Yeelirrie
Terrestrial Invertebrate Fauna Review

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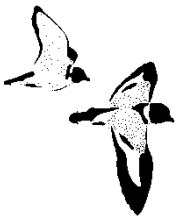

25th May 2015

Executive Summary

Background

Cameco Australia Pty Ltd (Cameco) proposes to develop the Yeelirrie Uranium Project, located approximately 420 km north of Kalgoorlie-Boulder, 70 km south-west of Wiluna and 110 km north-west of Leinster in the Murchison region of Western Australia. Cameco acquired the Yeelirrie Project in 2012 from BHP Biliton (BHP) and is in the process of reviewing the Environmental Review and Management Programme (ERMP) and related documents previously prepared for the Project.

As part of the environmental impact assessment, ecologia environment (ecologia) conducted a baseline significant invertebrate survey of the Yeelirrie Project Area (ecologia, 2011a), and developed an impact assessment for significant invertebrate fauna (ecologia, 2011b). Significant invertebrates are those listed under legislation or those considered to be Short-Range Endemic (SRE) species. Cameco commissioned Bamford Consulting Ecologists (BCE) to conduct a fauna review of the Yeelirrie Project and address matters relating to fauna as follows:

- Review the historical reports of fauna surveys completed at Yeelirrie to confirm;
    - The methods, reports and findings meet current guidelines and requirements;
    - Conservation rankings of significant species are current;
    - To identify and discuss any new issues that might have arisen since the previous work was completed in 2009, including information about species, new conservation rankings, etc.
- Undertake consultation with the relevant state agencies (DPaW and the OEPA) to determine adequacy and the position with the statistical approach (such as species accumulation curves) on SREs;
- Undertake a desktop determination of significant SRE fauna, particularly *Idiosoma* sp.
- Provide advice to Cameco of any gaps, including any new field work that may be required to finalise the studies;
- Prepare a standalone report that would be attached to the PER as an appendix alongside the field study reports that discusses the fauna review, updates and summarises the findings;
- Review ERMP fauna section and incorporate new findings as required;
- Rewrite the ERMP fauna section to reflect Cameco's new section structure.

As part of the invertebrate fauna review, information from the initial desktop assessment and survey work, conducted by ecologia (2011a, 2011b) was re-assessed to develop an updated fauna assemblage that accounts for administrative and legislative changes (e.g. changes in conservation status or taxonomy). Relevant fauna databases were re-visited and recent regional survey work was consulted (KLA, 2012; Outback Ecology, 2011; BCE, 2014). The ecologia surveys were conducted in accordance with Guidance Statement No. 20: Sampling of Short-range Endemic Invertebrate Fauna for Environmental Impact Assessment in Western Australia (EPA, 2009). In 2015, BCE conducted a targeted field assessment (searching for conservation significant invertebrate species) and revisited locations where *Idiosoma* sp, had been previously found in order to determine the relationship of the species to the Shield-backed Trapdoor Spider *Idiosoma nigrum.*

General Approach to Fauna Impact Assessment

The purpose of impact assessment is to provide government agencies with the information they need to decide upon the significance of impacts of a proposed development. BCE uses an impact assessment process with the following components:

- The identification of **fauna values**:
    - Assemblage characteristics: uniqueness, completeness and richness;
    - Species of conservation significance;
    - Recognition of ecotypes or vegetation/substrate associations (VSAs) that provide habitat for fauna, particularly those that are rare, unusual and/or support significant fauna;
    - Patterns of biodiversity across the landscape;
    - Ecological processes upon which the fauna depend.
- The review of **impacting processes** such as:
    - Habitat loss leading to population decline;
    - Habitat loss leading to population fragmentation;
    - Degradation of habitat due to weed invasion leading to population decline;
    - Ongoing mortality from operations;
    - Species interactions including feral and overabundant native species;
    - Hydrological change;
    - Altered fire regimes; and
    - Disturbance (dust, light, noise).
- The **recommendation** of actions to mitigate impacts.

Invertebrate Fauna Assemblage

A total of 42 invertebrate species was collected during the baseline surveys (ecologia, 2011a). A review of field surveys (ecologia, 2011a) and relevant databases revealed 18 conservation significant invertebrates have been recorded in the Yeelirrie area. This includes one species listed as Vulnerable under the EPBC and Wildlife Conservation Acts, three confirmed SRE taxa and 13 species with the potential to be SRE taxa (based on the current but limited knowledge). Significantly, the Shield-backed Trapdoor Spider *Idiosoma nigrum*, (listed as Vulnerable under the EPBC and Wildlife Conservation Acts) was recorded from 17 locations by BCE in March 2015. The three SRE species were recorded by ecologia during previous surveys (a slater or isopod of the family Platyarthridae or Bathytropidae, the isopod *Pseudolaureola* sp., and the tiger beetle *Pseudotetracha helmsi*), as were the 13 species considered to be possible SREs.

The Shield-backed Trapdoor Spider appears to occur in low densities but is widespread across the Yeelirrie lease, favouring Acacia shrublands with a sandy substrate. The species appears to be absent from the grey loamy-clay soils around some calcrete areas and in the main development footprint.

The isopod *Pseudolaureola* sp. was collected from Calcrete Outwash (site T04, within the proposed mine footprint) and is thought be an undescribed species. The species is considered a relic taxon of

the Gondwanan rainforest and all known species in the genus are SREs, therefore it is highly likely that this species is also a SRE (ecologia, 2011a).

Sixteen specimens of an undescribed slater genus and species from either the family Platyarthridae or Bathytropidae were collected within the project footprint, and were found within the Calcrete, Calcrete Outwash and Hardpan Mulga habitats (sites F11, T01, T02, T03, T07, T14 and T20, ecologia, 2011a). The undescribed genus from Yeelirrie is considered to be a SRE (ecologia, 2011a).

The tiger beetle (*Pseudotetracha helmsi*) was collected at three sites from the Yeelirrie Playa (YP4, YP6 and YP7). This species was previously known only from a few salt lakes located in the Murchison Bioregion and is considered a SRE. A further 13 species have the potential to be short-range endemic fauna. However, due to the limited survey work in the region and therefore limitations on distribution, habitat and taxonomy, these species were unable to be confirmed as SREs. Additionally, some new species were described from the Yeelirrie area (e.g. *Aname*, *Kwonkan* and *Cubaris* species) and as such their distribution and SRE status is unknown. They are considered potential SRE taxa because of their biology and the fact that closely related species exhibit short-range endemism.

The Mygalomorph spider *Kwonkan moriartii* has been recorded from two locations approximately 60 km east of the project area, but as three undescribed *Kwonkan* species were found at Yeelirrie and the taxonomy of the genus *Kwonkan* is due for revision (M. Harvey pers. comm.), *K. moriartii* may not in fact occur in the region.

Vegetation and Substrate Associations (VSAs)

Eight VSAs were identified across the project area and surrounding landscape. Mixed Shrubs over Spinifex Sandplain, Hardpan Mulga, Calcrete and Calcrete Outwash dominate most of the disturbance footprint with much smaller areas of rocky breakaway also included. Biodiversity is likely to be spread across the VSAs, with the most significant areas for invertebrate fauna considered to be those associated with calcrete (Calcrete, calcrete outwash, *Eucalyptus gypsophila* woodland).

A habitat analysis by Ecologia (2011a) showed no statistically significant difference between SRE species diversity and habitat type inside and outside the project footprint. SRE species distribution depends on micro-habitats ('island' habitats) rather than broadscale habitat types. Furthermore, all of the habitat types extend beyond the proposed project footprint indicating a potential for all species to be found outside the project footprint.

Impact Assessment

Potential impacts on the general invertebrate fauna assemblage are likely to be greater in Calcrete habitats, which have a higher proportional representation in the study area. Other VSAs in the project area, such as the Mulga and Spinifex Sandplains are considered widespread. One of the dominant ecological processes currently affecting the fauna assemblage in the project area is hydrology, with other processes including fire, feral species and interactions with native species, habitat degradation due to weed invasion and connectivity. Long-unburnt habitats are likely to be

important for some species, including the Shield-backed Trapdoor Spider *Idiosoma nigrum*. Impacts upon key fauna values are mostly considered to be Minor or less, with the exception of some SRE invertebrates closely associated with the VSAs predicted to experience the highest proportional level of impact. Localised, long-term reduction in population size can be predicted for these species.

Recommendations

Loss of habitat / habitat fragmentation

- Minimise the disturbance footprint;
- Clearly delineate areas to be cleared;
- Where possible, preserve habitats that support conservation significant fauna;
- Rehabilitate any cleared areas which are not needed after construction;

Habitat Management

- Maintain the Yeelirrie lease as livestock-free as part of the site's environmental management. This would be a significant and positive step towards the management and rehabilitation of fauna habitats.
- Decommission stock watering points to reduce the availability of artificial watering points for aggressive species away from the mine area.

