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).

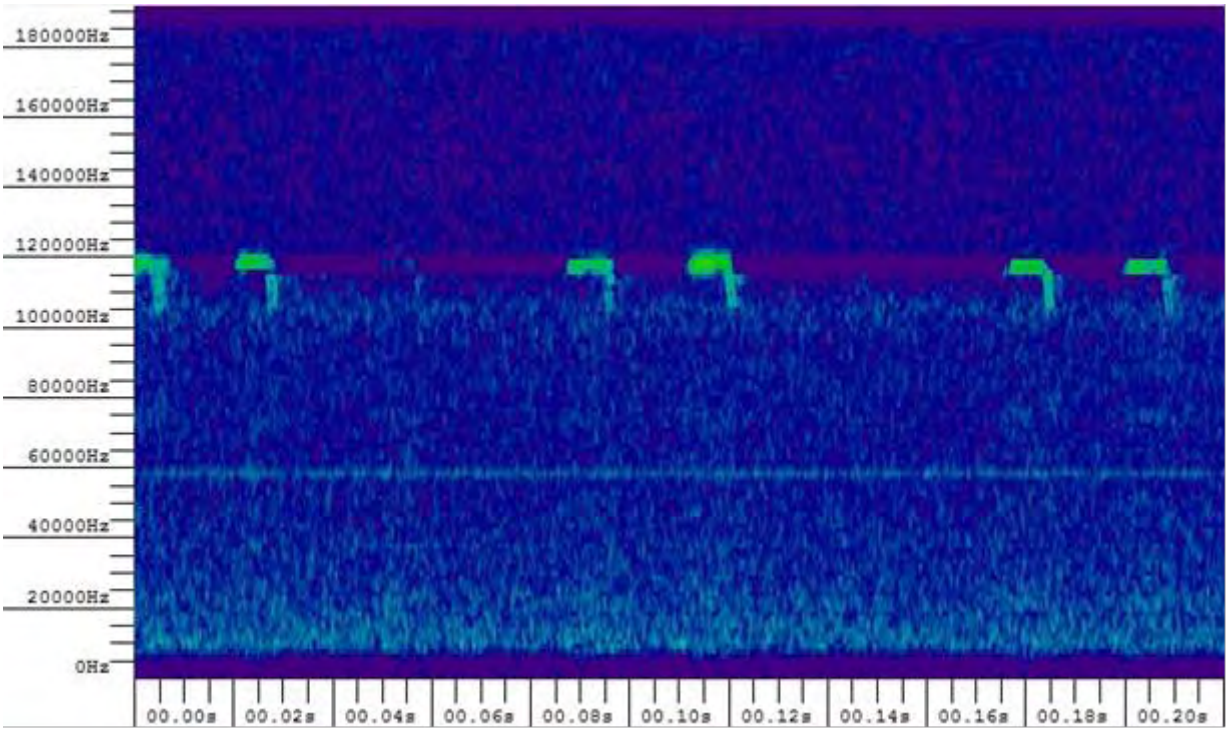


Figure 5.1 – Spectogram showing call frequency of Pilbara Leaf-nosed Bat recorded

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.

