 samples. The Michaelis-Menten estimator, used as stopping rule, indicated that the survey was 74.3% sufficient at the 20$^{th}$ sample. Furthermore, 93.27% sufficiency was approximated at the 76$^{th}$ sample for the entire dataset. These results confirm the confidence of the survey efficiency.

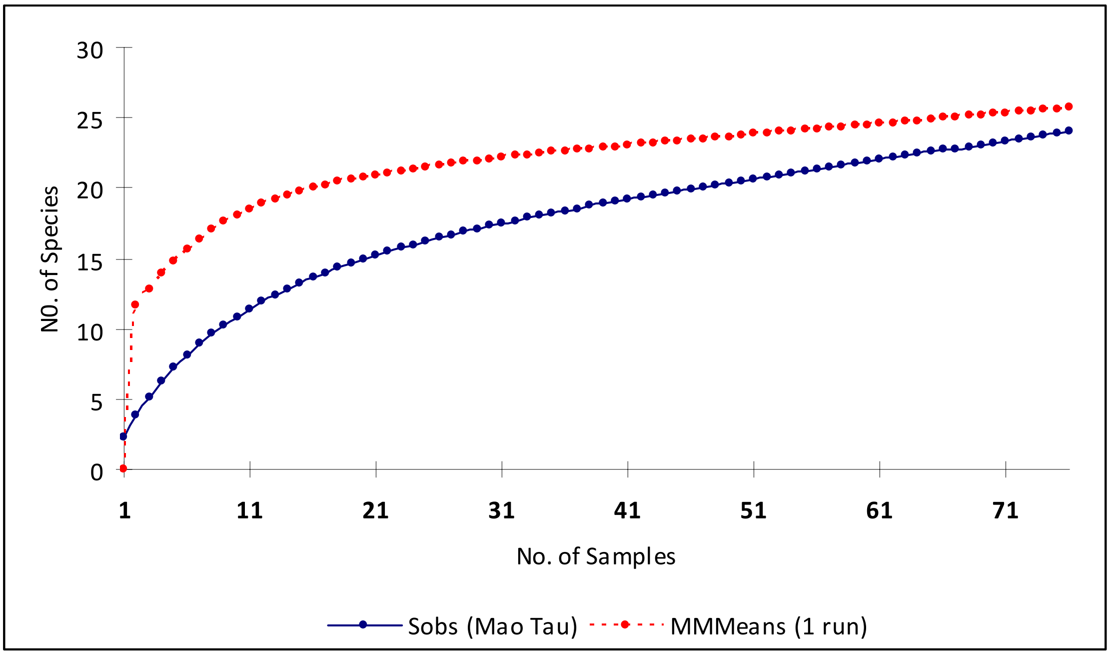


**Figure 4.1 – SAC of the SRE Fauna Data Using the Observed Number of Species (Sobs Mao Tau) and Michaelis-Menten Enzyme Kinetic Curve as a Stopping Rule**

## 4.3 SPECIMENS COLLECTED

A total of 685 invertebrate specimens were collected during the survey. These individuals represented six orders, 15 families, 22 genera and at least 26 species of invertebrates. One confirmed, one likely and five potential SRE species were recorded during the survey including Mygalomorph spiders, millipedes, scorpions and pseudoscorpions (Table 4.2, Figure 4.3). The taxonomy, distribution and SRE status of these genera are discussed in the following sections.

As typical in SRE surveys, many species were recorded in low abundance, being represented only by singletons and doubletons (Figure 4.2). Rarity makes it difficult to determine their distribution across the area. Three potential SRE species are represented by singletons: the scorpion *Urodacus* sp, the mygalomorph spider *Aname* 'MYG 001' and the pseudoscorpion *Austrohorus* sp. The pseudoscorpion

*Linnaeolpium* sp and the millipede *Antichiropus* 'Cloudbreak' were collected at just one site. The other two species are confirmed as having distribution spanning two or more sites.