Species interactions

- Develop a feral animal management plan.

Hydrological changes

- Develop an understanding of the surface and sub-surface drainage and possible effects of human activities upon groundwater in order to identify the potential for hydrological changes that could potentially impact fauna habitats

Habitat degradation due to weed invasions

- Develop a weed management/hygiene plan.

Changes in fire regime

- Develop a fire management plan (which includes regard for the ecological role of fire) to preserve habitat for fire sensitive species. .

Dust, noise, light and disturbance

- Minimise the production of dust, noise and light spill; especially where these may affect adjacent bushland. Establish long-term fauna monitoring sites to assess the impacts of these to monitor trends and identify areas of concern to dictate management.

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1 Introduction

1.1 Background

Cameco Australia Pty Ltd (Cameco) proposes to develop the Yeelirrie Uranium Project, centred on a large, shallow uranium deposit located in the Murchison region of Western Australia. The site is situated approximately 420 km north of Kalgoorlie-Boulder, 70 km south-west of Wiluna and 110 km north-west of Leinster (see Figure 1). The uranium deposit was discovered in 1972 by Western Mining Corporation (WMC) and has since had extensive exploration work conducted by WMC, and more recently by BHP Billiton (BHP). However, large scale mining has not been initiated.

BHP commissioned an environment impact assessment of the Yeelirrie Project, and developed a detailed Environmental Review and Management Programme (ERMP, BCE 2011a). As part of the environmental impact assessment, ecologia environment (ecologia) conducted a baseline significant invertebrate survey of the Yeelirrie Project Area (ecologia, 2011a), and developed an impact assessment for significant invertebrate fauna (ecologia, 2011b). Significant invertebrates are those listed under legislation or those considered to be Short-Range Endemic (SRE) species.

Cameco acquired the Yeelirrie Project in 2012 and plans to develop the uranium mine. As a result, Cameco is in the process of reviewing the Yeelirrie ERMP and related documents previously prepared for the Yeelirrie Project (by BHP), with the intention of submitting a revised environmental impact assessment (Public Environmental Review – PER). As part of this process, Cameco commissioned Bamford Consulting Ecologists (BCE) to conduct a fauna review of the Yeelirrie Project and address matters relating to fauna as follows:

- Review the historical reports of fauna surveys completed at Yeelirrie to confirm,
    - The methods, reports and findings meet current guidelines and requirements;
    - Conservation rankings of significant species are current;
    - To identify and discuss any new issues that might have arisen since the previous work was completed in 2009, including information about species, new conservation rankings, etc.
- Undertake consultation with the relevant state agencies (DPaW and the OEPA) to determine adequacy and the position with the statistical approach (such as species accumulation curves) on SREs;
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- Provide advice to Cameco of any gaps, including any new field work that may be required to finalise the studies;
- Prepare a standalone report that would be attached to the PER as an appendix alongside the field study reports that discusses the fauna review, updates and summarises the findings;
- Review ERMP fauna section and incorporate new findings as required;
- Rewrite the ERMP fauna section to reflect Cameco's new section structure.

This report details the terrestrial invertebrate assessment. The vertebrate fauna review is detailed in a separate report.

1.2 General approach to Fauna Impact Assessment

The purpose of impact assessment is to provide government agencies with the information they need to decide upon the significance of impacts of a proposed development. BCE uses an impact assessment process with the following components:

- The identification of **fauna values**:
  - Assemblage characteristics: uniqueness, completeness and richness;
  - Species of conservation significance;
  - Recognition of ecotypes or vegetation/substrate associations (VSAs) that provide habitat for fauna, particularly those that are rare, unusual and/or support significant fauna;
  - Patterns of biodiversity across the landscape;
  - Ecological processes upon which the fauna depend.
- The review of **impacting processes** such as:
  - Habitat loss leading to population decline;
  - Habitat loss leading to population fragmentation;
  - Degradation of habitat due to weed invasion leading to population decline;
  - Ongoing mortality from operations;
  - Species interactions including feral and overabundant native species;
  - Hydrological change;
  - Altered fire regimes; and
  - Disturbance (dust, light, noise).
- The **recommendation** of actions to mitigate impacts.

Descriptions and background information on these values and processes can be found in Appendices 1 to 4. Based on this impact assessment process, the objectives of investigations are to: identify fauna values; review impacting processes with respect to these values and the proposed development; and provide recommendations to mitigate these impacts.

1.3 Description of the Yeelirrie Project Area

The Yeelirrie project is located on Yeelirrie Station and forms part of the Shire of Wiluna (Figure 1). The proposed Yeelirrie development is situated within a wide, flat and long drainage valley that is characterised by extensive sand plains flanked by granite breakaways. The resource area is primarily situated in the centre of the project, along a paleo-drainage line and is approximately 9 km in length and approximately 1.5 km wide.

Cameco has indicated the footprint proposed by BHP in the initial ERMP is indicative of the updated development. Cameco proposes one minor deviation – the inclusion of a 50 ha evaporation pond (see Figure 2). The disturbance envelope also includes mine infrastructure (such as the metallurgical plant and ore stockpiles), which will closely surround the resource. Mine infrastructure located further afield include the quarry, the accommodation camp, associated access roads and borefield and pipeline corridors. Collectively, the resource area and infrastructure components form the indicative project footprint (disturbance envelope, see Figure 1).

The project area lies within the Eastern Murchison subregion of the Murchison Bioregion (Thackway and Cresswell, 1995, McKenzie *et al.* 2003). The proposed pit area lies across three main land types and five land systems. It is centred on calcrete drainage plains with mixed halophytic and non-halophytic shrublands (Cunya, Melaleuca, Mileura) and flanked by sand plains with Spinifex hummock grasslands (Bullimore) and Mulga Shrublands on hardpan (Yanganoo). The nominated uranium resource lies within the trunk valley of the ancient Yeelirrie paleodrainage system. Soil landscape systems have been described by DC Blandford & Associates (2009) within the project area. The vertebrate fauna assemblage has been described in detail by BCE (2011a, 2011b, 2015).

Figure 1. Location of the Yeelirrie project.