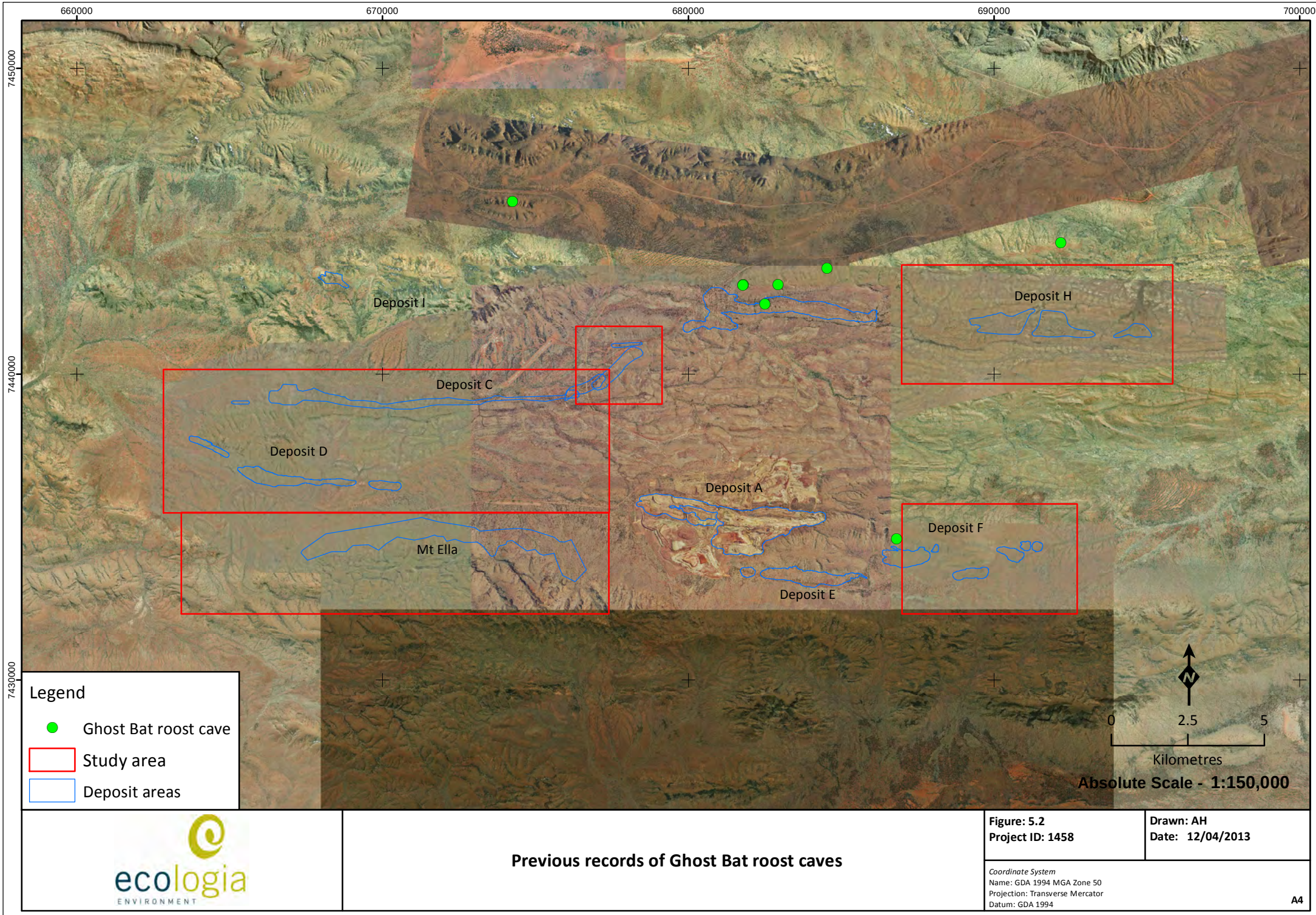
Table 5.2 – Previous Ghost Bat records

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**

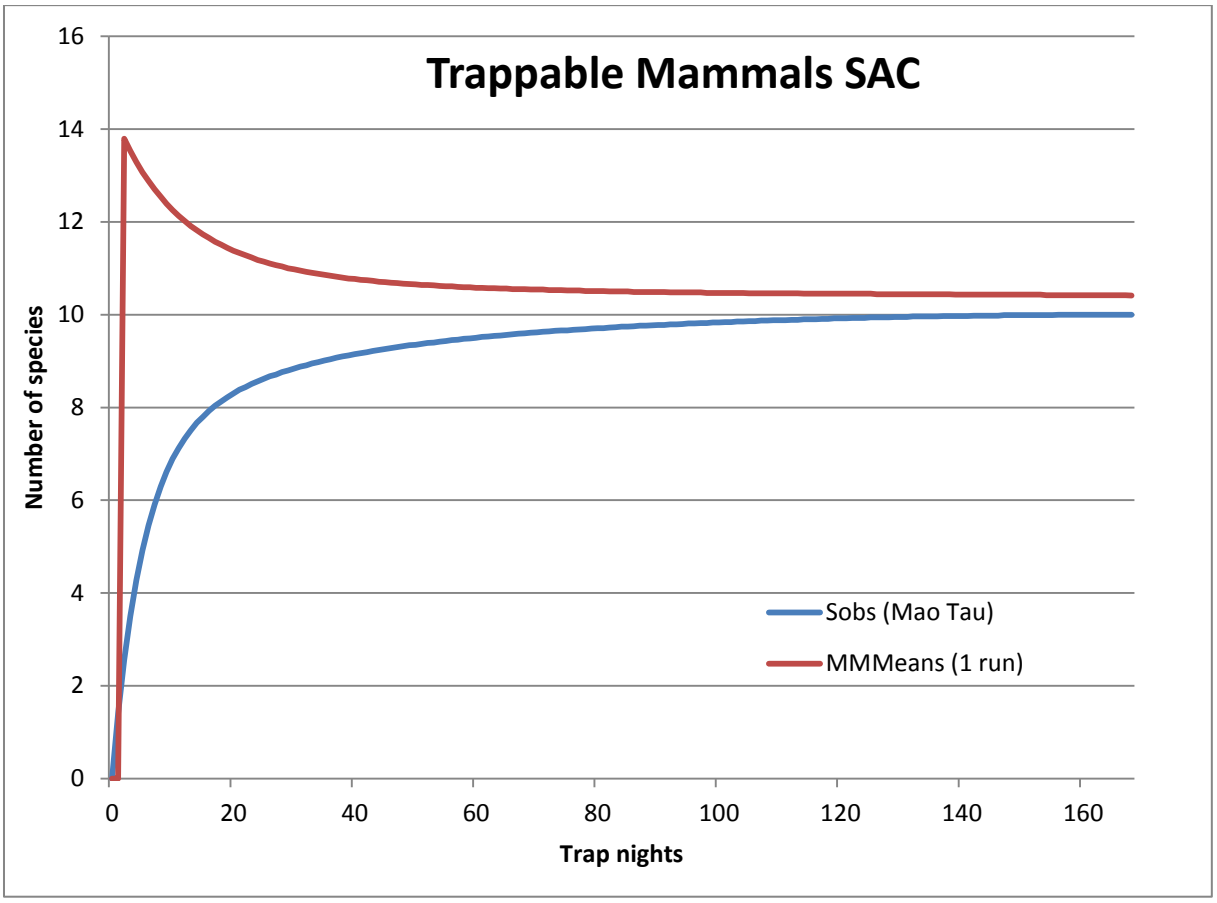


Figure 5.5 – Species accumulation curve for trappable mammals

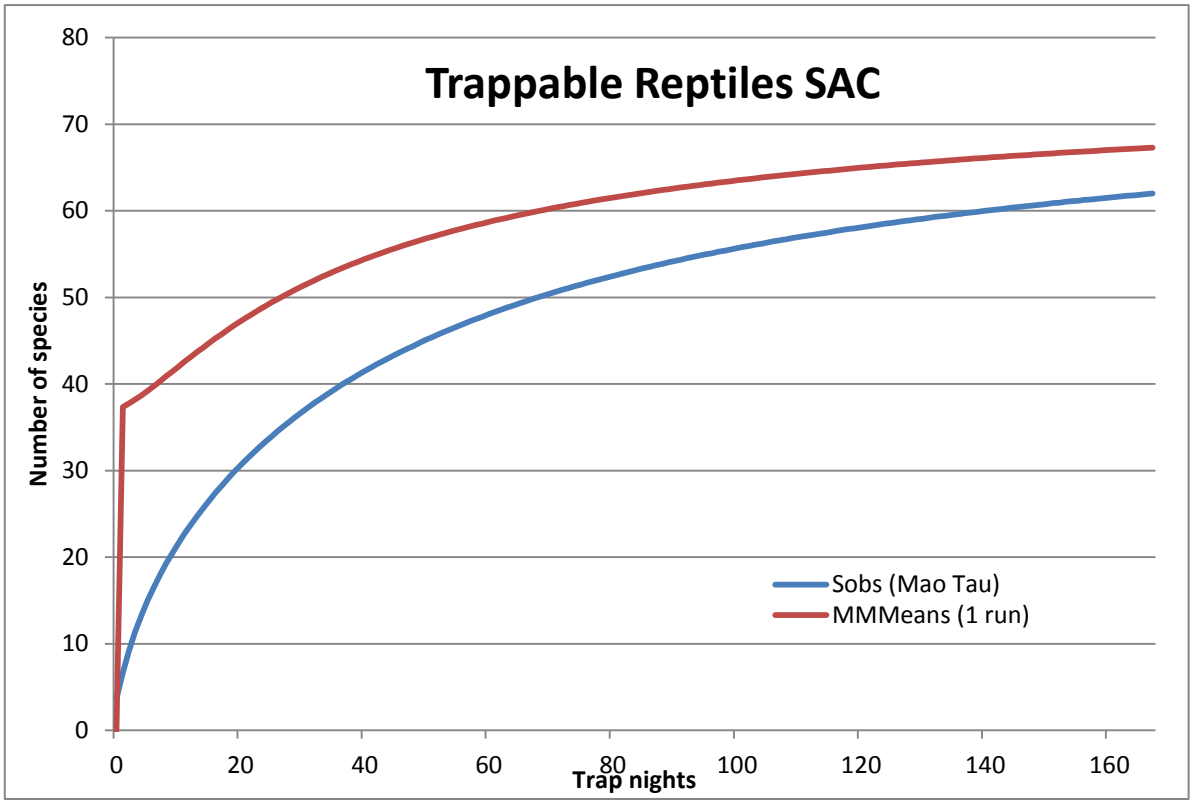


Figure 5.6 – Species accumulation curve for trappable reptiles

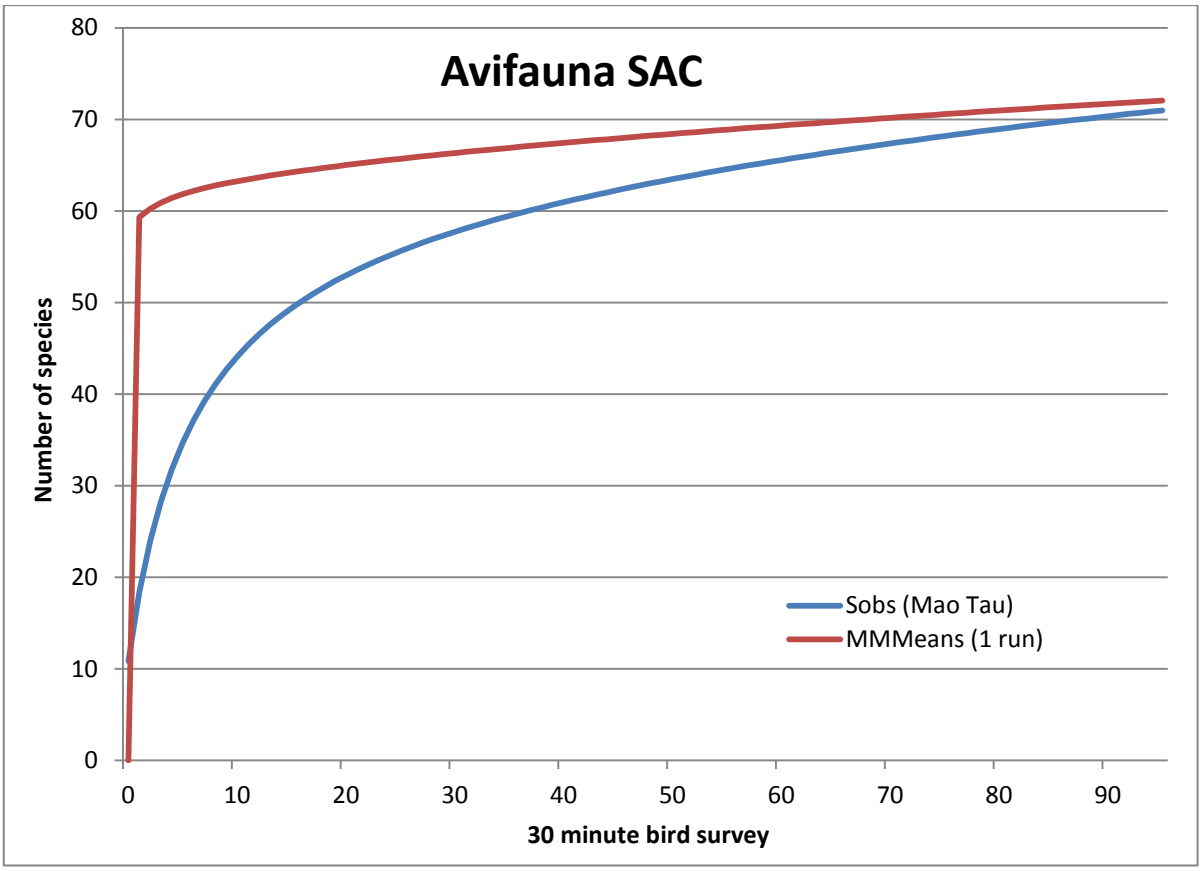


Figure 5.7 – Species accumulation curve for avifauna

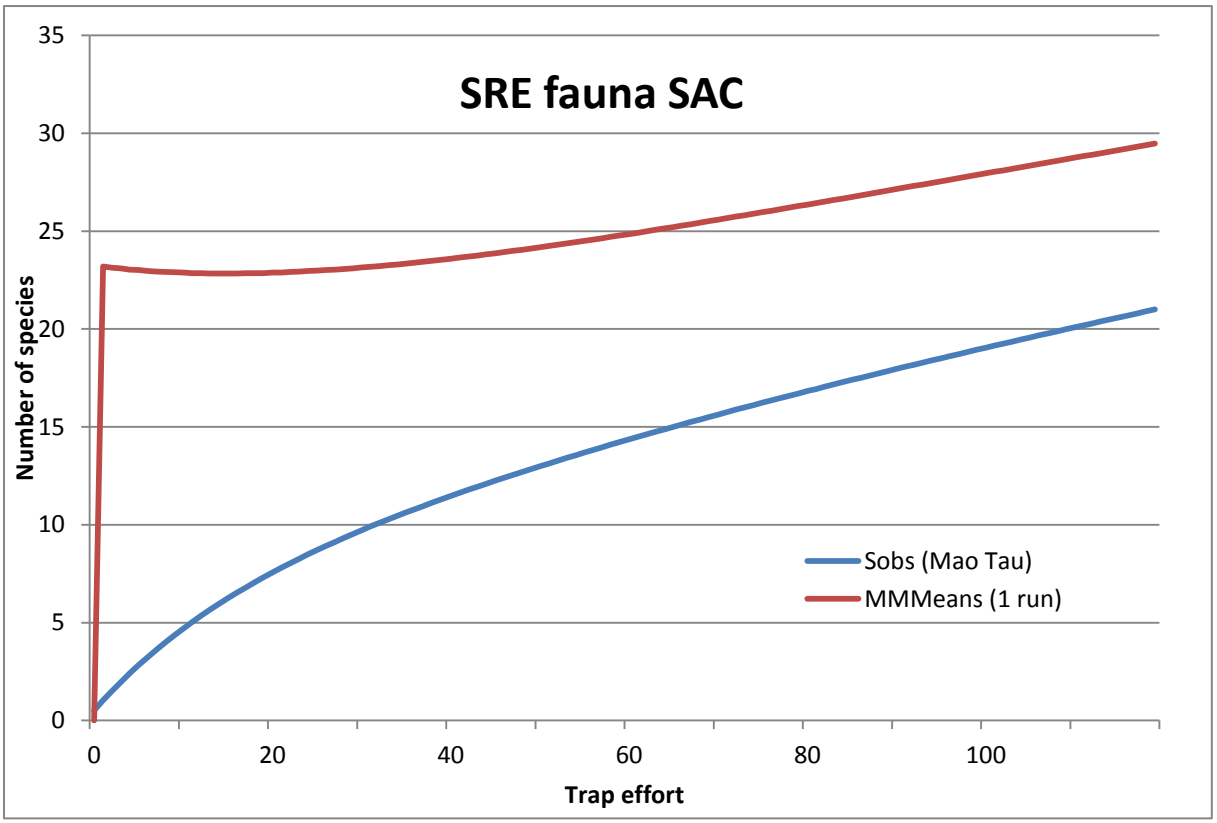


Figure 5.8 – Species accumulation curve for SRE fauna

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					

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2	K. Bankin	B. Greatwich	30/4/2013	R. Young	C. Nixon T. Brown	3/5/2013

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ACRONYMS

AIR	Ashburton Regional Inventory
BIF	Banded Ironstone Formations
DEC	Department of Environment and Conservation
DSEWPaC	Department of Sustainability, Environment, Water, Population and Communit**ies**
EIA	Environmental Impact Assessment
EPA	Environmental Protection Authority
EP Act	*Environmental Protection Act 1986*
EPBC Act	*Environment Protection and Biodiversity Conservation Act 1999*
IBRA	Interim Biogeographic Regionalisation for Australia
PIR	Pilbara regional Inventory
RT	Rio Tinto Iron Ore
SCA	Species Accumulation Curve
SRE	Short Range Endemic
WAM	Western Australian Museum
WC Act	*Wildlife Conservation Act 1950*

EXECUTIVE SUMMARY

Rio Tinto (RT) is currently conducting preliminary feasibility studies for the development of ore deposits C, D, D extension, F, G, H and Mt Ella, collectively termed the Greater West Angelas Study Area (the Study Area) located approximately 105 km north west of Newman,, covering a total of 175.65 km^2. The Study Area is situated on RT exploration / mining leases and encompasses the Turee Creek Borefield supplying water to West Angelas Mine.

As part of these investigations, *ecologia* was commissioned to conduct a single-phase subterranean fauna (troglofauna and stygofauna) survey of the Study Area. The baseline data may be supplemented with additional studies in the future. The subterranean survey was conducted in July–October 2012, following a drier than average dry season. The previous wet season (November 2011 – March 2012) however, recorded higher than average rainfall.

A total of 91 RC drill holes were sampled for troglofauna using custom designed leaf litter traps baited with banana. Only twenty two bores (24%) had access to ground water, with the remaining holes above the water table. Traps were positioned approximately 2 meters above water or blockage and left in the ground for ninety one days to ensure troglofauna colonisation. All samples were extracted and sorted in the *ecologia* Perth laboratory. The level of survey adequacy was estimated using species accumulation curves (SACs) as computed by Mao Tau.

A large proportion of the species collected were insects (orders Thysanura, Psocoptera, Hemiptera, Embioptera, Blattodea and Coleoptera), which have not been collected in the West Angelas area or the surrounding region before. The remainder of species recorded comprised of spiders, isopods and scolopendrid centipedes. Six (*Nocticola* sp. indet., *Prethopalpus* sp. indet., *Pseudodiploexochus* sp. nov., *Cormocephalus* CH1003, *Atelurinae* sp., indet., Anillini sp.indet.) of the recorded species are likely to have restricted distribution ranges and four (*Hydrobiomorpha* sp. indet., *Embioptera* sp. indet., Meenoplidae sp. indet., Trogiidae sp. indet.) are potentially restricted. Only spiders of the genus *Prethopalpus* and centipedes from the genus *Cormocephalus* have been recorded previously in the area, with the remaining eight genera/families representing new records. In addition, the spider *Prethopalpus* 'sp indet.' and the isopod *Pseudodiploexochus* 'sp. nov.' (the first ever to be recorded in the Pilbara region) represent new species. The centipede *Cormocephalus* 'HCI003' is the first eyeless scolopendrid specimen recorded to date.

