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RIO TINTO IRON ORE
GREATER WEST ANGELAS
TERRESTRIAL FAUNA ASSESSMENT

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RIO TINTO PTY LTD

GREATER WEST ANGELAS

TERRESTRIAL FAUNA ASSESSMENT

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ACRONYMS

ARI	Ashburton Regional Inventory
BoM	Bureau of Meteorology
CAMBA	China-Australia Migratory Bird Agreement
DEC	Department of Environment and Conservation
DSEWPaC	Department of Sustainability, Environment, Water, Population and Communities
DPaW	Department of Parks and Wildlife
EIA	Environmental Impact Assessment
EPA	Environmental Protection Authority
EPBC Act	*Environment Protection and Biodiversity Conservation Act 1999*
JAMBA	Japan-Australian Migratory Bird Agreement
NHMRC	National Health and Medical Research Centre
PRI	Pilbara Regional Inventory
SAC	Species Accumulation Curve
SM2BAT	SM2BAT+ 384 kHz ultrasonic acoustic recorder
SRE	Short Range Endemic
WAM	Western Australia Museum
WC Act	*Wildlife Conservation Act 1950*

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EXECUTIVE SUMMARY

Rio Tinto Iron Ore is currently conducting preliminary feasibility studies for the development of ore deposits C, D, D extension, G, F, H and Mt Ella, collectively termed the Greater West Angelas study area, located approximately 105 km north west of Newman. As part of these investigations, *ecologia* Environment was commissioned to conduct a two-phase vertebrate fauna and terrestrial invertebrate short-range endemic (SRE) survey of the study area. This survey will provide baseline data which may be supplemented with additional studies should approval to mine deposits be sought in the future.

The literature review identified that the potential vertebrate fauna assemblage consists of a total of 38 native and nine introduced mammal species, 129 bird species, 103 reptile species and eight amphibian species. Of these potential species, six mammal species, 12 bird species and three reptile species are listed as conservation significant. The literature review also identified 32 SRE species that have been previously recorded in the region surrounding the study area.

The survey was undertaken using a variety of sampling techniques, both systematic and opportunistic, in accordance with relevant guidelines. A summary of the vertebrate fauna survey effort consisted of;

- 12 trapping sites were open for 14 nights over two seasons, totalling 7,056 trapnights;
- 53.8 hours spent surveying for birds;
- 51.6 hours spent conducting diurnal searches;
- 25 hours spent conducting nocturnal searches;
- 576 hours of motion camera trapping; and,
- 340 hours of bat call recording analysis.

A summary of the invertebrate fauna survey effort consisted of:

- 12 sites consisting of dry pitfall and funnel traps were open for 14 nights, totalling 5,040 trapnights;
- 51.6 hours spent actively foraging (looking through leaf litter, under bark and stones etc); and
- A total of 60 leaf litter collections (1m^2 quadrat) taken from 18 locations.

A total of nine broad-scale habitat types have been identified within the study area; 'footslope or plain', 'hilltop, hillslope, ridge or cliff', 'mixed Acacia woodland', 'mesa top', 'cracking clay', 'major gorge and gully', 'major drainage', 'mulga woodland' and 'cleared area'. No habitats recorded were regarded as rare or unique to the study area.

A one-way ANOSIM test and MDS plot of the trapping sites within the different habitat types was completed for data collected systematically for both avifauna and terrestrial trapped fauna. The results from the one-way ANOSIM test suggested a slight difference between the habitats. The results of the MDS plot did not display visually a clear difference in habitat types for both avifauna and terrestrial trapped fauna. Overall, the results from the statistical habitat assessment suggested little difference in fauna assemblages between the different habitat types within the study area. This is likely due to the presence of a number of habitat generalist species recorded at many sites and in many habitats.

A total of 23 species of native mammal, two species of introduced mammal, 80 species of bird and 64 species of reptile were recorded during this survey. No species of amphibian were recorded.

The literature review identified 21 vertebrate fauna species of conservation significance as potentially occurring; six mammal species, 12 bird species and three reptile species. A total of six conservation significant species were recorded from the current survey, additionally, four species were assessed as having a high likelihood of occurrence with a further four species assessed as having a medium likelihood of occurrence. The remaining seven species were considered to have a low likelihood of occurrence.

The six species of conservation significance recorded from the study area consisted of; Pilbara Leaf-nosed Bat (Pilbara form) (EPBC VU, WC Act S1, DEC VU), Western Pebble-mound Mouse (secondary evidence only) (DEC P4), Fork-tailed Swift (EPBC M, WC Act S3), Australian Bustard (DEC P4), Bush Stone-curlew (signs only) (DEC P4) and Pilbara Barking Gecko (DEC P1).

A total of 33 invertebrate species from six different Orders were submitted for identification and SRE status assessment. Fifteen of these species were identified as potential SREs; two species of spider, one species of scorpion, six species of isopod, four species of pseudoscorpion and two species of centipede.

Systematically obtained data was assessed to determine survey adequacy through SACs. Extrapolation of the Michaelis-Menten (MM) curve suggested that 96.1% of trappable mammals, 92.1% of trappable reptiles, 98.5% of avifauna and 71.2% of SRE fauna had been recorded, indicating that the majority of fauna was recorded in all fauna groups.

When compared with previous surveys identified during the literature review, the current assessment recorded the highest number of mammal, bird and reptile species for the region. This is likely due to the size of the study area, variety of habitat types present and survey effort expended.

No significant limitations were experienced during the assessment. Given the minimal limitations experienced during the surveys and the fact that the majority of fauna species were recorded, the current assessment is considered adequate to allow assessment of impacts from future projects.

1 INTRODUCTION

1.1 PROJECT OVERVIEW

Rio Tinto Iron Ore (Rio Tinto) required biological surveys to be undertaken, in order to support a strategic assessment of the Greater West Angelas Project (the Project). The Project includes a series of iron ore deposits in the Pilbara region of Western Australia.

Rio Tinto is currently conducting preliminary feasibility studies for the development of ore deposits C, D, D extension, G, F, H and Mt Ella, collectively termed the Greater West Angelas study area (the study area) located approximately 105 km north-west of Newman (Figure 1.1). The study area comprises three separated areas covering a total of 175.65 km^2. The study area is situated on Rio Tinto exploration leases and encompasses the borefield supplying water to West Angelas mine. No pastoral leases intersect the study area.

As part of these investigations, *ecologia* Environment (*ecologia*) was commissioned to conduct a two-phase vertebrate fauna and terrestrial invertebrate short-range endemic (SRE) assessment of the study area. This survey will provide baseline data which may be supplemented with additional studies should approval to mine deposits be sought in the future.

1.2 LEGISLATIVE FRAMEWORK

The *Environmental Protection Act 1986* (EPBC Act) is "an Act to provide for an Environmental Protection Authority, for the prevention, control and abatement of environmental pollution, for the conservation, preservation, protection, enhancement and management of the environment and for matters incidental to or connected with the foregoing." Section 4A of this Act outlines five principles that are required to be addressed to ensure that the objectives of the Act are addressed. Three of these principles are relevant to native fauna and flora:

The Precautionary Principle

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

The Principle 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.

In addition to these principles, projects undertaken as part of the Environmental Impact Assessment (EIA) process are required to address guidelines produced by the Environmental Protection Authority (EPA), in this case Guidance Statement No. 56: *Terrestrial Fauna Surveys for Environmental Impact Assessment in Western Australia* (EPA 2004), principles outlined in EPA Position Statement No. 3: *Terrestrial Biological Surveys as an Element of Biodiversity Protection*(EPA 2002) and the *Technical Guide – Terrestrial Vertebrate Fauna Surveys for Environmental Impact Assessment, Guidance Statement 20: Sampling of Short Range Endemic Invertebrate Fauna for Environmental Impact Assessment in Western Australia* (EPA 2009).

In relation to terrestrial short range endemic (SRE) fauna, the EPA Guidance Statement *No. 56* 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.

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).

Native flora and fauna in Western Australia that are formally recognised as rare, threatened with extinction, or as having high conservation value are protected at a federal level under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) and at a state level under the *Wildlife Conservation Act 1950* (WC Act).

The EPBC Act also takes into consideration four international agreements related to migratory species, which include the Convention on the Conservation of Migratory Species of Wild Animals (Bonn Convention), the Japan-Australian Migratory Bird Agreement, the China-Australia Migratory Bird Agreement and the Republic of Korea-Australian Migratory Bird Agreement.

The EPBC Act was developed to provide for the protection of the environment, especially those aspects of the environment that are matters of national environmental significance, to promote ecologically sustainable development through the conservation and ecologically sustainable use of natural resources, and to promote the conservation of biodiversity. The EPBC Act includes provisions to protect native species (and in particular to prevent the extinction and promote the recovery of threatened species) and to ensure the conservation of migratory species. In addition to the principles outlined in Section 4A of the EPBC Act, Section 3A of the EPBC Act includes a principle of ecologically sustainable development dictating that decision-making processes should effectively integrate both long-term and short-term economic, environmental, social and equitable considerations. Schedule 1 of the EPBC Act contains a list of species that are considered Extinct, Extinct in the Wild, Critically Endangered, Endangered, Vulnerable and Conservation Dependent. Definitions of categories relevant to fauna occurring or potentially occurring in the project area are provided in Appendix A.

The Western Australian *Wildlife Conservation Act 1950* (WC Act) provides for the conservation and protection of wildlife in Western Australia. Under Section 14 of this Act, all flora and fauna within Western Australia is protected; however, the Minister may, via a notice published in the *Government Gazette*, declare a list of fauna identified as rare, likely to become extinct, or otherwise in need of special protection (Appendix A). These species are considered Threatened Fauna. The current listing was gazetted in September 2013.

In addition, the Department of Parks and Wildlife (DPaW – formerly DEC) maintains a ranked list of specially protected fauna, which includes Threatened Fauna and Priority Fauna. These rankings dictate which species should receive the highest priority for conservation management. Threatened fauna that are listed as Schedule 1 under the WC Act are further ranked by the DPaW

according to their level of threat using IUCN Red List categories and criteria. Schedule 1 species can be ranked as Critically Endangered (CR), Endangered (EN) or Vulnerable (VU).

Priority Fauna are placed into five categories. The first three Priority Fauna categories are species that have not yet been adequately surveyed to be listed under Schedule 1 or 2, and are ranked in order of priority for survey and evaluation of conservation status so that consideration can be given to their declaration as threatened fauna. Species that are adequately known and are rare but not threatened, meet IUCN criteria for Near Threatened, or that have been recently removed from the threatened list for other than taxonomic reasons, are placed in Priority 4. These species require regular monitoring. Species meeting criteria for the IUCN category of Conservation Dependent are placed in Priority 5. The three Threatened Fauna codes and five Priority codes are also summarised in Appendix A.

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.

1.3 SURVEY OBJECTIVES

Rio Tinto commissioned *ecologia* Environment (*ecologia*) to undertake a comprehensive biological survey of the terrestrial vertebrate and invertebrate SRE fauna of the study area. This study will aid in supporting EIA of the project for future development.

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

- maintain the abundance, species diversity and geographical distribution of terrestrial fauna; and
- protect specially protected (Threatened) fauna, consistent with the provisions of the WC Act.

The aim of this study was to provide information to Rio Tinto and the EPA to assess the impact of the project on the fauna populations that occur in the regional areas associated with the project, thereby ensuring that these objectives will be upheld.

This report satisfies the requirements documented in relevant EPA guidelines, by providing:

- a review of background information (including literature and database searches);
- an inventory of vertebrate and invertebrate fauna species occurring in the study area, incorporating recent published and unpublished records;
- a discussion related to the species of biological and conservation significance recorded or likely to occur within the study area and the surrounding region;
- a description of fauna habitats occurring in the study area;
- a description of the characteristics of the faunal assemblage;
- an appraisal of the current knowledge base for the area, including a review of previous surveys conducted in the area that are relevant to the current study; and
- a review of regional and biogeographical significance, including the conservation status of species recorded in the study area.

1.4 BACKGROUND SUMMARY OF FAUNA GROUPS

1.4.1 Vertebrate Conservation Significant Species

Australia's vertebrate fauna, in particular mammal and bird species, have experienced a high rate of decline and extinction over the last two hundred years (Johnson 2006), with approximately thirty species of mammals and birds becoming extinct and a further 57 species of mammals, birds, reptiles, frogs and fish, many hundreds of species of invertebrate considered endangered and likely to become extinct in near future.

Changes in fire regime and the introduction of feral animals, such as the Fox and the Cat resulted in a decrease and the extinction of several species. A number of ground dwelling birds, such as the Night Parrot and the Ground Parrot, and small to medium sized mammals (Lesser Bilby and Greater Stick-nest Rat) have reduced drastically in numbers or even became extinct. With the onset of progressively more impact by human activity, already rare fauna species that are generally restricted to a particular habitat or microhabitat, are identified and protected to preserve the existing populations within their habitat.

1.4.2 Terrestrial Invertebrate Short Range Endemics

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.

1.4.3 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.

1.4.4 Taxonomic Groups Likely to Support Short Range Endemism

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 several 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*.

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 Goldfields 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 *Antichiropus*'PM1', from the jarrah forests and northern Wheatbelt respectively. This genus extends from the Nullarbor Plain to the Pilbara region.

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.

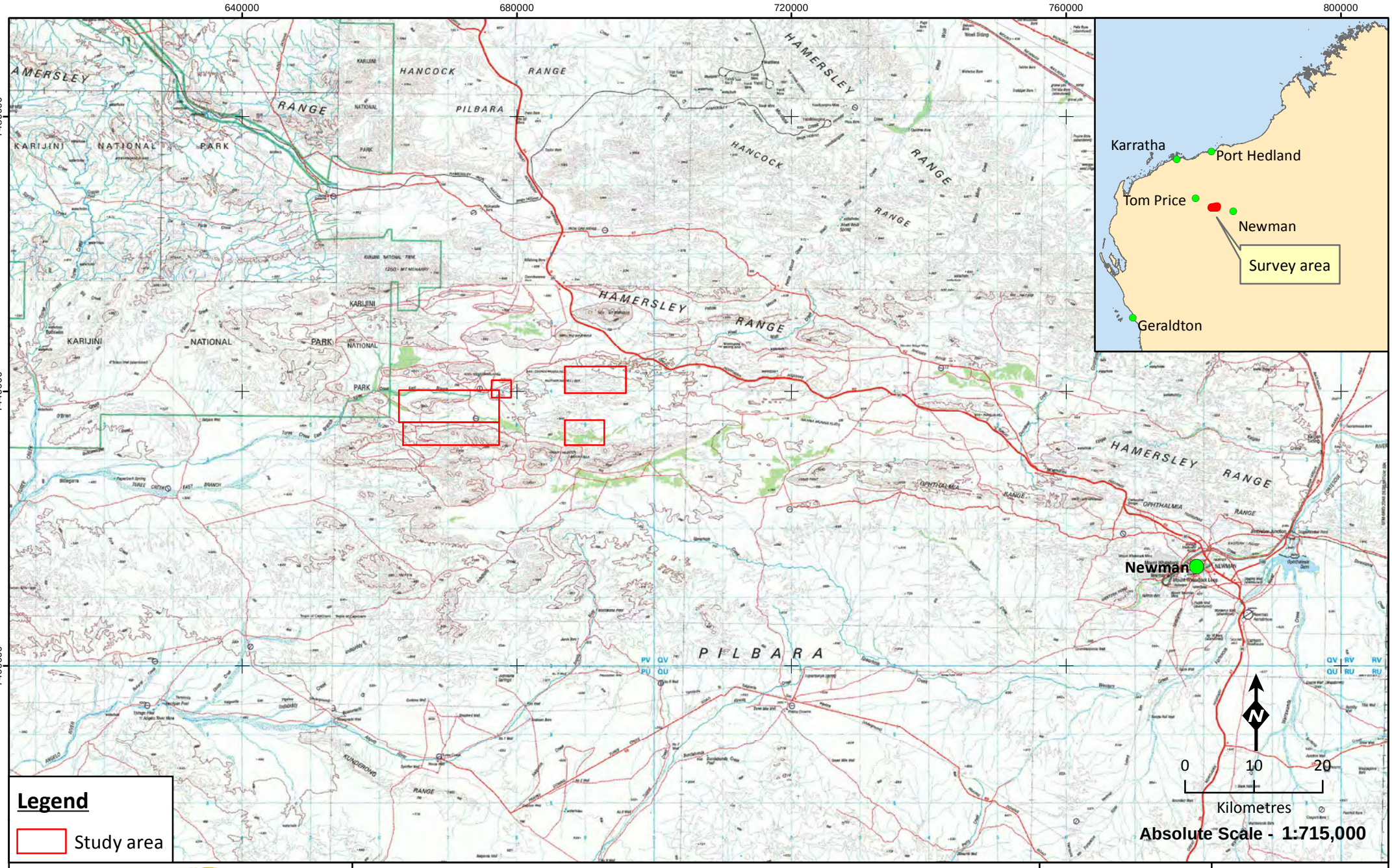
Molluscs (Phylum: Mollusca)

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 *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.

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.



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Location of Study area

Figure: 1.1
Project ID: 1458

Drawn:BG
Date: 13/02/2013

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

Unique Map ID: BG309

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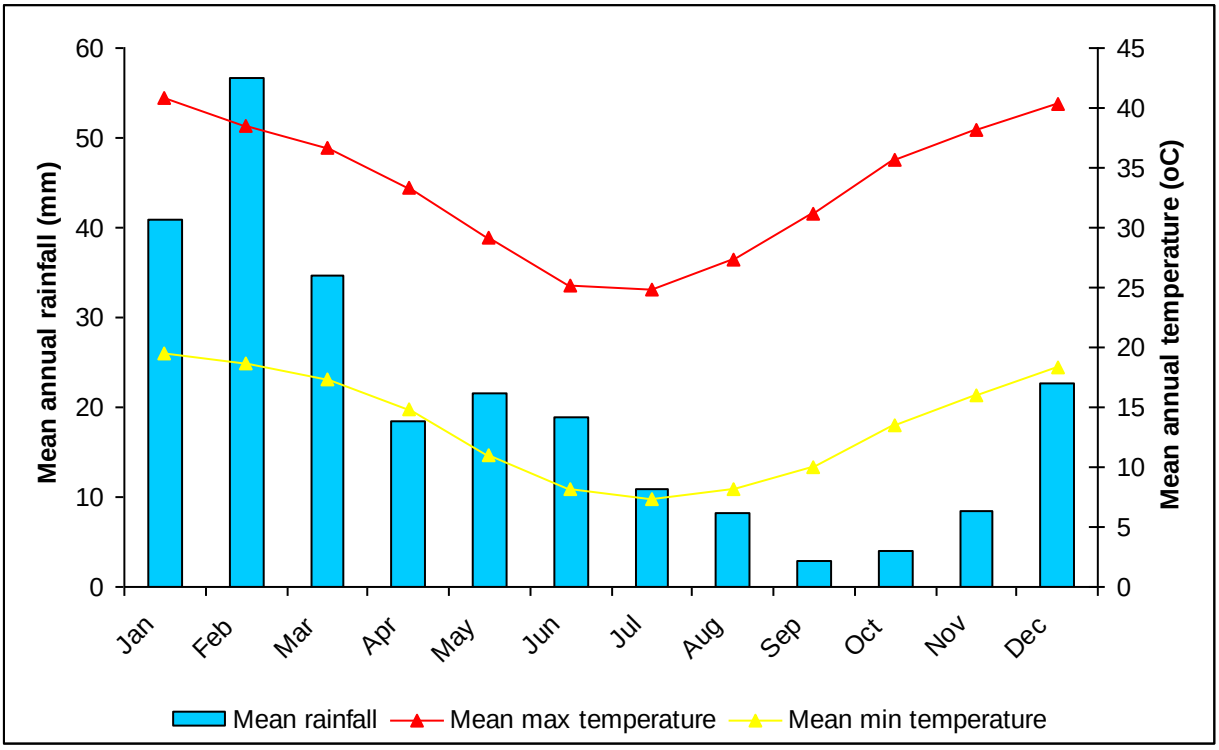
2 EXISTING ENVIRONMENT

2.1 CLIMATE AND WEATHER

The study area is located in the Pilbara region of WA. The Pilbara experiences an arid-tropical climate with two distinct seasons; a hot summer from October to April and a mild winter from May to September. Temperatures are generally high, with summer temperatures frequently exceeding 40°C. Light frosts occasionally occur inland during July and August.

Rainfall is generally localised and unpredictable (some years have recorded zero rainfall), and temperatures are high, resulting in annual evaporation exceeding rainfall by as much as 500 mm per year. The majority of the Pilbara has a bimodal rainfall distribution; from December to March rains result from tropical storms producing sporadic thunderstorms. Tropical cyclones moving south also bring heavy rains. From May to June, cold fronts move eastwards across the state and occasionally reach the Pilbara. These fronts usually produce only light rains. Surface water can be found in some pools and springs in the Pilbara all year round, although watercourses generally flow intermittently due to the short wet season (Beard 1975).

The nearest Bureau of Meteorology (BOM) station that has current temperature data is Paraburdoo Aero (Site No. 007185), 85 km west from the western boundary of the study area. Rainfall data is available from Turee Creek Station (Site No 007083) located 45.5 km south of the southern boundary of the study area. The study area location has a typical Pilbara climate of hot summers with sporadic summer storms and warm dry winters (BoM 2013). Figure 2.1 displays monthly rainfall and temperature averages with temperatures obtained from Paraburdoo Aero, rainfall obtained from Turee Creek Station.



Source: BOM (2013)

Figure 2.1 – Mean monthly climate data

An indication of weather experienced during the survey is shown in Appendix B. Phase 1 experienced typical early spring conditions, with daily maximum temperatures ranging from 28.2°C to 38.1°C (average 34.1°C) and daily minimums ranging from 11.4°C to 20.2°C (average 16.4°C). No rainfall was received during the survey.

Phase 2 experienced warmer conditions, with above average rainfall for the region experienced leading up to Phase 2. During the months of December 2012 and January 2013, a total of 185.2 mm of rain were received at Turee Creek Station (Site No 007083, (BoM 2013). No rainfall was recorded from Turee Creek Station during the survey period (Appendix B). Localised thunderstorms and associated heavy rainfall occurred on a number of days within the study area. The maximum temperature reached 43.1°C on the second day of surveying with an average of 39.6°C. The daily mimimum temperature ranged from 18.7°C to 31.4°C, averaging 24.5°C (BoM 2013, Appendix B).

2.2 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 7 (DSEWPaC 2012), the study area lies within the Pilbara Bioregion which comprises four subregions: Hamersley, Fortescue Plains, Chichester and Roebourne.

The study area lies within the Hamersley subregion (Figure 2.2) which in turn encompasses 6,215,092 ha of the southern section of the Pilbara Craton. It is composed of mountainous areas of Proterozoic sedimentary ranges and plateaus, dissected by gorges (basalt, shale and dolerite). General vegetation types include Mulga low woodland over bunch grasses on fine textured soils in valley floors, and *Eucalyptus leucophloia* over *Triodia brizoides* occur on the skeletal soils of the ranges. The climate is Semi-desert tropical, with an average 300 mm rainfall, usually in summer cyclonic or thunderstorm events. Winter rain is not uncommon. Drainage flows into either the Fortescue (to the north), the Ashburton to the south, or the Robe to the west (Kendrick and McKenzie 2001).

2.3 LAND SYSTEMS

The study area crosses the northern boundary of the area surveyed by Payne *et al* (1982) in the Regional Inventory of the Ashburton Rangelands and into the area surveyed by Van Vreeswyk *et al*. (2004) in the Regional Inventory of the Pilbara Rangelands. Both surveys documented the land systems present and their condition. Because the study area intersects the two regional surveys, they are discussed collectively for the purpose of the report. The Ashburton Regional Inventory (ARI) and Pilbara Regional Inventory (PRI) cover an area of approximately 275,323 km^2, encompassing the Ashburton River and Rous Creek, part of the Yannarie River catchment, as well as the coastal strip from and including Marrilla Station in the south, extending to Broome in the north-east.

Seven land systems mapped by Payne *et al* (1982) within the ARI and by Van Vreeswyk *et al*. (2004) in the PRI are present within the study area, each of which has been further classified by landform, soil, vegetation and drainage patterns. The seven land systems within the study area include Boolgeeda, Egerton, Elimunna, Newman, Platform, Rocklea and Wannamunna, with the Newman (71.4 km^2) and Boolgeeda (56.2 km^2) land systems being the most extensive. Summary descriptions of the characteristics of each land system are provided in Table 2.1, with land systems of the study area mapped in Figure 2.3.

The condition of the vegetation of each land system within the ARI and PRI has also been assessed. Regionally the majority of the area within each of these land systems has been determined to be in very good condition due to inaccessibility and lack of palatable vegetation. The Elimunna and

Wannamunna Land Systems are the exception, with only 39% and 44%, respectively characterised to be in good or very good condition. The remaining 17% has been determined to be in fair, poor or very poor condition. The condition of both land systems is due to the presence of vegetation that is attractive to grazing animals and prone to degradation if grazing pressure is excessive. The Wannamunna Land System is regionally restricted, comprising only 0.22% of the combined ARI and PRI areas surveyed by Payne *et al* (1982) and Van Vreeswyk *et al*. (2004). Within the study area it is also restricted, comprising only 0.3% of the total area. The area of each land system within the study area represents less than one percent of their individual regional distribution.

Given the aim of assessing the pastoral value of rangelands, the presence of the introduced grass **Cenchrus ciliaris* (Buffel grass) was not considered a negative indicator of condition, due to its perceived foraging value to pastoralists. However, this species is regarded as a serious environmental weed and the proportion of land systems in poor condition in an environmental context is therefore likely to be significantly higher, particularly for those land systems that support extensive stands of this species. Conversely the value of areas in which this species is not widespread is likely to be higher.

Table 2.1 – Land System information from the study area

Land System (% of study area)	Area (% of PRI and ARI combined)	Area within study area (% of Land System)	Description	Vegetation Condition Assessment	Landform (and % of Land System)	Vegetation Community
Boolgeeda (32.01%)	10337 km^2 (3.8%)	56.2 km^2 (0.54%)	Stony lower slopes and plains below hill systems supporting hard and soft spinifex grasslands and mulga shrublands.	Very good 82%, good 13%, fair 4%, poor 1%. Hard spinifex grasslands not preferred by livestock.	Low hill and rises (4%)	Hummock grasslands of *T. wiseana* and other *Triodia* spp. with very scattered *Acacia* spp. shrubs.
					Stony slope and upper plain (20%)	Hummock grasslands of *T. lanigera*, *T. wiseana* or scattered tall shrublands of *A. aneura*, *A. ancistrocarpa*, *A. atkinsiana* and other *Acacia* spp., with occasional *Eucalyptus* trees.
					Stony lower plain (65%)	Hummock grasslands of *T. wiseana*, *T. lanigera* or *T. pungens*. Also scattered to moderately close tall shrublands of *A. aneura* and other *Acacia* spp. with hard and soft *Triodia* spp. ground layer.
					Grove (small drainage foci) (1%)	Moderately closed woodlands or tall shrublands of *A. aneura* with sparse low shrubs and tussock or hummock grasses.
					Narrow drainage floor and channel (10%)	Scattered to closed tall shrublands or woodlands of *A. aneura*, *A. atkinsiana* and *C. hamersleyana* with sparse low shrubs and hummock and tussock grasses. Occasionally hummock grasslands of *T. pungens*.
Egerton (2.52%)	3868 km^2 (1.40%)	4.4 km^2 (0.11%)	Dissected hardpan plains supporting mulga shrublands and hard spinifex hummock grasslands.	Very good 89%, good 11%. Vegetation not preferred by livestock.	Hardpan plains (10%)	Very scattered to scattered tall shrublands of *Acacia aneura* and other *Acacia* spp. with prominent ground layer of *Triodia* spp.
					Dissected slopes (75%)	Hummock grasslands of *Triodia brizoides*, *T. wiseana* with isolated *Acacia* shrubs and *Eucalypt*s.
					Calcrete drainage margins (6%)	Hummock grasslands of *T. wiseana* with sparse *Eucalyptus socialis* trees or mallees and isolated low shrubs.
					Drainage floors and channels (9%)	Moderately close woodlands/tall shrublands of *A. aneura* with other shrubs including *Senna* spp., *Ptilotus obovatus* and *Eremophila forrestii* with *Triodia* spp. ground layer.

Land System (% of study area)	Area (% of PRI and ARI combined)	Area within study area (% of Land System)	Description	Vegetation Condition Assessment	Landform (and % of Land System)	Vegetation Community
Elimunna (1.15%)	656.6 km^2 (0.24%)	2.0 km2 (0.30%)	Stony plains on basalts supporting sparse *Acacia* and cassia shrublands and patchy tussock grasslands.	Very good 14%, good 25%, fair 35%, poor 21%., very poor, 5% Vegetation attractive to grazing animals and prone to degradation if grazing pressure is excessive.	Hills and low rises (10%)	Hummock grasslands of *Triodia wiseana* (hard spinifex) or very scattered shrublands of *Acacia* and *Senna* spp.
					Stony plains (45%)	Very scattered to scattered mixed height shrublands with *Acacia aneura* (mulga) other *Acacia*s, *Senna* spp. (cassias) and *Eremophila* spp. occasionally with patchy *Triodia* spp. (hard spinifex) understorey.
					Gilgai plains (26%)	Patchy tussock grasslands with *Eragrostis xerophila* (Roebourne Plains grass), *E. setifolia* (neverfail), *Astrebla pectinata* (barley Mitchell grass) with isolated shrubs mainly *Eremophila* and *Senna* spp.
					Hardpan plains (6%)	Very scattered tall shrublands of *A. aneura* and other *Acacia*s.
					Groves (1%)	Moderately close to close tall shrublands of *A. aneura* with numerous other shrubs and patchy perennial grasses.
					Drainage floors (12%)	Tussock grasslands with *Astrebla* and *Eragrostis* spp. Or very scattered to moderately close tall shrublands of *Acacia* spp. With various low shrubs and patchy tussock and/or hummock grasses.
Newman (40.66%)	21109 km^2 (7.7%)	71.4 km^2 (0.34%)	Rugged jaspilite plateaux, ridges and mountains supporting hard.	Very good 91%, good 7%, fair 1%, poor 1%. Inaccessible or poorly accessible and is unsuitable for pastoral purposes.	Plateaux, ridges, mountains and hills (70%)	Hummock grasslands of *Triodia wiseana*, *T. brizoides*, *T. plurinervata* with very scattered to scattered shrubs and trees including *Acacia* and *Senna* spp., *Grevillea wickhamii*, *Eucalyptus leucophloia* and other eucalypts. Occasionally hummock grass is *Triodia biflora*.
					Lower slopes (20%)	Similar to the vegetation community above.
					Stony plains (5%)	Hummock grasslands of *Triodia wiseana*, *T.* spp. (hard spinifex) with isolated to very scattered shrubs of *Acacia* and *Senna* spp. And occasional eucalypt trees. Occasionally hummock grasslands of *Triodia pungens* (soft spinifex).
					Narrow drainage floors with channels (5%)	Smaller floors support hummock grassland of *Triodia pungens* with very scattered shrubs. Larger floors and channel support tall shrublands/woodlands of *Acacia* spp. And *Eucalyptus victrix* with tussock grass or hummock grass understoreys.

Land System (% of study area)	Area (% of PRI and ARI combined)	Area within study area (% of Land System)	Description	Vegetation Condition Assessment	Landform (and % of Land System)	Vegetation Community
Platform (9.75%)	2552 km^2 (0.9%)	17.1 km^2 (0.67%)	Dissected slopes and raised plains supporting hard spinifex grasslands.	Very good 97%, good 3%. Vegetation on this system is not preferred by livestock and is of Very little use for pastoralism. The system is not susceptible to erosion.	Stony upper plains (25%)	Hummock grasslands of *Triodia wiseana* and other *Triodia* spp. (hard Spinifex) with isolated to very scattered *Acacia* spp. Shrubs
					Dissected slopes (60%)	Hummock grasslands of *Triodia wiseana*, *T. plurinervata* (hard Spinifex) with isolated to very scattered *Acacia* spp. Shrubs or *Eucalyptus leucophloia* (snappy gum)
					Drainage floors (15%)	Scattered to close tall shrublands/woodlands with *Acacia citrinoviridis* (black mulga), *A. tumida* (pindan wattle) and other *Acacia*s, occasional eucalypt trees, numerous low shrubs including *Senna* spp. (cassias), *Ptilotus obovatus* (cotton bush), *Corchorus walcottii* (grey Corchorus) and *Triodia pungens* (soft spinifex)
Rocklea (13.89%)	31089 km^2 (11.3%)	24.4 km^2 (0.08%)	Basalt hills, plateaux, lowers slopes and minor stony plains supporting hard spinifex (and occasionally soft spinifex) grasslands.	Very good 89%, good 7%, fair 2%, poor 2% Spinifex grasslands inaccessible and not preferred by livestock.	Hills, ridges, plateaux and upper slopes (65%)	Hummock grasslands of *T. wiseana*, *Triodia* spp. Or less frequently, of *T. pungens* with isolated to very scattered shrubs such as *A. inaequilatera* and *Senna* spp.
					Lower slopes (15%)	Hummock grasslands of *T. wiseana*, *Triodia* spp. Or less frequently, of *T. pungens* with isolated to very scattered shrubs such as *A. inaequilatera* and *Senna* spp.
					Stony plains and interfluves (10%)	Hummock grasslands of *T. wiseana* or less frequently *T. pungens* with isolated to very scattered shrubs such as *A. inaequilatera*. Occasionally grassy shrublands with *Acacia*, *Senna* and *Eremophila* spp.
					Gilgai plains (1%)	Tussock grasslands with *Astrebla pectinata*, *E. xerophila* and other perennial grasses.
					Upper drainage lines (4%)	Hummock grasslands of *T. wiseana* or *T. pungens* with very scattered to scattered *Acacia* shrubs and occasional *C. hamersleyana* trees.
					Drainage floors and channels (5%)	Scattered to moderately close tall shrublands or woodlands of *Acacia* and *Eucalyptus* spp. With numerous undershrubs and hummock grass understoreys or tussock grass understoreys.

2.4 VEGETATION

The vegetation of Western Australia was originally mapped at the 1:1,000,000 scale by Beard (1979), and was subsequently reinterpreted and updated to reflect the National Vegetation Information System standards (Shepherd *et al.* 2002). The study area lies within the Eremaean Botanical Province (Beard 1975). Two vegetation associations occur in the study area (Shepherd *et al.* 2001), and are described in Table 2.2 and displayed in Figure 2.4.

Table 2.2 – Vegetation associations of the study area

Shepherd Unit	Structure	Vegetation Description	Species	Area within the study area (km^2)	Percentage of the study area (%)
18	Low woodland; mulga (*Acacia aneura*)	*Acacia* open shrubland / *Ptilotus* mixed open forbland	*Acacia aneura*, *Acacia pruinocarpa*, *Acacia aneura* var. *Aneura, Eremophila fraseri*, *Eremophila foliosissima*, *Eremophila exilifolia, Senna* sp., *Solanum lasiophyllum*, *Ptilotus obovatus*.	89.5	51
82	Open hummock grassland	Hummock grasslands, low tree steppe; snappy gum over *Triodia wiseana*	*Eucalyptus leucophloia*, *Eucalyptus gamophylla*, *Senna artemisioides subsp.* x *sturtii*, *Dodonaea viscosa*, *Grevillea wickhamii*, *Triodia wiseana*, *Ptilotus rotundifolius*, *Acacia lycopodiifolia* and *Triodia wiseana*.	86.2	49

2.5 GEOLOGY

The majority of the Pilbara is composed of the granite terrain of the Pilbara Block in the north with the rugged sedimentary Hamersley Basin in the south and the sedimentary rocks overlain by Aeolian sands of the Canning Basin to the east. Drainage is mostly via major river catchments of the De Grey, Turner and Yule rivers in the north, and the Fortescue and Robe rivers in the west. All rivers are exoreic (i.e. flow into the ocean) with the exception of Savory Creek, which drains eastwards into Lake Disappointment (Van Vreeswyk *et al.* 2004). The geological stratigraphy in the Pilbara region of WA is relatively continuous, with similar geological processes occurring across the region, resulting in the enrichment of the iron deposits.