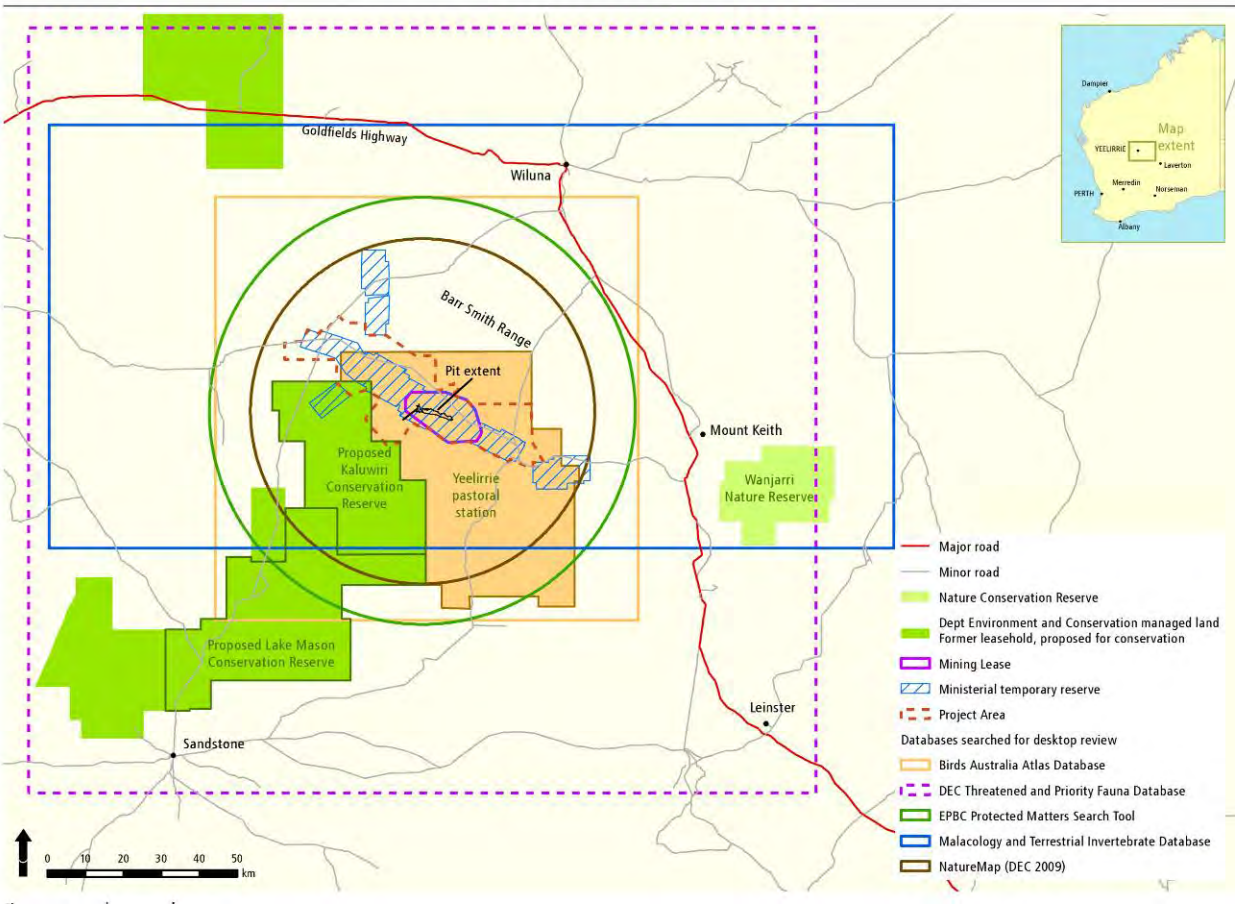


Figure 2. The Yeelirrie project disturbance envelope.

2 Methods

2.1 Desktop Assessment

2.1.1 Sources of information

As part of the invertebrate fauna review, previous survey work conducted at Yeelirrie was reviewed (ecologia, 2011a, 2011b) as well as other invertebrate studies conducted in the local area (KLA, 2012, Outback Ecology, 2011). The desktop assessment process was also reviewed. This builds on and updates the initial desktop assessment of the Yeelirrie project area conducted by ecologia (2011a). Information used for the desktop assessment has been re-assessed to develop an updated fauna assemblage that accounts for administrative and legislative changes (eg. changes in conservation status or taxonomy). Relevant fauna databases were re-visited and recent regional survey work was consulted. Sources of information used to update the Yeelirrie Desktop assessment are listed in Table 1.

Table 1. Sources of information used for the desktop assessment.

Database	Type of records held on database	Year / Area searched
NatureMap (DPaW 2015)	Records in the WAM and DPaW databases. Includes historical data and records on Threatened and Priority species in WA.	Site plus 40km buffer. Searched January 2015.
Ecologia	Invertebrate Assessment of the Yeelirrie Project Area, conducted by ecologia in 2009 and 2010.	2009 and 2010 – Yeelirrie
Fauna Assessment at Wiluna West (KLA, 2012)	Detailed Fauna Survey conducted by KLA in late 2011.	2011 – Wiluna West project, approximately 40 km north of Yeelirrie
Fauna Assessment at Wiluna Uranium Project (Outback Ecology, 2011)	Detailed Fauna Survey for Toro Energy Limited Wiluna Uranium Project	2011 – Wiluna.
Fauna Assessment of the Rosslyn Hill Mine	Detailed Fauna Survey conducted by BCE in late 2014.	2014 – Rosslyn Hill mining, 70 km north of Yeelirrie.
Vertebrate Fauna Assessment Yeelirrie Project - Baseline Report	Detailed Fauna Assessment of the Yeelirrie Project Area, conducted by BCE in 2009 and 2010	2009 – 2010 – Yeelirrie

2.1.2 Previous Surveys

Ecologia (2011a, 2011b) conducted a detailed assessment of the Yeelirrie project area during 2009 and 2010. The assessment was conducted over three parts:

1. Part One – consisting of five field surveys within and outside the project footprint between July 2009 and January 2010;
2. Part Two – a single field survey of three Yeelirrie Playas in February 2010; and
3. Part Three – a targeted *Idiosoma* field survey conducted in September 2010.

Sampling was conducted both within and outside the proposed project footprint and included foraging, wet pitfall trapping, burrow excavation, leaf litter and sediment collection and laboratory analysis. The sediment collection was from the Yeelirrie playa to search for aquatic invertebrates. A total of 42

invertebrate species was collected during the baseline surveys (ecologia, 2011a), of which four species were considered to be SREs (a trapdoor spider *Idiosoma* sp., a pseudoscorpion *Pseudolaureola* sp., a slater in the family Platyarthridae or Barthytropidae, and the beetle *Pseudotetracha helmsii*), and 13 were considered potential SREs (the trapdoor spiders *Aganippe* sp., *Aname* 'MYG170', *Aname* 'MYG212', , *Cubaris* sp. 1, *Cubaris* sp. 2, *Geophilida*, *Kwonkan* 'MYG171', *Kwonkan* 'MYG172', *Kwonkan* 'MYG210', *Kwonkan* 'MYG211', unidentified trapdoor spiders in the families Barychelidae and Cheridiidae, and the scorpion *Urodacus* 'yeelirrie') (see Table 3). The targeted *Idiosoma* survey (Part Three) determined the *Idiosoma* species collected from Yeelirrie to be an undescribed species: *Idiosoma* sp. Eleven of its burrows were recorded across four sites. The ecologia surveys were conducted in accordance with Guidance Statement No. 20: Sampling of Short-range Endemic Invertebrate Fauna for Environmental Impact Assessment in Western Australia (EPA, 2009). Additional surveys have been conducted nearby in the region and include at Rosslyn Hill (70km north of the project area, BCE 2014) and near Wiluna (KLA, 2012, Outback Ecology, 2011). The results of these assessments were drawn upon to develop this fauna review.

2.1.3 Legislation

Conservation significant fauna are protected under relevant state and federal legislation (EPBC Act, Wildlife Conservation Act – see Appendices 1 - 4). The latest editions of such legislation were consulted to update fauna the assemblage of any changes. This included:

- Schedule 1 of the Wildlife Conservation (Specially Protected Fauna) Notice 2014 released on 2 December 2014;
- EPBC Act – database review conducted January 2015.

2.1.4 Short-range Endemism

Invertebrate species considered to be short range endemics (SREs) are considered conservation significant, however many have no legislative or published recognition and their significance is based on interpretation of distribution information (Conservation Significance Level 3 – BCE, see Appendix 1). Harvey (2002) classes invertebrates as SRE species if they have a distribution of <10,000 km^2, and notes that the majority of species that have been classified as SREs have common life history characteristics such as poor powers of dispersal or confinement to discontinuous habitats. Several groups, therefore, have particularly high instances of short-range endemic species: terrestrial Gastropoda (snails and slugs), Oligochaeta (earthworms), Onychophora (velvet worms), Araneae (mygalomorph spiders), Pseudoscorpionida (pseudoscorpions), Schizomida (schizomids), Diplopoda (millipedes), Phreatoicidea (phreatoicidean crustaceans) and Decapoda (freshwater crayfish). The poor understanding of the taxonomy of many of the short-range endemic species hinders their conservation (Harvey 2002).

2.2 Field Assessment

BCE conducted a field assessment (assessment of conservation significant fauna and their associated habitats) of the Yeelirrie Area in March 2015. Two personnel visited the Yeelirrie project area and surrounds from the 14th – 18th March. During this trip, locations where *Idiosoma* sp, had been previously found by Ecologia were targeted in order to characterise the environment with which this species is associated, and to collect specimens to confirm the identification and determine the relationship of the species to the Shield-backed Trapdoor Spider *Idiosoma nigrum.* The Shield-backed Trapdoor Spider is listed under both state and commonwealth legislation, but *Ecologia* concluded the taxon they found at Yeelirrie was a related, undescribed but therefore unlisted species, although likely to be an SRE. The results of this assessment are provided in Section 3 and Appendix 6 and 7.

2.3 Impact Assessment

The impact assessment process for the BHP Yeelirrie ERMP is described in detail in BCE (2011b). While some impacts are unavoidable during a development, of concern are long-term, deleterious impacts upon biodiversity. This is reflected in documents such as the Significant Impact Guidelines provided by DSEWPaC (see Appendix 4). Significant impacts may occur if:

- There is direct impact upon a VSA and the VSA is rare, a large proportion of the VSA is affected and/or the VSA supports significant fauna.
- There is direct impact upon conservation significant fauna.
- Ecological processes are altered and this affects large numbers of species or large proportions of populations, including significant species.

The impact assessment process therefore involves reviewing the fauna values identified through the desktop assessment and field investigations with respect to the project and impacting processes. The severity of impacts on the fauna assemblage and conservation significant fauna can then be quantified on the basis of predicted population change.