There was little commonality of troglofauna species across different geological units, suggesting potential barriers in habitat connectivity and implying isolated species assemblages. However, this could be an artefact of a small sample size, given the low survey efficiency indicated by species accumulation curves (24%). Drilling and bulldozing occurred in D and D extension deposits during the troglofauna survey, causing vibration and air pressure in subterranean voids, hence possibly affecting capture of troglofauna. Further sampling may assist with a more accurate assessment.

It is recommended that all troglofauna specimens (those already collected as well as any future collections) undergo DNA assessment to ascertain correct species identification and thus their true distribution in the Study Area and its surrounds for future impact assessment. Given that the mafic volcanics and dolerite and gabbros geological units found in the Study Area are completely surrounded by sedimentary rocks, it is likely that species inhabiting them are only found within these island-like, isolated units, especially if further evidence suggests that each geology harbours a different troglofauna assemblage.

Stygofauna sampling consisted of sampling bore holes with modified haul nets to identify potential stygofauna assemblage of the Study Area and measurements of groundwater physico-chemistry to aid defining the aquifer conditions and their suitability for stygofauna.

The survey was limited to four accessible bores in Deposit F, which yielded no stygofauna specimens. Consequently, the stygofauna sampling cannot be considered adequate due to its small sample size and limited spatial coverage. Further sampling is recommended, particularly in deposits C, D, D extension G, and H.

1 INTRODUCTION

1.1 PROJECT OVERVIEW

Rio Tinto (RT) requires a series of biological surveys to be undertaken, in order to support 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.

RT is currently considering development of ore deposits C, D, D extension, F, G, 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 areas covering a total of 175.65 km^2. The Study Area is situated on RT exploration/mining leases and encompasses the Turee Creek Borefield supplying water to West Angelas Mine. No pastoral leases intersect the Survey Area.

As part of these investigations, *ecologia* Environment (*ecologia*) was commissioned to conduct a single-phase subterranean fauna (troglofauna and stygofauna) survey of the Study Area. This survey will provide baseline data which may be supplemented with additional studies in the future.

1.2 LEGISLATIVE FRAMEWORK

Federal and State legislation applicable to the conservation of native fauna include, but are not limited to the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act), the *Wildlife Conservation Act 1950* (WC Act) and the *Environmental Protection Act 1986* (EP Act). Section 4a of the EP Act requires that developments take into account the following principles applicable to native fauna:

- The Precautionary Principle

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

- The Principles of Intergenerational Equity

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

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

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

This document includes background information on the Project and a literature review of the subterranean fauna in reference to the habitats and environments of the Study Area. The conservation significance of the fauna in Western Australia is also outlined.

The document was prepared in order to satisfy the requirements of:

- The EPA Guidance Statement No. 54: Consideration of Subterranean Fauna in Groundwater and Caves during Environmental Impact Assessment in Western Australia (EPA 2003); and
- The EPA Guidance Statement No. 54a (Technical Appendix to Guidance Statement no. 54): Sampling Methods and Survey Considerations for Subterranean Fauna in Western Australia (EPA 2007).