The main source of the magnetic mineralization in the Pilbara is the Pincunah Formation, which is one of the prominent Banded Ironstone Formations (BIF) within the greenstone belts of the Pilbara Craton. The study area is intersected by three different geological formations: Mafic volcanics, Sedimentary Rocks and Dolerites and gabbros from the Archaean to Palaeoproterozoic era. The study area and local geology is presented in Figure 2.5. Definitions of the geological unit codes are provided in Table 2.3 (Hickman and Kranendonk 2008). Geology of the study area comprises 12.4% mafic volcanics, 66.4% sedimentary rock and 21.1% dolerites and gabbros geological units (Hickman and Kranendonk 2008).

Table 2.3 – Geology of the study area

Geological Code	Lith Association	Area within study area (km^2)	Definition of code
A4 - -Pp	Mafic volcanics	21.7	Archaean period
A3b	Sedimentary rocks	116.9	Archaean – palaeoproterozoic period
A2d	Dolerites and gabbros	37.0	Archaean period

2.6 SOILS

Twenty-one broad soil groups have been identified by Van Vreeswyk *et al*. (2004) as part of their study defining land systems within the Pilbara. Soils are predominantly red and shallow with stony mantles.

The most extensive soils in the Pilbara are shallow, stony soils on hills and ranges and sands on sandplains. In the south, the soils are predominantly red earths overlying hardpan on level to gently inclined plains. Lower flood plains have cracking and non-cracking clay soils. Duplex (texture-contrast) soils occur in localised areas on saline alluvial plains and elsewhere. These soils support the most preferentially grazed vegetation and are highly susceptible to erosion (Van Vreeswyk *et al.* 2004).

Within the study area, three soil units as classified by Bettenay *et al.* occur (Figure 2.6). These units are described below:

Fa13: Ranges of banded jaspilite and chert along with shales, dolomites, and iron ore formations; some areas of ferruginous duricrust as well as occasional narrow winding valley plains and steeply dissected pediments. This unit is largely associated with the Hamersley and Ophthalmia Ranges. The soils are frequently stony and shallow and there are extensive areas without soil cover: chief soils are shallow stony earthy loams (Um5.51) along with some soils on the steeper slopes (Uc5.11). Associated are soils on the limited areas of dissected pediments, while (Um5.52) and (Uf6.71) soils occur on the valley plains;

Fa14: Steep hills and steeply dissected pediments on areas of banded jaspilite and chert along with shales, dolomite, and iron ore formations; some narrow winding valley plains: chief soils are shallow stony earthy loams (Um5.51) along with some (Uc5.11) soils on the steeper slopes. (Dr2.33 and Dr2.32) soils whish occur on the pediments are more extensive than unit Fa13, while (Um5.52) and (Uf6.71) soils occur on the valley plains; and

Fb3: High-level valley plains set in extensive areas of unit Fa13. There are extensive areas of pisolitic limonite deposits: principal soils are deep earthy loams (Um5.52) along with small areas of Gn2.12) soils.

2.7 LITERATURE REVIEW

Several databases were consulted in the preparation of potential fauna (and conservation significant fauna) lists (Table 2.4). In addition, ecologia has conducted 18 surveys within 70 km of the study area, with a further eight publications, reporting on fauna surveys conducted in the same region, also consulted (Table 2.5). The location of previous surveys in relation to the study area is shown in Figure 2.7. The results of database searches and previous surveys for vertebrate and SRE fauna are presented in Appendix E. The online NatureMap database encompasses several datasets which include the WA Museum (WAM), DEC threatened fauna database and DEC survey return database.

The literature review has revealed that the potential vertebrate fauna assemblage consists of a total of 38 native and nine introduced mammal species, 129 bird species, 103 reptile species and eight amphibian species have the potential to occur within the study area (Appendix F). Of these potential

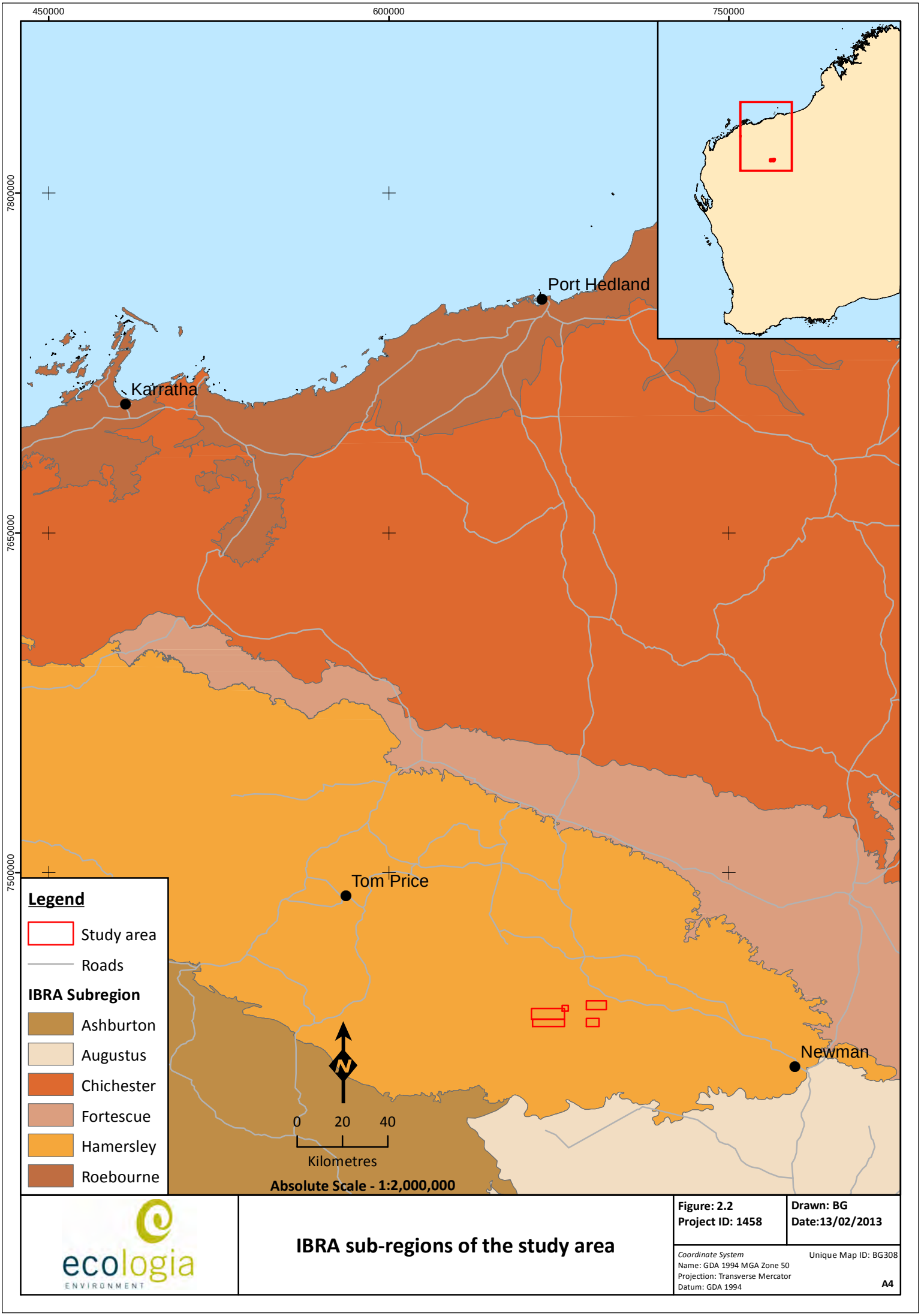
species, six mammal species, 12 bird species and three reptile species are listed as conservation significant. These are discussed in detail in section 5.3. The literature review revealed 32 SRE species have been previously recorded in the region (Appendix F).

Table 2.4 – Fauna databases searched to determine the potential vertebrate fauna assemblage

Database	Custodian	Search Details
NatureMap	DEC	Records within 40 km of study area
Threatened fauna search	DEC	Records within 40 km of study area
Protected Matters Search Tool	Department of Sustainability, Environment, Water, Population and Communities (DSEWPaC)	Records within 40 km of study area
Birdata	BirdLife Australia	Records within 100 km of the study area
Arachnid database	WAM	Records within 50 km of study area
Crustacea database	WAM	Records within 50 km of study area
Molluscs database	WAM	Records within 50 km of study area

Table 2.5 – Previous biological survey reports within 70 km of the study area

Survey Location and Author(s)	Distance to Project Area (km)	Comments
Vertebrate fauna		
ecologia internal database	0 – 50	Total of 14 surveys consisting of seven Level 2 surveys and seven Level 1 surveys
A vertebrate fauna survey of the proposed Hope Downs 4 Option 6 infrastructure corridor (Ninox 2009b)	30	Level 2 survey
Vertebrate fauna of the northern transport corridor option (Ninox 1995)	35	Level 1 survey
Marillana Creek Western Access Corridor - Biological Assessment (HGM 1999b)	35	Level 1 survey
Marillana Creek Iron Ore Project - Review of Biological Reporting (HGM 1999a)	45	Level 1 survey
Yandi Life of Mine Flora and Fauna (Maunsell 2003)	45	Level 1 survey
A fauna survey of the proposed Hope Downs 4 mining area (Ninox 2009a)	65	Level 2 survey
Vertebrate fauna of the proposed Junction Deposit mine and the central Pilbara transport corridor (Ninox 1994)	50	Level 1 survey
Yandicoogina Junction South West and Oxbow Fauna Survey (Biota 2010)	50	Level 2 survey
Invertebrate fauna		
ecologia internal database	30 - 70	Total of four surveys
Yandicoogina Junction South West and Oxbow Fauna Survey (Biota 2010)	50	Pitfall traps and foraging
A fauna survey of the proposed Hope Downs 4 mining area (Ninox 2009a)	65	Foraging and leaf litter sorting



ecologia ENVIRONMENT

IBRA sub-regions of the study area

Figure: 2.2	**Drawn: BG**
Project ID: 1458	**Date:13/02/2013**

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

Unique Map ID: BG308

A4

665000 670000 675000 680000 685000 690000 695000

7445000
7440000
7435000
7430000

Jamindie Land System

Wannamunna Land System

Deposit I

Deposit H

Egerton Land System

Deposit B

Deposit G

Platform Land System

Deposit C

Rocklea Land System

Elimunna Land System

Deposit D

Spearhole Land System

Deposit A

Deposit F

Boolgeeda Land System

Mt Ella

Deposit E

Newman Land System

N

Legend

Study area

Deposit area

0 2 4

Kilometres

Absolute Scale - 1:90,000

Pindering Land System

ecologia ENVIRONMENT

Landsystems of the study area

Figure: 2.3
Project ID: 1458

Drawn: BG
Date: 12/2/2013

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

Unique Map ID: BG310

A3

665000 670000 675000 680000 685000 690000 695000

7445000 7440000 7435000 7430000

82 29 Deposit I Deposit B Deposit H Deposit G 18 Deposit C Deposit D Mt Ella Deposit A Deposit F Deposit E

N

0 2.5 5

Kilometres

Absolute Scale - 1:90,000

Legend

Study area

Deposit area

ecologia ENVIRONMENT

Vegetation units of the study area

Figure: 2.4
Project ID: 1458

Drawn: BG
Date: 12/2/2013

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

Unique Map ID: BG286

A3

665000 670000 675000 680000 685000 690000 695000

7445000

7440000

7435000

7430000

Deposit I

Deposit G

Deposit B

A3b

Deposit H

A2d

Deposit C

Deposit D

Mt Ella

Deposit A

Deposit F

Deposit E

A4 - -Pp

A4 - -Pp

A2d

N

0 2.5 5

Kilometres

Absolute Scale - 1:90,000

Legend

Study area

Deposit area

ecologia ENVIRONMENT

Geology of the study area

Figure: 2.5
Project ID: 1458

Drawn: BG
Date: 12/2/2013

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

Unique Map ID: BG280

A3

665000 670000 675000 680000 685000 690000 695000

7445000 7440000 7435000 7430000

Fa13

Fa14

Deposit I

Deposit B

Deposit H

Deposit G

Fa13

Fb3

Deposit C

Deposit D

Fa14

Mt Ella

Deposit A

Deposit F

Deposit E

Fa13

Fb3

N

0 2.5 5

Kilometres

Absolute Scale - 1:90,000

Legend

Study area

Deposit area

ecologia ENVIRONMENT

Soils of the study area

Figure: 2.6
Project ID: 1458

Drawn: BG
Date: 12/2/2013

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

Unique Map ID: BG278

A3

700000

800000

7500000

HGM 1999b

Maunsell 2003

Ninox 1994

Biota 2010

HGM 1999a

Ninox 1995

Ninox 2009b

Ninox 2009a

Newman

0 10 20

Kilometres

Absolute Scale - 1:500,000

Legend

- *ecologia* (SRE)
- *ecologia* (vertebrate fauna L1)
- *ecologia* (vertebrate fauna L2)
- other company
- Study area

ecologia ENVIRONMENT

Previous survey locations

Figure: 2.7
Project ID: 1458

Drawn: BG
Date: 26/2/2013

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

Unique Map ID: BG287

A3

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3 METHODOLOGY

3.1 DETERMINATION OF SURVEY SAMPLING DESIGN AND INTENSITY

Prior to the development of field survey methodologies, a review was undertaken of factors likely to influence survey design and intensity (EPA 2004) (Table 3.1). Based on this review, it was deemed necessary for a Level 2 survey to be conducted within the study area.

Table 3.1 – Factors likely to influence survey design

Factor	Relevance
Bioregion – level of existing survey-knowledge of the region and associated ability to predict accurately.	A sound level of previous survey effort and knowledge exists. A total of 26 previous surveys within 70 km have been reviewed. The Hamersley sub-region of the Pilbara has been relatively well studied.
Landform special characteristics/specific fauna/specific context of the landform characteristics and their distribution and rarity in the region.	The study area lies within the Hamersley sub-region and contains typical habitat of the surrounding region. A large area of Mulga woodland habitat type occurs in the south-east of the study area.
Lifeforms, life cycles, types of assemblages and seasonality (e.g. migration) of species likely to be present.	A two-phase survey during spring and autumn with survey timing consistent with survey guidelines.
Level of existing knowledge and results of previous regional sampling (e.g. species accumulation curves, species/area curves).	A large number of previous surveys in the region, with a total of 26 previous surveys within 70 km have been reviewed.
Number of different habitats or degree of similarity between habitats within a study area.	Nine broad-scale habitats have been assessed as occurring within the study area. The Cracking Clay habitat associated with Elimunna landsystem is a restricted habitat type of the region. All other habitats occur broadly in the surrounding region. The Mulga woodland habitat is of high quality.
Climatic constraints (e.g. temperature or rainfall that preclude certain sampling methods).	Climatic conditions were typical for the time of year.
Sensitivity of the environment to the proposed activities.	The Cracking Clay habitat associated with Elimunna landsystem has been previously assessed as environmentally sensitive to degradation. The Mulga woodland habitat is of high quality. Other habitats are widespread in the surrounding region.
Size, shape and location of the proposed activities.	The study area comprises three separated areas covering a total of 175.65 km^2
Scale and impact of the proposal.	Not applicable as no assessment can be made at this stage as no defined impact areas are determined as yet.

3.2 SURVEY TIMING

The two phase Level 2 survey was conducted during spring 2012 and autumn 2013 (Table 3.2). Survey timing was determined as per guidelines (EPA 2004; EPA and DEC 2010).

Table 3.2 – Summary of survey timing and duration

Survey	Timing	Duration (days)	Person Days
Phase 1	26/09/2012 – 06/10/2012	11	74
Phase 2	18/03/2013 – 27/03/2013	10	60
Total		**21**	**134**

3.3 SITE SELECTION

Terrestrial fauna survey sites were selected to provide a good geographic spread over the study area and to be representative of the habitat types in the study area, with location of currently identified deposits taken into consideration. Habitat types occurring over a larger proportion of the study area were sampled using a larger number of trapping sites than less represented habitat types. Habitat types poorly represented by systematic sampling sites were further surveyed using opportunistic searches, targeting potentially sensitive habitats and habitats likely to support conservation significant species. Locations and details of all fauna survey sites are listed in Table 3.3 and mapped in Figure 3.1.

Descriptions and photographs of the systematic fauna trapping sites can be found in Appendix C.

Table 3.3 – Survey site locations

Site	Location	
	Easting	Northing
Systematic trap site		
GWA S1	690650	7441655
GWA S2	691892	7441631
GWA S3	687325	7432923
GWA S4	690271	7434157
GWA S5	675012	7434694
GWA S6	668071	7434246
GWA S7	666240	7436475
GWA S8	673177	7437814
GWA S9	688109	7440440
GWA S10	671504	7435248
GWA S11	673158	7438238
GWA S12	667740	7439331
Opportunistic search site		
GWA Opp S1	666513	7436849
GWA Opp S2	672777	7433992
GWA Opp S3	668377	7434089
GWA Opp S4	673142	7439083
GWA Opp S5	666358	7432530
GWA Opp S6	672027	7439426
GWA Opp S7	673911	7433876
GWA Opp S8	687382	7434157
GWA Opp S9	690830	7441558
GWA Opp S10	690386	7434554
GWA Opp S11	662985	7439744
GWA Opp S12	669725	7439306
GWA Opp S13	688095	7440343
GWA Opp S14	672883	7439043
GWA Opp S15	689013	7434085
GWA Opp S16	669913	7434817
GWA Opp S17	673195	7439118

Site	Location	
	Easting	Northing
GWA Opp S18	691928	7441786
GWA Opp S19	686882	7434209
GWA Opp S20	686848	7434423
GWA Opp S21	687482	7434412
GWA Opp S22	677757	7440130
GWA Opp S23	668089	7434460
GWA Opp S24	690500	7441055
Targeted SRE leaf litter collection site		
Forage Site 1	677545	7440245
Forage Site 2	688983	7433331
Forage Site 3	670572	7438925
Forage Site 4	663923	7437791
Forage Site 5	687086	7434227
Forage Site 6	689590	7433600
Forage Site 7	689663	7441394
Forage Site 8	693088	7441312

Datum: GDA 94
Zone: 50

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665000 670000 675000 680000 685000 690000 695000

7445000 7440000 7435000 7430000 7425000

Deposit I

Deposit B

Deposit H

GWA S1 GWA S2

GWA S9

GWA S12

Deposit C

Deposit G

GWA S11

GWA S8

GWA S7

Deposit D

GWA S10

GWA S5

GWA S6

Mt Ella

Deposit A

GWA S4

GWA S3

Deposit F

Deposit E

Legend

- Opportunistic search
- Targeted SRE leaf litter collection site
- SM2 opportunistic recording
- Trap site
- Motion camera
- Deposit areas
- Study area

N

0 2.5 5

Kilometres

Absolute Scale - 1:90,000

ecologia ENVIRONMENT

Location of fauna sites

Figure: 3.1
Project ID: 1458

Drawn: BG
Date: 24/9/2013

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

Unique Map ID: BG307

A3

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3.4 POTENTIAL CONSERVATION SIGNIFICANT VERTEBRATE FAUNA

After the results of the literature review, database searches and survey results were compiled, fauna species that are listed under current legislative frameworks were identified. Three conservation lists have been developed at national (EPBC Act) and state level (WC Act and DPaW priority list).

The likelihood of a conservation significant species being present within the study area was determined by examining the following:

- fauna habitats and their condition known to exist within the study area;
- distance of previously recorded conservation significant species from the study area;
- frequency of occurrence of conservation significant species records in the region; and
- time passed since conservation significant species were recorded within, or surrounding, the study area.

Each conservation or biologically significant species potentially occurring in the study area, was assigned a likelihood of occurrence based on the below category (Table 3.4). The level of available information for each species was also taken into consideration so that species are not allocated a low likelihood of occurrence because of insufficient survey information or cryptic behaviours and ecology.

Table 3.4 – Likelihood of occurrence categories

RECORDED	Species recorded during current survey
HIGH	Species recorded within, or in proximity to, the study area within 20 years; suitable habitat occurs in the study area
MEDIUM	Species recorded within, or in proximity to, the study area more than 20 years ago. Species recorded outside study area, but within 50 km; suitable habitat occurs in the study area
LOW	Species rarely, or not recorded, within 50 km, and/or suitable habitat does not occur in the study area

3.5 SRE STATUS

SRE status is based on the newly released 2013 WAM SRE categories which have been developed to describe the SRE status of WA taxa using: (a) unambiguous categories; and (b) explanations of uncertainty. This has been accomplished using a two-tier classification system. In the first tier of classification, geographic distribution and taxonomic certainty are the variables used to split taxa into “Confirmed SREs”, “Widespread (not SREs)”, and “Potential SREs”. In the second tier of classification, “Potential SREs” are categorised according to the reasons they have been placed into this category and the presence of proxy-indicators for Confirmed SRE or Widespread status (Table 3.5).

Table 3.5 – Western Australian Museum SRE categories (2013)

	Taxonomic Certainty	**Taxonomic Uncertainty**
Distribution < 10 000km^2	**Confirmed SRE** A known distribution of <10 00km^2. The taxonomy is well known. The group is well represented in collections and/ or via comprehensive sampling.	**Potential SRE** Patchy sampling has resulted in incomplete knowledge of the geographic distribution of the group. We have incomplete taxonomic knowledge. The group is not well represented in collections. This category is most applicable to situations where there are gaps in our knowledge of the taxon. **Sub-categories for this SRE designation are outlined below**
Distribution > 10 000km^2	**Widespread (not an SRE)** A known distribution of >10 000km^2. The taxonomy is well known. The group is well represented in collections and/ or via comprehensive sampling.	

SRE SUB-CATEGORIES

If a taxon is determined to be a "Potential SRE", the following sub-categories will further elucidate this status.

A. Data Deficient:

- There is insufficient data available to determine SRE status.
- Factors that fall under this category include:
    - Lack of geographic information
    - Lack of taxonomic information
    - The group may be poorly represented in collections
    - The individuals sampled (e.g. juveniles) may prevent identification to species level.

B. Habitat Indicators:

- It is becoming increasingly clear that habitat data can elucidate SRE status.
- Where habitat is known to be associated with SRE taxa and vice versa, it will be noted here.

C. Morphology Indicators:

- A suite of morphological characters are characteristic of SRE taxa.
- Where morphological characters are known to be associated with SRE taxa and vice- versa, it will be noted here.

D. Molecular Evidence:

- If molecular work has been done on this taxon (or a close relative), it may reveal patterns congruent or incongruent with SRE status.

E. Research & Expertise:

- Previous research and/or WAM expertise elucidates taxon SRE status.
- This category takes into account the expert knowledge held within the WAM taxonomy and nomenclature

All Likely, Potential and Unknown SREs should be treated as Confirmed SREs in accordance with the precautionary principle (Section 4A of the EP Act).

3.6 SAMPLING METHODS

The survey methods adopted by *ecologia* were aligned with relevant guidelines as identified in Section 1.2.

The survey was undertaken using a variety of sampling techniques, both systematic and opportunistic. Systematic sampling refers to data methodically collected over a fixed time period in a discrete habitat type, using an equal or standardised sampling effort. The resulting information can be analysed statistically, facilitating comparisons. Opportunistic sampling includes data collected non-systematically from both fixed sampling sites and as opportunistic records from chance encounters with fauna.

3.6.1 Systematic Sampling

3.6.1.1 Terrestrial Mammals, Herpetofauna and Invertebrates

Trapping for terrestrial mammals, herpetofauna and invertebrates was undertaken using a standardised trapping format comprising a combination of pit-fall traps, Elliott box traps, funnel traps and cage traps.

Each trapping site consisted of the following (Figure 3.2):

- Pit-trap and drift fence: Five PVC pipe (16 x 50 cm) and five 20 L plastic buckets (30 x 40 cm) were established at each site. A 10 metre flywire drift fence (30 cm high) bisected the pits, directing fauna into the traps.
- Elliott box traps: Ten medium sized Elliott box traps (9 x 9 x 32 cm) were placed at each site, and baited with Universal Bait (a mixture of peanut butter, rolled oats and sardines). Each Elliott trap was placed between the pit trap setups. Elliott traps were shaded using Air Cell roof insulation.
- Funnel traps: Funnel traps (Ecosystematica Type III) were placed in association with drift fences. Twenty funnel traps were used per site, with a trap being placed at each end of the drift fence. Funnel traps were shaded using Air Cell roof insulation.
- Cage traps: Two Sheffield small animal traps (22 cm x 22 cm x 55 cm) were used per site with one trap placed at each end of the trap line. Traps were baited with Universal Bait.

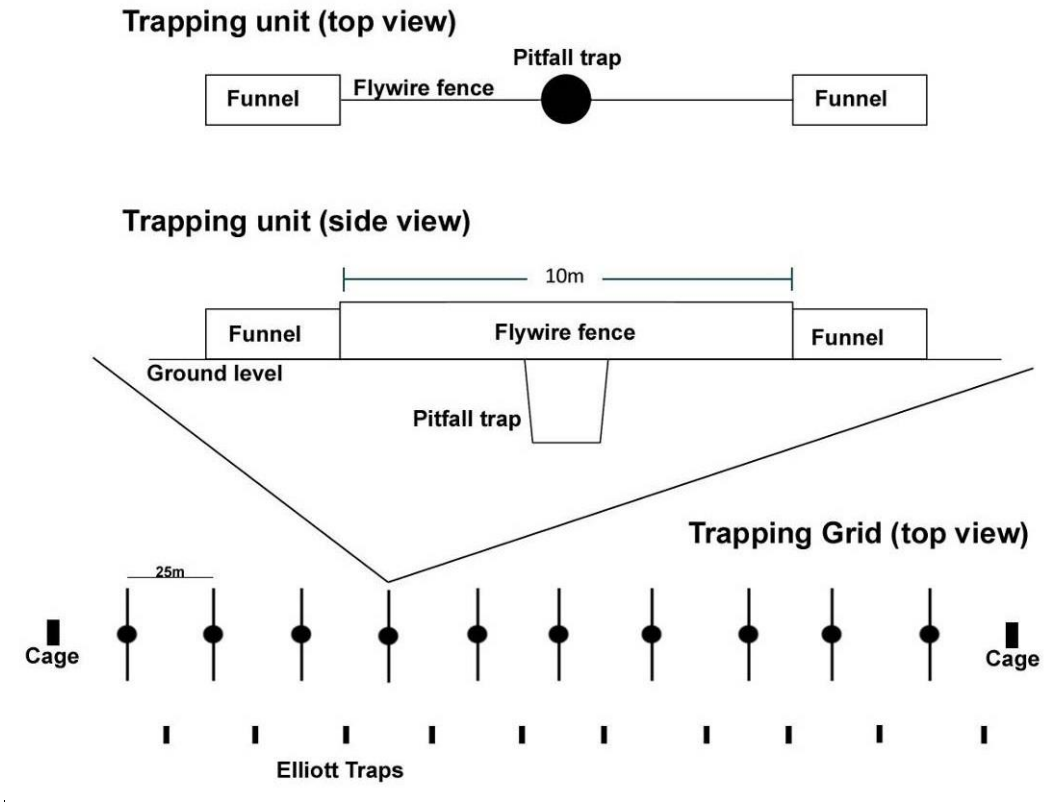

Figure 3.2 – Diagram of the systematic sampling trap arrangement

Figure 3.3 – Image of single *ecologia* trap point

3.6.1.2 Avifauna

Four 30 minute set-time surveys were used to document the avifauna present at each of the fauna sites for each phase of surveying. This totals two hours of systematic surveying per site per phase. During each set-time survey an ornithologist recorded the number of individuals of each species seen while actively searching similar habitat within 500 m of the survey site. This is aligned with survey methodology for the ongoing Birds Australia *Atlas of Australian Birds* project.

Survey effort was concentrated at survey sites within three hours of dawn, as this time is deemed to be the optimal times to record most bird species. Opportunistic surveys during the day and near dusk were also conducted, as they may yield species less frequently observed in the early morning, e.g. diurnal raptors.

3.6.1.3 Bats

Bat echolocation calls were recorded using SM2BAT+ 384 kHz ultrasonic acoustic recorders (SM2BAT). The SM2BAT has a high sampling frequency, enabling the full spectrum of the calls to be recorded without being transformed allowing greater accuracy and sensitivity. The SM2BAT was programmed to record from dusk to dawn for each night surveyed. Each systematic survey site was surveyed for one night per phase. Opportunistic sites were surveyed in areas which represented particularly good bat roosting and foraging habitat, such as rocky gorges.

3.6.1.4 SRE Leaf Litter Collection

At each site, three 1 m^2 quadrats (totalling 3 m^2) of leaf litter were collected and placed into a leaf-litter reducer separately (Figure 3.4). An additional eight opportunistic sites were also sampled. 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 3.4 – Example of the leaf litter reducer and Tullgren funnels

3.6.1.5 SRE Extraction Methods and Lab Sorting

Tullgren funnels were used to extract any animals from the collected leaf litter samples (Figure 3.4). The general principle of Tullgren funnels is that a sample of leaf litter is suspended below an incandescent lamp or heat source. Animals inhabiting the sample are forced downwards by the progressive drying of the sample and ultimately fall into the collecting vessel which is located below the sample. Samples are preserved in ethanol to allow DNA extraction if required.

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

All specimens collected 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 experts for further identification. Table 3.6 shows the list of taxonomic specialists used for identification and relevant experience.

Table 3.6 – Taxonomic specialists used for invertebrate identification

External Consultant	Institution	Relevant Experience
Dr Mark Harvey	Western Australian Museum	Taxonomic specialist in arachnids and millipedes
Dr Amber Beavis	Western Australian Museum	Taxonomic specialist in pseudoscorpions
Corey Whisson	Western Australian Museum	Taxonomic specialist in molluscs
Dr Bill Humphreys	Western Australian Museum	Taxonomic specialist in subterranean fauna
Dr Erich Volschenk	Private consultant	Taxonomic specialist in scorpions
Dr Simon Judd	Private consultant	Taxonomic specialist in isopods
Dr Volker Framenau	Private consultant	Taxonomic specialist in spiders

3.6.2 Opportunistic Data

3.6.2.1 Nocturnal Searching

The study area was searched at night using a combination of road transects and opportunistic ground searches using head torches and hand held spotlights to uncover nocturnal species, including geckos, snakes, frogs, birds and invertebrates.

Each systematic trapping site was surveyed by spotlight for at least 60 minutes for each phase. Sites GWA S1, 2 and 9 did not have nocturnal surveys completed due the long travel times required to reach these sites and the associated health and safety implications.

3.6.2.2 Diurnal Searching

Both trapping and opportunistic sites were searched by hand for both vertebrate and invertebrate cryptic species, which comprised searching beneath the bark of dead trees, breaking open old logs, stumps and dead free-standing trees, investigating burrows and over-turning logs and stones. Sites were selected on the basis of fauna habitat (targeting uncommon habitats or habitats poorly represented by trapping sites) and the possibility of their harbouring conservation significant fauna.

Fauna were also recorded while searching, travelling and during trap establishment within the study area during the day and night. Tracks, diggings, scats, burrows and nests were recorded where possible.

A total of 24 opportunistic survey sites were established during this survey, totalling 47.2 hours of diurnal searching.

3.6.2.3 Motion Camera Trapping

Motion sensor cameras were used in areas with a high likelihood of animal activity such as water sources to detect fauna species. The Bushnell Trophy Cam, model number 119415 was used. The camera is triggered by movement by a highly sensitive Passive Infra-Red motion sensor and functions day and night taking either video footage or photos (Bushnell Outdoor Products 2009).

A total of five motion cameras were set up at five sites for a total of 576 hours.

3.6.2.4 Invertebrate foraging

Opportunistic foraging involved physically searching through microhabitats for SREs. The underside of rocks and logs were closely investigated for SRE invertebrates. Snail shells were collected and trapdoor spiders excavated from their burrows, with their location and date of collection documented.

3.7 SURVEY EFFORT

Survey effort expended within the study area is shown in Table 3.7 and is summarised in the following sections.

3.7.1 Vertebrate Fauna

- 12 trapping sites were open for 14 nights, totalling 7,056 trapnights;
- 53.8 hours spent surveying for birds;
- 51.6 hours spent conducting diurnal searches;
- 25 hours spent conducting nocturnal searches;
- 576 hours of motion camera trapping; and
- 340 hours of bat call recordings analysis.

3.7.2 Conservation Significant Terrestrial Vertebrate Fauna

Excluding systematic trapping effort, targeted potential conservation significant vertebrate fauna were searched for opportunistically using the following methods:

- approximately 28 hours of opportunistic searches and 461 camera trap hours for evidence of Northern Quolls and Pilbara Olive Python;
- a total of 340 hours of bat call recordings were analysed for Ghost Bat and Pilbara Leaf-nosed Bat;
- approximately 12 hours of diurnal searches for Western Pebble-mound Mouse mounds;
- approximately six hours of bird surveys for Rainbow Bee-eater;
- five hours of spotlighting for the Pilbara Barking Gecko; and
- four hours of nocturnal call playback was performed for Bush Stone-curlew.

Other potential conservation significant species were not targeted specifically during searches due to their ability to occur within a variety of habitats (Peregrine Falcon, Grey Falcon, Australian Bustard) and difficulty in detection (*Ramphotyphlops ganei*), however all zoologists conducting the assessment were training in the identification and recognition of these species.

3.7.3 SRE Invertebrates

- Twelve sites consisting of dry pitfall and funnel traps were open for 14 nights, totalling 5,040 trapnights;
- 51.6 hours were spent actively foraging (looking through leaf litter, under bark and stones etc); and
- A total of 60 leaf litter collections (1m^2 quadrat) were taken from 18 locations.

Table 3.7 – Survey effort

Site	Pit Traps (trap nights)		Funnels (trap nights)		Elliotts (trap nights)		Cages (trap nights)		Bird Survey (min)		Leaf litter collection ($1m^2$quadrat)	Diurnal Opp Search (min)		Bat Recording (hour)		Nocturnal Search (min)		Camera Trapping (hour)	
	Ph1	Ph2	Ph1	Ph2	Ph1	Ph2	Ph1	Ph2	Ph1	Ph2		Ph1	Ph2	Ph1	Ph2	Ph1	Ph2	Ph1	Ph2
GWA S1	70	70	140	140	70	70	14	14	120	120	3	60	-	12	12	-	-	-	-
GWA S2	70	70	140	140	70	70	14	14	120	120	3	-	-	12	12	-	-	-	-
GWA S3	70	70	140	140	70	70	14	14	120	120	3	60	-	12	12	80	60	-	-
GWA S4	70	70	140	140	70	70	14	14	120	120	3	60	-	12	12	80	60	-	-
GWA S5	70	70	140	140	70	70	14	14	120	120	3	60	-	12	12	80	60	-	-
GWA S6	70	70	140	140	70	70	14	14	120	120	3	-	30	12	12	60	60	-	-
GWA S7	70	70	140	140	70	70	14	14	120	120	3	120	30	12	12	60	-	-	-
GWA S8	70	70	140	140	70	70	14	14	120	120	3	-	20	12	12	60	60	-	-
GWA S9	70	70	140	140	70	70	14	14	120	120	3	60	-	12	12	-	-	-	-
GWA S10	70	70	140	140	70	70	14	14	120	120	3	-	30	4	12	60	60	-	-
GWA S11	70	70	140	140	70	70	14	14	120	120	3	-	60	12	12	80	60	-	-
GWA S12	70	70	140	140	70	70	14	14	120	120	3	-	-	12	12	60	120	-	-
Opportunistic	-	-	-	-	-	-	-	-	320	30	24	1240	1270	24	36	340	-	432	144
Phase Total	**840**	**840**	**1680**	**1680**	**840**	**840**	**168**	**168**	**1760**	**1470**	**60**	**1660**	**1440**	**160**	**180**	**960**	**540**	**432**	**144**
Total	**1,680**		**3,360**		**1,680**		**336**		**3,230**		**60**	**3,100**		**340**		**1,500**		**576**	

3.8 FAUNA BROAD-SCALE HABITAT MAPPING

A fauna habitat type broadly describes an area of habitat that is distinguishable in its vegetation and land features from its surroundings, and that is likely to support fauna assemblages which are different to those in other fauna habitats. Fauna habitat types were identified, described and mapped taking in to consideration the following existing information:

- Vegetation associations (Beard 1981; Shepherd et al. 2002);
- IBRA subregions;
- Aerial photography; and
- On ground observations.