The presentation of this assessment follows the general approach to impact assessment as given in Section 1.2, but modified to suit the characteristics of the site and the limited availability of information on invertebrate fauna. Key components to the general approach to impact assessment are addressed as follows:

Fauna values

This section presents the results of the desktop and field investigations in terms of key fauna values (described in detail in Appendix 2). Because it is not possible to characterise the complete invertebrate fauna assemblage, the only fauna values with respect to invertebrates that can be assessed are:

- Species of conservation significance – based upon desktop assessment and site inspection;
- Recognition of ecotypes or vegetation/substrate associations (VSAs), particularly with respect to their important for significant invertebrate fauna - based upon desktop assessment and site inspection; and
- Ecological processes upon which the fauna depend - based upon desktop assessment and site inspection.

Impact assessment

This section reviews impacting processes (as described in detail in Appendix 3) with respect to the project and examines the potential effect of these impacts upon biodiversity of the alignment. It thus expands upon Section 1.2 and discusses the contribution of the project to impacting processes, and the consequences of this with respect to biodiversity. A major component of impact assessment is consideration of threats to species of conservation significance as these are a major and sensitive element of biodiversity. Therefore, the impact assessment includes the following:

- Review of impacting processes; will the proposal result in:
    - Habitat loss leading to population decline, especially for significant species;
    - Habitat loss leading to population fragmentation, especially for significant species;
    - Weed invasion that leads to habitat degradation;
    - Ongoing mortality;
    - Species interactions that adversely affect native fauna, particularly significant species;
    - Hydrological change;

  - Altered fire regimes; and
  - Disturbance (dust, light, noise).
- Summary of impacts upon significant species, and other fauna values.

The impact assessment concludes with recommendations based upon predicted impacts and designed to mitigate these.

2.3.1 Criteria for impact assessment

The significance of impacts can be related to proportional decline in regional populations of a species or a type of environment. Significance is thus contextual. For example, the EPA (2004) suggests that the availability of fauna habitats within a radius of 15km can be used as a basis to predict low, moderate or high impacts. In this case, a high impact is where the impacted environment and its component fauna are rare (<5% of the landscape within a 15km radius or within the Bioregion), whereas a low impact is where the environment is widespread (10% of the local landscape). In a similar way, under the Ramsar Convention, a wetland that regularly supports 1% of a population of a waterbird species is considered to be significant. These sorts of values are suitable when considering very large proposed developments in extensive landscapes, such as the Yeelirrie project. Impacts can then be described as follows:

- Negligible: Effectively no population decline or other change within 15km radius.
- Minor: Population decline of <1% within 15km radius.
- Moderate: Permanent population decline 1-10% within 15km radius.
- Major: Permanent population decline >10% within 15km radius.
- Critical: Taxon extinction within 15km radius.

3 Results

3.1 Invertebrate Fauna Assemblage

3.1.1 Overview of fauna assemblage

Invertebrates in general are beyond the scope of assessment for environmental impact assessment because there are so many species and their taxonomy is so poorly understood, but it is possible to focus on a small range of taxa that are significant either because they are listed under legislation or are considered to be SREs. Harvey (2002) notes several groups that have particularly high instances of SRE: Gastropoda (snails and slugs), Oligochaeta (earthworms), Onychophora (velvet worms), Araneae (mygalomorph spiders), Schizomida (schizomids; spider-like arachnids), Diplopoda (millipedes), Phreatoicidea (phreatoicidean crustaceans), and Decapoda (freshwater crayfish).

A review of field surveys (ecologia, 2011a and by BCE in March 2015) and relevant databases revealed 18 conservation significant invertebrates have been recorded in the Yeelirrie area (see Table 2, Table 3, Figure 3, Appendices 5 - 7). This includes one species listed as Vulnerable under the EPBC and Wildlife Conservation Acts, three confirmed SRE taxa and 13 species with the potential to be SRE taxa (based on the current but limited knowledge, see Table 2). A further seven significant invertebrate species were returned by databases but are not considered likely to be present due to lack of habitat and/or the project area being well outside the known range. These are discussed below (see also Table 4).

Significantly, *Idiosoma nigrum* was recorded by BCE at Yeelirrie during March 2015 (see Appendix 5 and 6). This was the *Idiosoma* sp. recorded by ecologia, but specimens collected in March 2015 were considered to be the listed Shield-backed Trapdoor Spider *I. nigrum* by Phoenix Environmental (2015). This species is listed as Vulnerable under the EPBC and Wildlife Conservation Acts.

The three SRE species were recorded by ecologia during previous surveys (a slater or isopod of the family Platyarthridae or Bathytropidae, the isopod *Pseudolaureola* sp., and the tiger beetle *Pseudotetracha helmsi*), as were the 13 species considered to be possible SREs. This assessment as possible SREs taxa is based on their biology or taxonomy (ie. closely related taxa are considered SREs).

Table 2. Composition of vertebrate fauna assemblage expected to occur within the survey area.

Taxa	Significant fauna recorded in the Yeelirrie area			
	CS1	CS2	SRE	Potential SRE
Mygalomorph Spiders	1			8
Isopods			2	2
Insects			1	0
Scorpion				1
Pseudoscorpion				1
Centipedes				1
Total	**1**	**0**	**3**	**13**

CS1 = listed under legislation; CS2 = listed as priority; SRE = short range endemic.

Table 3. Conservation status of significant invertebrate species recorded in the study area.
Based on ecologia 2011a and the BCE 2015 assessment and VSAs in which they were found. Environmental codes are described in Section 3.2 and in BCE 2011a.

Taxa	Species Name	Status	Footprint Collection		VSA					
		Potential	In	Out	HM	C	CO	SS	PB	PY
Mygalomorph	Shield-backed Trapdoor Spider *Idiosoma nigrum*	EPBC, WC Acts	No	Yes				X		
Isopod	Platyarthridae/ Bathytropidae	SRE	Yes	No	X	X	X			
Isopod	*Pseudolaureola* sp.	SRE	Yes	No			X			
Carabidae	*Tiger beetle* *Pseudotetracha helmsi*	SRE	No	Yes						X
Mygalomorph	*Aganippe* sp.	Potential SRE	No	Yes	X					
Mygalomorph	*Aname* 'MYG170'	Potential SRE	Yes	No	X	X	X			
Mygalomorph	*Aname* 'MYG212'	Potential SRE	Yes	Yes			X	X		
Mygalomorph	Barychelidae	Potential SRE	Yes	No			X			
Mygalomorph	*Kwonkan* 'MYG171'	Potential SRE	Yes	No	X					
Mygalomorph	*Kwonkan* 'MYG172'	Potential SRE	Yes	No		X			X	
Mygalomorph	*Kwonkan* 'MYG210'	Potential SRE	No	Yes	X					
Mygalomorph	*Kwonkan* 'MYG211'	Potential SRE	No	Yes	X					
Scorpion	*Urodacus* 'yeelirrie'	Potential SRE	Yes	Yes	X	X	X			
Pseudoscorpion	Cheiridiidae	Potential SRE	Yes	No			X			
Isopod	*Cubaris* sp. 1	Potential SRE	Yes	No		X				
Isopod	*Cubaris* sp. 2	Potential SRE	Yes	Yes	X			X		
Centipede	*Geophilida*	Potential SRE	Yes	No	X					

Environment Codes = HM (Hardpan Mulga), C (Calcrete), CO (Calcrete Outwash), SS (Mixed Shrubs over spinifex sandplain), PB (Play B), PY (Yeelirrie Playa, a component of Calcrete Outwash).

The Shield-backed Trapdoor Spider is listed as Vulnerable under the EPBC and WA Wildlife Conservation Acts. It was recorded from 17 locations by BCE during March 2015 (see Section 3.1.2, Appendix 5). This species appears to occur in low densities but is widespread across the Yeelirrie lease, favouring Acacia shrublands with a sandy substrate. The nearest known records come from Weld Range (approximately 200km to the west, BCE unpubl. records), where it is restricted to the slopes of ironstone ridges.

The isopod *Pseudolaureola* sp. was collected from Calcrete Outwash (site T04, within the proposed mine footprint) and is thought be an undescribed species. The species is considered a relic taxon of the Gondwanan rainforest and all known species in the genus are SREs, therefore it is highly likely that this species is also a SRE (ecologia, 2011a).

Sixteen specimens of an undescribed slater genus and species from either the family Platyarthridae or Bathytropidae were collected within the project footprint, and were found within the Calcrete, Calcrete Outwash and Hardpan Mulga habitats (sites F11, T01, T02, T03, T07, T14 and T20, ecologia, 2011a). These families are poorly known in Australia and Western Australia with only one described species from each (ecologia 2011a). The undescribed genus from Yeelirrie is considered to be an ancient Gondwanan group, and all of the previous examples of this morphology have been considered a SRE. Likewise, this species is considered to be a SRE (ecologia, 2011a).