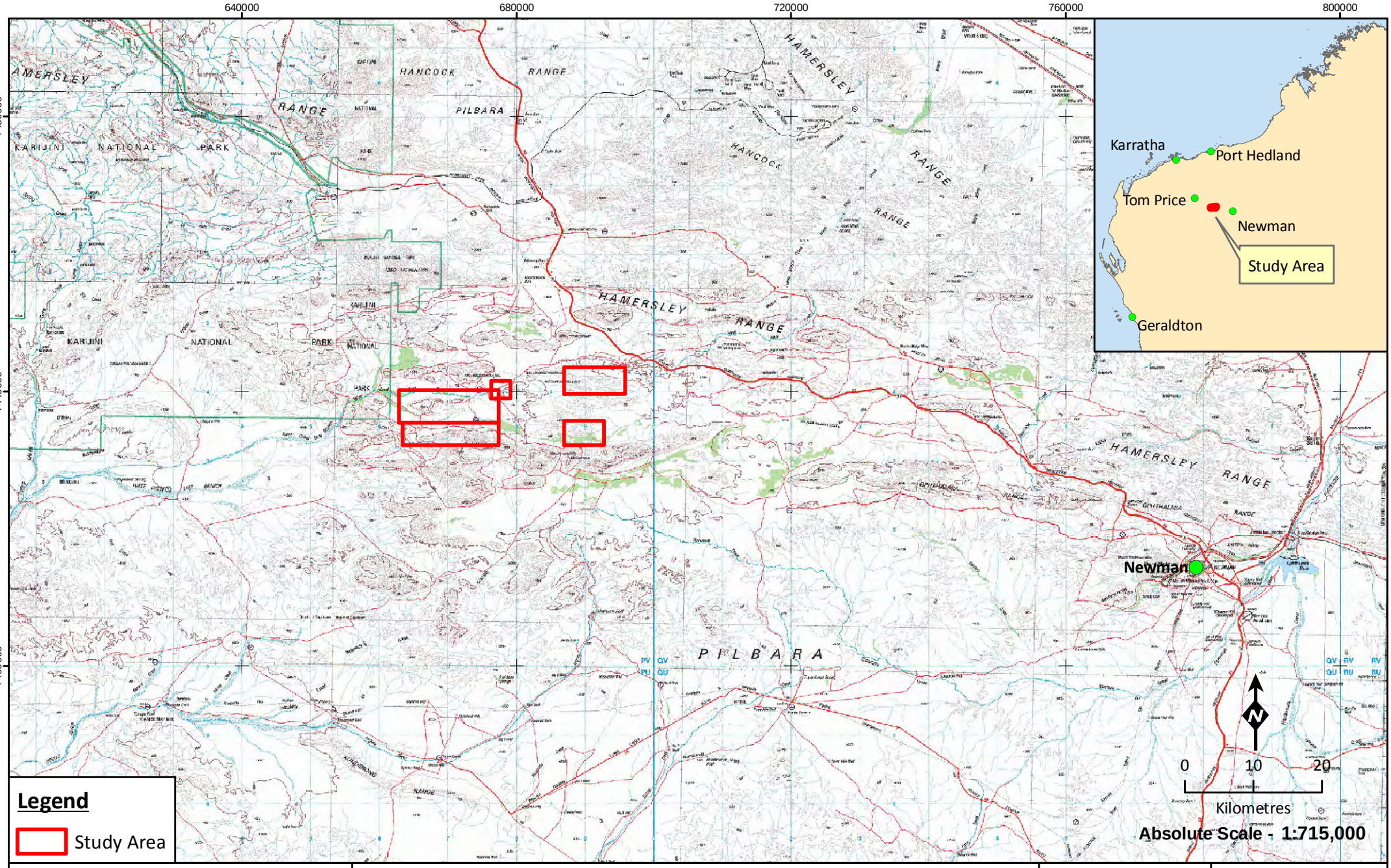
1.3 SURVEY OBJECTIVES

The primary objective of this study was to provide sufficient information to assess the impact of the Project on subterranean fauna in the area in the context of the following EPA objectives:

- Maintain the abundance, species diversity and geographical distribution of subterranean invertebrate fauna; and
- Avoid impacts to Specially Protected (Threatened) fauna, consistent with the provisions of the WC Act.

Specifically, this survey was carried out to satisfy the requirements of the EPA's Guidance Statements 54 and 54a, thus providing:

- A review of background information (including literature and database searches);
- An inventory of subterranean species occurring in the Study Area, incorporating recent published and unpublished records;
- An inventory of conservation significant subterranean fauna recorded or likely to occur within the Study Area and surrounds;
- An assessment of likely habitats that may potentially support subterranean fauna based on geological mapping data as well as bioregion and land system information; and
- An assessment to determine likely impacts of threatening processes on subterranean habitat within the Study Area.



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Location of Study Area

Figure: 1.1
Project ID: 1459

Drawn:BG
Date: 13/02/2013

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

Unique Map ID: BG277

A4

1.4 SUBTERRANEAN FAUNA OVERVIEW

Invertebrate groups dominate the subterranean fauna of Western Australia (WA). Crustacean groups including subterranean representatives are remipedes, ostracods, isopods, copepods, syncarids, amphipods and decapods. Hexapod groups include Blattodea (cockroaches), Orthoptera (crickets), Coleoptera (beetles), Hemiptera (bugs), Thysanura (thrips), Diplura and Collembola (springtails). Subterranean arachnid groups include Aranae (spiders), pseudoscorpions, schizomids, Trombidiformes (mites), Opiliones (harvestmen), and scorpions. Myriapod groups are also represented – diplopods (millipedes) and chiloipods (centipedes). Oligochaete, polychaete and aphanoneuran worms are represented. Two main gastropod groups are known to include subterranean fauna - Neotaeniglossa (family Hydrobiidae) and Basommatophora (family Planorbidae). Stygofauna communities are often dominated by crustaceans whereas troglofauna can include a wide range of taxonomic groups which have adapted to underground life.

Subterranean communities share the following characteristics (from Gilbert and Deharveng 2002):

1. High endemism but low local diversity relative to regional diversity;
2. A relatively small number of genetic lineages resulting in species dissimilar in appearance to related groups;
3. Many relicts from previous climatic conditions; and
4. Truncated food webs.

Traditionally, arid and semi-arid areas were considered poor potential habitat for subterranean fauna as these organisms are moisture-dependent (Harvey *et al.* 2008). However, recent descriptions of subterranean fauna in the arid and semi-arid zone of WA have indicated the presence of a diverse fauna, with an estimate of 4,140 subterranean taxa found in the western half of Australia (Guzik *et al.* 2010).

A total of 403 species have been described to date and additional 367 are known but undescribed (EPA 2012). Based on this estimate, over 80% of the fauna likely to be present have not yet been documented (Guzik *et al*. 2010). Whilst the potential scale for unique diversity of Australian subterranean fauna is not known, a summary of counts (adapted from EPA 2012) and estimates of diversity taken from a series of publications indicate that the Australian (and particularly WA) subterranean fauna is uniquely diverse (Table 1.1).

Table 1.1 – Australian counts and estimates of subterranean fauna diveristy

Country/State/Region	Number of taxa	Count/Estimate	Authors
Australia (whole)	~750	Count	(Humphreys 2008)
Australia – western half	4,140 770	Estimate Count	(Guzik *et al.* 2010)
Australia - NSW	422 (only 84 obligated subterranean)	Count	(Thurgate *et al.* 2001)
Pilbara Region (WA)	78 350 (after Pilbara Biological Survey) 500-550 (ground water species).	Count Count Count	(Eberhard *et al.* 2005a) (DEC 2009) (Eberhard *et al.* 2009)
Carnarvon Basin (WA)	~35	Count	(Humphreys 2008)
Christmas Island	18	Count	(Humphreys and Eberhard 2001)

Subterranean fauna commonly have restricted distributions and are classified as short range endemics (SREs), more so then their surface counterparts. Up to 70% of stygofauna recorded from the Pilbara are regarded as SREs (Eberhard *et al.* 2009). It is thought that the majority of troglofauna are also SRE's, even more so than stygofauna (Lamoreux 2004).

1.5 TROGLOFAUNA OVERVIEW

Troglofauna are communities of terrestrial subterranean animals that inhabit air chambers in underground caves or small, humid voids. They are divided into three ecological categories:

- Troglobites: obligate underground species that are unable to survive outside of the subterranean environment;
- Troglophiles: facultative species that live and reproduce underground but that are also found in similar dark, humid microhabitats on the surface; and,
- Trogloxenes: species that regularly inhabit underground caves and cavities for refuge but normally return to the surface environment to feed.

A fourth group; accidentals, wander into cave systems but cannot survive there (Howarth 1983).

A species is considered truly troglobitic if it displays morphological characteristics that appear to restrict it to subterranean habitats (Howarth 1983). These include a significant reduction or a complete loss of eyes, pigmentation andwings, as well as development of elongated appendages, slender body form and, in some species, a lower metabolism. Behavioural adaptations such as lack of a circadian rhythm (24-hour biological cycle) are also characteristic of true troglobites.

Troglobitic faunal assemblages are dominated by arthropods such as schizomids, pseudoscorpions, spiders, harvestmen, centipedes, millipedes, diplurans and mites. Many species are relict rainforest litter fauna from previous tropical climate eras (Humphreys 1993a) and therefore depend on subterranean habitats that are constantly humid.

The food resources for subterranean ecosystems are largely allochthonous (not formed in the region where found) and carried into caves and cavities by plant roots, water and animals (Howarth 1983).

True troglobites are incapable of dispersing on the surface and thus are subject to dispersal barriers due to geological structure of their habitat. Such dispersal limitations result in extremely small, fragmented species ranges and thus high levels of endemism (EPA 2003), which is characteristic of subterranean fauna worldwide (Strayer 1994). Examples include the millipede *Stygiochiropus peculiaris*, which is restricted to a single cave system at Cape Range (Humphreys and Shear 1993). Genetic analyses of some troglobitic mites from the Pilbara provide evidence that exceptions exist and that these microscopic organisms have wide-range distribution, suggesting that they may use other means of dispersal, possibly on the surface (Biota 2006b).

The presence of troglofauna in Western Australia is still somewhat poorly documented. To date, troglofauna have been recorded from karst limestone systems at Cape Range, Barrow Island and in the Kimberley (Biota 2005; Harvey 1988; Humphreys 2001); pisolitic mesa formations in the Pilbara (Biota 2006a), banded iron formations in the Pilbara and Midwest (Biota 2007; *ecologia* 2009a, b, 2010), Greenfields gold provinces in the Great Victorian Desert (*ecologia* 2009c) and in the cave systems of Yanchep (EPA 2005), Margaret River (Eberhard 2006) and across the Nullarbor (Moore 1995).

1.6 STYGOFAUNA OVERVIEW

Stygofauna are obligate, groundwater dwelling fauna, adapted to a subterranean aquatic environment. This environment is devoid of light, may have restricted available space (i.e. porous or

fissured rock) and relatively constant temperature. These species have evolved unique features such as a lack of pigmentation, elongated appendages, filiform body shape (worm like) and reduced or absent eyes. Many species are believed to be relict taxa with affinities with Tethys, Pangea and derived landmasses (Danielopol and Stanford 1994; Humphreys 1993b, 1999, 2001; Knott 1993).