To aid in determining the fauna habitat type and its characteristics, the following on ground parameters were taken into consideration:

- Vegetation type and structure;
- Soil characteristics (soil structure and substrate);
- Landscape and landform features; and
- Composition of terrestrial fauna species.

3.9 DATA ANALYSIS

3.9.1 Survey Adequacy

There are three general methods of estimating species richness from sample data: extrapolating species-accumulation curves (SACs), 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, which graphically illustrate the accumulation of new species as more individuals are recorded. Ultimately, the asymptote is reached at the level at which no new species are present. To eliminate features caused by random or periodic temporal variation, the sample order was randomised 1,000 times using EstimateS (version 8, Colwell 2009). In order to estimate the theoretical maximum for each fauna group, a Michaelis-Menten enzyme kinetic curve was calculated and used as a stopping rule technique.

Only the results of systematic surveys were included in SAC analysis, as this form of analysis assumes a standard sampling effort. Therefore, species recorded through opportunistic methods are not included. Separate analyses were carried out for each species group (mammal, reptile, bird, invertebrates).

3.9.2 Habitat Assessment

Habitat types have been established in the literature as playing an important role in SRE invertebrate and vertebrate fauna diversity. Variability of habitats has been strongly linked with invertebrate and vertebrate 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 12 sites sampled during the survey. The primary aim of the statistical analysis was to determine whether the vertebrate and invertebrate assemblages (containing SRE invertebrate groups) recorded from 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 ANOVA. Prior to running the ANOVA, a test of normality (Anderson –Darling) and Homogeneity (Barlett's and Levene) was performed in order test if the data set complies 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.

Analysis of the fauna survey data was undertaken to determine the similarities in fauna communities and identify any unique fauna habitats. Separate analyses were carried out for terrestrial fauna (mammal and reptile) and avifauna.

3.10 TAXONOMY AND NOMENCLATURE

Nomenclature for mammals, reptiles and amphibians within this report is as per *Western Australian Museum Checklist of the Vertebrates of Western Australia*, birds according to Christidis and Boles (2008). References used for fauna identification are listed in Table 3.8.

All invertebrate specimens collected during the SRE trapping have been lodged with the WA Museum and identified by external experts (Table 3.6).

Table 3.8 – References used for identification

Fauna Group	Reference
Mammals	Menkhorst and Knight (2011), Van Dyck and Strahan (2008)
Bats	Churchill (1998), Menkhorst and Knight (2011)
Birds	Simpson and Day (2004)
Reptiles	Cogger (2000), Wilson and Swan (2010)
Geckos	Storr *et al*. (1990), Wilson and Swan (2010)
Skinks	Storr *et al*. (1999), Wilson and Swan (2010)
Dragons	Storr *et al*. (1983), Wilson and Swan (2010)
Varanids	Storr *et al*. (1983), Wilson and Swan (2010)
Legless Lizards	Storr *et al*. (1990), Wilson and Swan (2010)
Snakes	Storr *et al*. (2002), Wilson and Swan (2010)
Amphibians	Tyler and Doughty (2009), Cogger (2000)

3.11 ANIMAL ETHICS

Surveying was conducted as per *ecologia*'s Animal Ethics Code of Practice, which conforms to Section 5 of the *Australian code of practice for the care and use of animals for scientific purposes* (NHMRC 2004).

In most cases, fauna were identified in the field and released at the point of capture. Where the taxonomy of specimens was not clearly discernible, or when species were collected that are known to exhibit significant morphological variation or are not yet fully described, vouchers specimens were lodged with the W.A. Museum (Appendix D). Voucher specimens were maintained according to WA Museum guidelines to ensure minimum stress to captured animals.

3.12 SURVEY TEAM AND LICENCES

Field survey team members are listed in Table 3.9. The survey was conducted under DEC Regulation 17 Licence SF008716.

Table 3.9 – Field survey personnel

Survey Member	Expertise	Qualification	Experience
Phase 1			
Astrid Heidrich	Herpetology	M.Sc.	7 years
Sean White	Invertebrate Zoology	B.Sc.	7 years
Nigel Jackett	Ornithology	B.Sc. (Hons)	7 years
Bruce Greatwich	Ornithology	B.Sc.	5 years
Leigh Smith	Herpetology	-	5 years
Farhan Bokhari	Invertebrate Zoology	B.Sc. (Hons)	5 years
Anna Nowicki	Zoology	B.Sc. (Hons)	3 years
Jesse Forbes-Harper	Zoology	B.A B.Sc. (Hons)	3 years
Phase 2			
Sean White	Invertebrate Zoology	B.Sc.	7 years
Mei Chen Leng	Invertebrate Zoology	B.Sc. (Hons)	7 years
Mariana de Campos	Botany	Ph.D.	7 years
Bruce Greatwich	Ornithology	B.Sc.	5 years
Anna Nowicki	Zoology	B.Sc. (Hons)	3 years
Jesse Forbes-Harper	Zoology	B.A B.Sc. (Hons)	3 years
External consultant			
Bob Bullen	Bat call analysis	-	15 years

4 RESULTS

4.1 BROAD-SCALE HABITATS

A total of nine broad-scale habitat types have been assessed as existing within the study area; 'footslope or plain', 'hilltop, hillslope, ridge or cliff', 'mixed Acacia woodland', 'mesa top', 'cracking clay', 'major gorge and gully', 'major drainage', 'mulga woodland' and 'cleared area'. Table 4.1 displays the area each habitat type occupied at the time of surveying, and the percentage of this occupancy compared to the other habitat types, within the study area. The fauna habitats are mapped in Figure 4.1 and described in greater detail in section 4.1.2 to 4.1.10. No habitats were recorded that are regarded as rare or unique to the study area.

Table 4.1 – Summary of fauna habitat type areas

Fauna Habitat	Area inside study area (km^2)	Percentage of total study area (%)
Footslope or plain	80.37	45.76
Hilltop, hillslope, ridge or cliff	51.95	29.58
Mixed Acacia woodland	26.15	14.89
Mesa top	11	6.26
Cracking clay	2.42	1.38
Major gorge and gully	1.70	0.97
Major drainage	0.51	0.29
Mulga woodland	0.49	0.28
Cleared area	1.06	0.60
Total	**175.65**	**100**

4.1.1 Broad-scale habitat survey effort

When survey effort in Table 3.7 is assessed against the corresponding habitats present, survey effort per habitat type can be seen. These results are shown in Table 4.2.

Table 4.2 – Survey effort per habitat type

Survey effort	Habitat Type								
	Footslope or plain	**Hilltop, hillslope, ridge or cliff**	**Mixed Acacia woodland**	**Mesa top**	**Cracking clay**	**Major gorge and gully**	**Major drainage system**	**Mulga woodland**	**Cleared area**
Systematic trap sites	GWA S4, S5, S7, S9, S11	GWA S6	GWA S10	GWA S1, S2	GWA S8	GWA S12	-	GWA S3	-
Pit traps (nights)	350	70	70	140	70	70	-	70	-
Funnels (nights)	700	140	140	280	140	140	-	140	-
Elliotts (nights)	350	70	70	140	70	70	-	70	-
Cages (nights)	70	14	14	28	14	14	-	14	-
Bird surveys (min)	1,200	240	240	480	240	240	350	240	-
Leaf litter collection ($1m^2$ quadrat)	27	6	3	9	3	6	-	3	-
Diurnal Opp Search (min)	360	380	180	100	20	1,540	280	240	-
Bat Recording (hour)	112	48	24	48	24	60	-	24	-
Nocturnal Search (min)	460	120	140	-	120	180	-	140	-
Camera Trapping (hour)	115	-	-	-	-	461	-	-	-

660000 665000 670000 675000 680000 685000 690000 695000

7445000 7440000 7435000 7430000 7425000

Legend

- Study area
- Mixed Acacia woodland
- Major drainage
- Footslope or plain
- Cracking clay
- Mesa top
- Mulga woodland
- Hilltop, hillslope, ridge or cliff
- Major gorge or gully
- Cleared area

N

0 2.5 5

Kilometres

Absolute Scale - 1:102,000

ecologia ENVIRONMENT

Fauna habitats

Figure: 4.1
Project ID: 1458

Drawn: BG
Date: 15/4/2013

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

Unique Map ID: BG301

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4.1.2 Footslope or plain

Footslope or plain was the most abundant habitat type and occupied 45.76% of the study area (Table 4.1). The vegetation cover on this habitat is typically comprised of *Eucalyptus leucophloia, E. gamophylla, Corymbia hamersleyana, A. pruinocarpa, A inaequilatera* and species in the *A. aneura* complex open woodland to sparse trees over *Acacia* spp*., Eremophila* spp., *Ptilotus* spp., *Senna* spp. and *Solanum lasiophyllum* open shrubland over *Triodia* spp. open hummock grassland Figure 4.2.

Due to the large area that this habitat type covers, a wider range of plant taxa are associated with it, particularly in the shrub and grass strata. The most abundant shrubs observed were *Acacia bivenosa, A. colei, A. acradenia, A. tetragonophylla, Eremophila fraseri, E. forrestii, E. caespitosa, E. latrobei, Ptilotus calostachyus, P. nobilis* subsp. *nobilis, Senna artemisioides* (various subspecies and varieties) and *Senna glutinosa* (various subspecies and varieties). The hummock grasses present in this vegetation type were *Triodia wiseana, T. basedowii, T. longifolia* and *T. pungens*. The footslope or plain habitat type included minor drainage lines, where *T. longifolia, Gossypium robinsonii and Acacia ancistrocarpa* were characteristic.

This habitat type was associated mostly with orange sandy-clay soils on flat ground. The soil was recorded as loose, a crust or rocky, with few to common ironstone rock, gravel and pebble cover. Common disturbances observed in this habitat type include introduced flora species and animal tracks.

Figure 4.2 – Footslope or plain habitat type

4.1.3 Hilltop, hillslope, ridge or cliff

The hilltop, hillslope, ridge or cliff habitat type was recorded from 29.58% of the surveyed area and was therefore the second most common habitat within the study area (Table 4.1). The vegetation of this fauna habitat typically includes *Eucalyptus leucophloia* and mulga (*Acacia aneura* complex) isolated trees over sparse shrubland of a combination or selection of *Senna artemisioides* subsp. *artemisioides, S. artemisioides* subsp. *filifolia, Ptilotus rotundifolius, Tribulus suberosus, Eremophila fraseri* and *Acacia ancistrocarpa* sparse shrubland to isolated shrubs over *Triodia pungens* hummock grassland (Figure 4.3). In general this habitat type has a predominantly open character with very little vegetation cover.

In some areas, there was also the presence of *Acacia pruinocarpa, A. maitlandii, Acacia synchronicia,* different varieties and subspecies of *Senna artenisioides* and *Senna glutinosa*, as well as sparse herbs. Variations in the lower stratum include the presence of *Triodia wiseana, Eriachne* spp. and *Cymbopogon obtectus.*

Some variation was observed in the landforms, soil composition and rock abundance in this habitat type. The most commonly observed characteristics were soils of sandy-clay texture, ranging from

orange to brown in colour and with abundant ironstone rocks, boulders and/or surface plates. The slope ranged from minor to very steep, with smaller vegetation cover in the steeper areas.

Figure 4.3 – Hilltop, hillslope, ridge or cliff habitat type

4.1.4 Mixed *Acacia* woodland

This habitat type occupied 14.89% of the study area (Table 4.1). Vegetation included open to medium dense woodland with a tree stratum of mulga (*Acacia aneura* complex) and scattered *Acacia pruinocarpa*, over *Acacia maitlandii* and *Ptilotus* sp. sparse shrubland, over *Triodia wiseana* and *T. pungens* open hummock grassland dominated the mixed *Acacia* woodland habitat type (Figure 4.4).

Many other *Acacia* species were present in this habitat type, including *A. bivenosa, A. ayersiana, A. pyrifolia, A. sibirica;* as well as *Senna* shrubs (mainly varieties and subspecies of *S. artemisioides* and *S. glutinosa*).

The soils consisted of loam clay with continuous layers of small ironstone pebbles on the surface. The habitat was mostly flat with no or very small drainage channels.

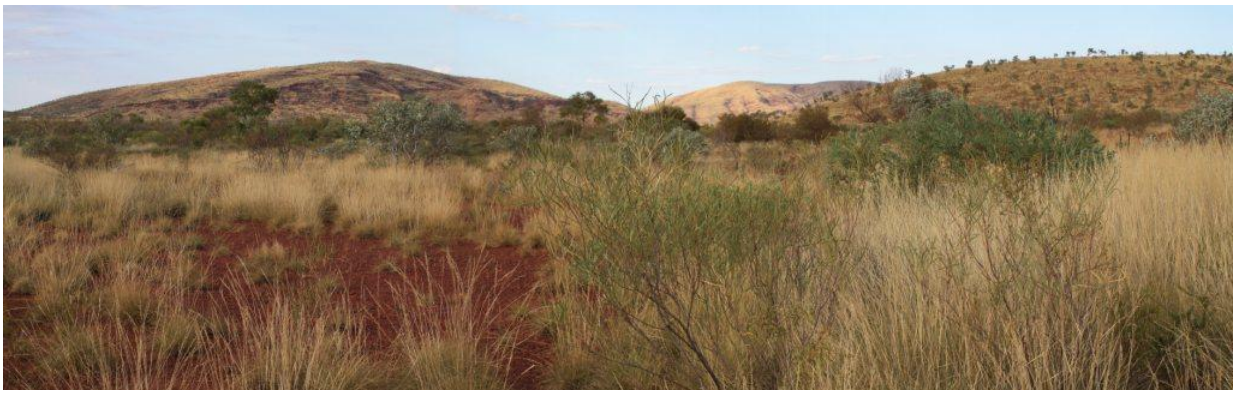


Figure 4.4 – Mixed Acacia woodland habitat type

4.1.5 Mesa top

The mesa top habitat type is located in the north-east corner of the study area, in Deposit H. Although similar to the hilltop, hillslope, ridge or cliff habitat type, it differs in that it is an elevated plateau, and supports dense vegetation in patches (Figure 4.5). The mesa top habitat type occupied 6.26% of the study area at the time of surveying (Table 4.1).

Mesa tops within the study area held an *Eucalyptus leucophloia, E. gamophylla, Acacia pruinocarpa* and mulga (*A. aneura* complex) open woodland to sparse trees, over *A. maitlandii, A. hamersleyensis, Keraudrenia velutina* and *Senna glutinosa* subsp. *glutinosa* open shrubland, over *Triodia pungens, T. longifolia* and/or *T. wiseana* open hummock grassland.

This habitat type included minor drainage lines, where *Gossypium robinsonii* was also present, as well as sparsely vegetated rocky outcrops. The geology of this habitat type is also notably different. Figure 2.5 shows the geology of the mesa top habitat type as unit A3b, which is described as sedimentary rocks. This geology differs from the mafic volcanic and dolerite and gabbros geology of the remaining area of the study area (Table 2.3).

Figure 4.5 – Mesa top habitat type

4.1.6 Cracking clay

The cracking clay habitat type was recorded from one location within the study area and occupied 1.38% of the total study area (Table 4.1). The cracking clay habitat type supported very few trees and tall shrubs and is characterised by open and sparse low vegetation with approximately half of its area being bare ground (Figure 4.6).

Isolated shrubs of *Salsola australis, Boerhavia paludosa* and *Ptilotus nobilis* subsp. *nobilis* were present over open tussock grassland of *Aristida* sp., *Brachyachne* sp. and *Astrebla pectinata.* The soil was recorded as dark orange sand-clay to clay with an undulating surface caused by crabholes and gilgai. Rocks and pebbles were very rare and when present, the rock type was consistently ironstone.

Although no signs of fire were evident, parts of the vegetation on the cracking clay habitat type were desiccated, leaving some areas completely bare.

Figure 4.6 – Cracking clay habitat type

4.1.7 Major gorge and gully

The major gorge and gully habitat type was recorded from sections within the hilltop, hillslope, ridge or cliff habitat type and occupies 0.97% of the study area (Table 4.1). The vegetation recorded commonly included *Acacia aptaneura* open woodland over *Ptilotus obovatus* isolated shrubs over *Themeda triandra* and *Eriachne* sp. open tussock grassland and *Triodia pungens* isolated hummock grasses.

Astrotricha hamptonii, Ficus brachyopoda and *Cyperus cunninghamii* were species found only in the major gorge and gully habitat, and are considered descriptive of this habitat type, although not dominant.

Major gorge and gully were frequently very steep and with an irregular surface, formed by surface plates and boulders of ironstone and with little exposed soil. The soil, when available, was described as orange-brown and sandy to sandy-clay (Figure 4.7).

Figure 4.7 – Major gorge or gully habitat type

4.1.8 Major drainage

The major drainage habitat type occupies only 0.29% of the study area (Table 4.1). The major drainage systems were characterised by open woodland of *Eucalypts victrix, Acacia citrinoviridis* and *Acacia aptaneura*, over *Senna artemisioides* subsp. *oligophylla*, *Rhagodia eremaea*, *Ptilotus obovatus*, *Tephrosia rosea* and Malvaceae spp. shrubland over *Themeda triandra* and *Bothriochloa* sp. sparse tussock grasses and/or *Triodia pungens* sparse hummock grasses (Figure 4.8).

Some variation in the vegetation composition was observed between the different major drainage systems, with varying prevalence of the taxa above mentioned, and in some cases, increased dominance of other species, such as *Pterocaulon sphacelatum, Gossypium robinsonii* or *Evolvulus alsinoides* var. *villisocalyx*.

This habitat occurred mostly on soils of sandy-clay texture that ranged from orange - red to brown in colour and with few to many rocks, pebbles and gravel. The soils were well drained and the rock type present in the major drainage systems was ironstone.

Figure 4.8 – Major drainage habitat type

4.1.9 Mulga woodland

Mulga woodland was recorded from one location and occupied 0.28% of the study area. The mulga woodland habitat type consists of both groved and banded mulga, where different species of the *Acacia aneura* complex were present in a closed woodland, over *Ptilotus obovatus* and juvenile mulga trees sparse shrubland, over *Maireana* sp. and *Salsola australis* isolated herbs and *Aristida* sp. and *Cymbopogon obtectus* isolated tussock grasses (Figure 4.9) creating distinct micro-habitats that include dense leaf litter and shaded zones.

The mulga complex was formed by a group of closely related species, formerly different varieties of *Acacia aneura* and currently split into different species. The most common species in the "mulga woodland" habitat type was *Acacia aptaneura* and *A. pteraneura*.

The soils of this habitat type were orange to red and sandy-clay with no rocks. The slope was negligible and this area of habitat was very consistent and with little variation.

Figure 4.9 – Mulga woodland habitat type

4.1.10 Cleared area

Some areas within the study area were cleared for infrastructure such as major roads (e.g. Borefields road) and airstrips. These areas are unique as they support very little vegetation, and have therefore been separated from the remaining habitat types. A total of 0.60% of the study area was recorded as being cleared.

4.1.11 Fauna habitat analysis

Common habitat types were sampled by a larger number of systematic trapping sites than less common habitat types. Six of the nine fauna habitats within the study area were sampled with systematic trapping sites during the Level 2 fauna assessment. Five trapping sites (GWA S4, S7, S8 S9 and S11) were installed in the dominant habitat type, footslope or plain. Two trap sites were installed within the Mesa top with dense shrubs habitat type (GWA S1 and S2). One trap site was installed within the Mulga woodland (GWA S3), Hilltop, hillslope, ridge or cliff (GWA S6), mixed Acacia woodland (GWA S10) and cracking clay (GWA S12).

No trapping sites were installed within the gorge and gully, cleared area or major drainage line habitat types. However, these habitat types were targeted with greater opportunistic survey effort to ensure adequate sampling of each habitat type across the study area.

A one-way ANOSIM test and MDS plot of the trapping sites within the different habitat types was completed for data collected systematically for both avifauna and trapped terrestrial fauna. The results from the one-way ANOSIM test suggest a difference between the habitats. Trapped terrestrial fauna results for the R value was 0.1473 (R value ranges from -1 to 1, with 1 indicating that the groups are dissimilar and -1 indicating that the groups are similar) and a p-value of 0.0027 (p-value of <0.05 indicating a significant difference). From Avifauna results,the R value was 0.3133 and a p-value of 0.0001. Both the results from the one-way ANOSIM test for systematically collected data suggest a difference between habitat types.

The results of the MDS plot visually do not display a clear difference in habitat types (Figure 4.10). The avifauna MDS plot shows a slight difference in birds recorded between mesa top with dense shrubs, cracking clay, hilltop, hillslope, ridge or cliff and mixed acacia woodland habitat types. The mulga woodland habitat, based on avifauna assemblage, visually appears to be the most distinct. The differences observed in the analysis of the above habitats, may be a result of reduced survey effort with one or two sites located in these habitats only. It is observed the dominate habitat type, footslope or plain overlaps the majority of all other habitats sampled. This is likely due to the increased survey effort (five systematic trap sites) in this habitat, resulting in the detection of more bird species.

As with the avifauna MDS plot, the trappable fauna MDS plot does not provide a clear difference in habitat types (Figure 4.10). The mulga woodland habitat type shows a tight cluster of similar species records, which is consistent with the avifauna results suggesting that this habitat type is most disjunct in its fauna assemblage, when compared to the other habitats. All other habitats appear to have significant overlap and similarity in the fauna assemblages recorded. This is likely due to a number of habitat generalist species which were recorded regularly. An example of this is the recording of the Sandy Inland Mouse (*Pseudomys hermmanbergensis*) and skink *Ctenotus pantherinus* at 12 of the 12 and 10 of the 12 systematic trapping sites respectively (Appendix F).

Overall, the results from the statistical habitat assessment suggest little difference in fauna assemblages between the different habitat types within the study area. These results are likely to be influenced by the presence of a number of habitat generalists recorded at many sites and in many habitats.

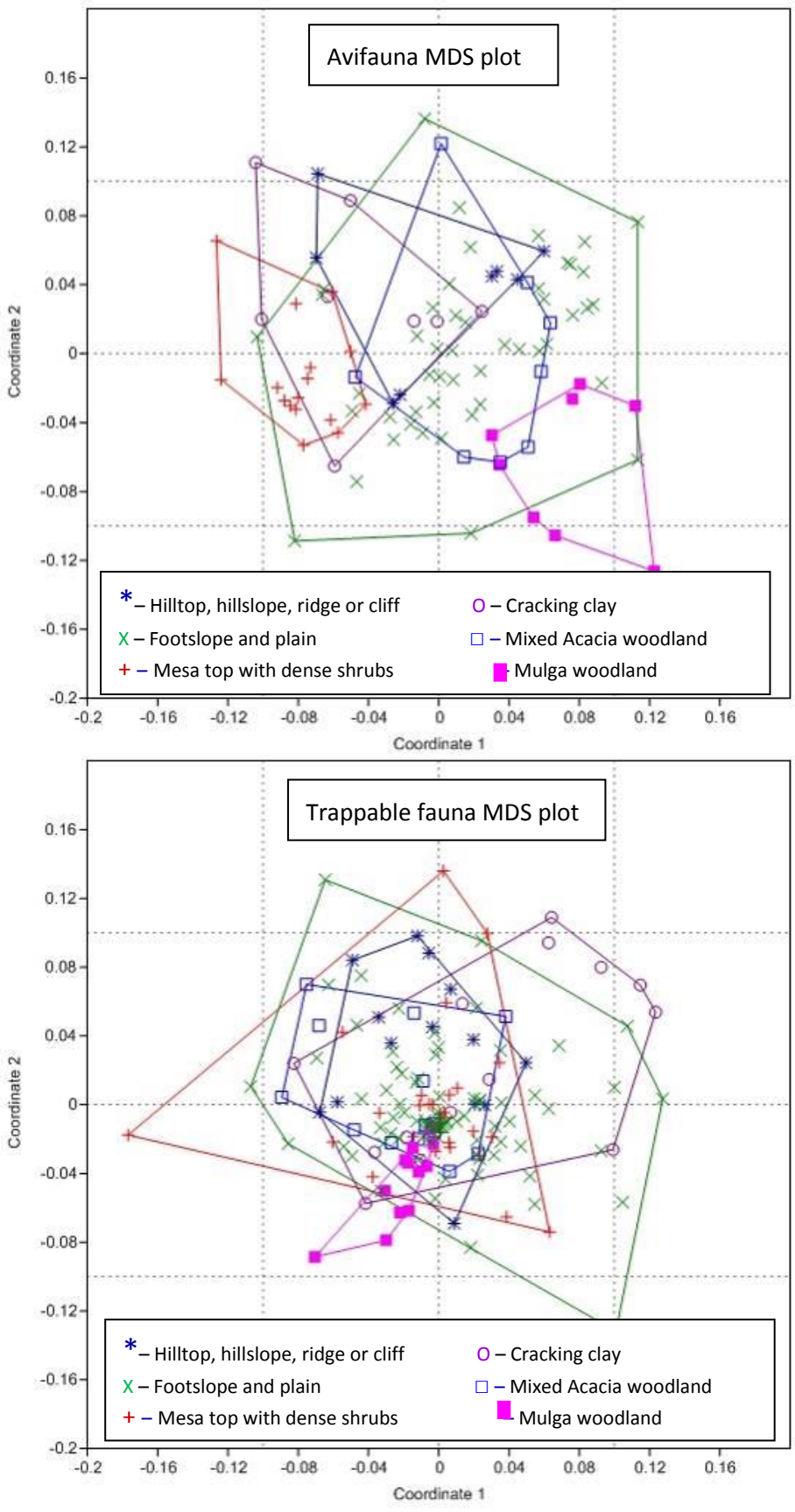


Figure 4.10 – Fauna habitat MDS plot analysis

4.2 VERTEBRATE FAUNA ASSEMBLAGE

A total of 23 species of native mammals, two species of introduced mammal, 80 species of bird and 64 species of reptile were recorded during this survey. No species of amphibian were recorded. Of the species recorded, six species were of conservation significance. The site by species matrix of species recorded during the Level 2 vertebrate fauna assessment is presented in Appendix F.

4.2.1 Mammals

A total of 23 native and two introduced mammals were recorded during this survey. This includes five dasyurids (small, carnivorous marsupials), three macropods (kangaroos), nine species of bat, five murids (mice), one species of canine (the dingo) and two species of introduced mammals (House Mouse and Rabbit) (Appendix F). The majority of species were recorded during both phases of surveying with the exception of the Delicate Mouse (*Pseudomys delicatulus*) which was only recorded during Phase 1 of surveying (Appendix F). Murids and dasyurids were captured in pitfall and Elliott traps at systematic trapping sites. Macropods were observed during diurnal and nocturnal opportunistic searches and nocturnal road spotting. Bats were identified from calls recorded on SM2BAT recorders.

There were a relatively large number of individuals of some murids and some dasyurid species recorded. The most frequently trapped species being the Sandy Inland Mouse (*Pseudomys hermannsburgensis*) with 73 records, the Common Rock-rat (*Zyzomys argurus*) with 52 records, the Pilbara Ningaui (*Ningaui timealeyi*) and the Stripe-faced Dunnart (*Sminthopsis macroura*) with 35 records each. Other abundant mammal species included Little Red Kaluta (*Dasykaluta rosamondae*; 34 records) and Desert Mouse (*Pseudomys desertor*; 29 records).

4.2.2 Birds

In total, 80 species of bird were recorded from the study area. The family Meliphagidae was the most diverse group recorded during this survey, comprising nine species of honeyeaters. The second most diverse group was the family Accipitridae which comprised seven species of birds of prey.

A large number of bird species were recorded during this survey when compared to other surveys conducted in the region (Appendix E). Several species were recorded in high numbers and from many of the sites, and can be considered to represent the common bird species of the study area; Budgerigar (1,010 records), Zebra Finch (840 records), Fork-tailed Swift (553 records), Weebill (411 records), Singing Honeyeater (288 records), Black-faced Woodswallow (182 records) and Yellow-throated Miner (152 records). Several of these species, such as Budgerigar, Black-faced Woodswallow and Fork-tailed Swift, are nomadic and appear in areas after high rainfall when food resources are high, or in the case of the Fork-tailed Swift are associated with thunderstorms.

4.2.3 Herpetofauna

In total, 64 species of reptiles were recorded during this survey. This included 21 skinks, 13 geckos (eight diplodactylid species, four gekkonid species and two carphodactylid species), 11 elapids (venomous snakes), six pygopods (legless lizards), five dragon species, six varanid (monitor lizard) species and one python. The activity of reptiles during the survey was moderate to high and resulted in good diversity of species recorded (Appendix E).

The most common species trapped were *Ctenophorus caudicinctus* (121 records*), Ctenotus pantherinus* (114 records), *Heteronotia binoei* (72 records), *Ctenotus helenae* (68 records), *Gehyra variegata and Ctenotus saxatilis* (61 records each), and *Carlia munda* (48 records), all of which are common species throughout the Pilbara region.

As typical for hot weather conditions, the activity of reptiles was recorded to be high and there was also a relatively large number of elapids recorded (11 species). Noteworthy is the record of the Pilbara Bandy Bandy (*Vermicella snelli*) which is rarely caught or observed due to its secretive nature.

No amphibian species were recorded.

Figure 4.11 – Photo of captured Pilbara Bandy Bandy

4.2.4 Vertebrate endemic species and species of biological significance

Species endemic to the Pilbara, recorded during the survey include: the Pilbara Ningaui (*Ningaui timealeyi*), Pilbara Leaf-nosed Bat (*Rhinonicteris aurantia* (Pilbara form)), Banded Knob-tailed Gecko (*Nephrurus wheeleri cinctus*), *Underwoodisaurus seorsus*, *Delma pax, Ctenotus rubicundus, C. rutilans*, Pilbara Rock Monitor (*Varanus pilbarensis*), *V. bushi* and Rufous Whipsnake (*Demansia rufescens*).

One individual of the small skink, *Ctenotus rutilans* was vouchered during phase 1 as field identification of morphology was not consistent with information in identification guides (Storr *et al.* 1999; Cogger 2000). Subsequent genetic analysis by the WAM confirmed the specimen as *Ctenotus rutilans*, despite a number of morphological characteristics not being typical of this species. Further taxonomic work is being carried out on this species complex to resolve current identification uncertainties (pers. comm. P. Doughty).

Figure 4.12 – Photo of vouchered *Ctenotus rutilans* indvidual from survey

A total of four individuals of the skink *Ctenotus robustus* (Figure 4.13) were recorded from site GWA S8 during phase 2 only (Appendix F). Based on previous records shown on NatureMap, these records represent an approximately 120 km range extension to the south for this species (DPaW 2013).

Figure 4.13 – Photo of *Ctenotus robustus* recorded from survey

4.3 POTENTIAL CONSERVATION SIGNIFICANT VERTEBRATE FAUNA

The literature review revealed a potential 21 vertebrate fauna species of conservation significance; six mammal species, 12 bird species and three reptile species (Appendix E). An assessment of their likelihood of occurrence was completed, based on the categories outlined in section 3.4, with the results summarised in Table 4.3. Regional records of conservation significant vertebrate fauna where point locations exist, have been mapped to aid in the assessment of likelihood of occurrence (Figure 4.14).

A total of six conservation significant species were recorded during the current survey (section 4.4). A further four species are assessed as having a high likelihood of occurrence and four species as having a medium likelihood of occurrence. The remaining seven species are considered to have a low likelihood of occurrence (Table 4.3).

Species that were recorded or assessed as having a high or medium likelihood of occurrence are discussed in further detail in section 5.3. Species assessed as low likelihood of occurrence are not discussed further.

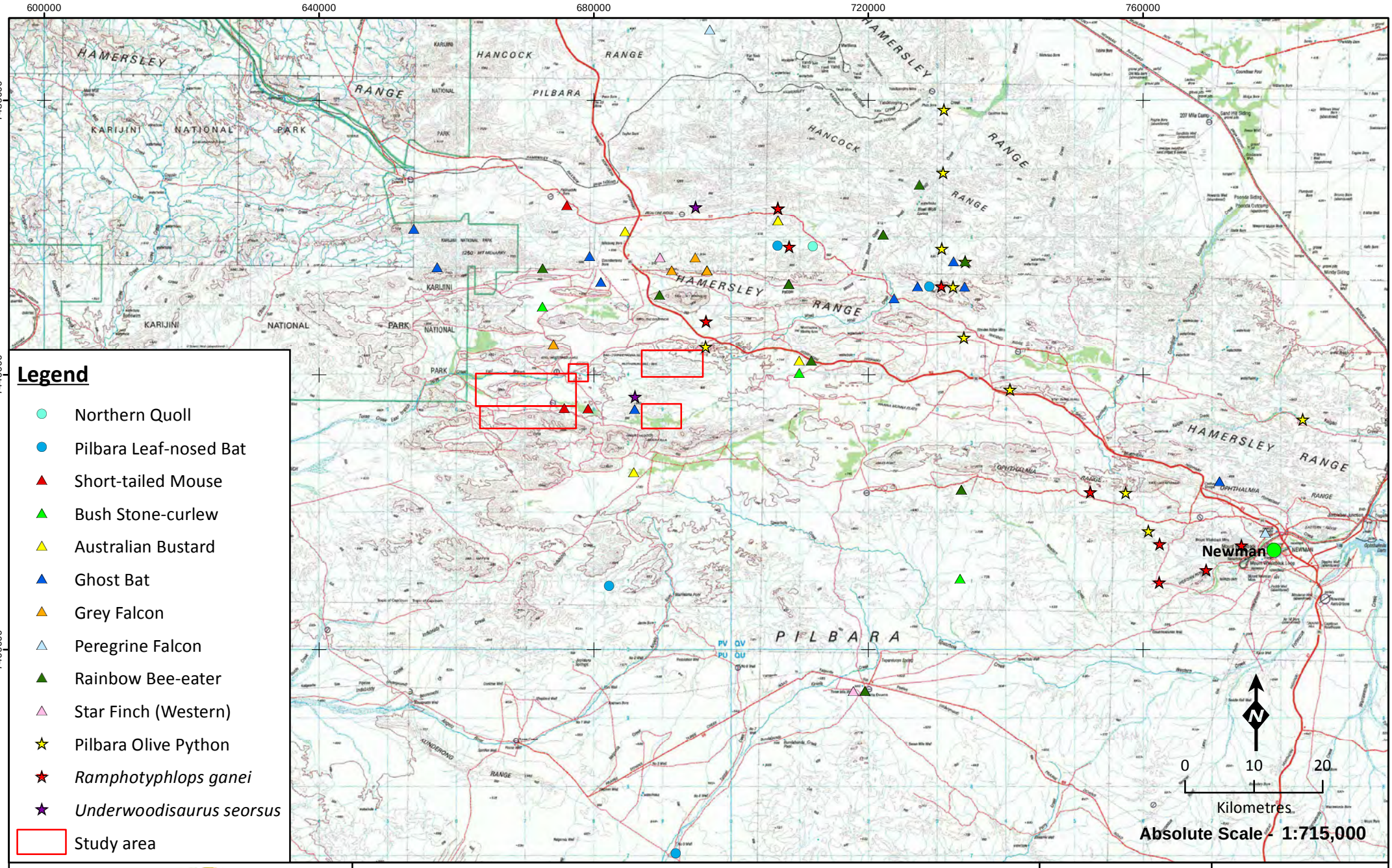
Table 4.3 – Likelihood of occurrence status of potential conservation significant vertebrate fauna

Species	Conservation Significance			Habitat	Previous Records	Likelihood of Occurrence
	EPBC Act	WC Act	DEC			
Mammals						
Northern Quoll *Dasyurus hallucatus*	EN	S1	EN	In the Pilbara, most common on dissected rocky escarpments, but also found in eucalypt forest and woodland. Typically rocky areas with suitable denning sites and access to surface water.	Three records from one location approx. 20 km north-east of study area from 2010 (DEC 2013).	**MEDIUM** Some suitable habitat present within the study area and recent record within 20 km.
Greater Bilby *Macrotis lagotis*	VU	S1	VU	Variety of habitats on soft soil including spinifex hummock grassland, acacia shrubland, open woodland and cracking clays.	Secondary evidence recorded during two previous surveys within 30 km (ecologia internal database, Ninox 1995). Not recorded on NatureMap within 100 km (DEC 2013).	**LOW** Low quality habitat present with lack of confirmed records close by.
Pilbara Leaf-nosed Bat *Rhinonicteris aurantia* (Pilbara form)	VU	S1	VU	Roost in caves with high humidity (95%) and temperature (32°C). Forage along water bodies with fringing vegetation.	Previous records from three locations within 30 km of the study area (DEC 2013).	**RECORDED** Foraging individuals recorded during this survey, no roost cave recorded.
Ghost Bat *Macroderma gigas*			P4	Roost in caves, rock piles and abandoned mines. Will travel 2 km from roost to hunt.	Calls and potential roost caves were previously recorded in close proximity to the study area (*ecologia* internal database).	**HIGH** Suitable hunting and roosting habitat is present within the study area. Species has been recorded previously.
Short-tailed Mouse *Leggadina lakedownensis*			P4	Spinifex and tussock grassland on cracking clays. Also acacia shrubland, samphire, woodlands, and stony ranges.	One previous record from within the study area from 1997 and three additional records from within 80 km area (DEC 2013).	**HIGH** Species was recorded from within the study area in 1997 (DEC 2013). Not recorded during this survey. Suitable habitat present.
Western Pebble-mound Mouse *Pseudomys chapmani*			P4	Footslopes of rocky ranges and rocky hills where the ground has continuous small pebbles and vegetated by spinifex.	Previously recorded throughout the region (DEC 2013) and during 12 surveys in the region (Ninox 1994; HGM 1999a, ecologia internal database, Ninox 2009a, 2009b, Biota 2010; 1999b; Maunsell 2003).	**RECORDED** Numerous active and inactive mounds were recorded within the study area during the survey.