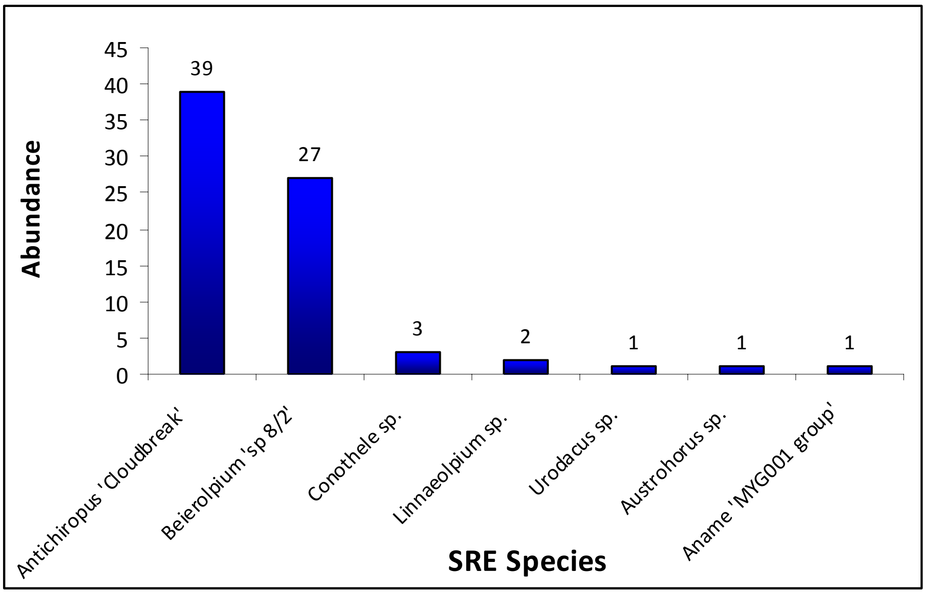


**Figure 4.2 – Abundance Histogram of SRE Groups**

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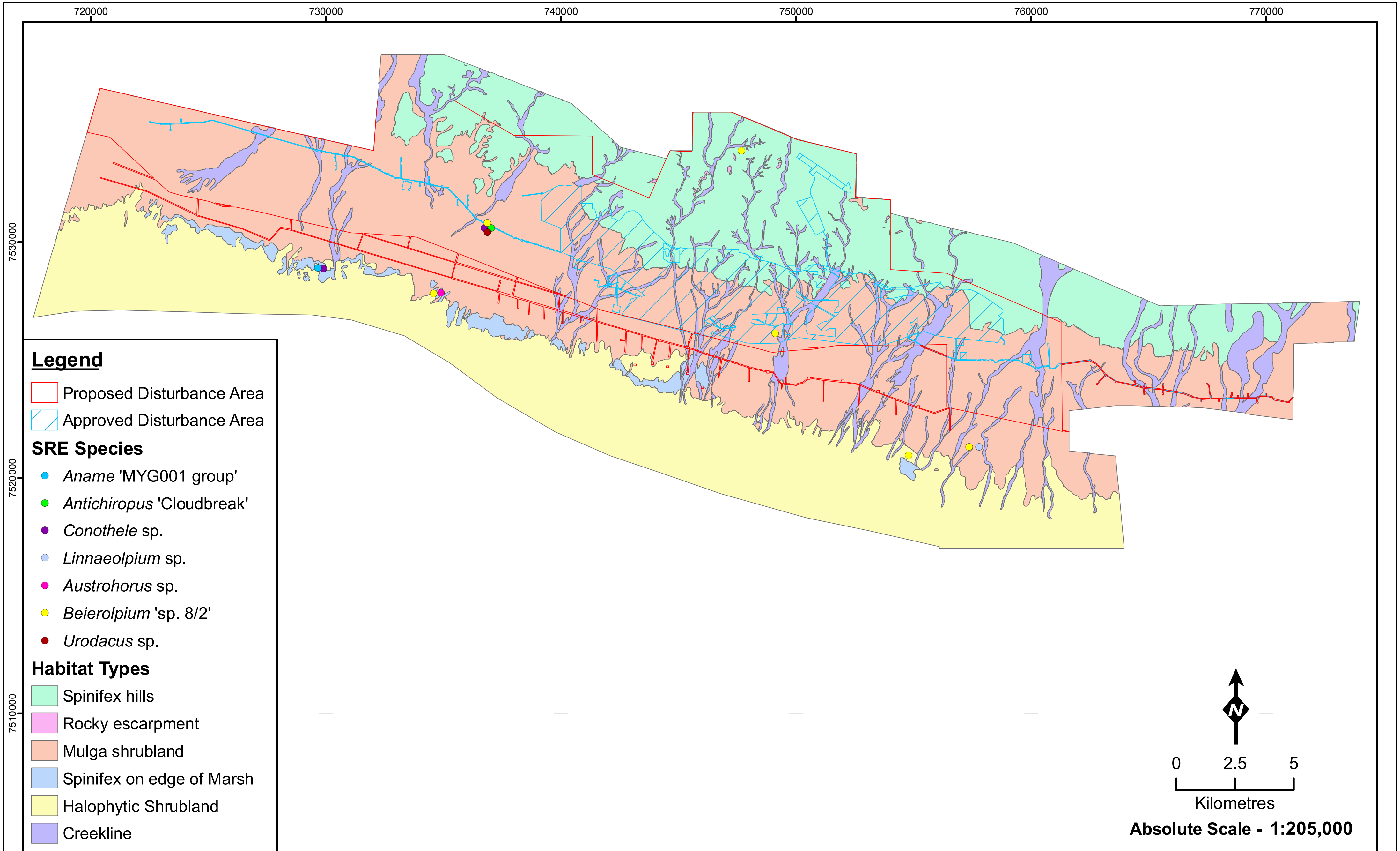
### Table 4.2 – Summary of Specimens Collected

| Class (Order) | Family | Genus | Species | SRE | Site Name | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | DP1 | VT |
| **Arachnida (Aranae)** | | | | | | | | | | | | | | | | | | | | | | | | | |
| | Ctenizidae | *Conothele* | sp. | Potential | 2 | | | | | | | | | | | | 1 | | | | | | | | |
| | Nemesiidae | *Aname* | MYG001 group' | Potential | | | | | | | | | | | | | 1 | | | | | | | | |
| **Arachnida (Scorpiones)** | | | | | | | | | | | | | | | | | | | | | | | | | |
| | Buthidae | *Lychas* | hairy tail grp' | No | | | | | | | | | | | | | | 2 | 1 | 1 | | 2 | | | |
| | Urodacidae | *Urodacus* | sp. | Potential | 1 | | | | | | | | | | | | | | | | | | | | |
| **Arachnida (Pseudoscorpiones)** | | | | | | | | | | | | | | | | | | | | | | | | | |
| | Atemnidae | *Oratemnus* | sp. | No | | | | | 2 | | | | 4 | | | | | | | 1 | | | | | |
| | Garypidae | *Synsphyronus* | sp. | No | | | | | | | | | | | | | | | | | | | | | 1 |
| | Olpiidae | *Austrohorus* | sp. | Potential | | 1 | | | | | | | | | | | | | | | | | | | |
| | | *Beierolpium* | sp 8/2' | Potential | 2 | 1 | | 2 | | 8 | 12 | | | | | | | | 2 | | | | | | |
| | | *Indolpium* | sp. | No | 9 | 2 | 2 | 11 | 58 | 14 | 10 | 4 | 1 | 15 | 37 | 4 | 21 | 9 | 9 | 11 | 27 | 6 | 32 | | |
| | | *Linnaeolpium* | sp. | Likely | | | | 2 | | | | | | | | | | | | | | | | | |
| **Gastropoda** | | | | | | | | | | | | | | | | | | | | | | | | | |
| | Pupillidae | *Pupoides* | cf. *beltianus* | No | 2 | | 3 | 15 | | 2 | 4 | | | 5 | | | | | | 2 | 3 | | | | |
| | | *Pupoides* | cf. *ischnus* | No | | | | 1 | | | | | | | | | | | | | | | | | |
| | | *Gastrocopta* | *mussoni* | No | | | 5 | 1 | | | 9 | | | 10 | | | | | | 3 | | | | | |
| | | *Gastrocopta* | *larapinta* | No | | | 7 | 14 | | 3 | 5 | 2 | | 2 | | | | | | | | | | | |
| | Subulinidae | *Eremopeas* | *interioris* | No | | 3 | 13 | | | | | | | | | | | | | 1 | | | | | |
| | Helicodiscidae | *Stenopylis* | *coarctata* | No | | | | 15 | | | | | | | | | | | | | | | | | |
| | Planorbidae | *Gyraulus* | sp. | No | | | 7 | | | | | | | | | | | | | | | | | 2 | |
| | | *Isidorella* | cf. *newcombi* | No | | | | | 2 | | | | | | | | | | | | | | | | |
| | Lymnaeidae | *Austropeplea* | cf. *lessoni* | No | | | | | 6 | | | | | | | | | | | | | | | 11 | |
| | Bithyniidae | *Gabbia* | sp. | No | | | | | | | | | | | | | | | | | | | | 23 | |
| **Malacostraca (Isopoda)** | | | | | | | | | | | | | | | | | | | | | | | | | |
| | Armadillidae | *Acanthodillo* | sp. 6 | No | | | | | | | | | | | | | 1 | | | | | | | | |
| | | *Buddelundia* | sp. 10 | No | 4 | | | 6 | 5 | | 17 | | | | | 3 | 3 | 2 | | 2 | | 1 | | | |
| | | *Buddelundia* | sp. 14 | No | | | 1 | | 4 | | 4 | | | 23 | | | | 3 | 1 | | | 1 | 1 | 3 | |
| | | *Buddelundia* | sp. 19 | No | 2 | | | | 1 | 1 | 5 | | | | 18 | | 1 | | | | | | | | |
| | | Gen nov. | sp. nov | No | | 1 | | 6 | | 4 | | | 2 | | | | | 2 | 4 | 1 | | | 1 | | |
| **Diplopoda (Polydesmida)** | | | | | | | | | | | | | | | | | | | | | | | | | |
| | Paradoxosomatidae | *Antichiropus* | Cloudbreak' | Yes | 39 | | | | | | | | | | | | | | | | | | | | |