Stygofauna are known to be present in the groundwater associated with a variety of geologies. These include (but are not limited to) calcrete aquifers associated with palaeochannels, haematite sandstone aquifers (e.g. Koolan Island), clay-sandstone aquifers on the Swan and Scott Coastal Plains

(ecologia 1998a, 2006a, b; Humphreys 2001; Rockwater 2006), porous aquifers (e.g. alluvium) (Mamonier *et al.* 1993), fractured-rock aquifers, springs and hyporheic habitats (Eberhard *et al.* 2005b). However, distribution patterns of stygofauna are determined by hydrogeological aquifer types rather than by affiliation of aquifers to a given geological unit. Two main types of aquifer relevant for stygofauna have been defined by Hahn and Fuchs (2009):

1. Compact aquifers (aquitard)

Compact aquifers comprise materials such as clay, loess, and very fine sands, as well as compact rocks, which have reduced pore spaces and thus a low hydraulic conductivity (kf < 10^{-6} m sec-1). Exchange with surface water for food and oxygen supply is reduced and living space is minimal in this type of aquifer, which is why these aquifers are either devoid of fauna or have depleted taxonomic richness and abundance.

2. Open aquifers

Open aquifers comprise porous, fractured and karstic groundwater circulation systems with at least moderate hydraulic conductivity (kf > 10^{-6} m sec-1). There is continuous exchange with surface water for food and oxygen supply and more abundant living space, which is why stygofauna communities are often found in this aquifer type (Hahn and Fuchs 2009). In addition, communities of porous and karstic aquifers have been found to be more similar to each other than the communities of compact and fractured aquifers (Hahn and Fuchs 2009).

Stygofauna are found in oxygenated groundwater, usually ranging from fresh to hyposaline, but they can occur in salinities up to seawater (EC = 54 mS/cm) (Humphreys 1999). Recent experience west of Lake Way near Wiluna has shown that palaeochannel aquifers with an EC of 60,000µS/cm can harbour diverse and abundant stygal assemblages (*ecologia* 2006a).

The presence of stygofauna in Western Australia has been well documented, especially from regions such as the Pilbara and Kimberley, and less so in the Midwest and South West regions of WA (Cho *et al.* 2005; De Laurentiis *et al.* 2001; Eberhard 2004; Humphreys 2001; Karanovic 2004; Wilson and Keable 2002). Australian stygofauna is dominated by crustaceans including Amphipoda (Bradbury and Williams 1997), Isopoda (Wilson 2001), Ostracoda (Karanovic 2005; Karanovic and Marmonier 2002, 2003; Martens and Rossetti 2002) and Speleogriphacea (Poore and Humphreys 2003; Poore and Humphreys 1998).

2 BIOPHYSICAL CLIMATE

2.1 CLIMATE AND WEATHER

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, extensive 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 for which both rainfall and temperature data is available is Paraburdoo Aero (Site No. 007185), 85 km west from the western boundary of the Study Area. The 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 (Site No. 007185), rainfall obtained from Turee Creek Station (Site No 007083).

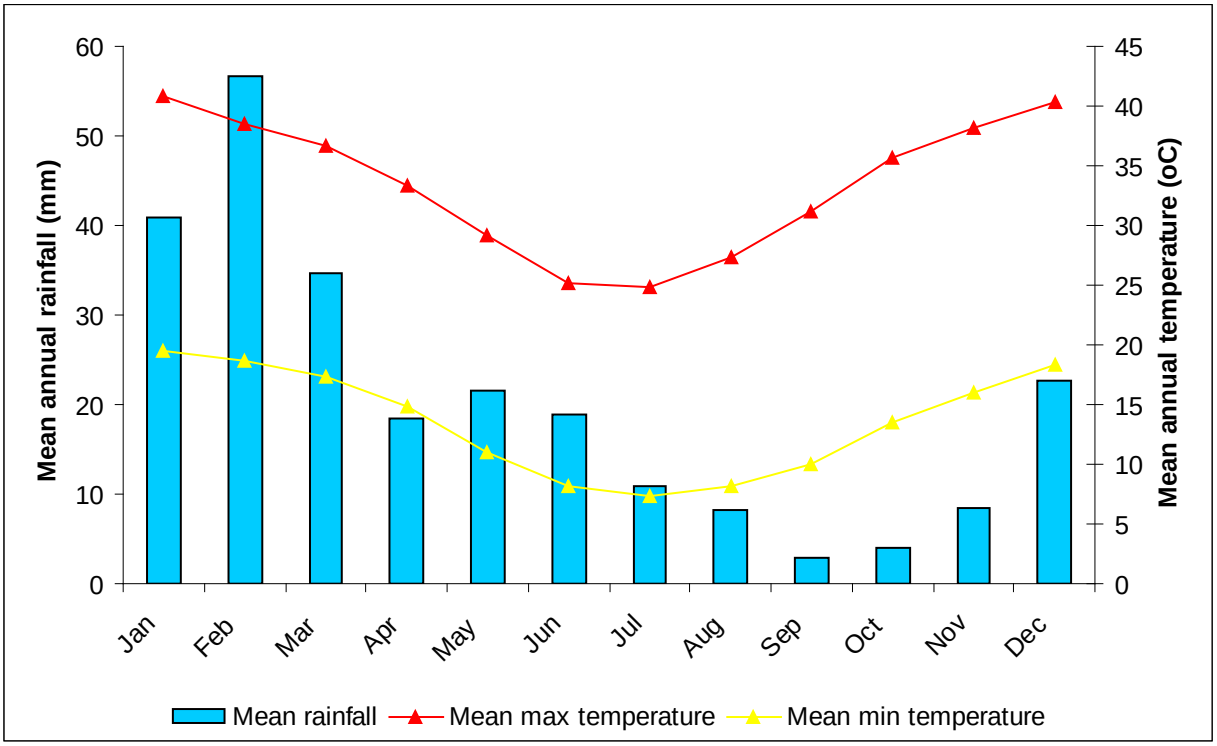
Rainfall data is available from Turee Creek Station (Site No. 007083) located 45.5 km south of the southern boundary of the Study Area. During the 2011 – 2012 wet season (November 2011 to March 2012) considerably higher rainfall fell compared to the long-term average (Table 2.1). The rainfall received in the six months preceding the trap retrieval for troglofauna were all below the long term monthly averages. Such statistics are not unusual as this period typically falls within the dry season in the Pilbara region, with higher than average rainfall occurring at the end of October and December 2012, after the retrieval of traps. Given the proximity to West Angelas, it is probable that rainfall recorded at Turee Creek is a more accurate reflection of the rainfall received by the Study Area.

Table 2.1 – Rainfall at Turee Creek and Paraburdoo meteorological stations

Total rainfall (mm)	Turee Creek Station		Paraburdoo Aero	
	Monthly total	Monthly average (1920-2012)	Monthly total	Monthly average (1974-2012)
August 2011	2	8.3	0	11.6
September 2011	0	2.9	0	3.6
October 2011	2.6	4	0	3.6
November 2011	30.2	8.5	8	8.3
December 2011	27.7	22.6	5	28.5
January 2012	126.3	41	205.2	52
February 2012	42	56.7	73.6	78.3
March 2012	72.5	34.7	77	46.4
April 2012	1.8	18.5	17.4	26.8
May 2012	0	21.6	0	16.4
June 2012	8.6	18.8	10.4	22.2
July 2012	1	10.9	1	14.6
August 2012	0	8.2	0	11.6

Total rainfall (mm)	Turee Creek Station		Paraburdoo Aero	
	Monthly total	Monthly average (1920-2012)	Monthly total	Monthly average (1974-2012)
September 2012	0	2.9	0.4	3.5
October 2012	21.8	4.2	32.8	4.4
November 2012	1.6	8.5	1.6	8.1
December 2012	144.8	22.6	33.6	28.5

Source: BOM (2013)



Source: BOM (2013)

Figure 2.1 – Mean monthly climate data

2.2 GEOLOGY, LAND SYSTEMS AND SOILS

2.2.1 Geology

The Study Area and local geology is presented in Figure 2.2, while Figure 2.3 shows regional geology. Definitions of the geological unit codes are provided in Table 2.2 (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 2.2 – 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

2.2.2 Soils

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. 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.

2.2.3 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 Survey Area intersects the two regional surveys, they are discussed collectively for the purpose of the report.

Seven land systems mapped by Payne *et al* (1982) within the Ashburton regional Inventory (AIR) and by Van Vreeswyk *et al*. (2004) in the Pilbara regional Inventory (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 2.3, with land systems of the Study Area mapped in Figure 2.5.

Table 2.3 – Summary of Land Systems present within the Study Area

Land System (% of Study Area)	Area (% of PIR and AIR 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.
Elimunna (1.15%)	656.6 km^2 (0.24%)	2.0 km2 (0.30%)			Hills and low rises (10%)	Hummock grasslands of *Triodia wiseana* (hard spinifex) or very scattered shrublands of *Acacia* and *Senna* spp.

Land System (% of Study Area)	Area (% of PIR and AIR combined)	Area within Study Area (% of Land System)	Description	Vegetation Condition Assessment	Landform (and % of Land System)	Vegetation Community
			Stony plains on basalts upporting 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.	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 PIR and AIR 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 *Acacias*, 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.