Species	Conservation Significance			Habitat	Previous Records	Likelihood of Occurrence
	EPBC Act	WC Act	DEC			
Birds						
Night Parrot *Pezoporus occidentalis*	EN	S1	CR	Mostly ground-dwelling; spinifex grasslands or samphire and chenopod shrublands near water bodies.	Recorded from Protected Matters Search only with no specific record information. .	**LOW** Ecology poorly known and rarely recorded.
Fork-tailed Swift *Apus pacificus*	M	S3		Nomadic, almost entirely aerial lifestyle over a variety of habitats; associated with storm fronts.	Recorded during one survey within 40 km of the study area (*ecologia* internal database).	**RECORDED** Recorded during the survey.
Rainbow Bee-eater *Merops ornatus*	M	S3		Open country, most vegetation types, dunes, banks; prefer lightly wooded, preferably sandy, country near water.	Recorded during the majority of previous surveys within 50 km of the study area (Biota 2010,Ninox 1994; HGM 1999a, b; Maunsell 2003)	**HIGH** Suitable habitat present within study area. Numerous previous records.
Eastern Great Egret *Ardea modesta*	M	S3		Wide range of wetland habitats, including floodwaters, rivers, shallows of wetlands, intertidal mudflats.	One location record within vicinity of study area (Maunsell 2003).	**LOW** Typical wetland habitat absent within study area.
Cattle Egret Ardea ibis	M	S3		Grassy habitats, shallow wetlands and water bodies, particularly damp pastures.	Recorded from Protected Matters Search only with no specific record information.	**LOW** Typical wetland habitat absent within study area.
Oriental Plover *Charadrius veredus*	M	S3		Open plains, including samphire; bare rolling country; bare claypans; open ground near inland swamps.	Recorded from Protected Matters Search only with no specific record information.	**LOW** Suitable habitat exists but no previous records.
Common Sandpiper *Actitis hypoleucos*	M	S3		Coastal and inland wetlands, with varying levels of salinity; mostly found on muddy margins or rocky shores; rarely mudflats.	One location record within vicinity of study area (Maunsell 2003).	**LOW** Typical wetland habitat absent within study area.
Grey Falcon *Falco hypoleucos*		S1	VU	Lightly wooded coastal and riverine plains.	Previously recorded close by (*ecologia* internal database) and four recent records close by (DEC 2013).	**MEDIUM** Suitable foraging habitat present within study area but infrequently recorded species.

Species	Conservation Significance			Habitat	Previous Records	Likelihood of Occurrence
	EPBC Act	WC Act	DEC			
Peregrine Falcon *Falco peregrinus*		S4	Other	Widespread; coastal cliffs, riverine gorges and wooded watercourses.	Recorded during two previous surveys within 50 km of the study area (ecologia internal database, Ninox 1994). Three additional records on NatureMap within 100 km (DEC 2013).	**MEDIUM** Suitable foraging and nesting habitat present within study area.
Australian Bustard *Ardeotis australis*			P4	Open grasslands, chenopod flats and low heathland.	Recorded during seven previous surveys within 50 km of the study area (Ninox 1994, 1995; HGM 1999a, 2009a, 2009b, ecologia internal database; 1999b).	**RECORDED** Recorded during this survey.
Bush Stone-curlew *Burhinus grallarius*			P4	Lightly wooded country next to daytime shelter of thickets or long grass.	Three records within 50 km of the study area (DEC 2013).	**RECORDED** Tracks recorded during this survey.
Star Finch (western) *Neochmia ruficauda clarescens*			P4	Vegetation around watercourses, particularly thick reed beds.	A few previous records (Biota2010, ecologia internal database).	**LOW** Typical wetland habitat absent within study area.
Reptiles						
Pilbara Olive Python *Liasis olivaceus barroni*	VU	S1	VU	Watercourses and areas of permanent water in rocky gorges, escarpments and gullies.	Eight records within 50 km with the closest one within 1 km to the north-east of the study area (DEC 2013). Recorded during three previous surveys in the local region (ecologia internal database,HGM 1999b; Maunsell 2003)	**HIGH** Some suitable habitat present and some previous records close by.
Ramphotyphlops ganei			P1	Variety of habitats; thought to prefer moist gorges.	Eleven records within 100 km, recent and historic (DEC 2013).	**MEDIUM** Suitable habitat present and some previous records close by.
Pilbara Barking Gecko *Underwoodisaurus seorsus*			P1	Rocky gorges and rock piles.	Type locality close by, two records within 20 km of the study area (DEC 2013).	**RECORDED** Recorded during this survey

Note: Description of conservation significant codes provided in Appendix A.



ecologia ENVIRONMENT

Regional conservation significant vertebrate fauna records

Figure: 4.14
Project ID: 1458

Drawn: BG
Date: 26/04/2013

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

Unique Map ID: BG311

A4

4.4 CONSERVATION SIGNIFICANT VERTEBRATE FAUNA RECORDED

Based on database searches and the results of previous biological surveys in the surrounding region, 6 mammal, 12 bird and 3 reptile species of conservation significance could potentially occur in the study area. Six species of conservation significance (two mammal, three bird and one reptile species) were recorded from within the study area, these records are summarised in Table 4.4 and mapped in Figure 4.15 and Figure 4.15.

Table 4.4 – Conservation significant fauna recorded during the survey

Species	Location			Comments*
	Easting	Northing	Site	
Mammals				
Pilbara Leaf-nosed Bat	671504	7435248	GWA S10	Single call on the 23/3/13 in middle of night indicating foraging individual.
Pilbara Leaf-nosed Bat	666240	7436475	GWA S7	Four calls on the 24/3/13 at different times of night indicating possibly more than one foraging individual.
Pilbara Leaf-nosed Bat	667740	7439331	GWA S12	Single call on the 23/3/13 in middle of night indicating foraging individual.
Western Pebble-mound Mouse	673665	7434462	Opportunistic	Active mound
Western Pebble-mound Mouse	672596	7434480	Opportunistic	Active mound
Western Pebble-mound Mouse	668157	7434280	Opportunistic	Active mound
Western Pebble-mound Mouse	672684	7434543	Opportunistic	Active mound
Western Pebble-mound Mouse	667710	7439402	Opportunistic	Active mound
Western Pebble-mound Mouse	675011	7434825	Opportunistic	Active mound
Western Pebble-mound Mouse	667803	7439414	Opportunistic	Active mound
Western Pebble-mound Mouse	666190	7436653	Opportunistic	Active mound
Western Pebble-mound Mouse	669120	7434586	Opportunistic	Active mound
Western Pebble-mound Mouse	669037	7434650	Opportunistic	Active mound
Western Pebble-mound Mouse	668923	7437248	Opportunistic	Active mound
Western Pebble-mound Mouse	668627	7434577	Opportunistic	Active mound
Western Pebble-mound Mouse	689675	7442560	Opportunistic	Active mound
Western Pebble-mound Mouse	677258	7438166	Opportunistic	Active mound
Western Pebble-mound Mouse	668967	7438036	Opportunistic	Active mound
Western Pebble-mound Mouse	666396	7434452	Opportunistic	Active mound
Western Pebble-mound Mouse	677714	7440975	Opportunistic	Active mound
Western Pebble-mound Mouse	690176	7440478	Opportunistic	Active mound
Western Pebble-mound Mouse	671568	7435429	Opportunistic	Active mound
Western Pebble-mound Mouse	671561	7435088	Opportunistic	Active mound
Western Pebble-mound Mouse	671480	7435074	Opportunistic	Inactive mound
Western Pebble-mound Mouse	668034	7434428	Opportunistic	Inactive mound
Western Pebble-mound Mouse	666413	7434675	Opportunistic	Inactive mound
Western Pebble-mound Mouse	670747	7436275	Opportunistic	Inactive mound
Western Pebble-mound Mouse	671842	7434792	Opportunistic	Inactive mound
Western Pebble-mound Mouse	687618	7441807	Opportunistic	Inactive mound

Species	Location			Comments*
	Easting	Northing	Site	
Western Pebble-mound Mouse	676489	7433398	Opportunistic	Inactive mound
Western Pebble-mound Mouse	676600	7433391	Opportunistic	Inactive mound
Western Pebble-mound Mouse	664911	7437248	Opportunistic	Inactive mound
Western Pebble-mound Mouse	690846	7442070	Opportunistic	Inactive mound
Birds				
Fork-tailed Swift	666240	7436475	GWA S7	Large flock of 400 individuals
Fork-tailed Swift	666240	7436475	GWA S7	40 individuals
Fork-tailed Swift	687325	7432923	GWA S3	10 individuals
Fork-tailed Swift	690270	7434157	GWA S4	70 individuals
Fork-tailed Swift	678869	7433283	Opportunistic	Eight individuals
Fork-tailed Swift	673382	7440840	Opportunistic	15 individuals
Fork-tailed Swift	687325	7432923	GWA S3	10 individuals
Australian Bustard	683491	7441236	Opportunistic	1 individual
Australian Bustard	673255	7440353	Opportunistic	1 individual
Australian Bustard	671862	7439462	Opportunistic	1 individual
Bush Stone-curlew	687166	7433154	GWA S3	Tracks only
Reptiles				
Underwoodisaurus seorsus	690650	7441655	GWA S1	One individual captured

Zone 50K;

Datum WGS 84

*Individuals = animals seen at the same time and, therefore, numbers are confirmed. Records = may be separate bird surveys or different days at a trap site and, therefore, some individuals may have been observed multiple times.

4.5 INVERTEBRATE SHORT RANGE ENDEMIC FAUNA RECORDED

A total of 33 species from six different Orders were submitted for identification and for SRE status assessment. A total of 15 species were identified as potential SRE species. The results and SRE status of submitted specimens are summarised in Table 4.5, with the location of potential SRE species mapped in Figure 4.16.

The results of potential SRE specimens submitted comprised the following: four species from two families of spiders (two potential SRE), six species from two families of scorpions (one potential SRE), 10 species from two families of isopods (six potential SRE), five species from three families of snails (no SRE), five species from one family of pseudoscorpions (four potential SRE) and three species from three families of millipedes and centipedes (two potential SRE).

Table 4.5 – SRE fauna results

Higher Taxon	Species	SRE status	Individuals (M/F/J)*	Method	Site^
Mygalomorphae (trapdoor spiders)					
Barychelidae	*Aurecocrypta* sp. indet.	Potential	0/0/1	Opportunistic capture	GWA S11
	Synothele 'MYG127'	Not SRE	1/0/0	Dry pitfall	GWA S2
Nemesiidae	*Aname mellosa*	Not SRE	2/0/0	Dry pitfall	GWA S10
	Yilgarnia 'MYG197'	Potential	1/0/0	Dry pitfall	GWA S7
Scorpiones (scorpions)					
Buthidae	*Lychas* sp. 'harveyi'	Not SRE	7/1/0	Dry pitfall	GWA S3, S4 ,S5, S10, S11, S12
	Lychas sp. 'pilbara1'	Not SRE	15/1/1	Dry pitfall	GWA S1, S2, S4, S5, S9
	Lychas bituberculatus	Not SRE	0/2/0	Dry pitfall	GWA S7
	Lychas sp. 'hairy tail'	Not SRE	1/0/0	Dry pitfall	GWA S2
	Isometroides 'pilbara1'	Not SRE	1/0/0	Dry pitfall	GWA S8
Urodacidae	*Urodacus* sp. indet.	Potential	0/0/10	Targeted dry pitfall	GWA Opp, S3
Isopoda (Isopods)					
Armadillidae	*Buddelundia* sp. nov. '10 1458A'	Potential	33/35/2	Dry pitfall	GWA S1, S2, S3, S4, S5, S6, S7, S9, S10, S12
	Buddelundia sp. nov. '10 1458B'	Potential	5/4/0	Dry pitfall	GWA S1, S5, S10, S11
	Buddelundia sp. nov. '10 1458C'	Potential	0/1/0	Dry pitfall	GWA S1
	Buddelundia sp. nov. '10 1458D'	Potential	3/1/0	Dry pitfall	GWA S2
	Buddelundia sp. nov. '15'	Not SRE	2/1/0	Dry pitfall	GWA S3, S4, S7
	Buddelundia sp. nov. '16'	Not SRE	5/7/2	Dry pitfall, forage	GWA S1, S2, S6, S7, Opp
	Buddelundia sp. nov. '68WA'	Potential	1/1/0	Dry pitfall, forage	GWA S5, FS1
	Buddelundinae genus ident. Buddelundinae 'PES999'	Not SRE	1/5/0	Dry pitfall	GWA FS4, S4, S6
	New genus. (close to *Buddelundia*) sp. nov. '1'	Not SRE	1/3/0	Dry pitfall	GWA S5, S8, S10

Higher Taxon	Species	SRE status	Individuals (M/F/J)*	Method	Site^
Unknown	Genus indet. sp. indet.	Potential	1/0/0	Dry pitfall	GWA S5
Molluscs (Snails)					
Bothriembryontidae	*Bothriembryon* sp. nov. 'Pilbara'	Not SRE	4	Leaf litter	GWA FS4
Pupilidae	*Gastrocopta mussoni*	Not SRE	12	Leaf litter	GWA FS3, FS4
	Gastrocopta cf. *hedleyi*	Not SRE	12	Leaf litter	GWA S1
	Pupoides cf. *pacificus*	Not SRE	11	Leaf litter	GWA FS4, S9, S12
Subulinidae	*Eremopeas interioris*	Not SRE	15	Leaf litter	GWA S1, S2
Pseudoscorpiones (Pseudoscorpions)					
Olpiidae	*Beierolpium* sp. indet.	Potential	0/0/1	Leaf litter	GWA S1
	Euryolpium sp. indet.	Potential	0/0/1	Leaf litter	GWA S3
	Indolpium sp. indet.	Unlikely	1/0/0	Leaf litter	GWA S11
	Xenolpium sp. indet.	Potential	5/4/1	Dry pitfall, Leaf litter	GWA S1, S2, S5, S7, S9, S11, FS4
	Genus indet. sp. indet.	Potential	0/0/3	Dry pitfall, forage	GWA Opp, S1, S6
Diplopoda (Millipedes and centipedes)					
Trigoniulidae	*Austrostrophus stictopygus*	Not SRE	3/3/3	Forage	GWA Opp, S2
Geophilidae	Genus ident. sp. indet.	Potential	0/0/1	Forage	GWA S2
Chilenophilidae	Genus ident. sp. indet.	Potential	0/0/1	Forage	GWA S2

*M=Male, F=Female, J=Juvenile

^Site FS = Forage Site

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665000 670000 675000 680000 685000 690000 695000

7440000 7435000 7430000 7425000

Deposit I
Deposit C
Deposit D
Deposit G
Deposit B
Deposit H
Deposit A
Deposit E
Deposit F
Mt Ella
Mt Ella

Legend

- Pilbara Leaf-nosed Bat
- Western Pebble-mound Mouse (Active mound)
- Western Pebble-mound Mouse (Inactive mound)
- Fork-tailed Swift
- Australian Bustard
- Bush Stone-curlew (tracks)
- *Underwoodisaurus seorsus*
- Deposit area
- Study area

N

0 2 4

Kilometres

Absolute Scale - 1:90,000

ecologia ENVIRONMENT

Conservation significant fauna recorded

Figure: 4.15
Project ID: 1458

Drawn: BG
Date: 24/9/2013

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

Unique Map ID: BG306

A3

655000 660000 665000 670000 675000 680000 685000 690000 695000

7445000 7440000 7435000 7430000 7425000

Deposit I

Deposit B

Deposit H

Deposit C

Deposit G

Deposit D

Mt Ella

Deposit A

Deposit E

Deposit F

Legend

Species

- *Aurecocrypta* sp. indet.
- *Beierolpium* sp. indet.
- *Buddelundia* sp. nov. '10 1458A'
- *Buddelundia* sp. nov. '10 1458B'
- *Buddelundia* sp. nov. '10 1458C'
- *Buddelundia* sp. nov. '10 1458D'
- *Buddelundia* sp. nov. '68WA'
- Chilenophilidae genus indet. sp. indet.
- *Euryolpium* sp. indet.
- Geophilidae genus indet. sp. indet.
- Isopod genus indet. sp. indet.
- Olpiidae genus indet. sp. indet.
- *Urodacus* sp. indet.
- *Xenolpium* sp. indet.
- *Yilgarnia* 'MYG197'
- Deposit area
- Study area

N

0 2.5 5

Kilometres

Absolute Scale - 1:107,000

ecologia ENVIRONMENT

Potential SRE fauna recorded

Figure: 4.16
Project ID: 1458

Drawn: BG
Date: 24/9/2013

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

Unique Map ID: BG305

A3

5 DISCUSSION

5.1 BROAD-SCALE HABITATS

5.1.1 EPBC listed species habitat

Habitat types were assessed for their suitability for EPBC Act listed conservation significant fauna that were recorded or assessed as medium or high likelihood of occurrence within the study area (Northern Quoll, Pilbara Leaf-nosed Bat, Fork-tailed Swift, Rainbow Bee-eater and Pilbara Olive Python). Detailed descriptions of the suitability of potential habitats identified for each species within the study area and the extent of these within the study area are summarised in Table 5.1 below.

Table 5.1 – Summary of potential habitats for EPBC Act listed fauna within the study area

Species	Fauna Habitat	Area inside study area (ha)	Percentage of Total study area (%)
Northern Quoll	**Potential denning habitat**. Areas of rocky gorges and gullies in the study area that may contain suitable den sites, preferably near a water source (Oakwood 2002).	1.70	0.97
	Foraging/dispersal habitat. Well-vegetated and/or rocky areas used for foraging/hunting, often associated with a creekline or river system, as well as habitat traversed by the species when moving from potential denning areas to suitable foraging areas and when seeking mates during the breeding season (Oakwood 2000) (includes footslopes and plains).	63.46	36.13
Pilbara Leaf-nosed Bat	**Potential roosting/breeding habitat**. Areas of rocky gorges and gullies in the study area that may contain suitable caves for roosting (Armstrong 2001).	1.70	0.97
	Foraging habitat. Habitat over which the species may fly while foraging, preferably well-vegetated areas, often associated with water and open valleys, which attract a higher number of insects (Armstrong 2008).	80.88	46.05
Fork-tailed Swift	**Potential nesting habitat**. This migratory species only breeds in north-east and mid-east Asia, and spends the winter in Australia (Johnstone and Storr 1998). Hence no nesting habitat can be impacted upon.	0	0
	Foraging habitat. This species is completely aerial while in Australia (Johnstone and Storr 1998), so does not directly utilise land or habitats. However, landform features such as valleys can have concentrations of aerial insects, which in turn attract this species.	175.65	100
Rainbow Bee-eater	**Potential nesting habitat**. The Rainbow Bee-eater nests in burrows usually dug at a slight angle on flat ground, sandy banks or cuttings (Boland 2004), with this habitat commonly found within major drainages.	0.51	0.29

	Foraging habitat. The Rainbow Bee-eater forages in a wide variety of habitats. Generally closely associated to major drainages or areas of woodland habitat (Boland 2004).	2.21	1.26
Pilbara Olive Python	**Potential critical habitat**. Areas that may contain escarpments, gorges, preferably with rock crevices and outcrops near water holes, which attract prey species (Pearson 2003).	1.70	0.97

5.1.2 Footslope and plain

The mammal species of the footslopes and plains comprise a variety of generalists such as the Little Red Kaluta (*Dasykaluta rosamondae*), Pilbara Ningaui (*Ningaui timealeyi*), Planigale (*Planigale* sp.) and Euro (*Macropus robustus*).

The avifauna of this habitat type is relatively poor due to the low density of the tree and shrub layer. Bird species that can be found in this habitat include generalists such as Zebra Finch, Painted Finch, Diamond Dove, Little Button-Quail and Spinifex Pigeon. Footslopes and plains can also include patches of moderately dense to dense shrubs that can attract a moderate number of bird species such as Singing Honeyeater, Masked Woodswallow, Black-faced Woodswallow, and Variegated Fairy-wren. Birds of prey utilise the open vegetation for hunting and Brown Falcons, Spotted Harriers and Whistling Kite can often be seen foraging above the spinifex plains.

The herpetofauna of the foothills and plains comprises a range of generalists that find shelter and shade under spinifex clumps, as the usually hard soil and rocks do not allow the construction of burrows. These include the skink *Lerista verhmens*, Rock Ctenotus (*Ctenotus saxatilis*), Leopard Ctenotus (*Ctenotus pantherinus*), Ring-tailed Dragon (*Ctenophorus caudicinctus*), Spiny-tailed Monitor (*Varanus acanthurus*), Pilbara Death Adder (*Acanthophis wellsi*), Moon Snake (*Furina ornata*), the legless lizard *Delma nasuta* and Central Blue-tongue Lizard (*Tiliqua multifasciata*).

The SRE invertebrate species inhabiting footslope and plain usually comprise mygalomorph (trapdoor) spiders (particularly from the families Idiopidae, Nemesiidae, Barychelidae and Dipluridae), scorpions, pseudoscorpions and isopods. Most SRE invertebrates prefer the southern footslopes where sun exposure is reduced and the level of moisture under shrubs and trees is increased (Main 1996; Main 1999). Some spiders from the family Idiopidae build their burrows on the flood plain, sealing their burrows at times of inundation.

Footslopes and plains were assessed as comprising suitable foraging habitat for the EPBC Act listed Pilbara Leaf-nosed Bat. Footslopes and plains are also preferred habitat for two other species of conservation significance: the Western Pebble-mound Mouse and the Australian Bustard, the latter of which is generally restricted to the plains and rarely occurs along the footslopes.

5.1.3 Hilltop, hillslope, ridge and cliff

The mammals of this habitat type typically comprise the Common Rock-rat (*Zyzomys argurus*), Woolley's False Antechinus (*Pseudantechinus woolleyae*), and Rothschild's Rock-Wallaby (*Petrogale rothschildi*). These species shelter in caves and crevices. The cliff faces of this habitat type also support cave structures that provide roosting habitat for a variety of bat species.

The avifauna of the hilltops, hillslopes, ridges and cliffs is of low variety and can includes a number of generalists such as the Painted Finch and the Spinifexbird and some specialised bird species such as the Striated Grasswren and Rufous-crowned Emu-wren. Cliffs can be inhabited by the Southern Boobook, which will utilise overhangs and caves for nesting. However, this habitat type generally

consists of open vegetation with limited dense vegetation cover from shrubs or trees and therefore birds inhabiting this habitat type typically live within or between the spinifex clumps.

The herpetofauna of this habitat type can vary between the four individual habitat subtypes that make up this habitat type. These are divided into the hilltops habitat subtype, the hillslopes habitat subtype, ridges habitat subtype, and cliffs habitat subtype. Species typically inhabiting the hilltops habitat subtype include generalists such as the Fat-tailed Gecko (*Diplodactylus conspicillatus*) and the geckos *Lucasium wombeyi* and *Heteronotia binoei*. The herpetofauna of the hillslopes habitat subtype and ridges habitat subtype usually comprises the skinks *Ctenotus saxatilis* and *C. rutilans*. The cliff habitat subtype is a fauna habitat that is typically inhabited by specialised reptile species such as the Pilbara Rock Monitor (*Varanus pilbarensis*), the Pygmy Python (*Antaresia perthensis*) and the Desert Cave Gecko (*Heteronotia spelea)*.

Regarding the SRE invertebrate fauna, hilltops, hillslopes, ridges and cliffs habitat type often lacks the microhabitats suitable for this fauna due to their exposed nature, often coupled with reduced layer of soil and leaflitter. However, isopods, pseudoscorpions and some mygalomorph spiders from the family Dipluridae may be found in this habitat type.

In addition, the hilltops, hillslopes, ridges and cliffs habitat type is of medium value for the *EPBC Act* listed Northern Quoll (foraging/dispersal habitat). This habitat type provides some suitable habitat for shelter and foraging, but also supports the conservation significant Pilbara Barking Gecko (*Underwoodisaurus seorsus*). Cliff faces can also provide suitable breeding habitat for the Peregrine Falcon (WC Act Schedule 4) and the Grey Falcon (WC Act Schedule 1).

5.1.4 Mixed Acacia woodland

The mammal species inhabiting mixed acacia woodlands include generalists and the patches of this habitat type recorded in the study area were of relatively large size. The Pilbara Ningaui, Planigale, and Euro are all common inhabitants of the mixed acacia woodlands habitat type.

The avifauna of the acacia woodland is usually most diverse after significant rainfall, and when acacia shrubs and trees are flowering. In particular, honeyeater species such as the Singing Honeyeater, Grey-headed Honeyeater and Crimson Chat were recorded and, in good conditions, Black-chinned and White-fronted Honeyeater can be common. Other species also occurred, including Crested Bellbird, Red-capped Robin, Grey-crowned Babbler, White-winged Triller, Chestnut-rumped Thornbill and Willie Wagtail. The presence of some of these species, such as Crested Bellbird, Grey-crowned Babbler, and Chestnut-rumped Thornbill, is less dependent on rainfall and flowering events, as they are more sedentary than species like Black-chinned and White-fronted Honeyeaters.

The herpetofauna of the mixed acacia woodland typically comprises mainly generalists, with species occurring along the foothills and plains such as the Tree Dtella (*Gehyra variegata*), the Spiny-tailed Geckos *Strophurus strophurus* and *S. wellingtonae*, and the skink *Menetia greyii*.

Some mygalomorph spiders are known to adapt to mixed Acacia shrublands, creating burrows beneath the shrubs, utilising their leaves and twigs to create elaborate trap door lids (family Idiopidae) or cryptic open burrows (family Nemessiidae) (Main 1985). Isopods often inhabit the leaflitter below the shrubs and trees and millipedes can be found in decaying logs.

Acacia woodland is known to provide a suitable habitat for the EPBC listed mygalomorph spider *Idiosoma* nigrum (Approved Conservation Advice for *Idiosoma nigrum* (shield-back spider), 2013), however the likelihood of the species occurring in the study area is low as the species is currently known to occur only in the Midwest and Wheatbelt regions.

5.1.5 Mesa top

The mammal diversity of the mesa is relatively poor due to the elevation and therefore the isolation from accessible surrounding habitats. However, mammal species that occupy the cliff faces and ridges can also occur on top of the mesas. These species include the Rothschild's Rock-wallaby, the Common Rock-rat and the Planigale. The two sites established on the mesa tops within the study area were located in an easily accessible section and therefore generalists such as the Little Red Kaluta, Pilbara Ningaui, Stripe-faced Dunnart, Ooldea Dunnart, Delicate Mouse, Desert Mouse and Sandy Inland Mouse were recorded.

The avifauna of the mesa top habitat shows a combination of species recorded in other habitat types. Typical woodland bird species, which are generally not recorded in hilly, rocky areas, were recorded in this habitat type, due to patches of dense woodland, in particular mulga (*A. aneura* complex), being present. Such bird species include the Tawny Frogmouth, Western Gerygone, Inland Thornbill, White-fronted Honeyeater, Spiny-cheeked Honeyeater and the Red-capped Robin.

The herpetofauna that can be found on mesa tops includes some generalists (*Gehyra variegata, Ctenotus pantherinus, C. helenae* and *C. saxatilis*). In addition, some specialists were found on the mesa top with dense shrubs such as the Pilbara Barking Gecko (*Underwoodisaurus seorsus*), the skink *Lerista zietz*i and the Southern Pilbara Beak-faced Gecko (*Diplodactylus savagei).*

Unlike the vertebrate fauna, the invertebrate fauna of mesa tops can be quite diverse and specialised. Many species with limited mobility can become "stranded" in this habitat type over time as the geological substrate around erodes. This is subsequently enhanced by the isolation of the mesa top elevation above the surrounding plain, presenting a potentially significant barrier to gene flow and thus enhancing processes of speciation by vicariance (Mayr 1942, 1959). If the mesa top habitat type contains suitable microhabitats (e.g. woodland with deep soil and litter beds, as in the study area) a number of groups can be expected to occur there. All groups of potential SRE invertebrates collected during the survey (mygalomorph spiders, scorpions, pseudoscorpions, isopods, diplopods and snails) were represented at least by one species in this habitat type.

Conservation significant species that are likely to occur on the mesa top include Long-tailed Dunnart (*Sminthopsis longicaudata*), Pilbara Barking Gecko and Western Pebble-mound Mouse.

5.1.6 Cracking clay

The cracking clay within the study area supported a relatively large number of Stripe-faced Dunnarts (*Sminthopsis macroura*) but also provided habitat for the Sandy Inland Mouse. The Common Rock-rat (*Zyzomys argurus*) was also recorded from this habitat type, which can be considered very unusual.

The avifauna of the cracking clay habitat is typically extremely sparse. The lack of shelter and cover in the form of shrubs and trees does not attract many bush bird species. However, some ground dwelling birds, such as the Crested Pigeon, Common Bronzewing, and some seed eaters, such as the Budgerigar, the Zebra Finch and the Painted Finch, were recorded feeding on seeding grass species. This, combined with the lack of shelter, attracts birds of prey such as the Whistling Kite and Spotted Harrier, which were recorded hunting on these plains. The Horsefields Bushlark was the only bird species recorded only within this habitat, which it is typically found in.

The herpetofauna of the cracking clay typically comprises ground dwelling species such as the Fat-tailed Gecko (*Diplodactylus conspicillatus*) and *Nephrurus wheeleri*. The Pebble Dragon (*Tympanocryptis cephalus*) is usually restricted to cracking clay, which was confirmed by the results of this survey.

The invertebrate fauna of cracking clay habitat is usually very sparse due to lack of moist microhabitats, with the exception of soil-dwelling species adapted to prolonged periods of hydration

and drought (e.g. some mygalomorph spiders from families Barychelidae and Idiopidae). While no spiders have been collected within this habitat type during the survey, a scorpion from the genus *Isometroides* has been recorded here. As this scorpion is a specialised predator of mygalomorph spiders and often takes shelter in the spider burrow following predation of the resident spider (Main 1956), the presence of mygalomorphs in this habitat type is implied. Isopods have also been recorded in this habitat type, which is somewhat surprising.

One species of conservation significance is strongly associated with the cracking clay habitat: the Northern Short-tailed Mouse, however, it was not recorded during the current assessment. The Australian Bustard can also be found in this open habitat type but is expected to not reside there due to the lack of shelter and cover.

5.1.7 Major gorge and gully

The mammals inhabiting major gorges and gullies include rock dwelling specialists such as Woolley's False Antechinus (*Pseudantechinus woolleyae*), Rothschild's Rock-wallaby (*Petrogale rothschildi*) and Common Rock-rat (*Pseudomys argurus*).

The avifauna of the gullies and gorges is relatively poor compared to other habitat types due to the sparse shrub and grass vegetation and the usually low number of flowering trees and shrubs. However, Grey Shrike-thrush, Western Bowerbird, Grey-headed Honeyeater, Black-faced Cuckoo-Shrike and Painted Finch can all be observed in large trees or near waterholes along gullies and gorges, in particular when water is present. Gorges and rocky areas are also favoured habitat for Little Woodswallows.

The typical herpetofauna of gorges and gullies includes unique species that are specialised for inhabiting this fauna habitat type. Reptile species include the Pilbara endemic skink *Egernia pilbarensis*, the skink *Egernia formosa*, Pilbara Rock Monitor (*Varanus pilbarensis*) and Russet Snake-eyed Skink (*Cryptoblepharus ustulatus*). In addition to reptiles, a few species of amphibian can be found in gorges in the Hamersley region. Microhabitats with moist soil, such as those found under logs, rocks and leaf litter in rocky gullies and gorges are suitable for the Gorge Toadlet (*Pseudophryne douglasi*).

Gorges and gullies are particularly suitable for invertebrate fauna as this habitat type often supports a high level of moisture and humidity. Millipedes, snails, pseudoscorpions and isopods can be found sheltering under rocks or in leaf litter while scorpions and mygalomorph spiders often inhabit areas with accumulated soil.

Gorges and gullies represent suitable, good quality habitat for three mammal species of conservation significance: the Northern Quoll (*Dasyurus hallucatus*), the Pilbara Leaf-nosed Bat (*Rhinonicteris aurantia*) and the Long-tailed Dunnart (*Sminthopsis longicaudata*). These species shelter in crevices and caves, and prey on the large number of insects found in gorge and gully areas. The blind snake *Ramphotyphlops ganei* is known to occur in rocky gullies. Gorges that contain water pools after rainfall events provide suitable conditions for the Pilbara Olive Python (*Liasis olivaceus barroni*).

5.1.8 Major drainage

Major drainage systems provide habitat for a large number of species. The mammals of this habitat include species that also occupy other habitats identified within the study area, such as Pilbara Ningaui, Planigale, Sandy Inland Mouse and Desert Mouse. In addition, the fauna assemblage of the major drainage system can also comprise more specialised species such as the Northern Brush-tailed Possum (*Trichosurus vulpecula arnhemensis*).

The herpetofauna of major drainage system typically includes generalists such as the skinks *Carlia munda*, *Ctenotus pantherinus* and *C. helenae*, as well as more specialised species such as the Long-nosed Dragon (*Amphibolurus longirostris*), which is almost restricted to this habitat type.

Major drainage systems provide suitable habitat for a variety of bird species that can be found in large numbers and variety due to the number of trees and density of the vegetation providing optimal food and shelter. Bird species typically found only along major creeklines include the White-plumed Honeyeater, Sacred Kingfisher, Little Corella, and Cockatiel.