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**Location of SRE and Potential SRE Species at Cloudbreak**

**Figure: 4.3**
**Project ID: 1301**

**Drawn: ND**
**Date: 24/01/11**

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

Unique Map ID: ND005

**A4**

### 4.3.1 Arachnida (Mygalomorphae)

#### 4.3.1.1 Trapdoor Spiders: Mygalomorphae

Four specimens of trapdoor spider were collected representing two species from the families Ctenizidae and Nemesiidae. As collected specimens were female, it is currently unknown whether the species collected are SREs. In this situation the precautionary principle is adhered to and the species are considered potential SREs. Both species have been collected outside the impact area (Figure 4.3).

**Family Ctenizidae**

***Conothele* sp.**

Three specimens of *Conothele* sp. were collected during the survey from sites 1 and 13 within the Creekline and Hummock Grassland on fringe of Fortescue Marsh habitats. This species was collected both inside and outside the proposed impact area. Members of the genus *Conothele* are found across arid and semi-arid Western Australia however, no species are currently described (Framenau and Harvey 2011). Males are required for species identification and as only females were collected, it is unknown whether the specimens from Cloudbreak represent a known species (Framenau and Harvey 2011).

**This species is considered a potential SRE**.

**Family Nemesiidae**

***Aname* 'MYG001 group'**

A single specimen of *Aname* 'MYG001 group' was collected outside the impact area at site 13 in Hummock Grassland on fringe of Fortescue Marsh habitat. The genus *Aname* currently includes 33 named species and can be found in a variety of habitats including sclerophyll forest, rainforest and desert (Framenau and Harvey 2011). Until recently, *Aname* 'MYG001 group' was thought to consist of a single species until recent molecular evidence showed genetic divergence (Framenau and Harvey 2011). At this stage the distributions of each species is unknown so it is not possible to determine whether any species of are SREs. In addition, the specimen collected was female and unable to be identified further so it is unknown whether the specimen from Cloudbreak represents a known species (Framenau and Harvey 2011).

**This species is considered a potential SRE**.

#### 4.3.1.2 Scorpions: Scorpiones

Seven scorpion specimens were collected representing two species from the families Buthidae and Urodacidae. One species is not considered a SRE and has been collected outside the impact area (Figure 4.3). The other species was only collected as a subadult and could not be identified to species level. It is currently unknown whether this species is a SRE until adult males are collected. This species is considered a potential SRE and has only been collected inside the proposed impact area (Figure 4.3).

**Family Buthidae**

***Lychas* 'hairy tail grp'**

Six specimens of *Lychas* 'hairy tail grp' were collected during the survey from sites 14, 15, 16 and 18. The family Buthidae is the most diverse and widespread scorpion family in Australia and in Western Australia, is represented by the genera *Isometrus*, *Isometroides* and *Lychas*. Most Australian Buthidae species appear to have wide distributions; however, a few taxa have confirmed SRE distributions (Volschenk 2011).

*Lychas* 'hairy tail grp' appears to consist of several cryptic species in a species complex. Current data suggests that this species group is not a SRE however, species may be identified in the future that qualify as SREs that are currently obscured within this complex (Volschenk 2011).

**This species is not considered a SRE** (Volschenk 2011).

**Family Urodacidae**

***Urodacus* sp.**

A single specimen of *Urodacus* sp. was collected from site 1. The family Urodacidae is endemic to Australia where it is represented by the genera *Urodacus* and *Aops*. *Urodacus* is most diverse in Western Australia and few species are recorded east of the Great Dividing Range in eastern Australia. (Volschenk 2011)

The specimen collected is a subadult and therefore species level identification is impossible. Some species of *Urodacus* (i.e. *U. koolanensis*, *U. planimanus*) are known to be SREs and several undescribed species of *Urodacus* are also known that appear to be SRE (Volschenk 2011). It is possible that the species collected represents a SRE however until adult males are collected species identification is not possible (Volschenk 2011).

This species was collected in Creekline habitat within Mulga woodland. Site 1 is also located within the proposed impact area.

**This species is considered a potential SRE** (Volschenk 2011).

#### 4.3.1.3 Pseudoscorpions: Pseudoscorpiones

A total of 320 pseudoscorpion specimens were collected from Cloudbreak comprising three families, six genera and six species. One species (*Linnaeolpium* sp.) is considered a likely SRE and another species (*Beierolpium* 'sp. 8/2') is considered a potential SRE. Due to lack of taxonomic information, the taxonomic experts could not comment on the SRE status of one species (*Austrohorus* sp.) and in this case the precautionary principle is adhered to and is considered a potential SRE. All potential and likely SRE pseudoscorpions were collected outside the impact area (Figure 4.3).

**Family Atemnidae**

***Oratemnus* sp.**

Seven specimens of *Oratemnus* sp. were collected during the survey from sites 5, 9 and 16. Atemnids are frequently found under the bark of trees in Western Australia, but the systematics of the group, particularly of the genus *Oratemnus*, is uncertain and the taxonomy of individual species is unclear (Framenau and Harvey 2011). However, based upon current evidence, it seems that most species will eventually be found to be widely distributed (Framenau and Harvey 2011).

**This species is not considered to represent a SRE** (Framenau and Harvey 2011).

**Family Olpiidae**

***Austrohorus* sp.**

One specimen of *Austrohorus* sp. was collected from outside the impact area at site 2 in the Hummock Grassland on fringe of Fortescue Marsh habitat. The specimens collected appeared very similar to other specimens found in Western Australia however, based on current levels of knowledge it is not possible to state whether it represents a SRE species (Framenau and Harvey 2011).