Wannamunna (0.03%)	630.1 km^2 (0.22%)	0.04 km^2 (0.006%)	Hardpan plains and internal drainage tracts supporting mulga shrublands and woodlands (and occasionally eucalypt woodlands).	Very good 19%, good 25%, fair 19%, poor 21%., very poor, 16% The system supports low shrubs and tussock grasses which are highly preferred by grazing animals and are prone to degradation if grazing pressure is excessive.	Stony plains (8%	Very scattered to scattered tall shrublands of *Acacia aneura* (mulga) with sparse low shrubs and *Triodia* sp. (hard spinifex) understorey
					Hardpan plains (56%)	Very scattered tall or low shrublands of *Acacia aneura*, *Eremophila* spp., *Ptilotus obovatus* (cotton bush), *Maireana villosa*.
					Calcrete platforms (1%)	Scattered shrublands with *Acacia aneura* and other *Acacia*s, *Senna* spp. and *Triodia wiseana* (hard spinifex)
					Groves (15%)	Moderately close to closed woodlands of *Acacia aneura* with numerous undershrubs and tussock grasses such as *Chrysopogon fallax* (ribbon grass) and *Themeda triandra* (kangaroo grass).
					Internal drainage plains (20%)	Moderately close to closed woodlands of *Acacia aneura* and *Eucalyptus victrix* (coolibah) with sparse undershrubs such as *Muehlenbeckia florulenta* (lignum) and *Chenopodium auricomum* (swamp bluebush) and patchy tussock grasses. Also grasslands of *Eriachne* sp. with isolated *Eucalyptus victrix* trees and shrubs such as *M. florulenta* or grassy scattered woodlands of *E. victrix*

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7445000 7440000 7435000 7430000

Deposit I

Deposit G

Deposit B

A3b

Deposit H

A2d

Deposit C

Deposit D

Deposit A

Deposit F

Deposit E

Mt Ella

A4 - -Pp

A4 - -Pp

A2d

N

0 2.5 5

Kilometres

Absolute Scale - 1:90,000

Legend

Study Area

Impact Area

ecologia ENVIRONMENT

Geology of the Study Area

Figure: 2.H
Project ID: 1459

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

600000
650000
700000
750000
7450000
7400000

A1
A3
A4 - -Pp
Czy
Cze
A2d
A3b
-Ppv
A4f
-Ppn
-Ppc
-Pmed
-Pmw
A2g

N

0 10 20
Kilometres

Absolute Scale - 1:490,000

Legend

Study Area

ecologia ENVIRONMENT

Regional geology of the Study Area

Figure: 2.0
Project ID: 1459

Drawn: BG
Date: 12/2/2013

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

Unique Map ID: BG276

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

Deposit A

Deposit F

Fa14

Mt Ella

Deposit E

Fa13

Fb3

N

0 2.5 5

Kilometres

Absolute Scale - 1:90,000

Legend

Study Area

Impact Area

ecologia ENVIRONMENT

Soils of the Study Area

Figure: 2.π
Project ID: 1459

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

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

0 2.5 5

Kilometres

Absolute Scale - 1:90,000

Legend

Study Area

Impact Area

Pindering Land System

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Landsystems of the Study Area

Figure: 2.p
Project ID: 1459

Drawn: BG
Date: 12/2/2013

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

Unique Map ID: BG279

A3

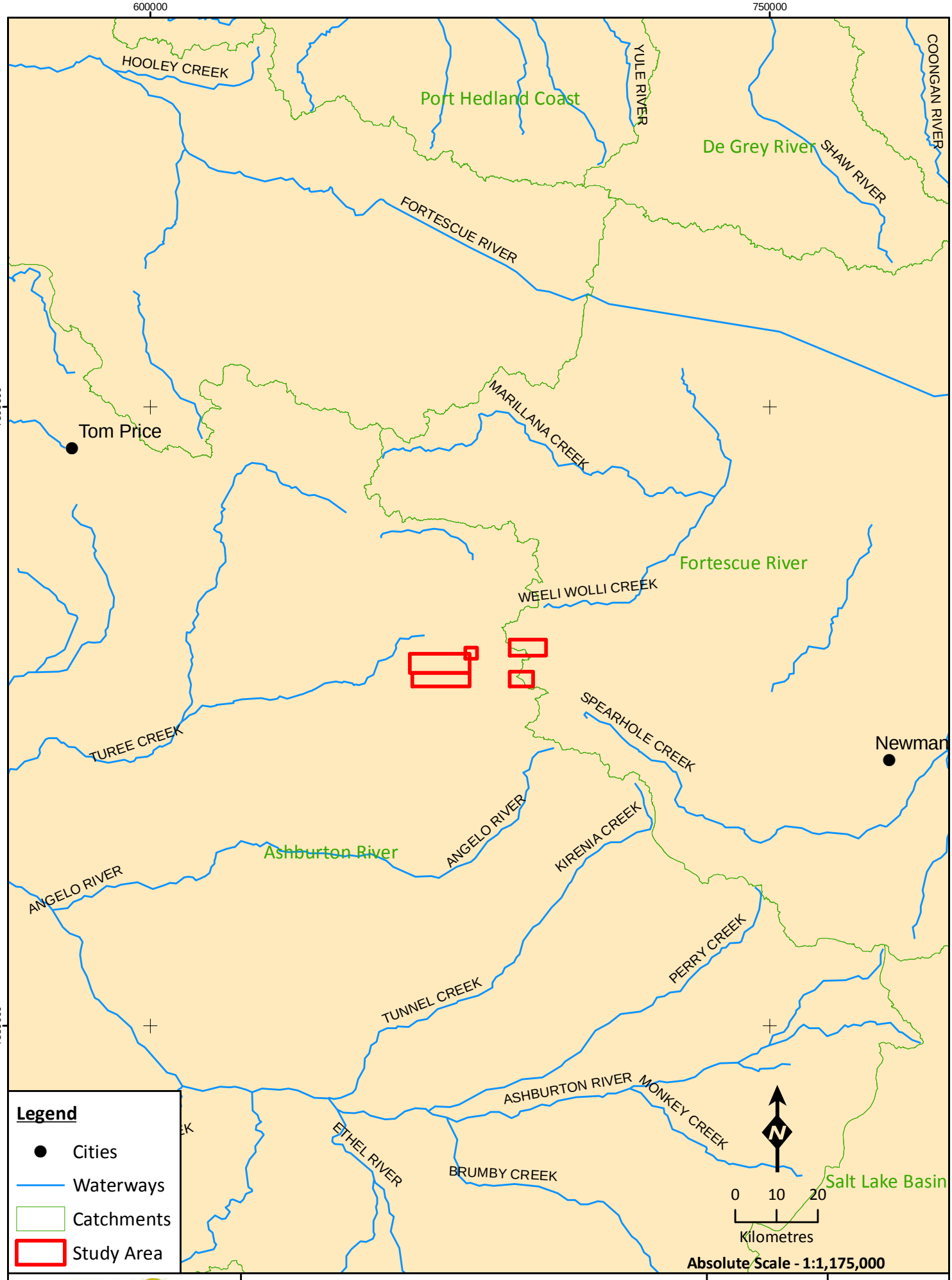
2.3 HYDROLOGY

The Study Area is located in the Hamersley Range, and is a part of both the Ashburton and the Fortescue Catchments (Figure 2.6). The closest creek to the Study Area is Turee Creek, a sub-tributary of the Ashburton River. Turee Creek flows west along a 4 km wide valley before turning sharply to exit the Hamersley Range (Johnson and Wright 2001). The West Angelas mine and Study Area are situated in the Turee Creek East sub-catchment, where drainage is fed by a number of smaller creeks (Johnson and Wright 2001). The creek system is ephemeral and does not support any permanent surface-water features (Johnson and Wright 2001).

2.4 HYDROGEOLOGY

Central Pilbara groundwater occurs in the Archaean/Proterozoic basement rocks and the Cainozoic deposits. It originates from direct rainfall recharge into basement rock outcrops and indirect recharge through runoff (Johnson and Wright 2001). The main aquifer in the area is the vuggy pisolite (Robe Pisolite) which overlies fractured basement rocks of the Woongarra volcanics and Boolgeeda Iron Formations (Johnson and Wright 2001). This aquifer lies within Tertiary paleochannels and the aquifer zone varies between 50 and 80 m in thickness and has an estimated permeability of 40-80 m per day (Johnson and Wright 2001).

Permeability and groundwater storage within the Jeenah formation is generally low except where there is local fracture systems associated with regional lineaments. Groundwater declines steeply from 10-20 m below ground level (m.b.l.) to up to 140 m.b.l. Steep water level gradients are indicative of low permeability or lack of hydraulic connection. Aquifers associated with mineralisation are deep, porous, permeable, confined aquifers, hydraulically isolated by low permeability surrounding rock.



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Regional Hydrology of the Study Area

Figure: 2.6	**Drawn: BG**
Project ID: 1459	**Date: 13/02/2013**

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

Unique Map ID: BG283

A4

2.5 PREVIOUS SURVEYS

The following databases and publications were consulted in the preparation of potential subterranean (and conservation significant) fauna lists (Appendix C):

- NatureMap Database;
- WA Museum Crustaceans database;
- WA Museum Molluscs database;
- WA Museum Arachnids/Myriapods;
- *ecologia* internal database;
- *ecologia* (1998b);
- Biota (2003); and,
- Biota (2008).

At least 24 subterranean species have been identified as occurring within 100 km radius of the Study Area. Many specimens lack detailed identification, with identification to order level only.

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3 METHODS

The methodology used was based on the principles outlined in the EPA Guidance statement 54A (EPA 2007). The methodology developed for the survey was compliant with these requirements and in accordance with the guidance received from the Department of Environment and Conservation (DEC) before the survey commenced.

3.1 DETERMINATION OF SURVEY DESIGN AND INTENSITY

Prior to the development of field survey methods, a review was undertaken of factors likely to influence survey design and intensity (Table 3.1). Based on this review, and in consideration of the level of disturbance and the results of a desktop study, a subterranean survey methodology was developed.