The fringes of the major drainage systems are known to support a number of SRE invertebrate species because they provide an increased level of moisture seeping in from the main water course and shade from large trees associated with river banks. Mygalomorph spiders from families Ctenizidae, Idiopidae and Nemesiidae are typically found in this type of habitat, as well as snails (including fresh-water species from the genus *Gyraulus*), millipedes and isopods.

Species of conservation significance that are commonly found within major creeklines include the Bush Stone-curlew and the Rainbow Bee-eater. The Bush Stone-curlew hides in the vegetation and will forage along water pools and in the surrounding areas. The Rainbow Bee-eater is an inhabitant of the trees and larger shrubs and sometimes builds its nests in the sand banks.The major drainage systems were assessed as comprising potential foraging/dispersal habitat for Northern Quoll, foraging habitat for Pilbara Leaf-nosed Bat and potential critical habitat for the Pilbara Olive Python. Northern Quoll can use this habitat type seasonally, during the breeding season, for dispersal using suitable tree hollows as temporary denning sites.

5.1.9 Mulga woodland

The mammal assemblage of the Mulga woodland habitat type is not distinctly dissimilar to assemblages in the surrounding habitat types. Generalists were recorded such as the Pilbara Ningaui, Stripe-faced Dunnart, Ooldea Dunnart and Sandy Inland Mouse.

Avifauna assemblage within this habitat type, despite being only small in area, was distinctly different, with abundance and diversity generally higher than other habitat types. This is thought to be due to the dense woodland structure of this habitat type. Bird species recorded exclusively within this habitat type included the Brown Quail, Bush Stone-curlew, Splendid Fairy-wren, Chestnut-rumped Thornbill and Grey Honey eater. Species such as the White-browed Babbler, Red-capped Robin, Spiny-cheeked Honeyeater, Inland Thornbill, Western Gerygone and Budgerigar are species also typical of the Mulga woodland and were recorded from this habitat type during the current survey.

Reptile species that are typically unique to mulga woodlands include the two monitor lizards *Varanus bushi* and, *V. caudolineatus*, and the Mulga Dragon (*Caimanops amphiboluroides*). Of these, one species, *Varanus bushi*, was observed during the survey however there was no reptile species that was exclusively recorded from this habitat type.

Mulga woodland provides suitable habitat for many SRE invertebrates. Some mygalomorph spiders are known to adapt to this habitat, creating burrows beneath the shrubs, utilising their leaves and twigs to create elaborate trap door lids (family Idiopidae) or cryptic open burrows (family Nemessiidae) (Main 1985). Scorpions build their burrows in patches of soft soil and pseudoscorpions and isopods often inhabit the leaflitter below the shrubs and trees while millipedes can be found in decaying logs. Many individuals of the scorpion *Urodacus* sp. indet. were recorded in this habitat type. The softer, upper soil substrate allowed this species to dig their spiralling burrows, where they shelter during the day.

5.1.10 Cleared area

No fauna assemblage can be described for cleared areas as they are not a distinct habitat type. Some fauna species that occur in habitats surrounding the cleared areas can utilise theses spaces for foraging however the lack of vegetation cover makes them susceptible to predation. At night, nocturnal bird of prey can be seen foraging, such as the Spotted Nightjar, Owlet Nightjar and Bush Stone-curlew. Diurnal birds of prey also use these areas, hunting the open grounds for small skinks, snakes or the occasional mammal.

5.2 VERTEBRATE FAUNA ASSEMBLAGE

5.2.1 Mammals

A total of 25 mammal species were recorded during the current survey, from a potential 47 species identified from the literature review. When compared against previous surveys of the region (Appendix E), it can be seen that this survey recorded the highest number of mammal species, with the next highest being 18 species (Ninox 2009b).

Abundance of the mammal species recorded was generally regarded as moderate. Excluding bat species, the most numerous recorded species were the small rodents; Sandy Inland Mouse (73 records), Common Rock-rat (52 records), the introduced House Mouse (41 records) and small dasyurids; Stripe-faced Dunnart (35 records), Pilbara Ningaui (35 records) and Little Red Kaluta (34 records). The activity levels of the majority of bat species were recorded as low, with high activity levels recorded for Finlayson's Cave Bat GWA S3, S5 and S11 and Gould's Wattled Bat at GWA S2 (Appendix F).

Most mammal species recorded are regarded as habitat generalists. The exceptions being Rothschild's Rock Wallaby, which is typically restricted to rocky habitats (recorded opportunistically within major gorge and gully habitat type) and the Western Pebble-mound Mouse (recorded by secondary evidence only, within footslope or plain habitat type). This is reflected within the MDS plot (Figure 4.10) for terrestrial trappable fauna (which includes small mammals), which shows no obvious visual differentiation between fauna trapped and corresponding habitat types.

A total of seven Dingo individuals were recorded (three on phase 1, four on phase two, Appendix F). Visually it appeared these individuals were consistent with normal dingo (*Canis lupus dingo*) morphology, indicating little interbreeding with the domestic dog (*Canis lupus familiaris*), with one individual recorded on Phase 2 being the uncommon black colour variation.

Conservation significant mammal species recorded included the Western Pebble-mound Mouse (DEC P4), recorded by secondary evidence (pebble mounds) only, and the Pilbara Leaf-nosed Bat (EPBC VU, WC Act S1 and DEC VU). The recording of the Pilbara Leaf-nosed Bat is of note, as this species has not been recorded on any previous surveys of the region, with the literature review recording this species from database searches only (Appendix E).

Of interest was no records of the conservation significant Ghost Bat (DEC P4). This is despite the Ghost Bat being known to be present within the study area, with a number of roost caves in close proximity (further discussed in Section 5.3.1.3). Churchill (2008) notes the Ghost Bat does not exclusively hunt using echolocation, but also hunts by eyesight and passive listening. As a result this species is difficult to record using standard ultrasonic recording devices.

Habitats were generally assessed as in good condition with little degradation from introduced fauna such as cattle. Of the nine potential introduced mammal species, just two were recorded, the House Mouse (41 records) and European Rabbit (eight records).

The SAC completed for trappable mammal species indicates the majority of trappable mammals were recorded (Section 5.6).

5.2.2 Birds

In total, 80 species of bird were recorded from the study area. This is the highest total when compared to previous surveys of the region, with the next highest being 69 (Ninox 1994). The high diversity is likely a result of relatively large study area, large variety of fauna habitats and two phases of surveying, with significant rainfall occurring between phases (Section 2.1).

The family Meliphagidae was the most diverse group recorded during this survey, with nine (out of a potential 12, Appendix E) species recorded. Included in the recorded honeyeaters was the rarely recorded Grey Honeyeater. Regarded as a mulga woodland habitat specialist, this species was recorded from site GWA S3 second phase only (Appendix F). The most abundantly recorded honeyeater species was the Singing Honeyeater, recorded a total of 288 times. The generalist nature of this species is indicated by the fact it was recorded at every systematic trapping site (Appendix F).

The recording of 10 of the potential 15 birds of prey (family Accipitridae and Falconidae, Appendix E) indicates good prey availability resulting from generally favourably climatic (predominately rainfall) conditions and high food resources. This is supported by high counts of irruptive birds such as the Budgerigar (1,010 records) and Zebra Finch (840 records). The recording of the Fork-tailed Swift in high numbers (533 records) is a result of favourable weather conditions for this species experienced during Phase 2. Notable thunderstorm activity occurred resulting in the Fork-tailed Swift being present in high numbers, including one very large flock of 400 individuals recorded at one time from GWA S7 (Appendix F).

A total of seven Brown Quail were recorded on phase 1 from GWA S3 (Appendix F), with the literature review revealing previous records from NatureMap only (Appendix E). The Brown Quail has only very recently been recorded from the Hamersley Pilbara subregion, with Johnstone and Storr (1998) describing the Brown Quail distribution as restricted to the Pilbara coast in the vicinity of Port Hedland. The NatureMap database shows there is just one record further south than the location of the study area (DPaW 2013).

The good condition of mulga woodland habitat in the vicinity of site GWA S3 is indicated by a number of mulga habitat specialist bird species recorded at this site. Splendid Fairy-wren, Western Gerygone, Chestnut-rumped Thornbill, Inland Thornbill, Grey Honeyeater, White-browed Babbler and Red-capped Robin were all exclusively or predominately recorded from this site. The mulga woodland habitat type only occupies a very small proportion of the habitats within the study area (0.28%), but is significant in supporting the high diversity of avifauna recorded within the study area.

Bird species of conservation significance recorded within the study area were the Fork-tailed Swift (EPBC M, WC Act S3) Australian Bustard (DPaW P4) and Bush Stone-curlew (tracks only, DPaW P4).

The SAC completed for avifauna indicates the majority of avifauna potentially occurring within the study area was recorded (Section 5.6).

5.2.3 Herpetofauna

A total of 64 reptile species were recorded within the study area. When compared to previous surveys of the region, this is the highest number recorded, with the next highest being 41 (Ninox 2009b). This high diversity when compared to other surveys is likely due to a combination of factors, such as relatively large survey area, variety in habitat types and favourable weather (high temperatures) conditions.

Of particular note was the recording of the skink *Ctenotus robustus*. This species was recorded from within the cracking clay habitat type during Phase 2, with four individuals trapped at site GWA S8 only (Appendix F). As noted in Section 4.2.4, this record represents a range extension of approximately 120 km south for this species, based on records from NatureMap (DPaW 2013).

Other noteworthy records include the recording of the fossorial skinks *Lerista timida* and *Lerista verhmens*. These small skinks have not been previously recorded according to the literature review (Appendix E), however these species were previously regarded as *Lerista muelleri* until the species complex was revised in 2007 (Smith and Adams 2007). The literature review also did not record the Pilbara Bandy Bandy (*Vermicella snelli,* Appendix E), which had a single individual trapped at site GWA S11 during phase 1 (Appendix F). This species is endemic to the Pilbara region, but is rarely encountered due to being cryptic in nature, seldom foraging in open ground. Instead they are largely fossorial and spend the majority of their life cycle below ground hunting their main prey item, blind snakes (Wilson and Swan 2010).

High elapid (front fang venomous snakes) diversity was encountered during the current assessment, with a total of 10 of the potential 11 species recorded (Appendix E). Of this group, the Moon Snake was the most abundant, with a total of nine individuals recorded (Appendix F). In contrast, the other two snake families Typhlopidae (blind snakes) and Boidae (pythons) were poorly represented, with zero out of five and one out of four species recorded respectively (Appendix E).

No amphibian species were recorded from the survey. The literature review revealed a total of eight species potentially occurring within the study area (Appendix E). Some burrowing frog species may be present within the study area (for example *Cyclorana maini*), however a lack of significant rain immediately prior and during surveying resulted in these species remain under ground and undetectable.

The SAC completed for reptile species indicates the majority of trappable reptiles were recorded (Section 5.6).

5.3 CONSERVATION SIGNIFICANT VERTEBRATE FAUNA

Based on the literature review, six mammal, 12 bird and three reptile species of conservation significance could potentially occur in the study area. Conservation significant vertebrate fauna that were recorded or assessed as high to medium likelihood of occurrence (section 4.3) are described in detail below.

5.3.1 Mammals

5.3.1.1 Northern Quoll (*Dasyurus hallucatus*)

Conservation Status: EPBC Act Endangered, WC Act Schedule 1 (Endangered).

Distribution and Habitat: The Northern Quoll formerly occurred across northern Australia, from the Pilbara region in Western Australia to south-eastern Queensland. A 75% reduction of available habitat occurred during the 20th century, so that the species is now restricted to the Pilbara and northern Kimberley in Western Australia, and a few discrete populations across the Northern Territory and eastern Queensland (Braithwaite and Griffiths 1994). Northern Quolls are most common on dissected rocky escarpments, but are also found in eucalypt forest and woodland (Oakwood 2008). They are both arboreal and terrestrial and use a variety of den sites, including rock crevices, tree hollows, logs, termite mounds, house roofs and goanna burrows (Oakwood 2000, 2008).

Ecology: Northern Quolls are the smallest of the Australian quolls. Northern Quolls are nocturnal and opportunistic omnivores feeding primarily on small vertebrates, large insects and soft fruits. Breeding tends to occur near creeklines, where individuals go to drink when water is available (Oakwood 2002).

The most common cause of adult mortality is predation by dingoes, feral cats, snakes, owls and kites (Maxwell *et al.* 1996; Oakwood 2008). Other causes of mortality include predation by domestic dogs,

motor vehicle strikes and pesticide poisoning. The level of predation is increased through the removal of groundcover by fire.

Likelihood of Occurrence: Medium. The Northern Quoll has been recorded three times from one location approximately 20 km north-east of study area in 2010 (DPaW 2013). These records are shown in Figure 4.14. The species was recorded from three more locations within 85 km of the study area, however the study area lies along the southern distribution limit of the Northern Quoll based on previous records (DPaW 2013). The major gorge and gully habitat represents suitable denning habitat for this species, within the micro-habitat of boulder piles and rock crevices. The hilltop, hillslope, ridge or cliff and major drainage system habitat types represent suitable foraging habitat, where Northern Quolls may occasionally occupy.

5.3.1.2 Pilbara Leaf-nosed Bat (*Rhinonicteris aurantia* (Pilbara form))

Conservation Status: EPBC Act Vulnerable, WC Act Schedule 1 (Vulnerable).

Distribution and Habitat: The Pilbara Leaf-nosed Bat is the Pilbara form of the Orange Leaf-nosed Bat (*Rhinonicteris aurantia*). While it is considered a separate form, formal reclassification has been hampered by the small sample size of the Pilbara population (Armstrong 2008).

Recent evidence suggests two main stronghold areas for the Pilbara Leaf-nosed Bat; in the western Pilbara and north of Marble Bar (Armstrong 2008). In the western Pilbara, they roost in caves formed in gorges that dissect siliceous sedimentary geology. They are most often observed in flight over waterholes in gorges, although they are rare even in the Hamersley Ranges where this habitat is common (Armstrong 2008). The Pilbara Leaf-nosed Bat roosts in disused mines and areas of high relief with gorges and watercourses (Armstrong 2001). They are unlikely to occur in the shallow 'breakaway' caves that occur along mesas and strike ridges.

Ecology: At dusk, Pilbara Leaf-nosed Bats emerge from their roosting sites to forage in gorges, small gullies and large watercourses for insects (van Dyck and Strahan 2008). They are susceptible to disturbance and will abandon roost caves if disturbed. Colonies in mines in the eastern Pilbara are subject to several pressures, including human visitation, and the collapse and flooding of disused mines (Armstrong 2008; DEWHA 2008b).

Likelihood of Occurrence: Recorded. The literature review indicates that this species has not been previously recorded within 30 km of the study area, with three previous records existing east and south of the study area (Appendix E, Figure 4.14). The study area is positioned further south then where this species has previously been regularly recorded, with just three previous records located south of these current records (DPaW 2013).

All records made indicate a foraging individual(s). The recording of four separate calls from site GWA S7 suggest potentially more than one individual present within the study area. The timing of calls in the middle of the night and a relatively low number of calls suggest the individual(s) have flown in to the study area from a roost location outside the study area. It is estimated that the Pilbara Leaf-nosed Bat has a maximum nightly foraging range of up to 10 km from their roost. This suggests a potential previously unknown roost site could be in relatively close proximity to the study area.

The Pilbara Leaf-nosed Bat is reliably detectable via echolocation call analysis, due to the high frequency of its call. The spectrogram showing the call frequency of the Pilbara Leaf-nosed Bat from GWA S7 is shown in Figure 5.1. This particular call had a peak frequency of 121,200 Hz, with all other potential microbat species of the Pilbara having a peak frequency ranging from a low of 11,400 Hz (White-striped Freetail Bat) to a high of 55,800 (Finlayson's Cave Bat) (McKenzie and Bullen 2009).

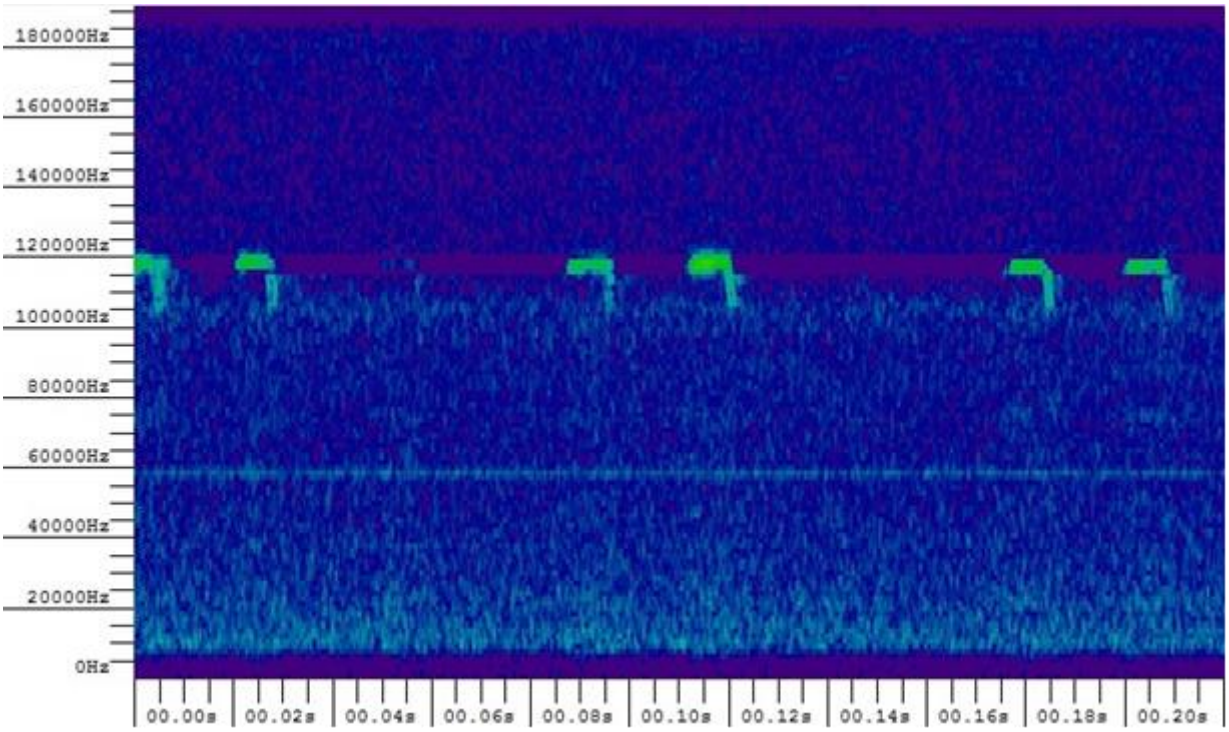


Figure 5.1 – Spectogram showing call frequency of Pilbara Leaf-nosed Bat recorded

5.3.1.3 Ghost Bat (*Macroderma gigas*)

Conservation Status: DEC Priority 4.

Distribution and Habitat: The Ghost Bat has a patchy but widespread distribution across northern Australia. Preferred roosting habitats in the Pilbara include caves beneath bluffs of low, rounded hills composed of Marra Mamba geology, and granite rock piles. Ghost Bats have also been known to roost in large colonies within sandstone caves, under boulder piles and in abandoned mines (Churchill 1998). Ghost Bats disperse widely during the non-breeding season but require warm caves with high relative humidity (80%) when rearing their young (Toop 1985). These maternity caves are uncommon with only eleven recorded in the Pilbara region (three natural caves and eight mines) (Armstrong and Anstee 2000b).

Ecology: The Ghost Bat is carnivorous and takes prey to an established feeding site to be eaten. These feeding sites are usually a rock overhang or small cave, and are easily recognised by the accumulation of discarded prey parts littering the floor (Richards *et al.* 2008). Foraging occurs in an area of approximately 60 ha, in a radius of approximately 2 km from the bats' roost (Tidemann *et al.* 1985).

Likelihood of Occurrence: High. Previous surveys completed by *ecologia* in 2001 and 2005 recorded a number of roost caves identified by Armstrong and Anstee (2000a) within and closeby to the the study area. The location and details of these caves are shown in Table 5.2 and mapped in Figure 5.2.

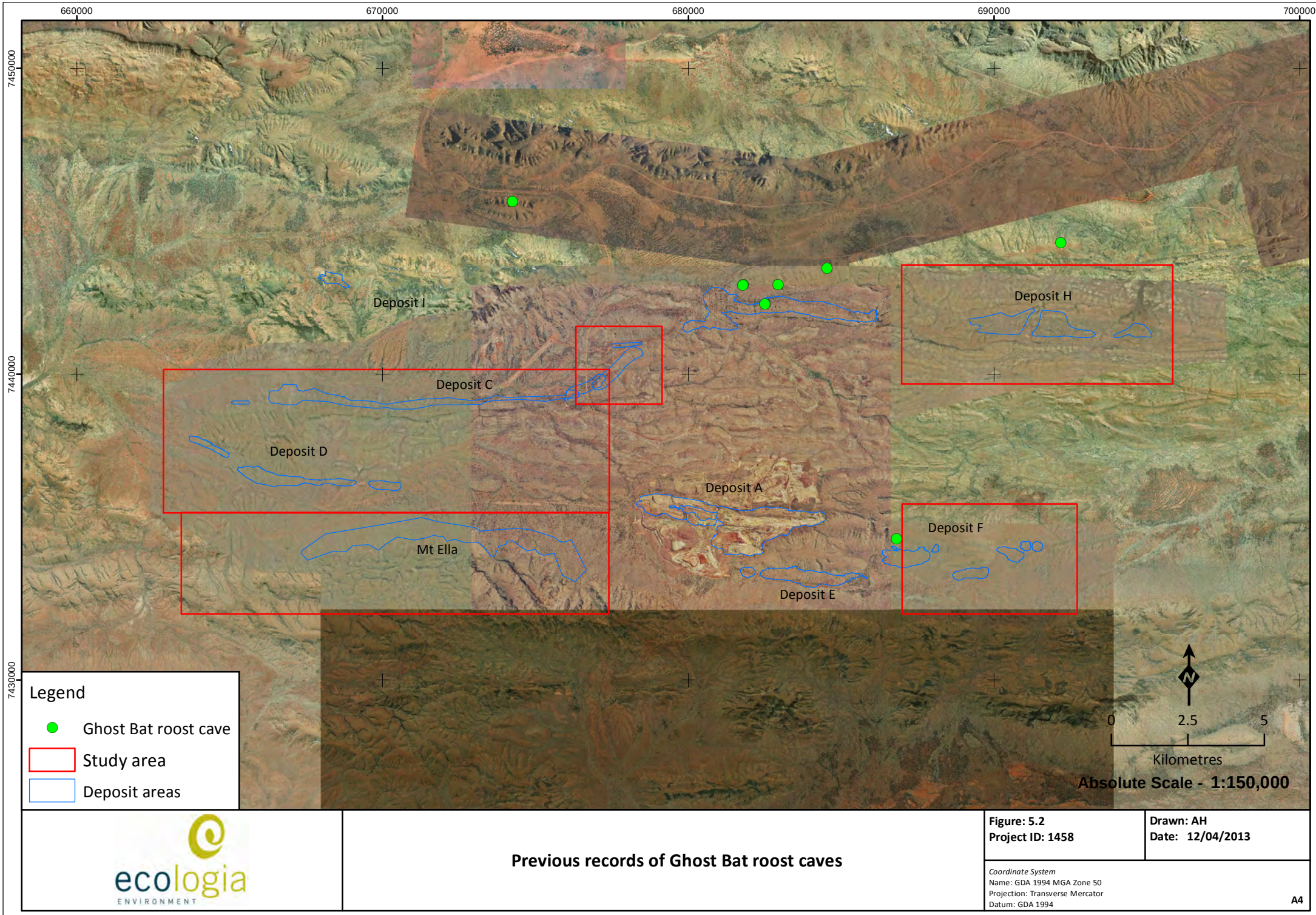
Table 5.2 – Previous Ghost Bat records

Cave name	Easting	Northing	Details
AA1	686812	7434617	Potential maternity cave (2001)
A1	681792	7442918	Signs of recent use (2001)
I1	684534	7443453	Signs of recent use (2001)

Cave name	Easting	Northing	Details
L2	682928	7442914	Signs of recent use (2001)
L3	681780	7442910	Signs of previous use but not recent (2001)
WA Adit	682500	7442300	Signs of previous use but not recent (2001)
AB1	674247	7445653	Signs of recent use (2001)
Cave 1	692183	7444296	Calls recorded close by but no evidence of activity (2005)

Despite the location of eight roost caves previously identified within close proximity to the study area, this species was not recorded. However, in order to avoid disturbance, previously known roost caves were not investigated on this current survey, with detection techniques restricted to call echolocation recordings using SM2BAT units. Churchill (2008) notes the Ghost Bat does not exclusively hunt using echolocation calls, but also hunts by eyesight and passive listening. As a result, the minimal use of echolocation when hunting reduces the likelihood of this species being record via the SM2BAT units.

Potential new roost caves were searched for within major gorge and gully and hilltop, hillslope, ridge and cliff habitat types, with no caves recorded, however, not all areas of potential habitat were searched, therefore roost caves could be present within the study area. Despite not being recorded on this survey, due to the previous records of this species it should be considered as present within the study area.



ecologia ENVIRONMENT

Previous records of Ghost Bat roost caves

Figure: 5.2
Project ID: 1458

Drawn: AH
Date: 12/04/2013

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

A4

5.3.1.4 Short-tailed Mouse (*Leggadina lakedownensis*)

Conservation Status: DEC Priority 4.

Distribution and Habitat: Populations of this small, secretive rodent are distributed across northern Australia, but records have been sporadic (Moro and Kutt 2008). They occupy a diverse range of habitats from the monsoon tropical coast to semiarid climates, including spinifex and tussock grasslands, samphire and sedgelands, acacia shrublands, tropical eucalypt and melaleuca woodlands and stony ranges. Most habitats, however, are seasonally inundated on red or white sandy-clay soils (Moro and Kutt 2008).

Ecology: The diet of the Short-tailed Mouse consists primarily of invertebrates, with plants supplementing their water requirements (Moro and Kutt 2008). Populations fluctuate greatly in response to rainfall, sometimes reaching plague proportions. The species is nocturnal and solitary, spending the day in simple, single-chambered burrows (Moro and Kutt 2008).

Likelihood of Occurrence: High. NatureMap lists three records from 1997 of which one record is located within the study area and the other two records are within 1 km of the study area (DPaW 2013). These specimens were lodged with WA Museum (M47672, M47673, M47777). The cracking clay habitat type represents ideal habitat for this species within the Pilbara region. The Short-tailed Mouse is regularly trapped using pitfall and Elliott traps, hence if a population was present within close proximity to site GWA S8 of at the time of surveying, it would be expected to record this species. The previous records of this species within the study area along with 2.42 km^2 of suitable habitat (cracking clay) suggest although not recorded on this survey, it is a high likelihood of occurrence.

5.3.1.5 Western Pebble-mound Mouse (*Pseudomys chapmani*)

Conservation Status: DEC Priority 4.

Distribution and Habitat: The Western Pebble-mound Mouse occurs across central and southern Pilbara and extends into the smaller ranges of the Little Sandy Desert (Start 2008). Abandoned mounds have been found in the Gascoyne and Murchison, indicating a recent decline in distribution. This decline is most likely attributable to foxes and exotic herbivores (Start 2008). However, the species appears relatively secure in its remaining range (Start 2008). The Western Pebble-mound Mouse inhabits gently sloping hills of rocky ranges where the ground is stony and vegetated by spinifex with a sparse overstorey of eucalypts and scattered shrubs of senna, acacia and *Ptilotus* spp.

Ecology: In suitable habitats, pebble mounds of this species can be found in large numbers, although not all of these mounds are active and occupied by Pebble-mound Mice at the same time. The demographic structure of the groups that inhabit the mounds and their patterns of movement around the mounds is still unknown (Anstee 1996; Anstee *et al.* 1997). Mounds can cover an area of 0.5 to 9.0 m^2, and a single mound can house up to 25 mice (Start 2008). Breeding occurs throughout the year with females producing several litters of four young per year (Start 2008).

Likelihood of Occurrence: Recorded. A total of 30 active and inactive mounds were recorded from within the study area (Table 4.4, Figure 4.15). The species has been recorded frequently in the surrounding region and during 12 previous surveys (Ninox 1994; HGM 1999a, DEC 2013, ecologia internal database, Ninox 2009a, 2009b, Biota 2010; 1999b; Maunsell 2003). Although not directly trapped, the presence of numerous active mounds (Figure 5.3) for this species indicate the Western Pebble-mound Mouse is present within the study area

Figure 5.3 – Active mound of Western Pebble-mound Mouse

5.3.2 Birds

5.3.2.1 Fork-tailed Swift (*Apus pacificus*)

Conservation Status: EPBC Act Migratory, WC Act Schedule 3.

Distribution and Habitat: The Fork-tailed Swift is a small, insectivorous species with a white throat and rump, and a deeply forked tail (Morcombe 2000). It is distributed from central Siberia and throughout Asia, breeding in north-east and mid-east Asia, and wintering in Australia and south New Guinea. It is a relatively common trans-equatorial migrant from October to April throughout mainland Australia (Simpson and Day 2004). In Western Australia the species begins to arrive in the Kimberley in late September, the Pilbara in November and the South-west by mid-December (Johnstone and Storr 1998). In Western Australia the Fork-tailed Swift is considered uncommon to moderately common near the north-west, west and south-east coasts, common in the Kimberley and rare or scarce elsewhere (Johnstone and Storr 1998).

Ecology: Fork-tailed Swifts are nomadic in response to broad-scale weather pattern changes. They are attracted to thunderstorms where they can be seen in flocks, occasionally of up to 2,000 birds. They rarely land, living almost exclusively in the air and feeding entirely on aerial insects, especially nuptial swarms of beetles, ants, termites and native bees (Simpson and Day 2004).

Likelihood of Occurrence: Recorded. Fork-tailed Swifts have previously been recorded in the region from the literature review and two databases (Appendix E). Seven separate observations were made of this species during the current assessment from five different locations (Table 4.4, Figure 4.15), totalling 553 records (Appendix F).

The large flock of 400 birds recorded from GWA S7 in conjunction with arriving thunderstorm cloud activity is of note, as this is a significant formation and consistent with the literature (Johnstone and Storr 1998). Following the arrival of this large flock, subsequent observations over the coming days consisted of smaller, looser flocks of birds foraging over the landscape. Although this species does not directly utilise habitats, observations were made of Fork-tailed Swifts flying at canopy level, activily hunting aerial insects following the rainfall on the proceeding days. The locations of these further observations were all in low lying habitats (mixed acacia woodland, footslope and plain) within the broad valley floor, suggesting although not directly utilising the habitats within the study area, landform features are still important for foraging activity of this species.

5.3.2.2 Rainbow Bee-eater (*Merops ornatus*)

Conservation Status: EPBC Act Migratory, WC Act Schedule 3.

Distribution and Habitat: The Rainbow Bee-eater is scarce to common throughout much of Western Australia, except for the arid interior, preferring lightly wooded, preferably sandy country near water (Johnstone and Storr 1998).

Ecology: In Western Australia the Rainbow Bee-eater can occur as a resident, breeding visitor, post-nuptial nomad, passage migrant or winter visitor. It nests in burrows usually dug at a slight angle on flat ground, sandy banks or cuttings, and often at the margins of roads or tracks (Simpson and Day 2004). Eggs are laid at the end of the metre-long tunnel from August to January (Boland 2004). Rainbow Bee-eaters are most susceptible to predation during breeding, as it spends significantly more time on the ground in this period.

Likelihood of Occurrence: High. In total, 16 previous surveys resulted in the observation of this species within 50 km of the study area (Ninox 1994; HGM 1999a, ecologia internal database, Biota 2010; 1999b; Maunsell 2003). Despite the lack of records of this species during this survey, the species has a high likelihood of occuring within the study area. Suitable foraging and nesting habitat is found within the major drainage system habitat type.

5.3.2.3 Peregrine Falcon (*Falco peregrinus*)

Conservation Status: WC Act Schedule 4 (Specially Protected Fauna).

Distribution and Habitat: This nomadic or sedentary falcon is widespread in many parts of Australia and some of its continental islands, but absent from most deserts and the Nullarbor Plain. The species is considered to be moderately common in the Stirling Range, uncommon in the Kimberley, Hamersley and Darling Ranges, and rare or scarce elsewhere (Johnstone and Storr 1998). The Peregrine Falcon occurs most commonly near cliffs along coasts, rivers and ranges, and around wooded watercourses and lakes.

Ecology: Peregrine Falcons feed almost entirely on birds, especially parrots and pigeons. They nest primarily on ledges on cliffs, granite outcrops and in quarries, but may also nest in tree hollows around wetlands. Eggs are predominantly laid in September (Johnstone and Storr 1998; Olsen *et al.* 2006).

Likelihood of Occurrence: Medium. The Peregrine Falcon has been recorded during two previous surveys within 50 km of the study area (ecologia internal database, Ninox 1994). Three additional records are listed on NatureMap within 100 km (DPaW 2013). Suitable habitat for hunting is present within the study area in the form of all fauna habitat types, with potential nest site habitat present along vertical cliff edges within the hilltop, hillslope, ridge and cliff habitat type.

5.3.2.4 Grey Falcon (*Falco hypoleucos*)

Conservation Status: WC Act Schedule 1 (Vulnerable)

Distribution and Habitat: Grey Falcons are a rare, nomadic species sparsely distributed across much of arid and semi-arid Australia. In Western Australia, they are restricted to the northern half, occurring in a variety of habitats ranging from wooded drainage systems through to open spinifex plains. Grey Falcons once occurred across much of Western Australia, with sightings as far south as York and New Norcia during colonial times. However, the current distribution is now thought to be restricted to north of 26 °S (Johnstone and Storr 1998). Because the distribution of this species is scarce over an extremely large area, sightings of this species are very uncommon.

The Grey Falcon occurs in a wide variety of arid habitats, including open woodlands and open acacia shrubland, hummock and tussock grasslands and low shrublands, and may also be seen around swamps and waterholes that attract prey (Ehmann and Watson 2008).

Ecology: Like other falcons, this species preys primarily on birds such as parrots and pigeons, although reptiles and mammals are also taken (Ehmann and Watson 2008). Two to three eggs are laid in winter in the nests of other birds of prey and ravens, typically in tall eucalypt trees near water (Garnett and Crowley 2000; Ehmann and Watson 2008).

Likelihood of Occurrence: Medium. The Grey Falcon has been previously recorded relatively close by (*ecologia* internal database) and four recent records were identified from within 16 km (DPaW 2013) (Figure 4.14). Suitable habitat for hunting is present within the study area in the form of all fauna habitat types, however the Grey Falcon is unlikely to nest in any natural habitats present within the study area. Conversely man-made structures such as radio and communication towers are commonly used by Grey Falcons in the Pilbara.

5.3.2.5 Australian Bustard (*Ardeotis australis*)

Conservation Status: DEC Priority 4.

Distribution and Habitat: The Australian Bustard occurs Australia-wide and utilises a number of open habitats, including open or lightly wooded grasslands, chenopod flats, plains and heathlands (Johnstone and Storr 1998).

Ecology: It is a nomadic species, ranging over very large areas, and its abundance varies locally and seasonally from scarce to common, largely dependent on rainfall and food availability. The Australian Bustard has an omnivorous diet, feeding on grasses, seeds, fruit, insects and small vertebrates.

Although the population size is still substantial, there has been a large historical decline in abundance, particularly south of the tropics, but also across northern Australia (Garnett and Crowley 2000). This is a result of hunting, degradation of its grassland habitat by sheep and rabbits, and predation by foxes and cats (Frith 1976; Garnett and Crowley 2000). Australian Bustards readily desert nests in response to disturbance by humans, sheep or cattle (Garnett and Crowley 2000).