**This species is considered a potential SRE** (Framenau and Harvey 2011).

**Garypidae**

***Synsphyronus* sp.**

A single specimen of *Synsphyronus* sp. was collected from under the bark of a tree at a vertebrate pitfall site. Although many species from this genus represent SRE species, tree-dwelling specimens tend to have wide distributions (Framenau and Harvey 2010).

**This species is not considered a SRE** (M. Harvey pers. comm., 2011)

***Beierolpium* 'sp. 8/2'**

Twelve specimens of *Beierolpium* 'sp. 8/2' were collected both inside and outside the impact area from sites 1, 2, 4, 6, 7 and 15 with Creekline, Snakewood and Mulga Woodland and Hummock Grassland on fringe of Fortescue Marsh habitats. Similar specimens have been collected throughout the Pilbara, Midwest and Great Victoria Desert (*ecologia* database) however, until a systematic revision of this genus is undertaken, it is not possible to establish the identity of the species (Framenau and Harvey 2011).

**This species is considered a potential SRE** (Framenau and Harvey 2011).

***Indolpium* sp.**

*Indolpium* sp. was the most abundant pseudoscorpion species collected during the survey with a total of 273 specimens collected from all sites. This species is very similar to specimens collected elsewhere is Western Australia and are thought to comprise the same species (Framenau and Harvey 2011). Based on current levels of knowledge, it is considered unlikely that this species represents a SRE (Framenau and Harvey 2011).

**This species is not considered a SRE** (Framenau and Harvey 2011).

***Linnaeolpium* sp.**

Two specimens of *Linnaeolpium* sp. were collected at Cloudbreak from site 4 within the Snakewood and Mulga Woodland habitat. This species was collected outside the proposed impact area. This genus was recently described for a troglobitic species found at Robe River Valley in the Pilbara and the specimens collected represent a new species (Framenau and Harvey 2011).

**This species is considered a likely SRE** (Framenau and Harvey 2011).

#### 4.3.1.4 Millipedes: Diplopoda: Polydesmida

**Family Paradoxosomatidae**

***Antichiropus* 'Cloudbreak'**

Thirty-nine specimens of *Antichiropus* 'Cloudbreak' were collected during the survey from site 1 in the Creekline habitat. The genus *Antichiropus* is the most abundant and diverse millipede group in Western Australia. Apart from one species (*Antichiropus variabilis*) in the jarrah forests of the southwest and a species (*Antichiropus* 'PM1') from the northern Wheatbelt, all species of this genus are known to be SREs (Framenau and Harvey 2011). This species has only been found within the proposed impact area (Figure 4.3).

**This species is considered to be a SRE** (Framenau and Harvey 2011).

#### 4.3.1.5 Snails: Gastropoda

A total of 181 snail specimens representing 10 species were collected during the survey. These species comprised three terrestrial families (Pupillidae, Subulinidae and Helicodiscidae) and three aquatic families (Planorbidae, Lymnaeidae and Bithyniidae). All of the species collected are native to Australia and none are considered to be SREs.

**Family Pupillidae**

***Pupoides* sp. cf. *P. beltianus***

Thirty-six specimens of *Pupoides* sp. cf *beltianus* were collected from sites 1, 3, 4, 6, 7, 10, 16 and 17. This was the most common snail collected during the survey. This species is known from Reynolds and Jervois Ranges in the Northern Territory, south to the Musgrave and Mann Ranges in South Australia and then west to the Barrow Ranges in Western Australia (Whisson and Slack-Smith 2011).

**This species is not considered a SRE** (Whisson and Slack-Smith 2011).

***Pupoides* sp. cf. *P. ischnus***

A single specimen of *Pupoides* sp. cf *ischnus* was collected from site 4. This species has a small patchy distribution in the inland parts of the Northern Territory (Whisson and Slack-Smith 2011). If the specimen from this survey was correctly identified as *P. ischnus*, it would indicate a substantial range extension westward (Whisson and Slack-Smith 2011).

**This species is not considered a SRE** (Whisson and Slack-Smith 2011).

***Gastrocopta mussoni***

Twenty-eight specimens of *Gastrocopta mussoni* were collected from sites 3, 4, 7, 10 and 16. This species is widespread across central Australia with records from Northern Territory, Western Australia, Queensland and South Australia (Whisson and Slack-Smith 2011).

**This species is not considered a SRE** (Whisson and Slack-Smith 2011).

***Gastrocopta larapinta***

*Gastrocopta larapinta* was the second most abundant snail species collected during the survey with 33 specimens collected from sites 3, 4, 6, 7, 8 and 10. This species is known from central Australia with a few records from Western Australia and Queensland (Whisson and Slack-Smith 2011).

**This species is not considered a SRE** (Whisson and Slack-Smith 2011).

**Family Subulinidae**

***Eremopeas interioris***

Seventeen specimens of *Eremopeas interioris* were collected during the survey from sites 2, 3 and 16. This species is known from northern Australia including the Kimberley region, Northern Territory and Queensland (Whisson and Slack-Smith 2011). This species is also known from the Pilbara region around Roy Hill, Port Hedland and the western Hamersley Range (Whisson and Slack-Smith 2011).

**This species is not considered a SRE** (Whisson and Slack-Smith 2011).

**Family Helicodiscidae**

***Stenopylis coarctata***

Fifteen specimens of *Stenopylis coarctata* were collected from site 4. This species is known throughout northern and central Australia as well as the Philippines, Indonesia, New Guinea and the Solomon Islands (Whisson and Slack-Smith 2011). Recently collected specimens at the WAM indicate that this species is also widespread throughout the Pilbara (Whisson and Slack-Smith 2011).

**This species is not considered a SRE** (Whisson and Slack-Smith 2011).

**Family Planorbidae**

***Gyraulus* sp.**

Nine specimens of *Gyraulus* sp. were collected from site 3 and DP1. The family Planoribidae comprises of freshwater snails and records of this family within the Pilbara region are sparse (Whisson and Slack-Smith 2011). This species is expected to have a wide dispersal as similar aquatic species are transported by flooding during the rainy season and, perhaps, by transport by aquatic birds (Whisson and Slack-Smith 2011).

**This species is not considered a SRE** (Whisson and Slack-Smith 2011).

***Isidorella* sp. cf. *I. newcombi***

Two specimens of the freshwater snail *Isidorella* sp. cf *newcombi* were collected from site 5. Populations of *I. newcombi* are fairly widely dispersed throughout arid areas of central and eastern Australia (Whisson and Slack-Smith 2011).