Table 3.1 – Factors influencing survey design and intensity

Factor	Relevance
Bioregion-level of existing survey knowledge of the region and associated ability to predict accurately	Regional knowledge of subterranean fauna is well established
Landform special characteristics/specific fauna/specific context of the landform characteristics and their distribution and rarity in the region	The Study Area covers seven land systems: the Boolgeeda, Egerton, Elimunna, Newman, Platform, Rocklea and Wannamunna. None of the land systems are exclusive to the Study Area.
Life forms, life cycles, types of assemblages and seasonality (e.g. migration) of species likely to be present	Troglobitic populations are likely to increase in size during and immediately after wet season, following an influx of nutrients into the underground systems (EPA 2007). Sampling in the current survey was conducted from 9 July 2012 to 5 October 2012, following a drier than average dry season. The previous wet season (November 2011 – March 2012) however recorded higher than average rainfall.
Level of existing knowledge and results of previous regional sampling (e.g. species accumulation curves, species/area curves)	Previous sampling in the Greater West Angelas area identified subterranean fauna (troglobitic spiders, millipedes and centipedes, stygobitic amphipods, copepods, ostracods and bathynelaceae).
Number of different habitats or degree of similarity between habitats within a survey area	Three geological units exist within the Study area – Sedimentary rocks, Mafic volcanics and Dolerites and Gabbros.
Climatic constraints (e.g. temperature or rainfall that preclude certain sampling methods)	No climatic constraints influenced the survey.
Technical constraints (e.g. condition and/or number of bore holes)	Ninety one troglofauna trapping sites were sampled successfully. Drilling and bulldozing occurred in D and D extension deposits during the troglofauna survey, causing vibration and air pressure in subterranean voids, hence possibly affecting capture of troglofauna. Stygofauna sampling was limited to four bores in Deposit F as all other boreholes were rehabilitated, did not reach groundwater or were blocked.
Scale and impact of the Project	The final sample size was determined by the overall Study Area and deposit areas.

3.2 SURVEY ADEQUACY

There are three general methods of estimating species richness from sample data: extrapolating species-accumulation curves (SAC), fitting parametric models of relative abundance, and using non-parametric estimators (Bunge and Fitzpatrick 1993; Colwell and Coddington 1994; Gaston 1996). In this report, the level of survey adequacy was estimated using species accumulation curves (SACs) as computed by Mao Tao. A SAC is a plot of the accumulated number of species found with respect to

the number of units of effort. The curve, as a function of effort, monotonically increases and typically approaches an asymptote, which is the total number of species. In addition, a Michaelis-Menten enzyme kinetic curve was calculated and used to apply a stopping rule. To eliminate features caused by random or periodic temporal variation, the sample order was randomised 100,000 times. All estimators applied to the data set were performed using EstimateS (version 8, Colwell 2009).

3.3 SURVEY TIMING

The EPA's Guidance Statement 54a recommends that the sampling is conducted in two phases, of which at least one occurs during wet season. If two phases of sampling are impractical, a single phase sampling event should be conducted during the wet season.

The survey was undertaken between 9 July and 5 October 2012 at the end of the dry season. Unusually high rain events occurred during the summer season prior to the survey, however the dry season was also drier than the long-term average.

3.4 SITE SELECTION

Sites were selected based on the best possible spread in each deposit with the information provided by RT. Once in the field, however, many of the bore holes could not be sampled. This was due to their rehabilitation over 20 years ago, and they either could not be located, were blocked or did not reach the water table. A total of 91 troglofauna traps were deployed with the recovery of 88 traps (two traps were lost in the retrieval process and one trap was accidentally bulldozed). A total of four bores were sampled for stygofauna, all within the Deposit F. Sampled bore holes and notes are shown in Appendix A (stygofauna samples highlighted in bold), with sample sites mapped in Figure 3.1.

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

Deposit A

Deposit F

Deposit E

Mt Ella

A4 - -Pp

A4 - -Pp

A2d

Legend

- Study Area
- Impact Area
- Stygofauna and troglofauna sampled
- Blocked / Non-existing bores
- Troglofauna sampled

N

0 2.5 5

Kilometres

Absolute Scale - 1:90,000

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Sample sites of the Study Area

Figure: 0.M
Project ID: 1459

Drawn: BG
Date: 12/2/2013

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

Unique Map ID: BG281

A3

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3.5 SAMPLING METHODS

The subterranean fauna survey conformed to requirements of a pilot study outlined in EPA Guidance Statement No. 54 - *Consideration of Subterranean Fauna in Groundwater and Caves during Environmental Impact Assessment in Western Australia* (2003), and EPA Technical Appendix to Guidance Statement No. 54: *Sampling Methods and Survey Considerations for Subterranean Fauna in Western Australia* (2007).

3.5.1 Troglofauna Trapping

Only drill holes which were sealed and unobstructed were used for sampling. Drill holes were sampled using custom-designed traps (DEC and EPA approved) filled with leaf litter and baited with banana. Leaf litter was soaked over several days and sterilised by microwaving at a high setting for three minutes (to destroy any terrestrial predators present in the leaf litter that could inhibit, predate or impact on troglofauna colonising the traps once in the ground). The leaf litter was then stored in an air-tight container to further develop over eight weeks before deployment.

The water level of each drill hole was measured (where possible) using a standing water level meter prior to traps being deployed. This information aids positioning of troglofauna traps above the water table. Traps were placed approximately two meters above the water table (or above the blockage if drill holes were blocked but still reached a reasonable depth for sampling) and positioned so that the trap rested against the wall of the hole. The drill holes were re-sealed after the insertion of traps to maintain humidity levels and to reduce contamination from surface fauna. Each site was demarcated with flagging tape and a sign "DO NOT DISTURB- TROGLOFAUNA TRAPPING IN PROGRESS". Site management were informed of the areas where trapping was occurring to minimise accidental disturbance and tampering.

Traps were left in the ground for 91 days to ensure troglofauna colonisation. After this period, the traps were recovered and the leaf litter from each trap was placed into plastic bags, which were immediately sealed to avoid contamination. Samples were returned to the *ecologia* Perth laboratory for fauna extraction and sorting prior to being sent to relevant taxonomic experts for identification.

3.5.2 Stygofauna Sampling

A standing water level dipper was used to determine the standing water level in each drill hole. This information assisted with information on the local aquifers for stygofauna. Water parameters such as conductivity (salinity), turbidity, temperature, Dissolved Oxygen and Redox potential were collected *in situ* using a portable water quality meter to assess habitat related to water quality.

Sampling was conducted using haul nets of appropriate diameter (depending on water bore diameter), lowered slowly into bores using rope to prevent the net from free falling to the bottom of the bore. A minimum of three hauls were performed with a 150 µm mesh net and a further three hauls were performed with a 50 µm mesh net. All samples were washed in a 50µm sieve and preserved in a vial with 100 % ethanol in case DNA assessment was required at a later date. All vials were labelled with the date, bore name and replicate number. Samples were stored in cool, dark conditions returned to the *ecologia* Perth laboratory for sorting prior to being sent to relevant taxonomic experts for identification.

3.5.3 Laboratory Sorting and Specimen Identification

Tullgren funnels were used to extract troglofauna from the collected leaf litter samples. The general principle of Tullgren funnels is that a sample of leaf litter is suspended above a vessel containing ethanol. Animals inhabiting the sample are forced downwards by the progressive drying of the sample and ultimately fall into the collecting vessel containing 100 % ethanol (in case for the need of

DNA assessment at a later date). Typically, drying is enhanced by placing an incandescent lamp or heat source above the sample.

After the leaf litter samples were processed on the Tullgren funnels, each sample was examined for dead animals that were not collected during the Tullgren funnel extraction. Each sample was emptied into a tray and examined using a fluorescent light magnifier. Any dead animals were collected and immediately placed into 100 % ethanol.

Extracted troglofauna samples and stygofauna samples were sorted under a Lecia S6 stereo microscope. All specimens were identified to the lowest taxonomic resolution by *ecologia* scientists. Specimens are then sent to Western Australian Museum (WAM) taxonomic specialist for further identification. A list of taxonomic specialists used for identification is shown in Table 3.2.

Table 3.2 – Taxonomic experts used to identify potential SRE subterranean taxa

Taxonomic Expert	Institution	Specialist Group
Dr Mark Harvey Mieke Burger Amber Beavis Julianne Waldock	Western Australian Museum	Arachnids Myriapods
Dr Volker Framenau Dr Erich Volschenk	Phoenix Environmental	Troglofauna
Dr Simon Judd	Private consultant	Isopods

3.5.4 Short Range Endemic Status

The likelihood of the invertebrate species to be considered a SRE was determined by expert taxonomists (Table 3.2) based on the current knowledge of the distribution and biology of each species, as follows:

- No – Not considered a SRE.
- Confirmed - Current knowledge confirms that this species is a SRE.
- Likely – Current knowledge suggests this species is probably a SRE. However, further research is required to confirm status.
- Potential – Current knowledge of this species or group is very limited however, there is the potential for this species to represent a SRE. Further research is required to confirm status.
- Unknown – No comment can be made regarding SRE status, usually due to uncertainty over species level due to life stage/sex, and/or lack of taxonomic knowledge.

All likely, potential and unknown SREs should be treated as confirmed SREs under the precautionary principle (Section 4a of the EP Act).

4 RESULTS

4.1 SURVEY ADEQUACY

4.1.1 Species Accumulation Curve (SAC)

Both the empirically observed SAC and the estimated Mao and Tau rarefaction curve suggest that a low proportion of the diversity of troglofauna of the region was sampled (Figure 4.1).