The tiger beetle (*Pseudotetracha helmsi*) was collected at three sites from the Yeelirrie Playa (YP4, YP6 and YP7). Tiger beetles are predatory and some are known to have restricted distributions around ephemeral salt lakes (ecologia, 2011a). This species was previously known only from a few salt lakes located in the Murchison Bioregion and is considered a SRE. A tiger beetle collected by BCE at Sir Samuel salt lake in March 2015 is not considered an SRE (Phoenix Environmental 2015).

A further 13 species have the potential to be short-range endemic fauna (see Table 3). However, due to the limited survey work in the region and therefore limitations on distribution, habitat and taxonomy, these species were unable to be confirmed as SREs. Their possible SRE status may simply be an artefact of the lack of regional collection. The 13 species nominated as potentially SREs were classified based on their biology or taxonomy (habitat restrictions, belong to groups known to exhibit short-range endemism or are closely related to short-range endemic taxa, ecologia 2011a). Several specimens collected by ecologia could not be identified to species level due to the poor taxonomic knowledge of such groups, however are considered potential SREs because of biology or knowledge of closely related species (ie. closely related species have restricted distributions). Additionally, some new species were described from the Yeelirrie area (e.g. *Aname*, *Kwonkan* and *Cubaris* species) and as such their distribution and SRE status is unknown. They are considered potential SRE taxa because of their biology and the fact that closely related species exhibit short-range endemism.

Additional conservation significant taxa known from the region and listed in ecologia (2011a) are summarised in Table 4 below. However these additional species are considered unlikely to occur at Yeelirrie. The project area is outside the known range of the Arid Bronze Azure *Ogyris subterrestris petrina* and Tree-stem Trapdoor Spider *Aganippe castellum*; in addition the Tree-tem Trapdoor Spider constructs a distinctive and easily-recognised burrow that was not found by either *ecologia* or BCE. Several fairy shrimp species (*Branchinella* spp.) are known from the larger salt lakes in the region, but none of them was found in the sediment sampling of the Yeelirrie playa conducted by *Ecologia* (2011a). The Mygalomorph spider *Kwonkan moriartii* has been recorded from two locations approximately 60 km east of the project area, but as three undescribed *Kwonkan* species were found at Yeelirrie and the taxonomy of the genus *Kwonkan* is due for revision (M. Harvey pers. comm.), *K. moriartii* may not in fact occur in the region.

Table 4. Conservation status of listed invertebrate species recorded in the region.
Based on desktop reviews, ecologia 2011a, but which are not considered likely to be present. Regional records refer to species recorded in the Murchison Bioregion.

Taxa	Species Name	Conservation Status			Habitat	Regional records	Expected status in project area
		EPBC	WCA	P			
Conservation Significance 1 (CS1)							
Arid Bronze Azure (butterfly)	*Ogyris subterrestris petrina*	Vul	S1		Woodland	Kalgoorlie	Unlikely
Conservation Significance 2 (CS2)							
Mygalomorph	*Kwonkan moriartii*			P2	Mulga	Wanjarri	Potential resident
Mygalomorph	*Aganippe castellum*			P4	Ironstone	Diemal	Unlikely
Crustacean	*Branchinella apophysata*			P1	Salt Lakes	Mt Margaret	Unlikely
Crustacean	*Branchinella denticulata*			P1	Salt Lakes	Kalgoorlie	Unlikely
Crustacean	*Branchinella simplex*			P1	Salt Lakes	Lake Annean	Unlikely
Crustacean	*Branchinella wellardi*			P1	Salt Lakes	Dalgaranga	Unlikely

See Appendix 4 for descriptions of conservation significance levels (as per Section 3.1.4).

3.1.2 *Idiosoma nigrum observations by BCE*

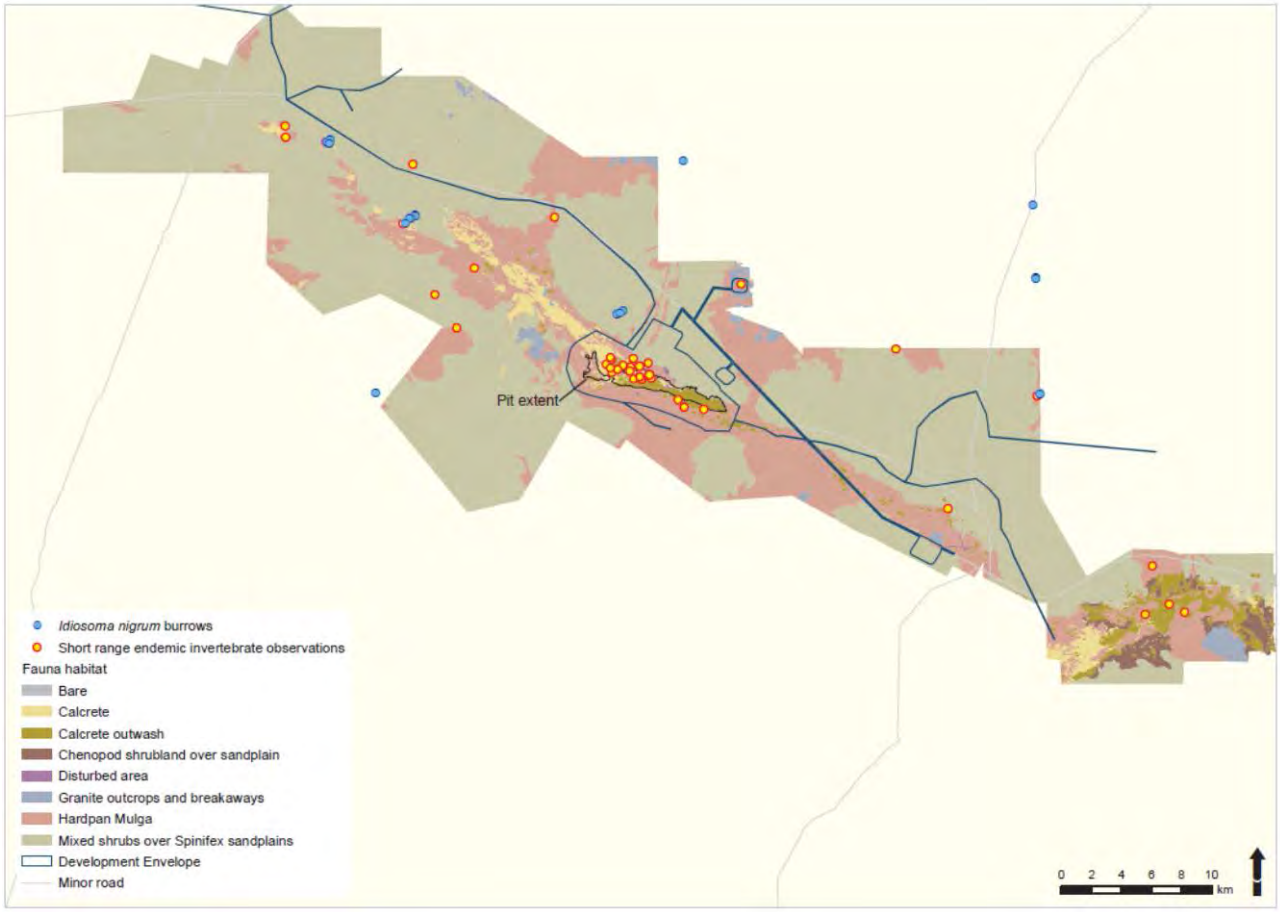
A total of 17 *Idiosoma* burrows was recorded across Yeelirrie in 2015 (see Appendix 5 and 6). The species was considered to be the Shield-backed Trapdoor Spider *Idiosoma nigrum* by Phoenix Environmental (2015) based upon two specimens collected in 2015. This is significant as the species is listed under both the EPBC and Wildlife Conservation Acts (Vulnerable). This determination also differs from the previous Yeelirrie invertebrate study (which recognised the species as *Idiosoma* sp. and not *I. nigrum*). *Idiosoma nigrum* occurs at Yeelirrie in apparently much lower densities than those observed elsewhere (BCE, 2011c).

Idiosoma nigrum constructs an elaborate burrow with a leaf litter and silk door, with leaf and twig trip-lines fanning out from the centre of the front of the burrow rim (Gray 2014, see Table 10). At Yeelirrie, *I. nigrum* appears to favour Acacia shrublands (with or without spinifex) on red, sandy-loam soil both on plains, sandy rises and slopes. In favoured areas, the soil is sandy and friable to depth of at least 30cm, and lacks the clay layer or hardpan that is common across much of the site. *I. nigrum* appears to be absent from the grey loamy-clay soils around some calcrete areas and in the main development footprint. Spiders also appear absent from shallow, rocky soils of the Barr-Smith Range.