**This species is not considered to be a SRE** (Whisson and Slack-Smith 2011).

**Family Lymnaeidae**

***Austropeplea* sp. cf. *A. lessoni***

Seventeen specimens of *Austropeplea* sp. cf. *lessoni* were collected during the survey from site 5 and DP1. This freshwater snail species is common in northern and eastern Australia and in Western Australia has been recorded as far south as the Gascoyne region (Whisson and Slack-Smith 2011).

**This species is not considered a SRE** (Whisson and Slack-Smith 2011).

**Family Bithyniidae**

***Gabbia* sp.**

Twenty-three specimens of *Gabbia* sp. were collected from DP1. Very little is known about this genus from the inland Pilbara so it is not possible to ascertain a species level identification however it is expected to have a wide distributional range (Whisson and Slack-Smith 2011).

**This species is not considered a SRE** (Whisson and Slack-Smith 2011).

#### 4.3.1.6 Slaters: Isopoda

A total of 134 isopod specimens were collected during the survey representing six species from three genera and a single family. All of these species have widespread distribution and therefore are not considered SRE species.

**Family Armadillidae**

***Acanthodillo* sp. 6**

A single specimen of *Acanthodillo* sp. 6 was collected from site 13. Members of this genus are often cryptic and partially subterranean (Judd 2011). This species is not rare but is infrequently collected and is known from widespread locations across the Pilbara (Judd 2011).

**This species is not considered a SRE** (Judd 2011).

***Buddelundia* sp. 10**

A total of 43 specimens of *Buddelundia* sp. 10 were collected from sites 1, 4, 5, 7, 12, 13, 14, 16 and 18 and was the most common isopod species collected in the survey. This species is a variation of the most common arid zone form of *Buddelundia* and has been collected elsewhere in the Pilbara (Judd 2011).

**This species is not considered a SRE** (Judd 2011).

***Buddelundia* sp. 14**

*Buddelundia* sp. 14 was the second most common isopod found in the survey with 41 species from sites 3, 5, 7, 10, 14, 15, 18, 19 and DP1. This species is one of the most common species in the Pilbara and is known from at least seven other locations (Judd 2011). This species is likely to be common and widespread and is likely to be found outside the Pilbara (Judd 2011).

**This species is not considered a SRE** (Judd 2011).

***Buddelundia* sp. 19**

Twenty eight specimens of *Buddelundia* sp. 19 were collected during the survey from sites 1, 5, 6, 7, 11 and 13. This species is known from only two other sites in the Pilbara (Judd 2011). The morphology of this species suggests that is more cryptic than other species (Judd 2011).

**This species is not considered a SRE** (Judd 2011).

**Gen. nov. sp. nov.**

Twenty one specimens of a new genus and species from the family Armadillidae were collected at sites 2, 4, 6, 9, 14, 15, 16 and 19. This species is undescribed but appears to be one of the most common species occurring in the Pilbara (Judd 2011).

**This species is not considered a SRE** (Judd 2011).

## 4.4 HABITAT ASSESSMENT ANALYSIS

Six different habitats occur within the study area and five of these were sampled for SRE species. The results of this survey indicate that the Creekline, Hummock Grassland both with 14 species (four SRE species each) and the Snakewood-Mulga woodland with 13 species (two SRE species), supports the most diverse range of invertebrates containing SRE groups followed by the Spinifex-covered hills (10 species; one SRE species) and Halophytic Shrubs with eight species (zero SRE species) (Figure 4.4). However, the Snakewood-Mulga woodland was the most abundant habitat with 170 specimens collected followed by the Halophytic Shrubs (140), Creekline (139), Hummock Grassland (109) and finally Spinifex-covered hills (87) (Figure 4.4). All of these habitat types extend outside the proposed impact area.

Two potential or confirmed SRE species: *Urodacus* sp. and *Antichiropus* sp. were unique to the Creekline habitat. Two species: *Aname* 'MYG001' and *Austrohorus* sp. were exclusively found on the Halophytic shrubs habitat. *Linnaeolpium* sp. was unique of the Snakewood and Mulga Woodland habitat. The other two potential SRE *Conothele* sp and *Beierolpium* 'sp 8/2' were found on more than one habitat type. However, according to the ANOVA test on the utilisation-availability data, there was no statistically significant difference between habitats types and species richness ($F= 0.32$, $P=0.85$, DF 4) and abundance ($F= 0.62$, $P> 0.656$, DF 4).