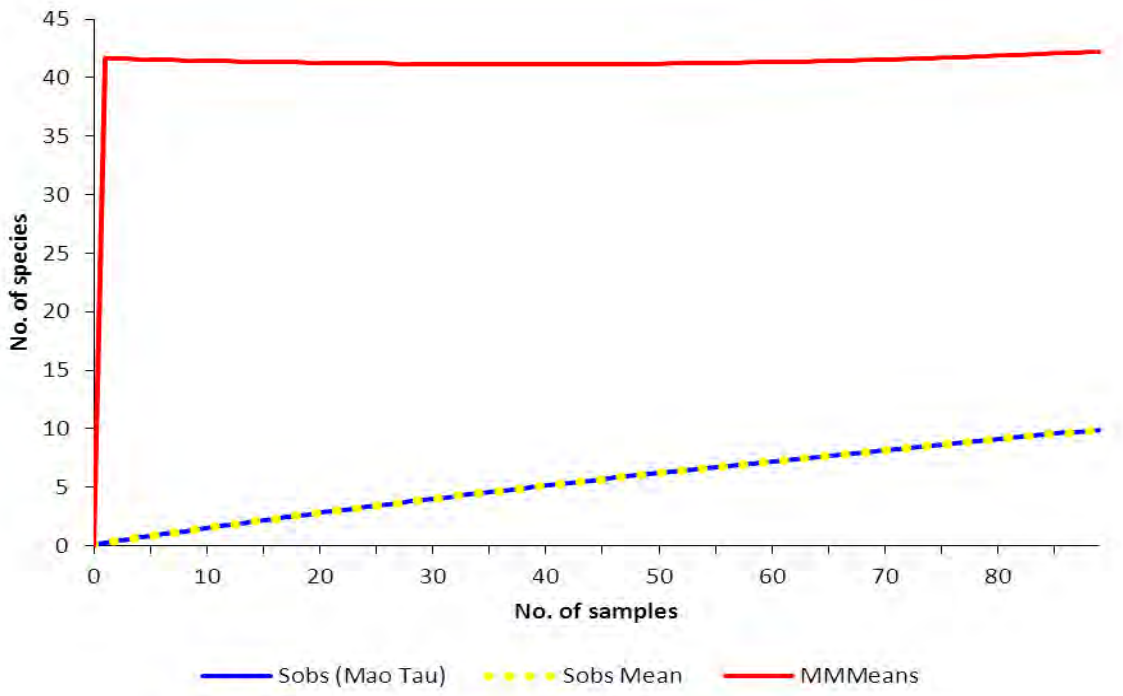

Figure 4.1 – SAC of the troglofauna data

The observed SAC (based on 100,000 randomisations) showed a gradual inclination upwards of species richness, however there was a large gap between the actual and predicted species richness curves. The Chao-1 estimator of total species richness predicted that the troglofauna assemblage in the Study Area consisted of approximately eleven species, with 95% confidence interval between ten and twenty species. Most of the other richness estimators resulted in estimate values between 11 and 42 (Table 4.1).

The Michaelis-Menten (MMS) estimator (used as a stopping rule) predicted that a total of 42 species potentially occur in the Study Area. This number indicates that approximately 24 % of the predicted troglobitic species were collected during this survey (i.e. 10 of the predicted 42).

Table 4.1 - Mean estimates of total species richness of troglofauna assemblage

Richness Estimators	Richness Estimate
ACE	14
ICE	33
Chao-1	11
Jack-1	18
Jack-2	25
Bootstrap	13
Michaelis-Menten	42

4.2 FIELD RESULTS

The survey yielded one hundred and nine invertebrate specimens representing eleven orders. Of these, ten species were identified as troglobitic. These species belong to the orders; Thysanura (silverfish), Psocoptera (booklice), Hemiptera (true bugs), Embioptera (webspinners), Blattodea (cockroaches), Coleoptera (beetles), Araneae (spiders), Isopoda (slaters) and Chilopoda (centipedes). Non-troglobitic specimens included Collembola (springtails), Blattodea, Coleoptera, Araneae and Diplopoda (millipedes).

Appendix B presents the full list of invertebrate species collected in the Study Area, with troglobitic species highlighted in bold. Troglobitic specimens collected are summarised in Table 4.2. The presence of troglobitic species in different geologies has been assessed (Figure 4.2). The x axis shows all 10 troglobitic species collected and the y axis shows the three geological units present in the Study Area: 1 – sedimentary rocks (A3b), 2 – dolerites and gabbros (A2d), 3 – mafic volcanics (A4 - -Pp).

Troglobitic specimens collected are mapped in Figure 4.3. Figure 4.3 also displays the geology of the Study Area (mapped by Hickman and Kranendonk 2008, Figure 2.2,), which gives an indication as to the geological associations and preferences of recorded troglobitic species.

The majority of troglobitic species recorded were collected as singletons and doubletons, with only the Blattodea specimens (*Nocticola* sp. indet.) and Coleoptera specimens (*Anillini* sp. indet.) collected in higher numbers 13 and 26, respectively).

Table 4.2 – Troglobitic specimens recorded

Order	Genus/Species	Easting	Northing	Bore ID	No. individuals
Thysanura	*Atelurinae* 'sp. indet.'	667471	7436527	WAD358	1
Psocoptera	*Trogiidae* 'sp. indet.'	691917	7441689	DHRC006	1
Hemiptera	*Meenoplidae* 'sp. indet.'	677142	7439755	WAG307	1
Hemiptera	*Meenoplidae* 'sp. indet.'	690832	7441805	WAH189	1
Embioptera	*Embioptera* 'sp. indet.'	676945	7436109	DExt13	1
Blattodea	*Nocticola* 'sp. indet.'	691491	7441209	DHRC010	2
Blattodea	*Nocticola* 'sp. indet.'	690832	7441805	WAH189	3
Blattodea	*Nocticola* 'sp. indet.'	693430	7441478	WAH048	8
Coleoptera	*Anillini* 'sp. indet'.	672131	7439118	WACRC332	26
Coleoptera	*Hydrobiomorpha*'sp. indet.'	665491	7437029	WAD329	2
Araneae	*Prethopalpus* 'sp indet.'	693112	7441491	WAH017	2
Isopoda	*Pseudodiploexochus* 'sp. nov.'	693112	7441491	WAH017	2
Chilopoda	*Cormocephalus* 'CHI003'	690369	7441601	WAH192	1

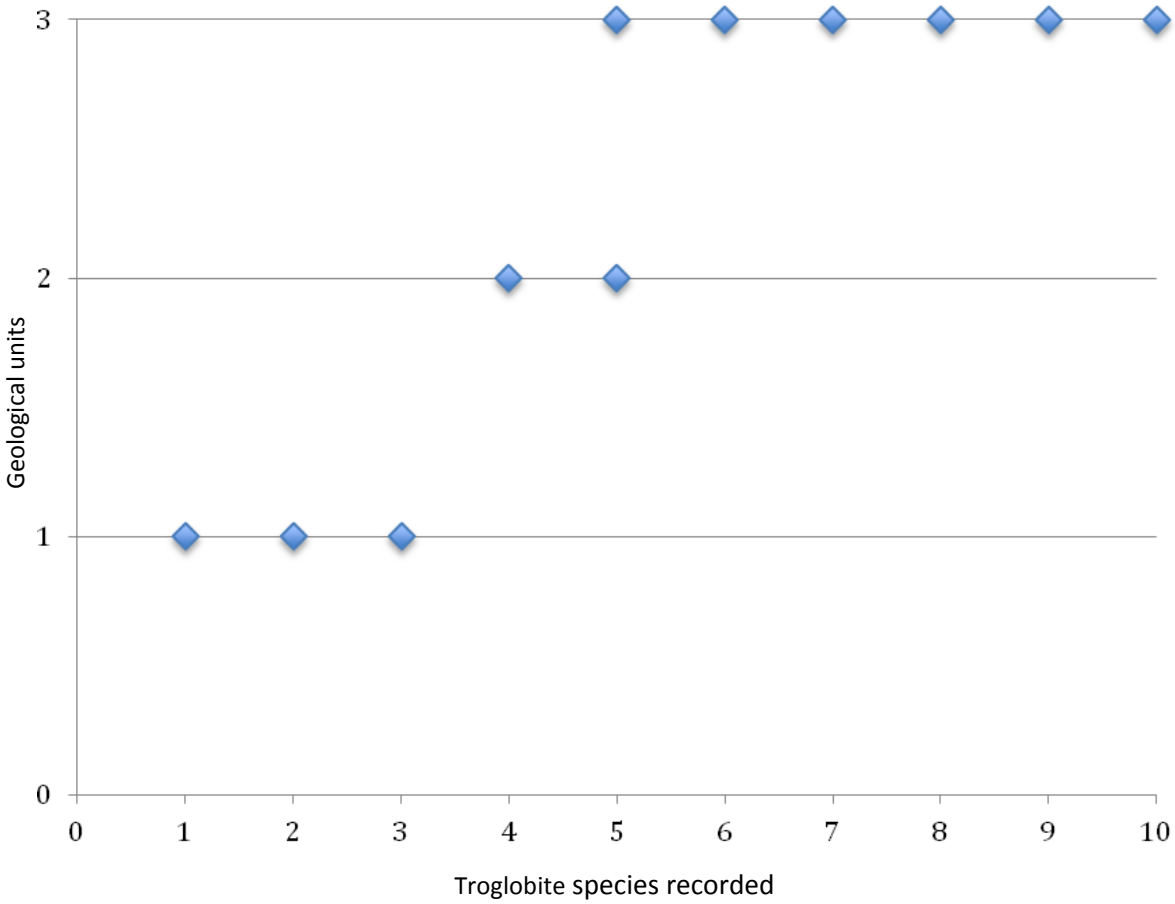

Figure 4.2 – Presence of troglobitic species in different geological units

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