BCE also recorded some opportunistic invertebrate observations during the fauna assessment:

1. *Anidiops* sp. burrows within Mulga Woodland. Several burrows were located and appear to be associated with the longer unburnt Mulga flanking minor drainage lines. A widespread group;
2. Horned Stick Inset *Paronchestus cornutus.* A very large stick insect that has a poorly-known and possibly restricted distribution from around the border of the Northern Territory, South Australia and Western Australia (Brock and Hasenpusch 2009), and thus the record from Yeelirrie represents a range extension and suggests that the species is probably widespread.

Figure 3. SRE fauna recorded across the Yeelirrie Project.



3.2 Vegetation and Substrate Associations (VSAs)

BCE (2011a) describes eight major VSAs occurring across the Yeelirrie project area (Figures 4 and 5):

- Granite Outcrops and Breakaways: supporting mixed shrubland on gravelly/sand. Some areas of chenopod shrubland on heavier soil also present;
- Hardpan Mulga. Mulga woodland with poorly-developed understorey on hard loam soils;
- Calcrete. Low calcrete rises with Eucalypt open woodland (variable) over a sparse shrubland;
- Calcrete Outwash. Clayey-loam and clay flats, subject to occasional inundation with some open claypans. These claypans are the playas recognised by Ecologia (2011a). Vegetation includes Acacia open shrubland, sometimes with thickets of *Melaleuca xerophila*, and chenopod shrub-heaths;
- Chenopod Shrubland over Sandplain. These shrublands occur in sandy soils on the margins of playas in the southeast of the project area;
- Spinifex Sandplain. Sandplains dominated by Triodia hummock grasslands and scattered shrubs with areas of open Acacia/Eucalypt woodland;
- Mulga over Spinifex Sandplain. Mulga woodland over Spinifex on sandy-loam soils; and
- Acacia woodland over sparse Spinifex. Areas of dense Acacia woodland with or without a Spinifex understorey of variable density.

Areas of each VSA within the project area are given in Table 5 (BCE, 2011a). The original disturbance footprint proposed by BHP was centred on the calcrete and calcrete outwash habitats (467 and 615 ha respectively) and extended on the adjacent sandplain and hardpan mulga (1431 and 835 ha). Minor areas of granite outcrop / breakaway were proposed for disturbance (15 ha) and the sandplains supporting chenopod shrubland (in the south-east) occurred outside the proposed disturbance. While BHP proposed to disturb parts of some VSAs, large areas were proposed to be included within a Yeelirrie Conservation Area, as part of the management and preservation of the site's biodiversity (see Table 5).

Table 5. Areas of fauna habitat within the project area

Habitat type	Project area (ha)	Disturbance Footprint (ha)	Habitat Recommended for Preservation
Granite Outcrops and Breakaways	1,866	17 (0.9%)	
Mixed Shrubs over Spinifex Sandplain*	69,840	821 (1.2%)	Yes
Hardpan Mulga	21,230	738 (3.5 %)	Yes
Calcrete	2,819	216 (7.7%)	Yes
Calcrete Outwash	3,095	548 (17.7%)	Yes
Chenopod Shrubland over Sandplain	1215	0 (0%)	
Bare and disturbed (not considered further in this study)	150	NA	

* Three VSAs not clearly defined by vegetation types so combined for the purposes of area calculation; all have spinifex in common.

Figure 4. Vegetation and substrate associations across the Yeelirrie project.

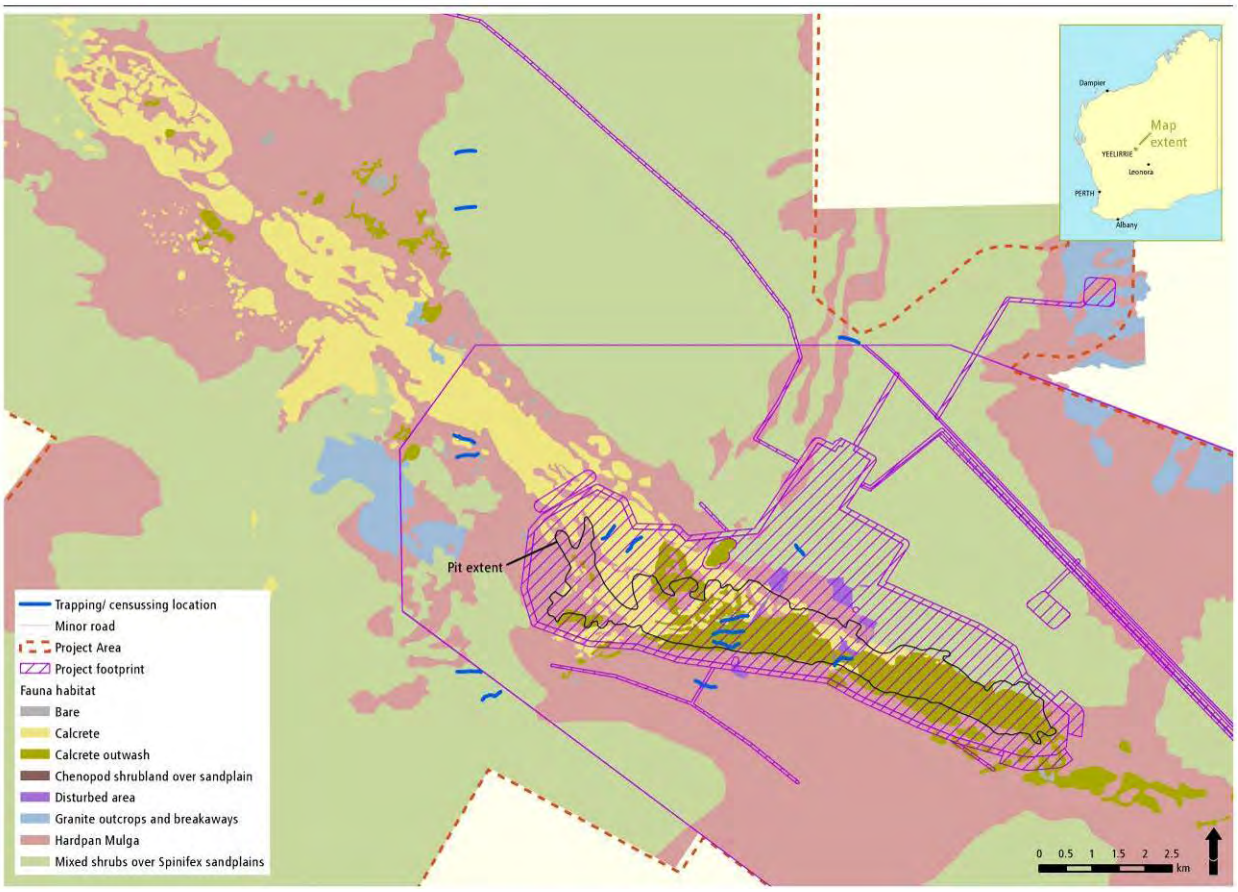
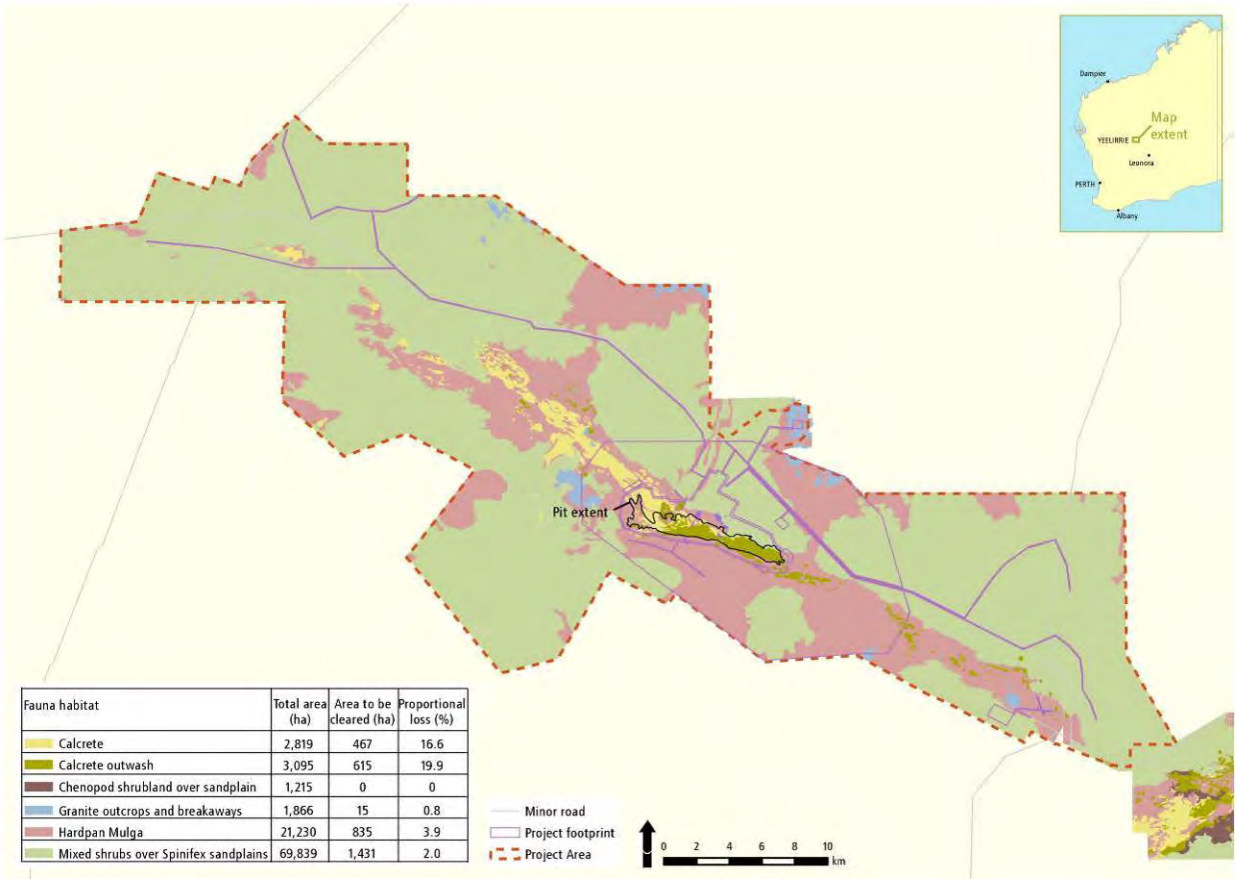