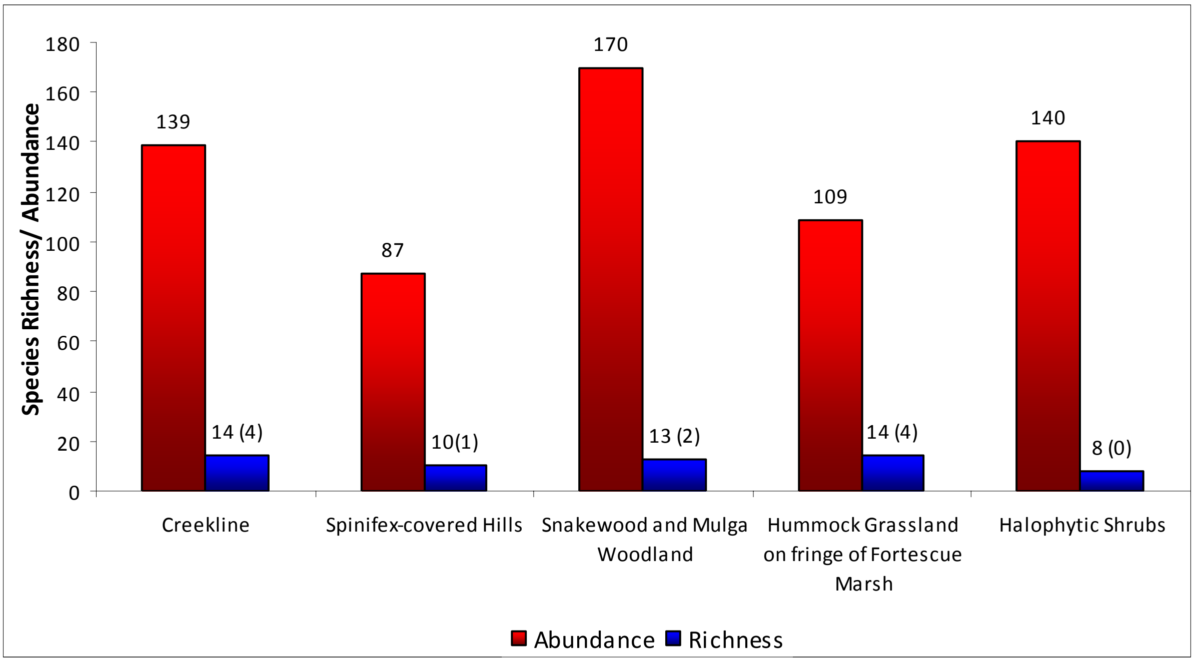
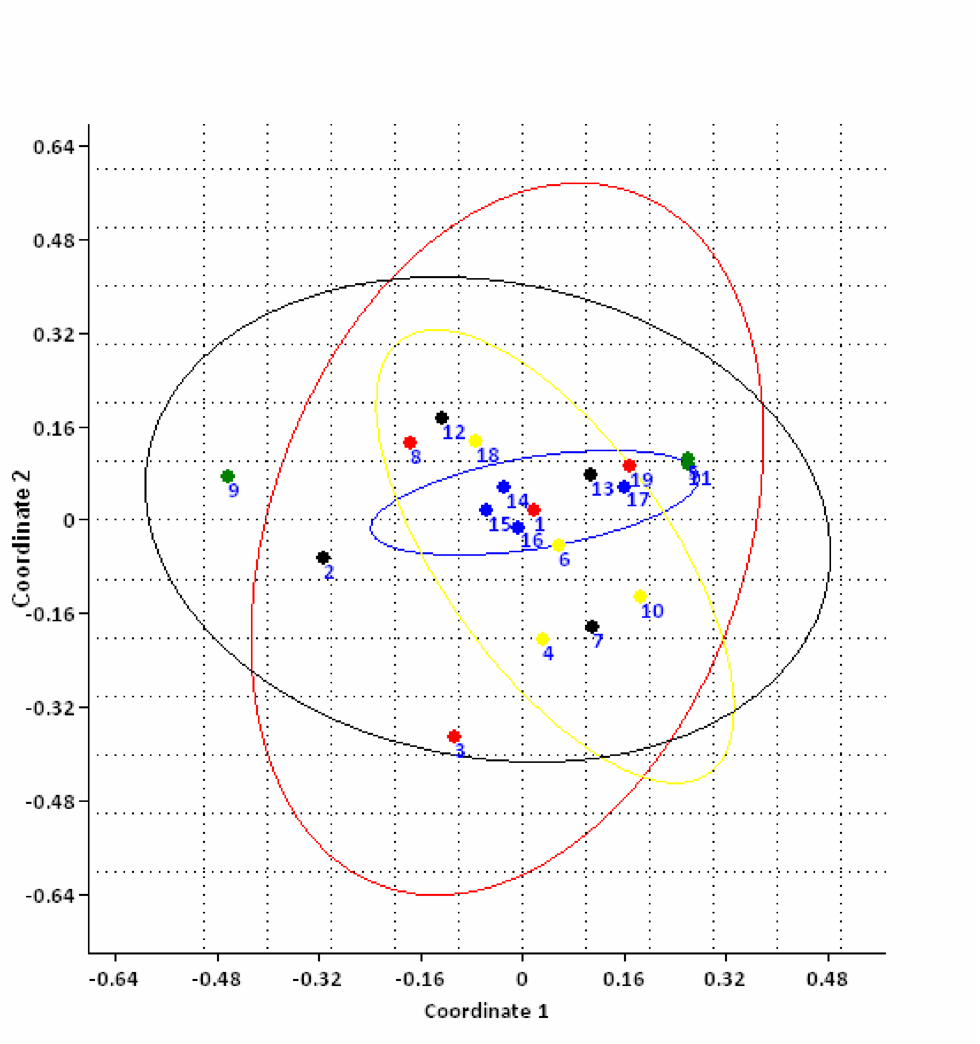



**Figure 4.4 – Total Number of Specimens (red), Species (blue) and SRE Species (brackets) Sampled in the Five Habitat Types**

A multivariate one-way ANOSIM test did not show statistical differences among the five habitat types (R= -0.07; P= 0.47; 999 permutations). Visual inspection of the ordination diagram did not reveal any clear pattern of sample grouping (Figure 4.5); the superposition of samples in the plot was due to several samples with only one SRE group and very similar density.

It can be reasonably inferred that the invertebrates assemblage containing SRE groups identified in this study is not associated with specific habitat i.e. each habitat type supports the same species diversity but not necessarily the same species.




**Stress 0.15**

**Figure 4.5 – Ordination Diagram (First two dimension) Non-metric Multidimensional Scaling of the Invertebrate Assemblage Containing SRE Groups (Bray-Curtis distance measure) Differentiating Creeklines (red), Spinifex covered hills (blue),Snakewood and Mulga woodland (yellow), Hummock Grassland on fringe of Fortescue Marshand (black) and Halophytic Shrubs (green). Each symbol represents a single collection site. Rare species (singletons) were removed prior to analysis. Individual ellipses represent 70% similarity**

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# 5 DISCUSSION

The survey was carried out in accordance with EPA Guidance Statement 20 (EPA 2009a) and a test of survey adequacy showed that the survey was sufficient, collecting approximately 93% of the expected SRE invertebrate species.

The desktop assessment carried out by (*ecologia* 2010) showed that the project area had a high potential to contain species from SRE groups including trap-door spiders, scorpions, pseudoscorpions, isopods, snails and centipedes. These results were confirmed during the field survey. Specimens from all these groups were collected.

Species of the genera *Conothele*, *Aname*, *Antichiropus* and *Beierolpium* were found in both the WAM database search and a review of surveys in nearby areas (*ecologia* 2010). Many of the snail species found in this survey were also found in the WAM database search of the area (*ecologia* 2010). This indicates that the species collected are similar to nearby areas in the Pilbara and the habitats at Cloudbreak are fairly typical of the Pilbara and support similar SRE groups.

The five potential SRE species and the likely and confirmed SREs are shown in Table 5.1. These include *Antichiropus* 'Cloudbreak' (confirmed), *Linnaeolpium* sp. (likely), *Conothele* sp. (potential), *Aname* 'MYG001 group' (potential), *Urodacus* sp. (potential), *Austrohorus* sp. (potential) and *Beierolpium* 'sp. 8/2' (potential). Two of these species were collected from multiple locations and within multiple habitat types. Two species (*Antichiropus* 'Cloudbreak' and *Urodacus* sp.) have not been collected outside the proposed impact area.