Likelihood of Occurrence: Recorded. Three individual Australian Bustards were recorded from three separate locations during this survey. This species has also been recorded during seven previous surveys within 50 km of the study area (Ninox 1994, 1995; HGM 1999a, 2009a, 2009b, ecologia internal database; 1999b) in addition to eight NatureMap records within 45 km of the study area (DPaW 2013). The Australian Bustard is likely to occur on any of the low lying habitats within the study area, such as cracking clay, footslope and plain and mixed acacia woodland.

5.3.2.6 Bush Stone-curlew (*Burhinus grallarius*)

Conservation Status: DEC Priority 4.

Distribution and Habitat: The Bush Stone-curlew occurs across much of Australia, except the arid interior and central south coast, preferring lightly wooded country near thickets or long grass that acts as daytime shelter (Johnstone and Storr 1998). Historically, this species was widely distributed throughout most of WA, but has since declined, particularly in the southern part of the State. Recent estimates indicate an Australian population of 15,000 individuals (Garnett and Crowley 2000). The Bush Stone-curlew inhabits woodlands, dry and open grasslands, and croplands with cover nearby (NSW National Parks and Wildlife Service 1999).

Ecology: The species is insectivorous, preying primarily upon beetles, although they will also eat seeds and shoots, frogs, lizards and snakes (Marchant and Higgins 1993; NSW National Parks and Wildlife Service 1999). They are usually seen in pairs, although may occasionally flock together during the breeding season (August to January) and are generally nocturnal, being especially active on moonlit nights (NSW National Parks and Wildlife Service 1999).

Since Bush Stone-curlews are a ground-dwelling and non-migratory species, they are quite susceptible to local disturbances by humans and to predation by cats and foxes (Frith 1976; Johnstone and Storr 1998). They are most common where land disturbance is minimal, and generally become rare or extinct around human settlements (Johnstone and Storr 1998).

Likelihood of Occurrence: Recorded. This species was recorded from secondary evidence only, with tracks recorded from GWA S3, which represents suitable habitat for this species (mulga woodland). In the local region, three additional records exist within 50 km of the study area (DEC 2013). This species is likely to occur in low lying habitat areas within micro-habitats of denser grass and shrub vegetation which provides cover for this species to shelter in during the day.

5.3.3 Reptiles

5.3.3.1 Pilbara Olive Python (*Liasis olivaceus barroni*)

Conservation Status: EPBC Act Vulnerable, WC Act Schedule 1 (Vulnerable).

Distribution and Habitat: The Pilbara subspecies of the Olive Python only occurs in the ranges of the Pilbara region of Western Australia. It inhabits watercourses and areas of permanent water in rocky gorges and gullies (Pearson 2006).

Ecology: This subspecies is an adept swimmer, often hunting in water, feeding on a variety of vertebrates such as rock wallabies, fruit bats, ducks and pigeons. Individuals spend the cooler winter months sheltering in caves and rock crevices. In the warmer months the pythons can move widely, usually in close proximity to water and rock outcrops (DEWHA 2008a). In late winter or early spring males will travel large distances to find, and mate with, females.

Population size estimates are difficult due to the Olive Python's cryptic nature and lack of reliable trapping or census techniques (DEWHA 2008a). The main threats to this subspecies come from predation by feral cats and foxes, particularly of juveniles, competition with foxes for food, and destruction of habitat (Pearson 2006).

Likelihood of Occurrence: High. Eight records of the Pilbara Olive Python exist within 50 km of the study area (ecologia internal database,HGM 1999b; Maunsell 2003), with the closest being just 1 km to the north-east of the study area (DPaW 2013) (Figure 4.14).

Habitat assessed as critical habitat where the Pilbara Olive Python is likely to exist within the study area, is in the form of the major gorge and gully habitat type. Individuals are likely to remain in this

habitat for extended periods of time, however males are known to travel long distances during the breeding season and could occur in any habitat type while moving between more typical habitat.

5.3.3.2 *Ramphotyphlops ganei*

Conservation Status: DEC Priority 1.

Distribution and Habitat: Very little is known about this elusive blind snake due to its fossorial lifestyle. Blind snakes are exclusively insectivorous, and like other members of their genus, *R. ganei* probably burrow into social insect colonies to feed on termites and ants, as well as their eggs and pupae (Wilson and Swan 2010). *R. ganei* has been found within the Pilbara region between Newman and Pannawonica (Wilson and Swan 2010).

Ecology: It has been suggested that *R. ganei* prefer to live in subterranean habitats near moist gullies and gorges (Wilson and Swan 2010), although there is a record from sandy soil vegetated with spinifex (NatureMap). This species is most likely threatened by removal of suitable habitat, and by drilling and/or any other mining activities impacting the subterranean environment.

Likelihood of Occurrence: Medium. This blindsnake has been recorded from eleven locations within 100 km of the study area (DEC 2013). The local previous surveys failed to record this species within 50 km (Appendix E). However, due to the elusive nature of this species, detecting presence remains difficult, despite the species potentially being present.

5.3.3.3 Pilbara Barking Gecko (*Underwoodisaurus seorsus*)

Conservation Status: DEC Priority 1.

Distribution and Habitat: This gecko is found only on ridge tops and in rocky gorges of the Hamersley Range and is currently known from four locations (Wilson and Swan 2010, DEC 2013; Doughty and Oliver 2011a).

Ecology: Little is known of the Pilbara Barking Geckos ecology, but it is presumably similar to other *Underwoodisaurus* and *Nephrurus* species, which are nocturnal ground dwellers that feed mostly on insects and smaller geckos (Wilson and Swan 2010).

Likelihood of Occurrence: Recorded. One individual Pilbara Barking Gecko was recorded during this survey from site GWA S1 during phase 2. The habitat of this location record is consistent with that in the recent description of this species (Doughty and Oliver 2011b). The species' type locality lies within 20 km of the study area and therefore the study area is likely to harbour a local population. Suitable habitat is present in the form of major gorge and gully, mesa top and hilltop, hillslope, cliff and ridge habitat types.

5.4 INVERTEBRATE SHORT RANGE ENDEMIC FAUNA

5.4.1 Mygalomorphae (trap door spiders)

Mygalomorphae are burrowing spiders, often displaying low dispersal abilities, low fecundity and high life expectancy (Main 1985; Main 1992). The order represents one of the primary target groups in surveys of short range endemic taxa (Harvey 2002) and contains several species of conservation significance, such as the EPBC Act listed *Idiosoma nigrum* Main, 1952 (Approved Conservation Advice for *Idiosoma nigrum* (shield-back spider), 2013), or the WC Act listed *Kwonkan eboracum Main,* 1983 and *Moggridgea tingle* (Western Australian Government 2012). The Western Australian mygalomorph fauna is vast and, taxonomically, many families and genera remain known poorly (e.g. Barychelidae: *Idiommata;* Idiopidae: *Aganippe;* Nemesiidae: *Aname, Chenistonia, Kwonkan).*

5.4.1.1 Family Barychelidae

Species: *Aurecocrypta* sp. indet.

Aurecocrypta sp. indet. was recorded from this survey from a single juvenile individual, captured opportunistically from GWA S11 (Table 4.5, Figure 4.16). Due to the life stage of this individual being juvenile, this specimen was unable to be identified to full species level. The record location is outside any deposit areas, recorded within the footslope and plain habitat type, which is the most extensive habitat type within the study area (Table 4.1, Figure 4.1). This species is a potential SRE (Beavis *et al.* 2013).

Species: *Synothele* 'MYG127'

A single adult male individual of this species was recorded from site GWA S7, captured within a dry pitfall trap (Table 4.5). This species is widespread and thus not considered an SRE (Beavis *et al.* 2013).

5.4.1.2 Family Nemesiidae

Species: *Aname mellosa*

A total of two male adults were recorded from site GWA S10, both captured within dry pitfall traps (Table 4.5). This species is widespread and thus not considered an SRE (Beavis *et al.* 2013).

Species: *Yilgarnia* 'MYG197'

A single male individual of this species was recorded from site GWA S7 within a dry pitfall trap (Table 4.5, Figure 4.16). The location of this site is within Deposit D in the footslopes and plain habitat type (Figure 4.1). It was not recorded at any other site outside the deposit area. This species has previously been recorded, and identified as a potential SRE species during the literature review (Appendix E). WAM have noted that this group is poorly represented in the collection, with only two specimens submitted. This species is considered a potential SRE (Beavis *et al.* 2013).

5.4.2 Scorpiones (scorpions)

Scorpiones is a relatively small order of arachnids, with approximately 1,700 described species (Fet *et al.* 2000). Scorpions are instantly recognisable by the presence of chelate pedipalps, pectenes and an elongate metasoma with a terminal sting. Scorpions are infamous for their venomous sting, which they use to subdue prey and for defence. In most species, the venom is relatively benign for humans, resulting in varying degrees of discomfort. The venom from 25 species only (all members of the family Buthidae) is known to be fatal to humans (Fet *et al.* 2000). Scorpions are important predators and, in some ecosystems, their diversity and abundance contribute significantly to the biomass of animal assemblages (Polis 1993).

5.4.2.1 Family Buthidae

Species: *Lychas* 'harveyi'

Lychas 'harveyi' is a well-defined and clearly recognised morphospecies. A total of eight individuals from six different sites were recorded (Table 4.5). Records are known from the Midwest and Pilbara regions of Western Australia where it is one of the most common scorpion species, and is therefore relatively widespread. *Lychas* 'harveyi' is not considered an SRE (Volschenk and Framenau 2013).

Species: *Lychas* 'pilbara1'

Lychas 'pilbara1' is a well-defined and clearly recognised morphospecies. *Lychas* 'pilbara1' has been recorded throughout the Pilbara region of Western Australia. During this survey, a total of 17 individuals from five separate sites were recorded (Table 4.5). Despite the widespread distribution, this species has a very patchy distribution and has not been recorded as common. *Lychas* 'pilbara1' is not considered an SRE (Volschenk and Framenau 2013).

Species: *Lychas bituberculatus*

Two *Lychas bituberculatus* individuals were recorded from site GWA S7 (Table 4.5). The species is widespread in the Pilbara and Kimberley regions of Western Australia. It is not considered an SRE (Volschenk and Framenau 2013).

Species: *Lychas* 'hairy tail'

Lychas 'hairy tail' is a well-recognised morphospecies. This survey recorded a single male individual from a dry pitfall trap from site GWA S2 (Table 4.5). Regional records are known from the Midwest and Pilbara regions of Western Australia where it is one of the most common scorpion species. It is not considered an SRE (Volschenk and Framenau 2013).

Species: *Isometroides* 'pilbara1'

Isometriodes 'pilbara 1' is a well-recognised morphospecies. A single male individual was recorded from site GWA S8 (Table 4.5). It is widespread throughout the Pilbara region of Western Australia. It is not considered an SRE (Volschenk and Framenau 2013).

5.4.2.2 Family Urodacidae

The family Urodacidae is endemic to Australia (Fet *et al.* 2000; Volschenk *et al.* 2000; Prendini and Wheeler 2005) where it is represented by the genera *Urodacus* and *Aops*.

Genus *Urodacus*

Urodacus was considered a member of the family Scorpionoidea for many years, but in a revision of the superfamily Scorpionoidea, Prendini (2000) placed *Urodacus* in its own family, Urodacidae. Unlike the species designations for Buthidae, Koch's (1977) species of *Urodacus* have been mostly supported by subsequent authors (Volschenk *et al.* 2000; Harvey and Volschenk 2002; Volschenk and Prendini 2008). The biggest issue confronting *Urodacus* taxonomy is the number of undescribed species being uncovered through current revisionary work (E. S. Volschenk unpublished data). Currently, 23 species of *Urodacus* are described; however, this may represent as little as 20% of the real diversity of this genus in Australia. *Urodacus* appears to be most diverse in Western Australia and few species are recorded east of the Great Dividing Range in eastern Australia. *Urodacus* contains both widespread and SRE species. During a large-scale survey of the Pilbara fauna, Volschenk *et al.* (2000) recorded nine undescribed species and only one formerly described species was reported in that study.

***Species: Urodacus* sp. indet**

A total of 10 unidentifiable females and juveniles of *Urodacus* were collected from a number of locations (Table 4.5). No adult male specimens were collected and therefore this species is unable to be morphologically identified to species level. Specimens have been preserved appropriately to allow for DNA analysis to species level if required. The individuals recorded are spread across much of the study area, both within deposit areas and outside, and in a variety of habitats (Figure 4.16). All records were made from low lying habitat types and within micro-habitats of softer soil substrates, where this species constructs burrows to shelter in during the day. All specimens recorded were caught through targeted pitfall trapping using plastic cups placed at the base of burrows. An example of a burrow from this species is shown in Figure 5.4.

Unidentifiable individuals have previously been recorded in the region and were assessed as potential SRE (Appendix E). As *Urodacus* includes range-restricted in addition to widespread species, all unidentified specimens are here considered potential SREs (Volschenk and Framenau 2013).

Figure 5.4 – Example of burrow of *Urodacus* sp. indet. recorded from current survey

5.4.3 Isopoda (isopods)

5.4.3.1 Family Armadillidae

Species: *Buddelundia* sp. nov. '10'

This is a species complex and is common and widespread in the Pilbara. There were at least four morphologically different forms found in this survey (*Buddelundia* sp. nov. 10 1458A – 1458D). Further work on this group of species is required to understand better their true SRE status. Morphological characteristics used in identification are subtle, with DNA analysis recommended for full resolution of species present. The four morphs recorded from this survey are described below, all of which are considered to be potential SREs (Judd 2012).

***Buddelundia* sp. nov. '10 1458A'**

This species was the most abundant recorded from the survey, with a total of 70 individuals recorded from 10 locations (Table 4.5). These locations range across various habitat types and are within and outside deposit areas (Figure 4.16).

***Buddelundia* sp. nov. '10 1458B'**

A total of nine individuals (five male, four female) were recorded from four separate locations from this study (Table 4.5). This form is relatively distinct from 1458A (Judd 2012).

***Buddelundia* sp. nov. '10 1458C'**

This species was represented by a single female specimen, recorded from a dry pitfall trap at site GWA S1 (Table 4.5). The location for this record is within the mesa top habitat type, with the single location record meaning this species was recorded from within deposit H only (Figure 4.16).

This species is very similar morphologically to *Buddelundia* sp. nov. '10 1458A' and was recorded from the same site. Further surveying for this species, including male specimens, is needed to provide a more definitive determination of species present (Judd 2012).

***Buddelundia* sp. nov. '10 1458D'**

A total of four individuals (three male, one female) of this species were recorded from site GWA S2 only (Table 4.5). The location for this record is within the mesa top habitat type, with the single location record meaning this species was recorded from within deposit H only (Figure 4.16).

Morphologically, this species appears to be much smaller to aid in distinguishing them from the more commonly recorded to *Buddelundia* sp. nov. '10 1458A'. Further surveying for this species is needed to provide a more definitive determination of species present (Judd 2012).

Species: *Buddelundia* sp. nov. '15'

This species had a total of three individuals from three separate sites recorded (Table 4.5). This species is a widespread species complex in the Pilbara. Further work is needed on the species complex, however at present this is not considered an SRE species (Judd 2012).

Species: *Buddelundia* sp. nov. '16'

A total of 14 individuals of this species were recorded from five locations (Table 4.5). This species is a widespread species complex in the Pilbara. Further work is needed on the species complex, however at present this is not considered an SRE species (Judd and Framenau 2013).

Species: *Buddelundia* sp. nov. '68WA'

Two individuals (one male, one female) of this species were recorded from two locations (GWA S5, FS1) (Table 4.5). Both locations fall within potential impact areas of deposit G and Mt Ella, both located within the footslope and plain habitat type (Figure 4.16).

Buddelundia sp. nov. '68WA' is a large and distinctive species that is part of a specialized group of *Buddelundia*. The specimens identified on this survey are very similar to (or the same species as) a confirmed SRE species (*Buddelundia* sp. nov. 68) (Judd 2012), however enough morphological traits exist to determine them as separate species at this stage. There are many species very similar to these specimens with the majority being SRE species. As a result, *Buddelundia* sp. nov. '68WA' is considered a potential SRE species (Judd 2012).

Species: Buddelundinae genus. indet. Buddelundinae 'PES999'

A total of six individuals of *Buddelundinae* 'PES999' were recorded (Table 4.5). This species belongs to an undescribed genus with close morphological affinities to *Buddelundia* spp. It is a widespread species in the Pilbara region and not considered an SRE (Judd and Framenau 2013).

Species: New genus (close to *Buddelundia*) sp. nov. '1'

A total of four individuals of this species were recorded (Table 4.5). This is a new genus which is closely related to *Buddelundia* but is thought to be more primitive. The species within this genus lack many of the morphological characteristics that are useful in determining species of *Buddelundia* spp.

Consequently, they are harder to identify. However, this species appears relatively widely distributed in the Pilbara region and is not considered an SRE (Judd 2012).

5.4.3.2 Family Unknown

Species: Genus indet. sp. indet.

A single male specimen (*ecologia* database reference number EE12:0260) in poor condition, was recorded from site GWA S5 (Table 4.5). This single record was from within Mt Ella deposit within the footslope and plain habitat type (Figure 4.16).

This specimen was in poor condition when submitted for identification, making identification through morphology difficult. Unfortunately, both antenna, which are an important diagnostic characteristic in determining families of terrestrial isopods, were missing. Despite this, the individual appeared to be morphologically unique and unlike other isopods previously recorded from the Pilbara (Judd 2012). This specimen could potentially belong to the family Philosciidae or may be an introduced species, although this is unlikely (Judd 2012).

Complete specimens in better condition are required before a more accurate assessment as to the SRE status of this species, however this species should be considered a potential SRE at present (Judd 2012).

5.4.4 Molluscs (snails)

5.4.4.1 Family Bothriembryontidae

Bothriembryontidae is a family of air-breathing land snails in the superfamily Orthalicoidea. The family has Gondwanaland distribution and comprises 12 genera. The genus *Bothriembryon* is endemic to Australia and includes over 40 described species.

Species: *Bothriembryon* sp. nov. 'Pilbara'

A total of four individuals from site GWA FS4 were recorded from this survey (Table 4.5). This species is currently undescribed but previous records suggest that this species is widespread throughout the Pilbara region and not considered an SRE species (Whisson 2013).

5.4.4.2 Family Pupillidae

Pupillidae is a family of mostly minute, air-breathing land snails in the superfamily Pupilloidea. The family comprises 12 genera and harbours both widespread and range-restricted species.

Species: *Gastrocopta mussoni*

This species had 12 individuals recorded from two locations (Table 4.5). Previous records show this species to be widespread and is therefore not considered an SRE (Whisson 2013).

Species: *Gastrocopta cf. hedleyi*

A total of 12 individuals of this species were recorded from a single location only (Table 4.5). This species is likely to be conspecific with *Gastrocopta hedleyi,* which is a widespread species. This species is not considered a SRE species (Whisson 2013).

Sub-family Pupillinae

Species: *Pupoides cf. pacificus*

This species had 11 individuals recorded from three locations (Table 4.5). It is most likely conspecific with *Pupoides pacificus,* which is a widespread species. This species is not considered an SRE species (Whisson 2013).

5.4.4.3 Family Subulinidae

Species: *Eremopeas interioris*

A total of 15 individuals of this species were recorded from two locations (Table 4.5). Current information suggests this species is widespread and is not considered an SRE species (Whisson 2013).

5.4.5 Pseudoscorpiones (Pseudoscorpions)

The Western Australian pseudoscorpion fauna is fairly diverse with representatives of 17 different families. They are found in a variety of biotopes, but can be most commonly collected from the bark of trees, from the underside of rocks, or from leaf litter habitats (Burger *et al.* 2013).

5.4.5.1 Family Olpiidae

Species *Beierolpium* sp. indet.

A single juvenile from the genus *Beierolpium* was collected from site GWA S1 (Table 4.5). This means this species was recorded from within deposit H only, within the mesa top habitat type (Figure 4.1). Due to the juvenile life form of this individual, it cannot be identified to species level. A full taxonomic revision of the genus *Beierolpium* in Western Australia is necessary to confirm the specimen's species identity and distribution. At this stage this specimen is designated as a potential SRE due to taxonomic uncertainty (Burger *et al.* 2013).

Species: *Euryolpium* sp. indet.

A single juvenile from the genus *Euryolpium* was collected from site GWA S3 (Table 4.5), outside any deposit areas within the mulga woodland habitat type (Figure 4.1). Due to the juvenile life form of this individual, it cannot be identified to species level.

Species of *Euryolpium* are commonly found under bark and under rocks throughout Australia. They can be locally abundant, and at least one species is quite widespread across northern Australia (Burger *et al.* 2013). At this stage this specimen is designated as a potential SRE due to taxonomic uncertainty (Burger *et al.* 2013).

Species: *Indolpium* sp. indet.

A single male from the genus *Indolpium* was collected during the survey from site GWA S11 (Table 4.5). Similar specimens have been collected from other regions of Western Australia, however more data is required before the morpho-group can be accurately given species identifications (Burger *et al.* 2013)..

Based on current levels of knowledge from abundance and frequency of collection of specimens from this genus, it is unlikely that these specimens represent SREs. Therefore this species is currently not considered an SRE (Burger *et al.* 2013).

Species: *Xenolpium* sp. indet.

A total of 10 individuals (five male, four female, and one juvenile) of this species were recorded from seven separate locations (Table 4.5). These locations are from within and outside deposit areas and across different habitat types (Figure 4.1).

The specimens collected appear to represent a single species. Species of this genus need further taxonomic investigation to determine their SRE status. At present this species is considered a potential SRE (Burger *et al.* 2013).

Species: Genus indet. sp. indet.

Three juvenile olpiid pseudoscorpions from three separate sites (GWA opp, S1, S6, Table 4.5) could not be identified to genus level because of juvenile life stages. These locations are all from within deposit areas (Figure 4.1).

Due to the taxonomic uncertainty within olpiid pseudoscorpions, this species has been assigned potential SRE status. (Burger *et al.* 2013).

5.4.6 Diplopoda (millipedes and centipedes)

5.4.6.1 Family Trigoniulidae

Species: *Austrostrophus stictopygus*

Austrostrophus is the only genus of spirobolid millipede collected to date in the Pilbara. It is easily recognized by its large size, the punctations on the last body segment and a fringe of projections found on the trailing edge of each body segment (Hoffman 2003). There are two species of the genus found in Western Australia: *Austrostrophus* `DIP018` and *A. stictopygus*. They are very similar in appearance and can only be distinguished from each other by the structure of the male gonopods, which need to be dissected out to be examined.

A total of nine individuals (three male, three female and three juvenile, Table 4.5) were collected during this survey. Due to the abundant and widespread distribution of this species, it is not considered an SRE (Burger *et al.* 2013).

5.4.6.2 Family Geophilidae

Species: Genus ident. sp. indet

A single individual of a centipede from the family Geophilidae was recorded from site GWA S2 (Table 4.5). This single location is within deposit H and the mesa top habitat type (Figure 4.1). The specimen was recorded by opportunistic foraging, and was recorded at the same location as the centipede from family Chilenophilidae. The microhabitat for the species was within a small rocky gully, underneath dense leaf litter and woody/rocky debris.

The current taxonomy of Geophilidae centipedes is limited, hence identification to genus and species level is not possible (Beavis *et al.* 2013). The literature review revealed genus ident. sp. indet specimens from the family Geophilidae have previously been recorded from the region (Appendix E) Due to taxonomic uncertainties, this species is considered a potential SRE (Beavis *et al.* 2013).

5.4.6.3 Family Chilenophilidae

Species: Genus ident. sp. indet

As with the Geophilidae centipede discussed above, a single individual of a centipede from the family Chilenophilidae was recorded from site GWA S2 (Table 4.5). The single location is within deposit H and the mesa top habitat type (Figure 4.1). The microhabitat for the species was within a small rocky gully, underneath dense leaf litter and woody/rocky debris.

The current taxonomy of Chilenophilidae centipedes is limited, hence identification to genus and species level is not possible (Beavis *et al.* 2013). Due to taxonomic uncertainties, this species is considered a potential SRE (Beavis *et al.* 2013).

5.5 IMPACT ASSESSMENT

Due to that fact that this study for the Greater West Angelas Project is not for any specific development or mining project at present, identifying specific and direct impacts to fauna is not possible. If deposits are selected in the future to be further developed, the results from this study can be consulted as preliminary data to determine specific impacts, with further surveying of specific deposits recommended to gain a better understanding of potential impacts.

SRE fauna are particularly vulnerable to potential impacts due to their restricted distributions. Consequently, all SRE species recorded only within deposit areas should be searched for outside deposit areas to ensure particular species are not significantly impacted upon. Currently, nine potential SRE species are recorded from within deposit areas only; *Yilgarnia* 'MYG197', *Buddelundia* sp. nov. '10 1458C', *Buddelundia* sp. nov. '10 1458D', *Buddelundia* sp. nov. '68WA', isopod genus indet. sp. indet., *Beierolpium* sp. indet., pseudoscorpion genus indet. sp. indet., centipede (family Geophilidae) genus indet. sp. indet. and centipede (family Chilenophilidae) genus indet. sp. indet. (Table 4.5, Figure 4.1). Any future development will need to address the issue of distribution boundaries of each SRE species that was found within the impact areas.

There are no potential significant vertebrate fauna impacts likely for any vertebrate fauna species (including conservation significant species) at a regional level from the project. However, some local impacts to conservation significant species or endemic or bioregional species may occur.

Ghost Bats and Pilbara Leaf-nosed Bats are regarded as being shy of human presence and will abandon their roosts if disturbed. Any future developments should avoid any impacts to Ghost Bat (and Pilbara Leaf-nosed Bat if present) roost caves.

In general, vertebrate fauna species of high mobility should be able to move away from disturbance and avoid any significant impacts. Species that have low mobility or are burrowing species, are more susceptible to development impacts and may experience a local impact to individuals. Examples being the Western Pebble-mound Mouse as it shelters in burrow systems below ground during the day, and burowing species such as *Lerista* spp. skinks.

The skink *Ctenotus rutilans*, due to taxonomic uncertainty with this species (section 4.2.4), may be sensitive to impacts if undescribed species within this complex are present. Due to the apparent range extension to *Ctenotus robustus* (section 4.2.4) from this survey, an impact to this species would result in a range reduction. However, the scale of the Greater West Angelas Project is not considered large enough to result in any significant impact to either of these two skink species.

5.6 SURVEY ADEQUACY

Systematically obtained data (trapping results for terrestrial fauna and set-time survey for birds, excluding opportunistic data) was analysed for survey adequacy. Parametric analysis of systematically obtained survey data for birds and terrestrial faunal groups revealed that survey effort was adequate. Table 5.3 provides a summary of the theoretical maximum number of species using seven different methods of estimating richness. The Michaelis-Menten (MM) equation provides the most accurate representation of the potential species number. This is compared against the actual number of species observed, with any inconsistencies smoothed by an algorithm (Mao Tau), which simulates an infinite number of randomisations of the sample order.

Analysis of the mammal trapping data produced a reasonably smooth SAC, nearing the asymptotic plateau (Figure 5.5). Extrapolation of the Michaelis-Menten (MM) curve suggests that 96.1% of the theoretical total number of mammals able to be trapped had been captured at the completion of the 168 trap nights of the Level 2 vertebrate fauna survey (Table 5.3). These results indicate that the majority of mammal species were recorded during the survey.

Analysis of the reptiles trapping data produced a reasonably smooth SAC, almost reaching the asymptotic plateau (Figure 5.6). Extrapolation of the Michaelis-Menten (MM) curve suggests that 92.1% of the herpetofauna theoretically occurring in the study area were trapped. The MM estimator generated a theoretical maximum of 67 species, whilst other richness estimates were as high as 75.95 (Table 5.3), suggesting further survey effort could have identified as many as 10 more species.

The SAC analysis of the avifauna set-time survey dataset also produced a typical SAC, becoming very close to an asymptotic plateau (Figure 5.7). Used as a stopping rule, the MM estimator indicated that the survey was 98.5% adequate at the completion of 96 set-time surveys. The MM estimator generated a theoretical maximum of 72 species (71 species actually recorded), however other richness estimates were as high as 87 (Table 5.3), suggesting further survey effort could have recorded up to 16 additional species.

In contrast to vertebrate fauna groups, the SRE fauna SAC analysis shows a less rounded line, indicating that further sampling may have recorded additional species (Figure 5.8). Used as a stopping rule, the MM estimator indicated that the survey was 71.2% adequate. The MM estimator generated a theoretical maximum of 29.47 species (21 species actually recorded). Higher variations between total richness estimators for SRE fauna was recorded in contrast to vertebrate fauna groups, with estimators ranging from a low of 25.76 (Bootstrap) to 47.79 species (ACE) (Table 5.3), suggesting recording up to a further 26 species may be possible with further survey effort.

It is worth noting the SRE fauna SAC analysis uses systematic data collected from pitfall trapping data only, and does not include opportunistic methods such as leaf litter sorting and foraging which target specific SRE species groups.

Table 5.3 – Mean estimates of total species richness of different fauna groups

Richness Estimators	Total Richness Estimate			
	Trappable mammals	Trappable reptiles	Birds	SRE
ACE	10	68.31	77.88	47.79
ICE	10	68.09	81.09	45.47
Chao-1	10	68.88	78	39.2
Jack-1	10	72.93	82.88	32.9
Jack-2	9.02	75.95	87.84	42.75
Bootstrap	10.14	67.62	76.46	25.76
Michaelis-Menten	10.41	67.3	72.16	29.47
Species trapped/observed	**10**	**65**	**71**	**21**