Figure 5. Vegetation and substrate associations across the wider Yeelirrie area.



Fauna habitat	Total area (ha)	Area to be cleared (ha)	Proportional loss (%)
Calcrete	2,819	467	16.6
Calcrete outwash	3,095	615	19.9
Chenopod shrubland over sandplain	1,215	0	0
Granite outcrops and breakaways	1,866	15	0.8
Hardpan Mulga	21,230	835	3.9
Mixed shrubs over Spinifex sandplains	69,839	1,431	2.0

3.3 Patterns of biodiversity

Investigating patterns of biodiversity can be complex and are often beyond the scope even of level 2 investigations. However some overall trends were observed at Yeelirrie during field assessments. Important patterns of distribution are:

- The Shield-backed Trapdoor Spider favours the Acacia shrublands within the Mixed Shrubs over spinifex sandplain VSA, however was also recorded in areas mapped as Hardpan Mulga (but in areas of sandy soil within the Hardpan Mulga). It occurs at low densities and all locations where the species was recorded lie outside the project footprint. However, as both the spinifex sandplain and Hardpan Mulga extend within the project footprint the species is considered likely to occur within the proposed disturbance area;
- During the ecologia field assessment, Hardpan Mulga was the richest VSA in SRE species, followed by Calcrete Outwash, Calcrete and Mixed Shrubs over Spinifex Sandplain. However, the Calcrete showed the highest specimen abundance (due to a greater survey effort) followed by Hardpan Mulga, Calcrete Outwash and Mixed Shrubs over Spinifex Sandplain. Ecologia (2011a) found that three invertebrate species had statistically significant associations with VSAs: the spider *Aname* 'MYG170' (Calcrete), the slater Platyarthridae/Bathytropidae (Calcrete Outwash) and the scorpion *Urodacus* 'yeelirrie' (Hardpan Mulga);
- The VSAs with the highest levels of impact include the Calcrete and Calcrete Outwash. These VSAs support:
    - Calcrete - five SRE species recorded including *Aname* 'MYG170', *Cubaris* sp. 1, *Kwonkan* 'MYG172', Platyarthridae/Bathytropidae and *Urodacus* 'yeelirrie';
    - Calcrete Outwash - Seven SRE species recorded including *Aname* 'MYG170', *Aname* 'MYG212', Barychelidae, Cheiridiidae, Platyarthridae/Bathytropidae, *Pseudolaureola* sp. and *Urodacus* 'yeelirrie';
- All of the VSAs extend beyond the proposed project footprint indicating a potential for all species to be found outside the project footprint; and
- Outside the project footprint important habitats include the relictual rocky breakaways.

3.4 Ecological processes

The nature of the landscape and the fauna assemblage indicate some of the ecological processes that may be important for ecosystem function (see Appendix 4 for descriptions and other ecological processes). These include:

Local hydrology. The orebody is situated on a major paleo-drainage line which supports a series of small seasonal wetlands and playas. Several of the VSAs present (such as those associated with calcrete), may be reliant upon groundwater and the local hydrology will be important for all VSAs.

Fire. While some habitats associated with the orebody may burn infrequently (eg. chenopod shrublands), the adjacent spinifex grasslands are highly flammable and mulga communities are fire sensitive. Spinifex grasses are highly flammable and are able to withstand high intensity fires by regenerating quickly from seed and rootstock following a fire event (Latz 1995). Mulga, however, is highly sensitive to fire and can be permanently removed by high intensity fires (mature Mulga trees and

seedlings readily succumb to moderately intense fire and generally do not resprout). High intensity fires, repeat fire events or the lack of rainfall following a fire can deplete Mulga seed supply and cause long-term change (Bradstock *et. al.*, 2012). In the absence of traditional burning regimes adopted by indigenous Australians, large areas of fire-sensitive Mulga (including the associated animals and plants) can be replaced by spinifex dominated communities (Bradstock *et. al.*, 2012).

The project area will be prone to fire in dry weather and while appropriate fire regimes can benefit biodiversity, inappropriate regimes can lead to a loss of biodiversity. Some fauna species expected in the project area are sensitive to fire as they rely on long-unburnt habitats to survive (eg. Trapdoor spiders such as *Idiosoma nigrum*). A mosaic burning regime is known to benefit biodiversity and can also aid in the control of unplanned wildfires. Rocky areas can also act as fire refuges and allow for the development of fire-sensitive habitats over time (eg. Callitris woodland along the Barr Smith Range).

Feral species and interactions with over-abundant native species. The fauna assemblage has already been impacted by feral species due to the grazing by introduced herbivores (eg. cattle and goat), and the possible decline of some species. Increased human activity within bushland areas often results in an increase in the abundance of feral species. Feral fauna should be managed to reduce impacts on native fauna species. Livestock have historically caused significant degradation to fauna habitats at Yeelirrie, particularly around permanent water. Yeelirrie has been destocked however cattle from neighbouring properties were recorded widely across the lease (during 2015). As a result of recent rainfall several seasonal wetlands supported small numbers of cattle.

Habitat degradation due to weed invasion. There was little evidence of weed invasion in most VSAs across the site but increasing human activity has the potential to increase habitat degradation through weed invasion. This in turn will impact on fauna when vegetation density changes. Weed management practises should be implemented as part of environmental management.

Connectivity and landscape permeability. The orebody lies on a major paleo-drainage line and is likely to have a connectivity function for fauna moving along it (to the north-west and south-east). Other VSAs occurring away from the orebody (such as spinifex sandplains and mulga) are widespread across the landscape. This connectivity function may be especially important in maintaining continuity of populations of SRE invertebrates that have poor powers of dispersal.

3.5 Summary of fauna values

Fauna values within the Yeelirrie study area can be summarised as follows:

Fauna assemblage. The invertebrate fauna assemblage expected at Yeelirrie is considered to be relatively intact, within a relatively intact, largely uncleared landscape, although a number of species are likely to have been impacted by long-term pastoralism.

Species of conservation significance. At least 18 species of conservation significance are expected to be present. The EPBC listed Shield-backed Trapdoor Spider *Idiosoma nigrum* was confirmed as present, three species present are categorised as short-range endemic and a further 13 species were considered to have the potential to be SRE taxa. Database searches revealed the possibility of at least a further one further listed species to occur, the spider *Kwonkan moriartii*, although the taxonomy of this genus is

uncertain and three *Kwonkan* species, considered to be SREs, were found by ecologia (2011a). Nine of the 16 SRE species recorded have only been collected from within the project footprint.