*Antichiropus* 'Cloudbreak' and *Urodacus* sp. were both collected at the same site within a creekline inside the proposed impact area. These species potentially exist along the entire length of the creek and may therefore be found outside the impact area. Species from the genus *Antichiropus* and *Urodacus* were found in both the WAM database search and previous surveys from nearby areas and are discussed in the Cloudbreak desktop study (*ecologia* 2010). The remaining five potential or likely SREs have been found outside the impact area so the impact to these species is reduced.

Habitat types reflect underlying geology, soil, surface hydrology and position in the landscape, and provide a reasonable surrogate of habitat parameters in respect to SREs. However, habitat type in this study was not a significant determinant of species richness and species abundance of SREs. The results demonstrated that the SRE groups have no preference for any of the four habitats in which they were located. The Low Halophytic Shrubland was the only habitat that did not record any SRE species. This is likely to be caused by the lack of tall vegetation and leaf-litter resulting in very few suitable micro-habitats for SRE groups. All habitats are well represented and connected within the tenement and potentially extend beyond.

Biota (2004) and Mattiske (2005; 2007) mapped the habitats of over 380 $km^2$ within the Cloudbreak study area. Approximately 233 $km^2$ (40%) of these mapped habitats will be impacted by the project. None of the habitats surveyed within the Cloudbreak study area are considered unique to the proposed impact area. It should be noted that the four habitat types in which the SRE species were located are very likely to extend beyond the limits of the mapped area, meaning that the analysis presented here is a precautionary one. Under this conservative conservation analysis, approximately 60% of the habitats for SREs would be retained.

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**Table 5.1 – Summary of SRE and Potential SRE Species Collected during the Survey and Assessment of Impact**

| Species | SRE Status | Habitat Type(s) | Collected Outside Impact Area (Y/N) | % Habitat Impact | Assessment of impact from proposal | Significance of Impact |
|---|---|---|---|---|---|---|
| *Conothele* sp. | Potential | Creekline<br>Hummock Grassland on fringe of Fortescue Marsh | Yes | 44 | Partially impacted - recorded outside | Low |
| *Aname* 'MYG001 group' | Potential | Hummock Grassland on fringe of Fortescue Marsh | Yes | 0.4 | Will not be impacted | None |
| *Urodacus* sp. | Potential | Creekline | No | 52 | Directly impacted - habitat type well<br>represented outside | Moderate |
| *Austrohorus* sp. | Potential | Hummock Grassland on fringe of Fortescue Marsh | Yes | 0.4 | Will not be impacted | None |
| *Beierolpium* 'sp. 8/2' | Potential | Creekline<br>Hummock Grassland on fringe of Fortescue Marsh<br>Snakewood and Mulga Woodland<br>Spinifex-covered Hills | Yes | 54 | Partially impacted - recorded outside | Low |
| *Linnaeolpium* sp. | Likely | Snakewood and Mulga Woodland | Yes | 54 | Will not be impacted | None |
| *Antichiropus* 'Cloudbreak' | Yes | Creekline | No | 52 | Directly impacted - habitat type well<br>represented outside | Moderate |

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# 6 CONCLUSIONS

The main conclusions of the survey were:

- The survey methods of the SRE survey were consistent with the EPA Guidance Statement 20 to sample for SRE fauna. Species accumulation curves were used to assess survey adequacy and these indicate that the survey was sufficient;
- Twenty six species were collected at Cloudbreak of which one is a confirmed SRE (*Antichiropus* 'Cloudbreak'), one is a likely SRE (*Linnaeolpium* sp.) and five are potential SREs (*Conothele* sp., *Aname* 'MYG001 group', *Urodacus* sp., *Austrohorus* sp. and *Beierolpium* 'sp. 8/2');
- *Linnaeolpium* sp., *Conothele* sp., *Aname* 'MYG001 group', *Austrohorus* sp. and *Beierolpium* 'sp. 8/2' have all been collected outside the impact area;
- *Antichiropus* 'Cloudbreak' and *Urodacus* sp. are known from single locations within the impact area;
- A habitat analysis showed no statistically significant difference between species diversity and habitat type. The invertebrate assemblage distribution depends on suitability of micro-habitats rather than broad scale habitat types; and
- All habitat types present within the impact area are likely to extend outside the impact area, so it is possible that *Antichiropus* 'Cloudbreak' and *Urodacus* sp. occur outside the impact area.

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# 7 STUDY TEAM

The FMG Cloudbreak 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:

| | |
|---|---|
| Lazaro Roque-Albelo, | BSc, MSc, PhD, Senior Invertebrate Zoologist |
| Catherine Hall | BSc Hon, Invertebrate Zoologist |
| Nicki Thompson | BSc Hon, Invertebrate Zoologist |
| Nicholas Dight | BSc, Invertebrate Zoologist |
| Sean White | BSc, Invertebrate Zoologist |


Special Thanks:

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

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# APPENDIX A SURVEY SITE CO-ORDINATES

**Survey Site Co-ordinates (UTM: Datum GDA94)**

| Site ID | UTM Zone | Easting | Northing |
|---|---|---|---|
| 1 | 50K | 723527 | 7528300 |
| 2 | 50K | 733236 | 7526736 |
| 3 | 50K | 741745 | 7525219 |
| 4 | 50K | 749664 | 7519989 |
| 5 | 50K | 747906 | 7534025 |
| 6 | 50K | 749452 | 7524765 |
| 7 | 50K | 751427 | 7528180 |
| 8 | 50K | 768923 | 7525414 |
| 9 | 50K | 724293 | 7533237 |
| 10 | 50K | 746065 | 7523752 |
| 11 | 50K | 755825 | 7522921 |
| 12 | 50K | 764412 | 7523099 |
| 13 | 50K | 745985 | 7524392 |
| 14 | 50K | 725898 | 7530305 |
| 15 | 50K | 729927 | 7528628 |
| 16 | 50K | 759403 | 7528789 |
| 17 | 50K | 762017 | 7527985 |
| 18 | 50K | 762977 | 7527130 |
| 19 | 50K | 737364 | 7536345 |