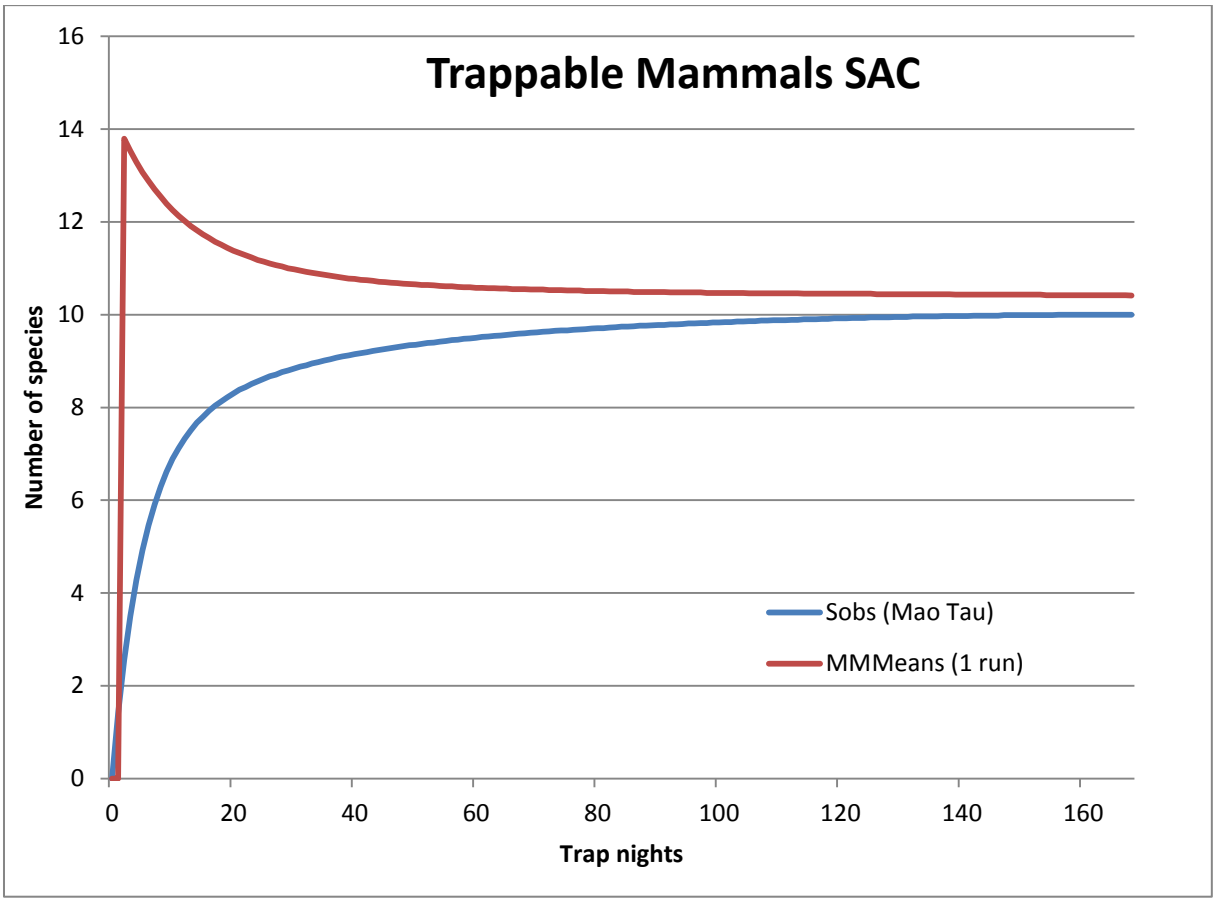


Figure 5.5 – Species accumulation curve for trappable mammals

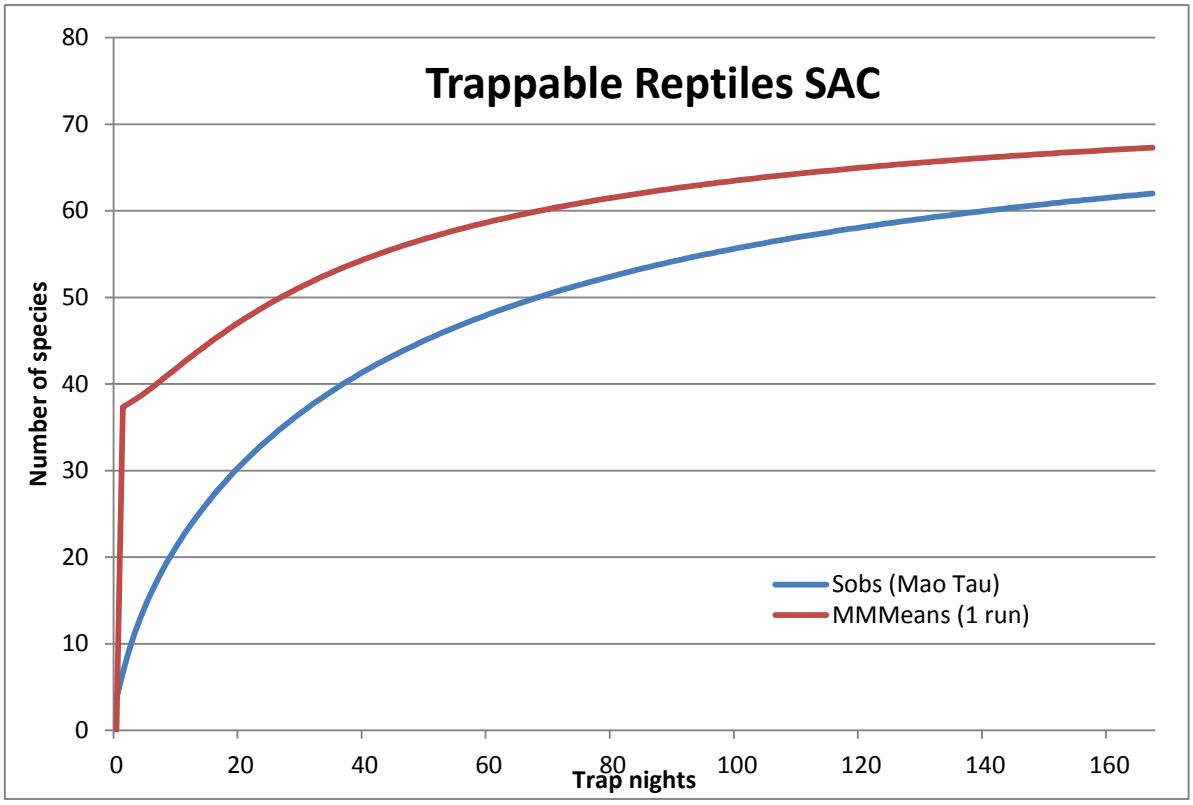


Figure 5.6 – Species accumulation curve for trappable reptiles

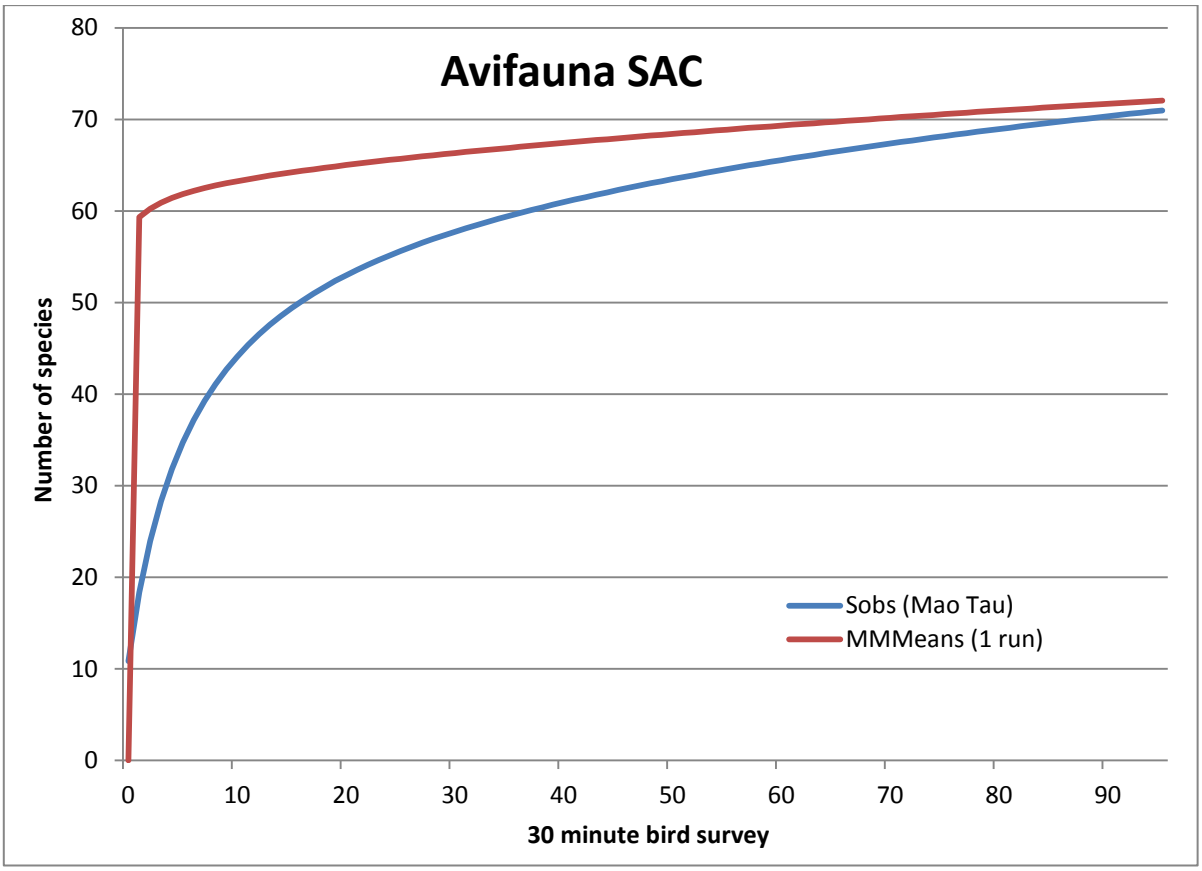


Figure 5.7 – Species accumulation curve for avifauna

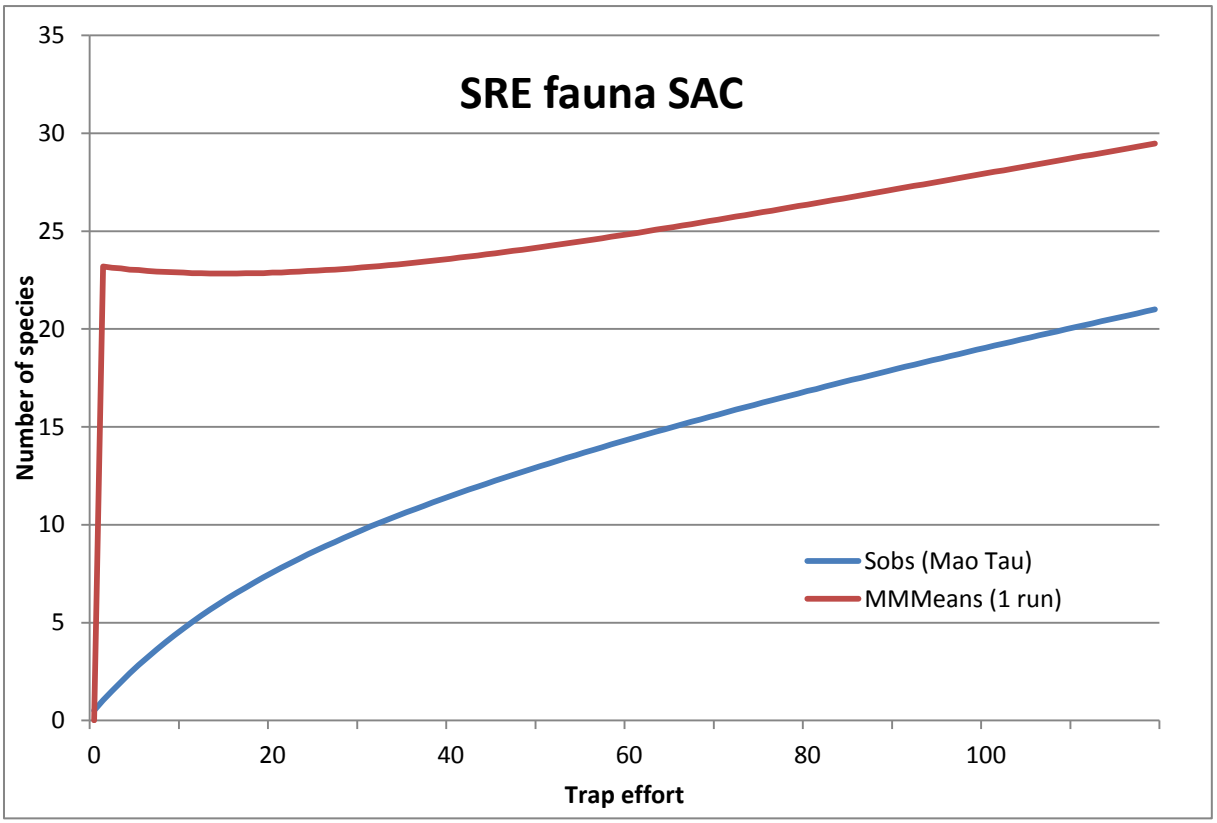


Figure 5.8 – Species accumulation curve for SRE fauna

5.7 SURVEY LIMITATIONS AND CONSTRAINTS

Limitations of the current survey are summarised in Table 5.4 below. No significant limitations were experienced during the surveys. Limited vehicle access to some habitat types (major gorge and gully, hilltop, hillslope, ridge and cliff) meant restricted systematic survey effort could be completed in these habitats type. Less represented habitats within the survey design of the systematic trap sites were compensated with opportunistic surveying. Given no significant limitations were encountered, the level of survey undertaken was considered adequate.

Table 5.4 – Summary of survey limitations

Constraint	Relevant (yes/no)	Comment
Competency/experience of the consultant carrying out the survey.	No	All members of the survey team were experienced in Pilbara fauna identification and fauna surveys.
Scope (what faunal groups were sampled and were some sampling methods not able to be employed because of constraints such as weather conditions).	No	All faunal groups were adequately sampled.
Proportion of fauna identified, recorded and/or collected.	No	The majority of fauna species expected to occur within the study area were recorded, as indicated by SACs (Section 5.6). All captured vertebrate species were identified in the field. Invertebrate samples were identified by external specialists and lodged with WA Museum.
Sources of information (previously available information as distinct from new data).	No	Twenty-six biological surveys have been conducted in the vicinity of the study area. Data from these surveys were used included to provide regional context.
The proportion of the task achieved and further work which might be needed.	Partially	A two-phase Level 2 vertebrate and SRE fauna assessment was completed. The level of assessment for the Project is assessed as adequate. Additional SRE assessments may be required once detailed project design is developed
Timing/weather/season/cycle.	No	The Level 2 terrestrial fauna assessment was conducted during weather and seasonal conditions that are optimal for increased fauna activity and was in accordance with guidelines (EPA 2004).
Disturbances which affected results of the survey (e.g. fire, flood, accidental human intervention).	No	There were no disturbances recorded during this survey.
Intensity (in retrospect was the intensity adequate).	No	The survey intensity was adequate, all habitat types were surveyed systematically or opportunistically, and most of the species expected to occur were recorded.
Completeness (e.g. was relevant area fully surveyed).	No	All habitat types were accessible and were represented in the assessment.
Resources (e.g. degree of expertise available in animal identification to taxon level).	No	All zoologists were suitably qualified and experienced in identification of Pilbara fauna. There were no resources issues encountered.
Remoteness and/or access problems.	No	Sufficient contextual information was available on the Pilbara region and the study area.
Availability of contextual (e.g. biogeographic) information on the region).	No	Survey methods were suitable to record all fauna groups, including freshwater fish.
Efficacy of sampling methods (i.e. any groups not sampled by survey methods).	No	There were no disturbances and inefficiencies recorded during this survey.

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6 CONCLUSION

The main conclusions from this study are as follows:

- A total of nine broad-scale habitat types have been assessed as existing within the study area; footslope or plain, hilltop, hillslope, ridge or cliff, mixed Acacia woodland, mesa top, cracking clay, major gorge and gully, major drainage, mulga woodland and cleared area. No habitats recorded are regarded as rare or unique to the study area.
- A total of 23 species of native mammals, two species of introduced mammal, 80 species of bird and 64 species of reptile were recorded during this survey. No species of amphibian were recorded.
- Six species of conservation significance (two mammal, three birds, one reptile) were recorded from within the study area; Pilbara Leaf-nosed Bat (Pilbara form) (EPBC VU, WC Act S1, DEC VU), Western Pebble-mound Mouse (signs only) (DEC P4), Fork-tailed Swift (EPBC M, WC Act S3), Australian Bustard (DEC P4), Bush Stone-curlew (signs only) (DEC P4) and Pilbara Barking Gecko (DEC P1).
- A total of 33 invertebrate species from six different Orders were submitted for identification and SRE status assessment. The results from identifications showed 15 of these species identified as potential SRE species; two species of spider, one species of scorpion, six species of isopods, four species of pseudoscorpions and two species of centipedes.
- Due to the fact that this study for the Greater West Angelas Project is not for any specific development or mining projects at present, identifying specific and direct impacts to fauna is not possible. If deposits are selected for further development in the future, further surveying of specific deposits is recommended to gain a better understanding of potential impacts. Currently, nine potential SRE species are recorded from within deposit areas only. There are no potential significant vertebrate fauna impacts likely for any vertebrate fauna species (including conservation significant species) at a regional level from the Project.
- Systematically obtained data was assessed to determine survey adequacy through SACs. Extrapolation of the Michaelis-Menten (MM) curve suggests that 96.1% of trappable mammals, 92.1% of trappable reptiles, 98.5% of avifauna and 71.2% of SRE fauna were recorded. This indicated that the majority of fauna were recorded for all fauna groups, however increased surveying is likely to record further species, particularly SREs.
- No significant limitations were experienced during the surveys. Given the lack of limitations and the fact that the majority of fauna were recorded, the survey can be considered adequate and to have met its objectives.

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APPENDIX A EXPLANATION OF CONSERVATION CODES

Appendix A1 Definitions of categories under the *Environment Protection and Biodiversity Conservation Act 1999*

Category	Definition
Endangered (EN)	The species is likely to become extinct unless the circumstances and factors threatening its abundance, survival or evolutionary development cease to operate; or its numbers have been reduced to such a critical level, or its habitats have been so drastically reduced, that it is in immediate danger of extinction.
Vulnerable (VU)	Within the next 25 years, the species is likely to become endangered unless the circumstances and factors threatening its abundance, survival or evolutionary development cease to operate.
Migratory (M)	Species are defined as migratory if they are listed in an international agreement approved by the Commonwealth Environment Minister, including: the Bonn Convention (Convention on the Conservation of Migratory Species of Wild Animal) for which Australia is a range state; the agreement between the Government of Australian and the Government of the People's Republic of China for the Protection of Migratory Birds and their environment (CAMBA); or the agreement between the Government of Japan and the Government of Australia for the Protection of Migratory Birds and Birds in Danger of Extinction and their Environment (JAMBA).

Appendix A2 Definition of Schedules under the *Wildlife Conservation Act 1950*

Schedule	Definition
Schedule 1 (S1)	Fauna which are rare of likely to become extinct, are declared to be fauna that is in need of special protection.
Schedule 2 (S2)	Fauna which are presumed to be extinct, are declared to be fauna that is in need of species protection.
Schedule 3 (S3)	Birds which are subject to an agreement between the governments of Australia and Japan relating to the protection of migratory birds and birds in danger of extinction, are declared to be fauna that is in need of species protection.
Schedule 4 (S4)	Declared to be fauna that is in need of species protection, otherwise than for the reasons mentioned above.

Appendix A3 Definition of DEC Threatened and Priority Fauna Codes

Threatened	**Definition**
Critically Endangered (CR)	Considered to be facing an extremely high risk of extinction in the wild.
Endangered (EN)	Considered to be facing a very high risk of extinction in the wild.
Vulnerable (VU)	Considered to be facing a high risk of extinction in the wild.
Priority	**Definition**
Priority 1 (P1)	*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.
Priority 2 (P2)	*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.
Priority 3 (P3)	*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.
Priority 4 (P4)	*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 if present circumstances change. These taxa are usually represented on conservation lands.
Priority 5 (P5)	*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.

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APPENDIX B DAILY WEATHER DATA DURING SURVEY

Date	Minimum Temperature (°C)	Maximum Temperature (°C)	Rainfall (mm)
Phase 1			
25/9/12	13.8	32.0	0
26/9/12	11.4	32.4	0
27/9/12	16.4	29.4	0
28/9/12	16.3	28.2	0
29/9/12	15.9	34.2	0
30/9/12	15.4	35.6	0
1/10/12	20.2	36.5	0
2/10/12	21.2	35.9	0
3/10/12	17.0	34.7	0
4/10/12	16.0	37.7	0
5/10/12	17.0	38.1	0
Average	**16.4**	**34.1**	**0**
Phase 2			
18/03/13	26.0	42.8	0
19/03/13	24.9	43.1	0
20/03/13	28.8	42.3	0
21/03/13	31.4	40.9	0
22/03/13	23.2	41.7	0
23/03/13	25.3	41.2	0
24/03/13	23.8	40.6	0
25/03/13	21.9	41.1	0
26/03/13	20.8	31.1	0
27/03/13	18.7	31.7	0
Average	**24.5**	**39.6**	**0**

Note: Temperature data recorded from Paraburdoo weather station, rainfall data recorded from Turee Creek weather station (BoM 2013).

APPENDIX C SITE DESCRIPTIONS

Vegetation and Fauna Habitat Description	Site Photo
GWA S1 **Habitat type: Mesa top** Open woodland within rocky hillslopes. Tree species consisting of *Acacia aneura*, *Eucalyptus leucophloia,* *Eucalyptus gamophylla* and *Acacia pruinocarpa*. Shrub species consisting of mixed *Acacia* spp. and *Gossypium robinsonii*. Grasses are dominated by *Triodia* sp. which occurs at medium density. Sparse wood and leaf litter exist with evidence of recent fire. Numerous rocky outcrops and continuous surface layer of small pebbles.	
GWA S2 **Habitat type: Mesa top** Very open woodland within rocky hillslopes. Tree species consisting of *Acacia aneura* and *Eucalyptus leucophloia*. Mixed shrub species of *Acacia* spp. and medium dense *Triodia* sp. within five years of regeneration from fire. Minor drainage lines exist with numerous rocky outcrops and continuous surface layer of small pebbles.	

GWA S3 **Habitat type:** Mulga woodland Moderately dense woodland consisting exclusively of mature Mulga (*Acacia ayersiana*) in very good condition on flat plain. Few shrub species consisting of *Eremophila* spp., *Mairina* sp. and various native grasses. Soil profile lose in firmness, with texture consisting of clay sand of reddish-brown colour.	
GWA S4 **Habitat type:** Footslope and plain Hummock spinifex grassland plain extending from footslopes of nearby rocky hills. Open tree species consisting of *Acacia aneura* and *Eucalyptus leucophloia*. Many shrub species of medium density consisting of *Acacia maitlandii, Acacia inaequilatera, Acacia* spp., *Senna* sp. *Eremophila* sp. and *Gossypoium robinsonii*. *Triodia* sp. in medium to high density in patches of early regeneration to mature. Soil loam clay with continuous surface layer of pebbles.	

GWA S5 **Habitat type:** Footslope and plain *Triodia* sp. hummock grassland on gentle sloping plain with large rocky range approximately 600 m to the south. Very scattered *Corymbia hamersleyana* and *Acacia aneura* trees, mixed open shrub species of *Acacia maitlandii, Acacia inaequilatera, Ptilotus* sp. and denser patches of *Acacia pruinocarpa*. Almost no leaf or wood litter, soil consisting of loam clay with a continuous layer of small surface pebbles.	
GWA S6 **Habitat type: H**illtop, hillslope, cliff and ridge Trapping site transects from foot to mid-slope of rocky hill towards a ridge. Dominated by *Triodia* sp. with scattered *Eucalyptus leucophloia* trees with shrub species consisting of *Acacia inaequilatera*, *Acacia maitlandii* and *Eremophila* sp., shrub species denser in minor drainage channels coming off the range. Numerous rocky outcrops.	

GWA S7 **Habitat type:** Footslope and plain Located on a sloping plain at the footslopes of a small range to the north. *Triodia* sp. shrubland with isolated denser patches of *Acacia aneura*. Other shrub species consisting of *Acacia pruinocarpa* and *Acacia maitlandii*. Soil consisting of loam clay with a continuous layer of small surface pebbles.	
GWA S8 **Habitat type:** Cracking Clay Flat tussock grassland plain with native grasses A*ristida latifolia, Astrebla pectinata* and *Brachyachne convergens* growing in open to very dense patches. Scattered and isolated *Acacia aneura* trees with *Acacia tetragonophylla* and *Acacia synchronicia* shrubs. Soil consisting of clay with wide vertical cracks within the soil profile.	

GWA S9 **Habitat type:** Footslope and plain Located within a small drainage line amongst an east-west orientated valley. *Triodia* sp. hummock grassland with occasional *Eucalyptus leucophloia, Eucalyptus gamophylla* and *Corymbia hamersleyana* trees. Shrub density within the drainage line is high, becoming scattered towards hills. Shrub species consisting of *Acacia inaequilatera, Senna* sp. and *Gossypium robinsonii*. Soil consisting of loam clay with a continuous layer of small surface pebbles and outcropping close to hills.	
GWA S10 **Habitat type:** Mixed Acacia woodland Open to medium dense woodland consisting mainly of *Acacia aneura* with scattered *Acacia pruinocarpa*. Shrubs consisting of *Acacia maitlandii* and *Ptilotus* sp. with *Triodia* sp. ground cover. Soil consisting of loam clay with a continuous layer of small surface pebbles.	

GWA S11 **Habitat type:** Footslope and plain A diverse site consisting of mix of *Triodia* sp. hummock and tussock grassland on a flat plain. Medium density of shrubs consisting of *Acacia maitlandii*, *Acacia tetragonophylla* and *Hakea lorea*. Tree species consisting of *Acacia aneura* and *Acacia pruinocarpa*. Soil characteristics variable with influence from nearby cracking clay (GWA S8) and more typical rocky plain.	
GWA S12 **Habitat type:** Major gorge and gully Hummock grassland located within mouth of gorge and extending drainage line on footslopes of nearby rocky hill. Dense, mature *Triodia* sp. with *Acacia maitlandii*, *Acacia pruinocarpa* and scattered *Eremophila* sp. shrubs. Regular *Eucalyptus leucophloia*, concentrated around the drainage line with *Acacia aneura* also present. Very rocky with exposed outcropping.	

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APPENDIX D VERTEBRATE VOUCHER SPECIMENS LODGED WITH WA MUSEUM

WA Museum specimen no.	Species	Site captured	Easting	Northing	Habitat
WAM TS099	*Ctenotus rutilans*	GWA S4	690271	7434157	Foot slope of rocky hill, moderately dense hummock grassland with open (clusters of denser areas) of mixed acacia spp. shrubs

APPENDIX E LITERATURE REVIEW OF POTENTIAL SPECIES

Appendix E1: Mammals

Family and Species	Common name	Conservation Status			*ecologia* internal database	Ninox 2009b	Ninox 1995	HGM 1999a	HGM 1999b	Maunsell 2003	Ninox 2009a	Ninox 1994	Biota 2010	NatureMap	DEC Threatened fauna	EPBC Protected matters	This survey
		EPBC Act	WC Act	DEC													
TACHYGLOSSIDAE																	
Tachyglossus aculeatus	Echidna				●												
DASYURIDAE																	
Dasykaluta rosamondae	Little Red Kaluta				●	●					●			●			●
Dasyurus hallucatus	Northern Quoll	**EN**	**S1**	**EN**										●		●	
Ningaui timealeyi	Pilbara Ningaui				●	●		●					●	●			●
Planigale sp.	Planigale				●	●								●			●
Pseudantechinus roryi	Rory's Pseudantechinus													●			
Pseudantechinus woolleyae	Woolley's Pseudantechinus					●								●			
Sminthopsis dolichura	Little Long-tailed Dunnart													●			
Sminthopsis macroura	Stripe-faced Dunnart				●									●			●
Sminthopsis youngsoni	Lesser Hairy-footed Dunnart													●			
Sminthopsis ooldea	Ooldea Dunnart				●									●			●
THYLACOMYIDAE																	
Macrotis lagotis	Bilby	**VU**	**S1**	**VU**	●		●									●	
MACROPODIDAE																	
Macropus robustus	Euro				●		●	●	●	●		●		●			●
Macropus rufus	Red Kangaroo				●	●	●		●			●		●			●
Petrogale rothschildi	Rothschild's Rock-wallaby				●		●							●			●
PTEROPODIDAE																	
Pteropus scapulatus	Litte Red Flying-fox				●												
HIPPOSIDERIDAE																	
Rhinonicteris aurantia (Pilbara form)	Pilbara Leaf-nosed Bat	**VU**	**S1**	**VU**										●		●	●
MEGADERMATIDAE																	
Macroderma gigas	Ghost Bat			**P4**	●									●	●		

Family and Species	Common name	Conservation Status			*ecologia* internal database	Ninox 2009b	Ninox 1995	HGM 1999a	HGM 1999b	Maunsell 2003	Ninox 2009a	Ninox 1994	Biota 2010	NatureMap	DEC Threatened fauna	EPBC Protected matters	This survey
		EPBC Act	WC Act	DEC													
EMBALLONURIDAE																	
Saccolaimus flaviventris	Yellow-bellied Sheathtail Bat				●	●					●		●	●			●
Taphozous georgianus	Common Sheathtail Bat				●	●					●		●	●			●
Taphozous hilli	Hill's Sheathtail Bat				●	●								●			
VESPERTILIONIDAE																	
Chalinolobus gouldii	Gould's Wattled Bat				●	●		●			●	●	●	●			●
Nyctophilus bifax daedalus	Northwestern Long-eared Bat				●												
Nyctophilus geoffroyi	Lesser Long-eared Bat				●									●			●
Scotorepens greyii	Little Broad-nosed Bat				●	●						●	●	●			●
Vespadelus finlaysoni	Finlayson's Cave Bat				●	●					●	●	●	●			●
MOLOSSIDAE																	
Chaerophon jobensis	Northern Freetail Bat				●	●		●			●			●			●
Mormopterus beccarii	Beccari's Freetail Bat				●	●								●			●
Mormopterus planiceps	Southern Freetail Bat				●												
Tadarida australis	White-striped Freetail Bat				●	●		●					●	●			
MURIDAE																	
Leggadina lakedownensis	Short-tailed Mouse			**P4**										●	●		
Notomys alexis	Spinifex Hopping-mouse													●			
Pseudomys chapmani	Western Pebble-mound Mouse			**P4**	●	●		●	●	●	●	●	●	●	●		●
Pseudomys delicatulus	Delicate Mouse					●								●			●
Pseudomys desertor	Desert Mouse				●						●			●			●
Pseudomys hermannsburgensis	Sandy Inland Mouse				●	●		●			●	●	●	●			●
Zyzomys argurus	Common Rock-rat				●	●						●	●	●			●
CANIDAE																	
Canis lupus dingo	Dingo				●			●	●		●	●		●			●
INTRODUCED MAMMALS																	
**Mus musculus*	House Mouse				●			●				●		●			●

Family and Species	Common name	Conservation Status			*ecologia* internal database	Ninox 2009b	Ninox 1995	HGM 1999a	HGM 1999b	Maunsell 2003	Ninox 2009a	Ninox 1994	Biota 2010	NatureMap	DEC Threatened fauna	EPBC Protected matters	This survey
		EPBC Act	WC Act	DEC													
**Canis lupus familiaris*	Dog				●									●			
**Vulpes vulpes*	Red Fox															●	
**Felis catus*	Cat				●				●	●		●		●		●	
**Oryctolagus cuniculus*	Rabbit				●									●		●	●
**Equus asinus*	Donkey				●		●						●	●			
**Equus caballus*	Horse				●									●			
**Camelus dromedarius*	Camel										●			●			
**Bos taurus*	Cow				●		●	●		●	●	●	●	●			

Appendix E2: Birds

Family and Species	Common name	Conservation Status			*ecologia* internal database	Ninox 2009b	Ninox 1995	HGM 1999a	HGM 1999b	Maunsell 2003	Ninox 2009a	Ninox 1994	Biota 2010	NatureMap	Birdata	DEC Threatened fauna	EPBC Protected matters	This survey
		EPBC Act	WC Act	DEC														
CASUARIIDAE																		
Dromaius novaehollandiae	Emu				●		●	●		●		●		●				
PHASIANIDAE																		
Coturnix ypsilophora	Brown Quail													●				●
Coturnix pectoralis	Stubble Quail												●		●			
ANATIDAE																		
Dendrocygna eytoni	Plumed Whistling-Duck													●				
Tadorna tadornoides	Australian Shelduck													●				
Anas gracilis	Grey Teal				●			●				●	●					
Anas superciliosa	Pacific Black Duck				●			●		●				●				
Aythya australis	Hardhead				●													
COLUMBIDAE																		
Phaps chalcoptera	Common Bronzewing				●	●	●			●		●		●	●			●
Ocyphaps lophotes	Crested Pigeon				●	●	●		●	●		●	●	●	●			●
Geophaps plumifera	Spinifex Pigeon				●	●	●		●	●		●	●	●	●			●
Geopelia cuneata	Diamond Dove				●	●	●		●	●	●	●	●	●	●			●
Geopelia striata	Peaceful Dove				●					●		●	●	●				
PODARGIDAE																		
Podargus strigoides	Tawny Frogmouth				●			●						●	●			●
EUROSTOPODIDAE																		
Eurostopodus argus	Spotted Nightjar				●	●		●		●	●	●		●	●			●
AEGOTHELIDAE																		
Aegotheles cristatus	Australian Owlet-nightjar				●	●			●	●		●		●	●			●
APODIDAE																		

Family and Species	Common name	Conservation Status			*ecologia* internal database	Ninox 2009b	Ninox 1995	HGM 1999a	HGM 1999b	Maunsell 2003	Ninox 2009a	Ninox 1994	Biota 2010	NatureMap	Birdata	DEC Threatened fauna	EPBC Protected matters	This survey
		EPBC Act	WC Act	DEC														
Apus pacificus	Fork-tailed Swift	M	S3		●											●	●	●
PHALACROCORACIDAE																		
Microcarbo melanoleucos	Little Pied Cormorant				●			●		●			●					
Phalacrocorax sulcirostris	Little Black Cormorant				●					●				●				
ARDEIDAE																		
Ardea pacifica	White-necked Heron				●		●	●						●				
Ardea modesta	Eastern Great Egret	M	S3							●							●	
Ardea ibis	Cattle Egret	M	S3														●	
Egretta novaehollandiae	White-faced Heron				●	●		●				●						
Nycticorax caledonicus	Nankeen Night-Heron				●					●								
THRESKIORNITHIDAE																		
Threskiornis spinicollis	Straw-necked Ibis				●													●
ACCIPITRIDAE																		
Elanus axillaris	Black-shouldered Kite				●					●								●
Lophoictinia isura	Square-tailed Kite				●						●							
Hamirostra melanosternon	Black-breasted Buzzard				●	●								●				
Haliastur sphenurus	Whistling Kite				●	●				●		●	●	●				●
Milvus migrans	Black Kite				●									●				
Accipiter fasciatus	Brown Goshawk				●			●				●		●				●
Accipiter cirrocephalus	Collared Sparrowhawk				●			●		●		●		●	●			●
Circus assimilis	Spotted Harrier				●		●	●				●		●	●			●
Aquila audax	Wedge-tailed Eagle				●	●								●	●			●
Hieraaetus morphnoides	Little Eagle				●			●		●			●	●				●
FALCONIDAE																		
Falco cenchroides	Nankeen Kestrel				●	●			●	●		●	●	●	●			●
Falco berigora	Brown Falcon				●	●	●	●		●	●	●		●	●			●

Family and Species	Common name	Conservation Status			*ecologia* internal database	Ninox 2009b	Ninox 1995	HGM 1999a	HGM 1999b	Maunsell 2003	Ninox 2009a	Ninox 1994	Biota 2010	NatureMap	Birdata	DEC Threatened fauna	EPBC Protected matters	This survey
		EPBC Act	WC Act	DEC														
Falco longipennis	Australian Hobby				●	●		●	●	●		●		●				●
Falco hypoleucos	Grey Falcon		**S1**	**VU**	●									●		●		
Falco peregrinus	Peregrine Falcon		**S4**	**Other**	●							●						
OTIDIDAE																		
Ardeotis australis	Australian Bustard			**P4**	●	●	●	●	●		●	●		●	●	●		●
BURHINIDAE																		
Burhinus grallarius	Bush Stone-curlew			**P4**										●		●		●
RECURVIROSTRIDAE																		
Himantopus himantopus	Black-winged Stilt													●				
CHARADRIIDAE																		
Charadrius veredus	Oriental Plover	**M**	**S3**														●	
Elseyornis melanops	Black-fronted Dotterel				●			●		●		●		●				
SCOLOPACIDAE																		
Actitis hypoleucos	Common Sandpiper	**M**	**S3**							●								
TURNICIDAE																		
Turnix velox	Little Button-quail				●		●	●	●			●		●	●			●
CACATUIDAE																		
Eolophus roseicapillus	Galah				●	●	●	●		●	●	●		●	●			●
Cacatua sanguinea	Little Corella				●	●		●	●	●	●	●	●	●	●			
Nymphicus hollandicus	Cockatiel				●			●						●				●
PSITTACIDAE																		
Barnardius zonarius	Australian Ringneck				●	●	●		●	●	●	●	●		●			●
Psephotus varius	Mulga Parrot				●													●
Melopsittacus undulatus	Budgerigar				●	●	●	●	●		●	●		●	●			●
Neopsephotus bourkii	Bourke's Parrot				●													
Pezoporus occidentalis	Night Parrot	**EN**	**S1**	**CR**													●	

Family and Species	Common name	Conservation Status			*ecologia* internal database	Ninox 2009b	Ninox 1995	HGM 1999a	HGM 1999b	Maunsell 2003	Ninox 2009a	Ninox 1994	Biota 2010	NatureMap	Birdata	DEC Threatened fauna	EPBC Protected matters	This survey
		EPBC Act	WC Act	DEC														
CUCULIDAE																		
Centropus phasianinus	Pheasant Coucal												●					
Chalcites basalis	Horsfield's Bronze-Cuckoo				●	●		●		●	●		●	●	●			●
Chalcites osculans	Black-eared Cuckoo				●				●						●			
Cacomantis pallidus	Pallid Cuckoo				●	●	●	●	●		●				●			
STRIGIDAE																		
Ninox connivens	Barking Owl					●				●		●						
Ninox novaeseelandiae	Southern Boobook				●			●				●		●				●
TYTONIDAE																		
Tyto javanica	Eastern Barn Owl				●													●
HALCYONIDAE																		
Dacelo leachii	Blue-winged Kookaburra				●			●		●			●					
Todiramphus pyrrhopygius	Red-backed Kingfisher				●	●		●		●	●	●	●	●	●			●
Todiramphus sanctus	Sacred Kingfisher				●	●	●	●	●			●		●				
MEROPIDAE																		
Merops ornatus	Rainbow Bee-eater	**M**	**S3**		●			●	●	●		●	●	●		●	●	
CLIMACTERIDAE																		
Climacteris melanura	Black-tailed Treecreeper				●		●	●				●						
PTILONORHYNCHIDAE																		
Ptilonorhynchus guttatus	Western Bowerbird				●	●		●	●	●		●		●	●			●
MALURIDAE																		
Malurus splendens	Splendid Fairy-wren				●									●	●			●
Malurus leucopterus	White-winged Fairy-wren				●	●	●	●		●		●		●	●			●
Malurus lamberti	Variegated Fairy-wren				●	●	●	●	●	●	●	●	●	●	●			●
Stipiturus ruficeps	Rufous-crowned Emu-wren				●	●				●				●	●			●
Amytornis striatus	Striated Grasswren				●	●		●		●				●	●			

Family and Species	Common name	Conservation Status			*ecologia* internal database	Ninox 2009b	Ninox 1995	HGM 1999a	HGM 1999b	Maunsell 2003	Ninox 2009a	Ninox 1994	Biota 2010	NatureMap	Birdata	DEC Threatened fauna	EPBC Protected matters	This survey
		EPBC Act	WC Act	DEC														
ACANTHIZIDAE																		
Pyrrholaemus brunneus	Redthroat													●	●			
Smicrornis brevirostris	Weebill				●	●	●		●	●	●	●	●	●	●			●
Gerygone fusca	Western Gerygone				●	●	●		●	●	●	●	●	●	●			●
Acanthiza robustirostris	Slaty-backed Thornbill				●							●		●	●			
Acanthiza chrysorrhoa	Yellow-rumped Thornbill				●									●				
Acanthiza uropygialis	Chestnut-rumped Thornbill				●	●	●				●	●		●	●			●
Acanthiza apicalis	Inland Thornbill				●	●			●		●			●	●			●
PARDALOTIDAE																		
Pardalotus rubricatus	Red-browed Pardalote				●		●	●		●		●	●	●				●
Pardalotus striatus	Striated Pardalote				●	●	●	●	●	●		●	●	●	●			●
MELIPHAGIDAE																		
Certhionyx variegatus	Pied Honeyeater				●			●						●				
Lichenostomus virescens	Singing Honeyeater				●	●	●	●	●	●	●	●	●	●	●			●
Lichenostomus keartlandi	Grey-headed Honeyeater				●	●	●	●		●	●	●	●	●	●			●
Lichenostomus penicillatus	White-plumed Honeyeater				●	●		●	●	●		●	●	●	●			
Purnella albifrons	White-fronted Honeyeater				●		●					●						●
Manorina flavigula	Yellow-throated Miner				●	●	●	●	●	●	●	●	●	●	●			●
Acanthagenys rufogularis	Spiny-cheeked Honeyeater				●	●	●			●	●		●	●	●			●
Conopophila whitei	Grey Honeyeater				●									●				●
Epthianura tricolor	Crimson Chat				●			●		●		●		●	●			●
Sugomel niger	Black Honeyeater				●			●				●		●	●			
Lichmera indistincta	Brown Honeyeater				●		●	●	●	●		●	●	●	●			●
Melithreptus gularis	Black-chinned Honeyeater				●					●				●				●
POMATOSTOMIDAE																		
Pomatostomus temporalis	Grey-crowned Babbler				●	●	●	●		●	●	●	●	●	●			●