# APPENDIX B SRE SURVEY SITE DESCRIPTIONS

| Vegetation and Habitat Description | Site Photo |
|---|---|
| **Site 01**<br>**Location:**<br>50K 737128E 7530539N<br>**Habitat type:** Creekline<br>**Vegetation:**<br>**Leaf litter: S**parse<br>**Soil type:** Red-brown clay with surface crust<br>**Disturbance:** Minor erosion channels, livestock tracks, surface dust from vehicles |  |
| **Site 02**<br>**Location:**<br>50K 734565E 7527822N<br>**Habitat type:** Hummock Grassland on edge of Fortescue Marsh<br>**Vegetation:**<br>**Leaf litter:** Concentrated under trees/shrubs<br>**Soil type:** Red-brown clay, corse gravel and loose soil<br>**Disturbance:** Livestock tracks |  |
| **Site 03**<br>**Location:**<br>50K 741051E 7524875N<br>**Habitat type:** Creekline<br>**Vegetation:**<br>**Leaf litter: C**oncentrated under trees/shrubs<br>**Soil type:** Brown clay-loam, loose soil<br>**Disturbance:** Livestock tracks |  |
| **Site 04**<br>**Location:**<br>50K 757582E 7521311N<br>**Habitat type:** Snakewood and Mulga Woodland<br>**Vegetation:**<br>**Leaf litter:** Concentrated under trees/shrubs<br>**Soil type:** Brown, clay-loam, loose soil, stones/boulders<br>**Disturbance:** Livestock tracks |  |

| Vegetation and Habitat Description | Site Photo |
|---|---|
| **Site 05**<br>**Location:**<br>50K 754864E 7520667N<br>**Habitat type:** Halophytic Shrubland<br>**Vegetation:**<br>**Leaf litter:** Sparse<br>**Soil type:** Brown sandy clay, surface crust, stones/boulders<br>**Disturbance:** Livestock tracks |  |
| **Site 06**<br>**Location:**<br>50K 749115E 7526128N<br>**Habitat type:** Snakewood and Mulga Woodland<br>**Vegetation:**<br>**Leaf litter:** Concentrated under trees/shrubs<br>**Soil type:** Brown clay-loam, slight cracking, surface crust loose soil<br>**Disturbance:** Livestock tracks |  |
| **Site 07**<br>**Location:**<br>50K 754792E 7520959N<br>**Habitat type:** Hummock Grassland on edge of Fortescue Marsh<br>**Vegetation:**<br>**Leaf litter:** Concentrated under trees/shrubs<br>**Soil type:** Brown clay, surface crust, stones/boulders<br>**Disturbance:** Livestock tracks |  |
| **Site 08**<br>**Location:**<br>50K 751014E 7522031N<br>**Habitat type:** Creekline<br>**Vegetation:**<br>**Leaf litter:** Widespread<br>**Soil type:** Brown clay -loam, slight cracking, surface crust<br>**Disturbance:** Livestock tracks |  |

| Vegetation and Habitat Description | Site Photo |
|---|---|
| **Site 09**<br>**Location:**<br>50K 753618E 7521110N<br>**Habitat type:** Halophytic Shrubland<br>**Vegetation:**<br>**Leaf litter:** Concentrated under trees/shrubs<br>**Soil type:** Brown clay-loam, surface crust, loose soil<br>**Disturbance:** Livestock tracks |  |
| **Site 10**<br>**Location:**<br>50K 730371E 7533574N<br>**Habitat type:** Snakewood and Mulga Woodland<br>**Vegetation:**<br>**Leaf litter:** Widespread<br>**Soil type:** Brown clay-loam, surface crust, loose soil, stones/boulders<br>**Disturbance: M**inor erosion channels, livestock tracks, surface dust from Livestock; |  |
| **Site 11**<br>**Location:**<br>50K 721879E 7530726N<br>**Habitat type:** Halophytic Shrubland<br>**Vegetation:**<br>**Leaf litter:** Widespread<br>**Soil type:** Brown clay-loam, surface crust, loose soil**,** stones/boulders<br>**Disturbance:** Minor erosion channels, livestock tracks, surface dust from livestock |  |
| **Site 12**<br>**Location:**<br>50K 725761E 7530186N<br>**Habitat type:** Hummock Grassland on edge of Fortescue Marsh<br>**Vegetation:**<br>**Leaf litter:** Negligible<br>**Soil type:** Brown clay, surface crust, stones/boulders (many 50-90% cover)<br>**Disturbance:** Livestock tracks |  |

| Vegetation and Habitat Description | Site Photo |
|---|---|
| **Site 13**<br>**Location:**<br>50K 729915E 7528906N<br>**Habitat type:** Hummock Grassland on edge of Fortescue Marsh<br>**Vegetation:**<br>**Leaf litter:** Concentrated under trees/shrubs<br>**Soil type:** Brown clay, slight cracking, surface crust, stones/boulders (common: 30-50% cover)<br>**Disturbance:** Livestock tracks |  |
| **Site 14**<br>**Location:-**<br>50K 746601E 7532229N<br>**Habitat type:** Spinifex-covered Hills<br>**Vegetation:**<br>**Leaf litter:** Sparse<br>**Soil type:** Brown clay, stones/boulders (continuous >90% cover)<br>**Disturbance:** Minor erosion channels |  |
| **Site 15**<br>**Location:**<br>50K 747672E 7533910N<br>**Habitat type:** Spinifex-covered Hills<br>**Vegetation:**<br>**Leaf litter:** Concentrated under trees/shrubs<br>**Soil type:** Brown clay, stones/boulders (continuous >90% cover)<br>**Disturbance:** Minor erosion channels |  |
| **Site 16**<br>**Location:**<br>50K 751933E 7529137N<br>**Habitat type:** Spinifex-covered Hills<br>**Vegetation:**<br>**Leaf litter:** Concentrated under trees/shrubs<br>**Soil type:** Brown clay, slight cracking, surface crust, stones/boulders (many: 50-90% cover)<br>**Disturbance:** Minor erosion channels |  |

| Vegetation and Habitat Description | Site Photo |
|---|---|
| **Site 17**<br>**Location:**<br>50K 762754E 7523842N<br>**Habitat type:** Spinifex-covered Hills<br>**Vegetation:**<br>**Leaf litter:** Concentrated under trees/shrubs<br>**Soil type:** Red-brown clay, surface crust, loose soil<br>**Disturbance:** Livestock tracks |  |
| **Site 18**<br>**Location:**<br>50K 734810E 7536640N<br>**Habitat type:** Snakewood and Mulga Woodland<br>**Vegetation:**<br>**Leaf litter:** Widespread<br>**Soil type:** Brown clay, coarse gravel, stones/boulders, (many: 50-90% cover)<br>**Disturbance:** Minor erosion channels |  |
| **Site 19**<br>**Location:**<br>50K 748371E 7534135N<br>**Habitat type:** Creekline<br>**Vegetation:**<br>**Leaf litter:** Sparse<br>**Soil type:** Brown clay, surface crust, stones/boulders (continuous >90% cover)<br>**Disturbance:** Major erosion channels |  |