Family and Species	Common name	Conservation Status			*ecologia* internal database	Ninox 2009b	Ninox 1995	HGM 1999a	HGM 1999b	Maunsell 2003	Ninox 2009a	Ninox 1994	Biota 2010	NatureMap	Birdata	DEC Threatened fauna	EPBC Protected matters	This survey
		EPBC Act	WC Act	DEC														
Pomatostomus superciliosus	White-browed Babbler				●		●		●					●	●			●
PSOPHODIDAE																		
Cinclosoma castaneothorax	Chestnut-breasted Quail-thrush				●													
NEOSITTIDAE																		
Daphoenositta chrysoptera	Varied Sittella				●									●	●			
CAMPEPHAGIDAE																		
Coracina maxima	Ground Cuckoo-shrike				●						●			●	●			
Coracina novaehollandiae	Black-faced Cuckoo-shrike				●	●	●	●	●	●	●	●	●	●	●			●
Lalage sueurii	White-winged Triller				●	●	●	●	●	●		●		●	●			●
PACHYCEPHALIDAE																		
Pachycephala rufiventris	Rufous Whistler				●	●	●	●	●	●	●	●	●	●	●			●
Colluricincla harmonica	Grey Shrike-thrush				●	●		●	●	●	●	●	●	●	●			●
Oreoica gutturalis	Crested Bellbird				●	●	●	●	●	●	●	●	●	●	●			●
ARTAMIDAE																		
Artamus personatus	Masked Woodswallow				●	●			●			●	●	●				●
Artamus cinereus	Black-faced Woodswallow				●	●	●	●	●	●	●	●	●	●	●			●
Artamus minor	Little Woodswallow				●	●				●			●	●	●			●
Cracticus torquatus	Grey Butcherbird				●	●	●				●	●		●	●			●
Cracticus nigrogularis	Pied Butcherbird				●	●	●	●	●	●	●	●		●	●			●
Cracticus tibicen	Australian Magpie				●	●		●	●	●	●	●		●	●			●
RHIPIDURIDAE																		
Rhipidura albiscapa	Grey Fantail				●	●					●			●	●			●
Rhipidura leucophrys	Willie Wagtail				●	●	●	●	●	●	●	●	●	●	●			●
CORVIDAE																		
Corvus bennetti	Little Crow				●	●							●	●	●			●
Corvus orru	Torresian Crow				●	●	●	●	●	●	●	●	●	●	●			●

Family and Species	Common name	Conservation Status			*ecologia* internal database	Ninox 2009b	Ninox 1995	HGM 1999a	HGM 1999b	Maunsell 2003	Ninox 2009a	Ninox 1994	Biota 2010	NatureMap	Birdata	DEC Threatened fauna	EPBC Protected matters	This survey
		EPBC Act	WC Act	DEC														
MONARCHIDAE																		
Grallina cyanoleuca	Magpie-lark				●	●		●	●	●	●	●	●	●	●			●
PETROICIDAE																		
Petroica goodenovii	Red-capped Robin				●	●	●		●		●	●		●	●			●
Melanodryas cucullata	Hooded Robin				●	●	●	●	●	●		●	●	●	●			●
ALAUDIDAE																		
Mirafra javanica	Horsfield's Bushlark				●									●				●
ACROCEPHALIDAE																		
Acrocephalus australis	Australian Reed-Warbler									●								
MEGALURIDAE																		
Cincloramphus mathewsi	Rufous Songlark				●			●		●		●	●	●	●			●
Cincloramphus cruralis	Brown Songlark				●			●										●
Eremiornis carteri	Spinifexbird				●	●	●	●		●				●	●			●
HIRUNDINIDAE																		
Petrochelidon ariel	Fairy Martin				●			●							●			
Petrochelidon nigricans	Tree Martin				●			●			●	●	●	●	●			
NECTARINIIDAE																		
Dicaeum hirundinaceum	Mistletoebird				●	●	●			●		●		●	●			●
ESTRILDIDAE																		
Taeniopygia guttata	Zebra Finch				●	●	●	●	●	●	●	●	●	●	●			●
Neochmia ruficauda subclarescens	Star Finch (western)			**P4**	●								●	●				
Emblema pictum	Painted Finch				●	●	●	●		●	●	●	●	●	●			●
MOTACILLIDAE																		
Anthus novaeseelandiae	Australasian Pipit				●	●		●	●		●			●				●

Appendix E3: Reptiles

Family and Species	Common name	Conservation Status			*ecologia* internal database	Ninox 2009b	Ninox 1995	HGM 1999a	HGM 1999b	Maunsell 2003	Ninox 2009a	Ninox 1994	Biota 2010	NatureMap	DEC Threatened fauna	EPBC Protected matters	This survey
		EPBC Act	WC Act	DEC													
CHELUIDAE																	
Chelodina steindachneri	Flat-shelled Turtle													●			
AGAMIDAE																	
Amphibolurus longirostris					●	●	●	●	●		●	●	●	●			●
Caimanops amphiboluroides					●						●						
Ctenophorus caudicinctus	Ring-tailed Dragon				●	●	●	●			●	●	●	●			●
Ctenophorus isolepis	Central Military Dragon				●			●				●	●	●			
Ctenophorus nuchalis	Central Netted Dragon				●							●					
Ctenophorus reticulatus	Western Netted Dragon				●						●			●			
Diporiphora valens					●									●			●
Diporiphora winneckei	Blue-lined Dragon													●			
Pogona minor	Dwarf Bearded Dragon				●	●					●	●		●			●
Tympanocryptis cephalus	Pebble Dragon													●			●
DIPLODACTYLIDAE																	
Crenadactylus ocellatus	Clawless Gecko				●									●			
Diplodactylus conspicillatus	Fat-tailed Gecko				●							●		●			
Diplodactylus pulcher					●	●								●			●
Diplodactylus savagei					●	●								●			●
Lucasium stenodactylum					●	●				●		●	●	●			●
Lucasium wombeyi					●									●			●
Oedura marmorata	Marbled Velvet Gecko				●					●		●	●	●			●
Rhynchoedura ornata	Beaked Gecko				●	●		●				●		●			●
Strophurus elderi					●									●			●
Strophurus jeanae					●												
Strophurus strophurus					●												

Family and Species	Common name	Conservation Status			*ecologia* internal database	Ninox 2009b	Ninox 1995	HGM 1999a	HGM 1999b	Maunsell 2003	Ninox 2009a	Ninox 1994	Biota 2010	NatureMap	DEC Threatened fauna	EPBC Protected matters	This survey
		EPBC Act	WC Act	DEC													
Strophurus wellingtonae					●	●								●			●
CARPHODACTYLIDAE																	
Nephrurus wheeleri					●									●			●
Underwoodisaurus seorsus					●									●			●
GEKKONIDAE																	
Gehyra pilbara							●					●		●			
Gehyra punctata					●	●		●					●	●			●
Gehyra variegata					●	●		●		●	●	●		●			●
Heteronotia binoei	Bynoe's Gecko				●	●		●		●	●	●		●			●
Heteronotia spelea	Desert Cave Gecko				●									●			●
PYGOPODIDAE																	
Delma butleri					●												
Delma elegans					●									●			●
Delma haroldi					●									●			
Delma nasuta					●	●					●		●	●			●
Delma pax					●	●					●		●	●			●
Delma tincta					●	●					●			●			●
Lialis burtonis					●			●			●			●			●
Pygopus nigriceps					●									●			●
SCINCIDAE																	
Carlia munda					●	●		●			●	●	●	●			●
Carlia triacantha					●	●								●			●
Cryptoblepharus buchananii						●								●			
Cryptoblepharus ustulatus					●	●						●		●			●
Ctenotus ariadnae														●			
Ctenotus duricola					●	●		●			●	●		●			●

Family and Species	Common name	Conservation Status			*ecologia* internal database	Ninox 2009b	Ninox 1995	HGM 1999a	HGM 1999b	Maunsell 2003	Ninox 2009a	Ninox 1994	Biota 2010	NatureMap	DEC Threatened fauna	EPBC Protected matters	This survey
		EPBC Act	WC Act	DEC													
Ctenotus grandis					●									●			
Ctenotus hanloni					●								●				
Ctenotus helenae					●	●						●		●			●
Ctenotus leonhardii					●									●			
Ctenotus pantherinus	Leopard Ctenotus				●	●		●			●	●	●	●			●
Ctenotus piankai					●												
Ctenotus robustus																	●
Ctenotus rubicundus					●								●	●			
Ctenotus rutilans					●	●					●			●			●
Ctenotus saxatilis	Rock Ctenotus				●	●					●	●		●			●
Ctenotus schomburgkii					●	●					●			●			●
Ctenotus serventyi					●			●						●			
Ctenotus uber					●	●								●			
Cyclodomorphus melanops	Slender Blue-tongue				●	●	●	●			●		●	●			●
Egernia cygnitos	Western Pilbara Spiny-tail Skink				●									●			●
Egernia formosa					●							●		●			●
Egernia pilbarensis	Pilbara Skink				●		●					●					
Eremiascincus fasciolatus	Narrow-banded Sand Swimmer													●			
Eremiascincus richardsonii	Broad-banded Sand Swimmer										●			●			
Lerista flammicauda														●			
Lerista jacksoni	(L. muelleri group)													●			
Lerista labialis												●					
Lerista macropisthopus														●			
Lerista muelleri					●	●					●			●			●
Lerista neander					●	●								●			●
Lerista timida																	●

Family and Species	Common name	Conservation Status			*ecologia* internal database	Ninox 2009b	Ninox 1995	HGM 1999a	HGM 1999b	Maunsell 2003	Ninox 2009a	Ninox 1994	Biota 2010	NatureMap	DEC Threatened fauna	EPBC Protected matters	This survey
		EPBC Act	WC Act	DEC													
Lerista verhmens																	●
Lerista zietzi					●			●						●			●
Menetia greyii					●						●	●		●			●
Menetia surda					●	●								●			
Morethia ruficauda					●	●						●		●			●
Notoscincus ornatus												●					
Tiliqua multifasciata	Central Blue-tongue				●	●					●			●			●
VARANIDAE																	
Varanus acanthurus	Spiny-tailed Monitor				●	●		●						●			●
Varanus brevicauda	Short-tailed Pygmy Monitor				●	●								●			●
Varanus bushi	Pilbara Mulga Monitor							●						●			●
Varanus caudolineatus					●									●			
Varanus giganteus	Perentie				●									●			●
Varanus gouldii	Sand Monitor				●							●		●			
Varanus panoptes	Yellow-spotted Monitor				●	●		●						●			●
Varanus pilbarensis	Pilbara Rock Monitor				●					●		●		●			
Varanus tristis tristis	Racehorse Monitor				●	●						●		●			●
TYPHLOPIDAE																	
Ramphotyphlops ammodytes														●			
Ramphotyphlops ganei				**P1**										●	●		
Ramphotyphlops grypus					●	●								●			
Ramphotyphlops hamatus					●	●								●			
Ramphotyphlops pilbarensis														●			
BOIDAE																	
Antaresia perthensis	Pygmy Python				●									●			●
Antaresia stimsoni	Stimson's Python				●									●			

Family and Species	Common name	Conservation Status			*ecologia* internal database	Ninox 2009b	Ninox 1995	HGM 1999a	HGM 1999b	Maunsell 2003	Ninox 2009a	Ninox 1994	Biota 2010	NatureMap	DEC Threatened fauna	EPBC Protected matters	This survey
		EPBC Act	WC Act	DEC													
Aspidites melanocephalus	Black-headed Python				●									●			
Liasis olivaceus barroni	Pilbara Olive Python	**VU**	**S1**	**VU**	●			●		●				●	●	●	
ELAPIDAE																	
Acanthophis wellsi	Pilbara Death Adder				●	●								●			●
Brachyurophis approximans					●									●			●
Demansia psammophis	Yellow-faced Whipsnake				●			●			●		●	●			●
Demansia rufescens	Rufous Whipsnake				●			●						●			●
Furina ornata	Moon Snake				●					●				●			●
Parasuta monachus	Hooded Snake				●	●								●			●
Pseudechis australis	Mulga Snake				●	●		●		●				●			●
Pseudonaja mengdeni	Western Brown Snake				●									●			●
Pseudonaja modesta	Ringed Brown Snake				●									●			●
Suta fasciata	Rosen's Snake					●								●			●
Suta punctata	Spotted Snake													●			
Vermicella snelli	Pilbara Bandy Bandy																●

Appendix E4: Amphibians

Family and Species	Common name	Conservation Status			*ecologia* internal database	Ninox 2009b	Ninox 1995	HGM 1999a	HGM 1999b	Maunsell 2003	Ninox 2009a	Ninox 1994	Biota 2010	NatureMap	DEC Threatened fauna	EPBC Protected matters	This survey
		EPBC Act	WC Act	DEC													
HYLIDAE																	
Cyclorana maini	Sheep Frog				●	●					●	●		●			
Litoria rubella	Little Red Tree Frog				●		●		●			●		●			
LIMNODYNASTIDAE																	
Neobatrachus aquilonius	Northern Burrowing Frog													●			
Neobatrachus sutor	Shoemaker Frog													●			
Notaden nichollsi	Desert Spadefoot				●												
Platyplectrum spenceri	Centralian Burrowing Frog				●												
MYOBATRACHIDAE																	
Pseudophryne douglasi	Gorge Toadlet													●			
Uperoleia russelli	Northwest Toadlet				●												

Appendix E5: Previous SRE species recorded from the region

Class (Order)	Family	Taxa	SRE status*
Arachnida (Araneae)			
	Miturgidae	'Genus indet.' 'sp. indent.'	Potential
	Selenopidae	*Anyphops* 'sp. indent.'	Potential
Arachnida (Mygalomorphae)			
	Actinopodidae	*Missulena* 'sp. indent.'	Potential
	Actinopodidae	*Missulena* `MYG044`	Potential
	Barychelidae	*Synothele* `MYG055`	Potential
	Idiopidae	*Aganippe* `MYG083`	Potential
	Idiopidae	*Aganippe* 'sp (female)`	Potential
	Idiopidae	*Anidiops* `MYG083`	Potential
	Nemesiidae	*Chenistonia* `MYG088 female`	Potential
	Nemesiidae	*Chenistonia* `MYG088`	Potential
	Nemesiidae	*Teyl* `MYG027`	Potential
	Nemesiidae	*Yilgarnia* `MYG197`	Potential
Arachnida (Pseudoscorpiones)			
	Chthoniidae	*Austrochthonius* 'sp. indet.'	Potential
	Olpiidae	*Austrohorus* 'sp. indet.'	Potential
	Olpiidae	*Austrohorus* 'sp. A'	Unknown
	Olpiidae	*Austrohorus* 'sp. B.'	Unknown
	Olpiidae	*Beierolpium* 'sp. indet.'	Potential
	Olpiidae	*Beierolpium 'sp 8/2'*	Potential
	Olpiidae	*Beierolpium 'sp 8/3'*	Potential
	Olpiidae	*Beierolpium 'sp 8/4 small'*	Potential
Arachnida (Scorpiones)			
	Urodacidae	*Urodacus* 'sp. indent.'	Potential
Chilopoda (Geophilomorpha)			
	Unknown	'Genus indet.' 'sp. indent.'	Unknown
Diplopoda (Polydesmida)			
	Paradoxosomatidae	*Antichiropis* sp.	Potential
	Paradoxosomatidae	*Antichiropus* `DIP006`	Potential
	Paradoxosomatidae	*Antichiropus* `DIP007 (?, female)`	Potential
	Paradoxosomatidae	*Antichiropus* `DIP007 (?, juv.)`	Potential
	Paradoxosomatidae	*Antichiropus* `DIP007`	Potential
	Paradoxosomatidae	*Antichiropus* `Wonmunna`	Potential
Gastropoda (Stylommatophora)			
	Camaenidae	Gen. Nov. sp. Z	Potential
	Camaenidae	Gen. Nov. sp. `small Mount Robinson`	Potential
	Succineidae	*Succinea* sp.	Potential
Myriapoda (Geophilomorpha)			
	Geophilidae	'Genus indet.' 'sp. indent.'	Potential

* SRE status defined in Section 3.5

APPENDIX F FAUNA SPECIES RECORDED DURING SURVEY

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Appendix E1: Mammals site x species matrix

FAMILY and species	Common name	EPBC Act	WC Act	DEC	GWA s1		GWA s2		GWA s3		GWA s4		GWA s5		GWA s6		GWA s7		GWA s8		GWA s9		GWA s10		GWA s11		GWA s12		GWA Opp	
					Phase 1	Phase 2	Phase 1	Phase 2	Phase 1	Phase 2	Phase 1	Phase 2	Phase 1	Phase 2	Phase 1	Phase 2	Phase 1	Phase 2	Phase 1	Phase 2	Phase 1	Phase 2	Phase 1	Phase 2	Phase 1	Phase 2	Phase 1	Phase 2	Phase 1	Phase 2
DASYURIDAE																														
Dasykaluta rosamondae	Little Red Kaluta						1					10	1	7		4	2	6						2		1				
Ningaui timealeyi	Pilbara Ningaui					1	4	2	1	4		5	1	1				1					2	1	1	1	7	3		
Planigale sp.	Planigale																		1									1		
Sminthopsis macroura	Stripe-faced Dunnart				3	1	1		2	1		6		1		1			7		2	1			2	4		3		
Sminthopsis ooldea	Ooldea Dunnart							1	1	5	1	2	1																	
MACROPODIDAE																														
Macropus robustus	Euro																				1								10	2
Macropus rufus	Red Kangaroo																		2										2	
Petrogale rothschildi	Rothschilds Rock Wallaby																												2	2
HIPPOSIDERIDAE																														
Rhinonicteris aurantia (Pilbara form)	Pilbara Leaf-nosed Bat	**VU**	**S1**	**VU**																										
EMBALLONURIDAE																														
Taphozous georgianus/hilli	Common Sheathtail Bat																													
Saccolaimus flaviventris	Yellow-bellied Sheathtail Bat																													
VESPERTILIONIDAE																														
Chalinolobus gouldii	Gould's Wattled Bat																													
Nyctophilus geoffroyi	Lesser Long-eared Bat																													
Scotorepens greyii	Little Broad-nosed Bat																													
Vespadelus finlaysoni	Finlayson's Cave Bat																													
MOLOSSIDAE																														
Chaerophon jobensis	Northern Freetail Bat																													
Mormopterus beccarii	Beccari's Freetail Bat																													
MURIDAE																														
Pseudomys chapmani	Western Pebble-mound Mouse			**P4**																									S	S
Pseudomys delicatulus	Delicate Mouse				1										1		1						1				2			
Pseudomys desertor	Desert Mouse					2		1		1		5		1			3				2	9		1	3	1				
Pseudomys hermannsburgensis	Sandy Inland Mouse				2			1	6	2		1	11	7	8	3	5	4		3	1		6	2	6		4			1
Zyzomys argurus	Common Rock-rat					1		13					1	1	7	8		1		2	1	2					4	11		
CANIDAE																														
Canis lupus dingo	Dingo								1																				3	4
INTRODUCED MAMMALS																														
**Mus musculus*	House mouse				2						1	1	1	6	1		2	1			1	6	3		5	5	5	1		
**Oryctolagus cuniculus*	Rabbit							1																					6	1

Bat activity status:

	Low
	Medium
	High

S = sign of activity

Appendix E2: Birds site x species matrix

FAMILY and species	Common name	EPBC Act	WC Act	DEC	GWA s1		GWA s2		GWA s3		GWA s4		GWA s5		GWA s6		GWA s7		GWA s8		GWA s9		GWA s10		GWA s11		GWA s12		GWA Opp	
					Phase 1	Phase 2	Phase 1	Phase 2	Phase 1	Phase 2	Phase 1	Phase 2	Phase 1	Phase 2	Phase 1	Phase 2	Phase 1	Phase 2	Phase 1	Phase 2	Phase 1	Phase 2	Phase 1	Phase 2	Phase 1	Phase 2	Phase 1	Phase 2	Phase 1	Phase 2
PHASIANIDAE																														
Coturnix ypsilophora	Brown Quail								7																					
COLUMBIDAE																														
Phaps chalcoptera	Common Bronzewing				4	1	2						3							1						3	4	1	14	
Ocyphaps lophotes	Crested Pigeon					7	1		2	1	2	1		2				4	11	48	3	3		2	24	4	4			
Geophaps plumifera	Spinifex Pigeon																												16	2
Geopelia cuneata	Diamond Dove								23	2												1	4		2			2	19	2
PODARGIDAE																														
Podargus strigoides	Tawny Frogmouth				2																								5	
EUROSTOPODIDAE																														
Eurostopodus argus	Spotted Nightjar				1		1		1		2												1							3
AEGOTHELIDAE																														
Aegotheles cristatus	Australian Owlet-nightjar										1	1	1							1			1					1		3
APODIDAE																														
Apus pacificus	Fork-tailed Swift	**M**	**S3**							20		70						440												23
THRESKIORNITHIDAE																														
Threskiornis spinicollis	Straw-necked Ibis																												5	
ACCIPITRIDAE																														
Elanus axillaris	Black-shouldered Kite										1	1					1				1									3
Haliastur sphenurus	Whistling Kite								1											1										
Accipiter fasciatus	Brown Goshawk									1																				
Accipiter cirrocephalus	Collared Sparrowhawk												1												1					
Circus assimilis	Spotted Harrier				3				2	1			2		3				4	2			2				1		2	3
Aquila audax	Wedge-tailed Eagle								1											1									1	1
Hieraaetus morphnoides	Little Eagle																												1	
FALCONIDAE																														
Falco cenchroides	Nankeen Kestrel										1	1						2						1						
Falco berigora	Brown Falcon				1						2		1	1			2	1	2	1			2		1		1	1	6	7
Falco longipennis	Australian Hobby								1										1											
OTIDIDAE																														
Ardeotis australis	Australian Bustard			**P4**																									3	
BURHINIDAE																														
Burhinus grallarius	Bush Stone-curlew			**P4**						S																				
TURNICIDAE																														
Turnix velox	Little Button-quail						1						5		3		2		5	1		1	10		4		6		18	1
CACATUIDAE																														
Eolophus roseicapillus	Galah								13		4	14							1	38			10							
Nymphicus hollandicus	Cockatiel								35	10	1									66						20				
Barnardius zonarius	Australian Ringneck				9	8		6				2	8			6	7					7	5			3			2	
Psephotus varius	Mulga Parrot										8													2						
Melopsittacus undulatus	Budgerigar								65	10	64	8	31	4	76		82	5	348			2	14		141	30	9	14	95	12
CUCULIDAE																														
Chalcites basalis	Horsfield's Bronze-Cuckoo										1												1							
STRIGIDAE																														
Ninox novaeseelandiae	Southern Boobook																												1	
TYTONIDAE																														
Tyto javanica	Eastern Barn Owl																													1

Appendix E2: Birds site x species matrix

FAMILY and species	Common name	EPBC Act	WC Act	DEC	GWA s1		GWA s2		GWA s3		GWA s4		GWA s5		GWA s6		GWA s7		GWA s8		GWA s9		GWA s10		GWA s11		GWA s12		GWA Opp	
					Phase 1	Phase 2	Phase 1	Phase 2	Phase 1	Phase 2	Phase 1	Phase 2	Phase 1	Phase 2	Phase 1	Phase 2	Phase 1	Phase 2	Phase 1	Phase 2	Phase 1	Phase 2	Phase 1	Phase 2	Phase 1	Phase 2	Phase 1	Phase 2	Phase 1	Phase 2
HALCYONIDAE																														
Todiramphus pyrrhopygius	Red-backed Kingfisher						1				3		1	1			1	1			1		2		1	2	2		1	
PTILONORHYNCHIDAE																														
Ptilonorhynchus guttatus	Western Bowerbird										1	1									1				2				1	1
MALURIDAE																														
Malurus splendens	Splendid Fairy-wren								5	6																				
Malurus leucopterus	White-winged Fairy-wren								2	2	3	9							18	10					5	2			5	4
Malurus lamberti	Variegated Fairy-wren					2	10	10		6	9	14	4	7					4		2	1	12	4	14	8			23	6
Stipiturus ruficeps	Rufous-crowned Emu-wren																3	8							2	10	8	3		
ACANTHIZIDAE																														
Smicrornis brevirostris	Weebill				46	42	37	30			17	19	11	32	7	11	9	5			27	22		3		7	31	18	30	7
Gerygone fusca	Western Gerygone				1		4		20	10	4	1					3						11	2	1				7	2
Acanthiza uropygialis	Chestnut-rumped Thornbill								37	11																				6
Acanthiza apicalis	Inland Thornbill					2	2		12	7	1	1						2					8	11				6	7	
PARDALOTIDAE																														
Pardalotus rubricatus	Red-browed Pardalote													2		1	3					2							1	
Pardalotus striatus	Striated Pardalote				4		2				5										2	3							3	
MELIPHAGIDAE																														
Lichenostomus virescens	Singing Honeyeater				11	3		3	2	7	13	30	11	15	6	10	16	20	11	31	5	7	5	11	13	28	6	2	13	9
Lichenostomus keartlandi	Grey-headed Honeyeater				12	16					11	11	9		7	2	9	2			23	20					4	1	7	
Purnella albifrons	White-fronted Honeyeater					1						2																		
Manorina flavigula	Yellow-throated Miner				23	22	8	15		18	3	2	6	2		6	7	6			9	2		1		8	5	1	7	1
Acanthagenys rufogularis	Spiny-cheeked Honeyeater				14		2		11	21	8	3	2				15						2	6	2		3		5	2
Conopophila whitei	Grey Honeyeater									3																				
Epthianura tricolor	Crimson Chat				4						2		3	7			12				31								11	3
Lichmera indistincta	Brown Honeyeater				2	4	1	8																						
Melithreptus gularis	Black-chinned Honeyeater																2					3								
POMATOSTOMIDAE																														
Pomatostomus temporalis	Grey-crowned Babbler				3	6	6	12		4	9	12		2	4	5	9	12				2			2		7	4		2
Pomatostomus superciliosus	White-browed Babbler								7															4						
CAMPEPHAGIDAE																														
Coracina novaehollandiae	Black-faced Cuckoo-shrike						1		3	1		2	4	3		1	1					2	2		1		1		1	2
Lalage sueurii	White-winged Triller								2	7	10	1	2								4		1		4					
PACHYCEPHALIDAE																														
Pachycephala rufiventris	Rufous Whistler				5	13	5	5	8	4	3	7	3					4			2	2	5	9	1		2	3	5	3
Colluricincla harmonica	Grey Shrike-thrush				2	11	1	2		1	4	2	1	7		3	3	4			3	5		6	3		1		2	
Oreoica gutturalis	Crested Bellbird					5	1	5	1	6	2	19	2	5	1	2	3	9	1		1	2	2	1	5	1	3	1	2	
ARTAMIDAE																														
Artamus personatus	Masked Woodswallow						25																		12					
Artamus cinereus	Black-faced Woodswallow				8	3			10		16	7	6	23		12	11	6		3	17	21	12	1	4	3		5	12	2
Artamus minor	Little Woodswallow				3						1	6			5	24						4				5	2	6	4
Cracticus torquatus	Grey Butcherbird				1	4	2	1	5	6	1	1		1				1		1	1	1	5	3	1		1	2		
Cracticus nigrogularis	Pied Butcherbird				5	7	2	4	3	4	1	6	1	1	1	2		2			4	3								
Cracticus tibicen	Australian Magpie					4	3					2		1							1	2	1					3	2
RHIPIDURIDAE																														
Rhipidura albiscapa	Grey Fantail												1										3						2	
Rhipidura leucophrys	Willie Wagtail					6	1	4	4	6	7	11	3	6	5	5	6	12			11	7	5	8	4		3	2	6	3

Appendix E2: Birds site x species matrix

FAMILY and species	Common name	EPBC Act	WC Act	DEC	GWA s1		GWA s2		GWA s3		GWA s4		GWA s5		GWA s6		GWA s7		GWA s8		GWA s9		GWA s10		GWA s11		GWA s12		GWA Opp	
					Phase 1	Phase 2	Phase 1	Phase 2	Phase 1	Phase 2	Phase 1	Phase 2	Phase 1	Phase 2	Phase 1	Phase 2	Phase 1	Phase 2	Phase 1	Phase 2	Phase 1	Phase 2	Phase 1	Phase 2	Phase 1	Phase 2	Phase 1	Phase 2	Phase 1	Phase 2
CORVIDAE																														
Corvus bennetti	Little Crow				2																									
Corvus orru	Torresian Crow					2			2	2		3	1	3		2	3		1	1		1	1				1	2		
MONARCHIDAE																														
Grallina cyanoleuca	Magpie-lark						1																							
PETROICIDAE																														
Petroica goodenovii	Red-capped Robin				1	1			28	8													1	4						
Melanodryas cucullata	Hooded Robin						1			2	1	2		3				1	3	3	1			2	1				2	1
ALAUDIDAE																														
Mirafra javanica	Horsfield's Bushlark																		3											
MEGALURIDAE																														
Cincloramphus mathewsi	Rufous Songlark											3		4					3		4	1							2	1
Cincloramphus cruralis	Brown Songlark																													1
Eremiornis carteri	Spinifexbird										6	14	2	1	6	3	7	11			4	2	3	5	3	10	2	3	3	
NECTARINIIDAE																														
Dicaeum hirundinaceum	Mistletoebird																				1									
ESTRILDIDAE																														
Taeniopygia guttata	Zebra Finch				2			2	24	17	49	44	35	58	126	17	64	4	113	15	2	4	116	7	24	15	32	11	49	10
Emblema pictum	Painted Finch							8				5			31	4				2		1		2			20		2	
MOTACILLIDAE																														
Anthus novaeseelandiae	Australasian Pipit																		1											

Appendix E3: Reptiles site x species matrix

FAMILY and species	Common name	EPBC Act	WC Act	DEC	GWA s1		GWA s2		GWA s3		GWA s4		GWA s5		GWA s6		GWA s7		GWA s8		GWA s9		GWA s10		GWA s11		GWA s12		GWA Opp	
					Phase 1	Phase 2	Phase 1	Phase 2	Phase 1	Phase 2	Phase 1	Phase 2	Phase 1	Phase 2	Phase 1	Phase 2	Phase 1	Phase 2	Phase 1	Phase 2	Phase 1	Phase 2	Phase 1	Phase 2	Phase 1	Phase 2	Phase 1	Phase 2	Phase 1	Phase 2
AGAMIDAE																														
Amphibolurus longirostris					3			3																2	1		1		3	4
Ctenophorus caudicinctus	Ring-tailed Dragon				7	2	1	2		1	5	7	4	2	10	3	7	1	2		5	1	3	8	6	3	1	1	13	26
Diporiphora valens												1																		
Pogona minor	Dwarf Bearded Dragon						9	1		1											2					1		1		2
Tympanocryptis cephalus	Pebble Dragon																			3										
DIPLODACTYLIDAE																														
Diplodactylus pulcher									3		2													1						
Diplodactylus savagei					2		2																							
Lucasium stenodactylum						1	1				5						1	1			4	2			1	1			1	
Lucasium wombeyi					1			1													1	1							1	
Oedura marmorata	Marbled Velvet Gecko																													3
Rhynchoedura ornata	Beaked Gecko								3												2									
Strophurus wellingtonae					2				2		1	1						2			12		1	1						
Strophurus elderi					2																									
CARPHODACTYLIDAE																														
Nephrurus wheeleri																											1	1		
Underwoodisaurus seorsus				**P1**		1																								
GEKKONIDAE																														
Gehyra punctata															3												1		2	
Gehyra variegata					9	5	1	4	6	5			2	3				2				1	3	4	3	5	4	1	3	
Heteronotia binoei	Bynoe's Gecko				1	6	1	3			2	6	2		5	12	5	8				1	2	7	1	2	1	7		
Heteronotia spelea	Desert Cave Gecko														1													1		
PYGOPODIDAE																														
Delma elegans															1												1	1		
Delma nasuta					1	1									1		1								1			2		
Delma pax						1																					1			
Delma tincta													1								1									
Lialis burtonis												1	1									1	1	1		1		1	1	
Pygopus nigriceps									1	5	1						1	1			1	1								
SCINCIDAE																														
Carlia munda						2	7	3				4	1	1	1	1	4	1		3	3	3	2	1	3	6	2			
Carlia triacantha						1																								
Cryptoblepharus ustulatus							1																				1		2	17
Ctenotus duricola						1	1			1			1	7	2	1	1					3	1		2					
Ctenotus helenae					1	2	4	2			4	6	4	1	1	1	7	3			6	3	8	2	2		7	4		
Ctenotus pantherinus	Leopard Ctenotus				4	2					6	3	7	5	8	1	13	6	5	7	10	3		8	7	2	4	13		
Ctenotus robustus																				4										
Ctenotus rutilans						1					2	2		1		1								1	1					
Ctenotus saxatilis	Rock Ctenotus				1	4		5		1		1	1		4	4		1		1	1	14	1	2			1	15		4
Ctenotus schomburgkii									7	18		2									3									
Cyclodomorphus melanops	Slender Blue-tongue							3									1	1				1								
Egernia cygnitos																												1		
Egernia formosa																														2
Lerista muelleri								1								1							1							
Lerista neander											1						1				1									
Lerista timida					1		3																							

Appendix E3: Reptiles site x species matrix

FAMILY and species	Common name	EPBC Act	WC Act	DEC	GWA s1		GWA s2		GWA s3		GWA s4		GWA s5		GWA s6		GWA s7		GWA s8		GWA s9		GWA s10		GWA s11		GWA s12		GWA Opp	
					Phase 1	Phase 2	Phase 1	Phase 2	Phase 1	Phase 2	Phase 1	Phase 2	Phase 1	Phase 2	Phase 1	Phase 2	Phase 1	Phase 2	Phase 1	Phase 2	Phase 1	Phase 2	Phase 1	Phase 2	Phase 1	Phase 2	Phase 1	Phase 2	Phase 1	Phase 2
Lerista verhmens					1																									
Lerista zietzi						1	1	1			1																		2	2
Menetia greyii							1																							
Morethia ruficauda							3														3	1			1		1		1	
Tiliqua multifasciata	Central Blue-tongue																	1		3		2				1		1	1	
VARANIDAE																														
Varanus acanthurus	Spiny-tailed Monitor				1	1					1	1	1	2	3	8					6	5						2		
Varanus brevicauda	Short-tailed Pygmy Monitor										3	1	1	2		1		1						4		1				
Varanus bushi	Pilbara Mulga Monitor					1	1			1	2	2												2		1				
Varanus giganteus	Perentie																												1	2
Varanus panoptes	Yellow-spotted Monitor								1																					4
Varanus tristis	Racehorse Monitor				1		1			2														3		1		1		1
BOIDAE																														
Antaresia perthensis	Pygmy Python							1							2														1	1
ELAPIDAE																														
Acanthophis wellsi	Pilbara Death Adder																							1						
Brachyurophis approximans																							1				1	1		
Demansia psammophis	Yellow-faced Whipsnake								1									1	1	1		1	1							
Demansia rufescens	Rufous Whipsnake						1									2											1			
Furina ornata	Moon Snake					1							1				1								2		1	1	1	1
Parasuta monachus	Hooded Snake							1																						2
Pseudechis australis	Mulga Snake				1	1		1		1								1		1									3	
Pseudonaja mengdeni	Western Brown Snake											1										3							2	
Pseudonaja modesta	Ringed Brown Snake								1															2						
Suta fasciata	Rosen's Snake																							1						2
Vermicella snelli	Pilbara Bandy Bandy																								1					