Vegetation and Substrate Associations (VSAs). Eight VSAs were identified across the project area and surrounding landscape. Mixed Shrubs over Spinifex Sandplain, Hardpan Mulga, Calcrete and Calcrete Outwash dominate most of the disturbance footprint with much smaller areas of rocky breakaway also included. The uranium orebody sits under the calcrete habitats, which are regionally uncommon although are not restricted to the project area. Potential impacts on the general invertebrate fauna assemblage are likely to be greater in Calcrete habitats, which have a higher proportional representation in the study area. Other VSAs in the project area, such as the mulga and spinifex sandplains are considered widespread.

Patterns of biodiversity. Biodiversity is likely to be spread across the VSAs, with the most significant areas for invertebrate fauna considered to be those associated with calcrete (Calcrete, calcrete outwash, *Eucalyptus gypsophila* woodland). Outside the project footprint important habitats include the relictual rocky breakaways.

Key ecological processes. One of the dominant ecological processes currently affecting the fauna assemblage in the project area is hydrology, with other processes including fire, feral species and interactions with native species, habitat degradation due to weed invasion and connectivity. Long-unburnt habitats are likely to be important for some species, including the Shield-backed Trapdoor Spider *Idiosoma nigrum*.

4 Impact assessment

4.1 Overview of Impacts

The following sections examine possible impacts upon fauna values based upon the impacting or threatening processes outlined in Appendix 2. Recommendations relating to impacts are made in Section 6.

4.1.1 Loss of habitat leading to population decline

Some loss of habitat is inevitable but can be minimised through controls during clearing. Rehabilitation of disturbed areas may also be implemented as soon as possible after clearing. The small area of impact in relation to the surrounding landscape means that loss of habitat is unlikely to have long-term adverse impacts upon most invertebrate populations in the region. An exception to this is the proportions of calcrete and calcrete outwash VSAs predicted to be cleared: 216 ha (7.7%) and 548 ha (17.7%, see Table 5) respectively. Some of the SRE invertebrates have a close association with these VSAs and therefore could experience population declines of these proportions. These include the mygalomorph spider *Aname* MYG170 with a significant association with Calcrete and the undescribed isopod (Platyarthidae/Bathytropidae) with Calcrete Outwash. The only records of the tiger beetle, barychelid spider, pseudoscorpion and the isopod *Cubaris* sp 1 were from either the Calcrete outwash or Calcrete, but the sample sizes were small and thus close associations with the VSAs cannot be concluded.

4.1.2 Loss of habitat leading to population fragmentation

Some landscape features within the project area may have a connectivity function for fauna, aiding them to move through the landscape. Therefore, impacts upon these features could disrupt this movement, facilitating population fragmentation. There is the potential for some invertebrate species largely confined to the Calcrete and Calcrete Outwash habitats to have their populations fragmented by the proposed development, and the mine and associated infrastructure would reduce the capacity of even moderately mobile fauna to move along the paleo-drainage system. For example, remaining patches of *E. gypsophila* woodland would be fragmented and this may affect the ability of some fauna species to move across the landscape.

4.1.3 Degradation of habitat due to weed invasion

Weed invasion of the project area is currently minimal. Further impacts from weeds can be minimised by maintaining reasonable hygiene measures.

4.1.4 Ongoing mortality

Increased mortality is inevitable during clearing operations and from ongoing activities, such as fauna attracted into production areas (eg. in search of food, such as death of insects underneath lights, or water). In general, areas to be cleared are small within the context of the regional landscape so mortality during clearing is likely to represent only small proportions of regional populations. For common species, levels of mortality are unlikely to be significant in a conservation sense, but there are welfare issues. However, the viability of species that occur at low population densities in areas adjacent to the project area may be compromised by ongoing mortality.

4.1.5 Species interactions

Changes in species interactions often occur with development. Introduced species, including the feral cat, fox and rabbit may have adverse impacts upon native species and development can alter their abundance. Introduced grazing species, such as the rabbit, goat, camel and domestic livestock, can also degrade habitats and deplete native vegetation. Changes in the abundance of some native species at the expense of others, due to the provision of fresh watering points, can be a concern. Harrington (2002) found the presence of artificial fresh water points in the semi-arid mallee rangelands to influence the abundance and distribution of certain bird species. Common, water-dependent birds were found to out-compete some less common, water- independent species. Over-abundant native herbivores, such as kangaroos, can also adversely affect native vegetation. It is not known how invertebrates might be affected by such species interactions, although it is likely that feral herbivores will degrade native vegetation and this could adversely impact invertebrates.

4.1.6 Hydroecology

An alteration to the water table can indirectly impact native fauna through the resultant effects on vegetation. A lowering of the water table can lead to impacts on phreatophytic vegetation that relies on deep, constant, sources of groundwater to survive and carry out processes such as flowering and setting seed (Eamus *et al.* 2006). Phreatophytic plants provide important habitat for a variety of SRE species that live under the bark of trees, leaf litter and under rocks, including mygalomorph spiders, pseudoscorpions and some land snails (ecologia, 2011a). In contrast, raising the water table may result in the drowning of plants if they become permanently inundated. The proposed project is located in the Yeelirrie Valley floor flow path, and it is anticipated that the project would alter temporary baseline surface water regime, specifically during high rainfall events (ecologia, 2011a). For the purpose of the invertebrate impact assessment, it is estimated that flooding of an area for more than a three week period could be detrimental to SRE fauna in the arid dry zone (ecologia, 2011a).

Interruptions of hydroecological processes are a concern where VSAs may be impacted, resulting in impacts to fauna species. The two Mulga environments are likely to be reliant on surface and sub-surface flows that may be altered by clearing, earthworks and drainage management. The calcrete environments are almost certainly reliant on groundwater. As a result, habitat degradation may occur beyond the clearing footprint.

4.1.7 Altered fire regimes

While the biota of the region is probably adapted to a particular fire regime, it is likely this regime has been altered since European settlement. Utilising a mosaic burning regime is likely to benefit both native flora and fauna, and aid in the control of unplanned wildfires. Mulga in particular is sensitive to fire, while biodiversity in spinifex grasslands can be altered by changes in the fire regime. Although not part of the mining process, mining activities can lead to a change in the fire regime. Some fauna species expected in the project area are sensitive to fire as they rely on long-unburnt habitats to survive (eg. Trapdoor spiders such as *Idiosoma nigrum*).

4.1.8 Disturbance

Impacts of dust, light, disturbance and noise upon fauna are considered likely. This may impact invertebrate fauna if there is an increase in artificial lighting in the project area. For example, mortality of insects was noted around existing operations due to insects being attracted to lights; the consequence of such mortality is not understood but on a precautionary basis should be minimised.

Recent work around Olympic Dam has found off-site impacts on bird assemblages related to disturbance (John Read, pers. comm.).

4.1.9 Bioaccumulation

Bioaccumulation of heavy metals and radionuclides within the environment may occur in both the short and long-term. Heavy metals and radionuclides may enter the environment through seepage of contaminants from tailings facilities or dispersal of radioactive dust. An organism may accumulate heavy metals through direct ingestion, inhalation or ingestion of contaminated organisms. While heavy metals occur naturally in the environment, they become a concern for fauna when their environmental concentration increases to the extent that the capacity of a species to regulate the internal concentration of metals is lost. Bio-accumulation and even toxicity may be a concern where large volumes of water are stored and can be accessed by fauna.

4.1.10 Summary of impacts

Impacts upon key fauna values are summarised in Tables 6 and 7 and are mostly considered to be Minor or less, with the exception of some SRE invertebrates closely associated with the VSAs predicted to experience the highest proportional level of impact. Localised, long-term reduction in population size can be predicted for these species. Habitat degradation as a result of weed incursion and/or fire, and the activities of feral fauna, may also be of some concern. Recommendations made in these tables are expanded in Section 6.

Table 6. Impact assessment of the conservation significant species that are expected to occur in the survey area.

	Species	Collected Outside the Project Footprint (Y/N)	Habitat Outside the Project Footprint (Y/N)	VSA	Management	Residual Impact
Listed Taxa	Species					
Mygalomorph	*Idiosoma nigrum*	Yes	Yes	Acacia Sandplain	Minimise Footprint	Minor
	Short-range Endemics					
Isopod	Platyarthridae/ Bathytropidae	No	Yes	Calcrete Outwash Hardpan Mulga	Minimise Footprint	Moderate
Isopod	*Pseudolaureola* sp.	No	Yes	Calcrete Outwash	Minimise Footprint	Moderate
Tiger Beetle	*Pseudotetracha helmsi*	Yes	Yes	Playa; Calcrete and calcrete outwash	Minimise Footprint	Insufficient data – potentially Moderate
	Potential Short-range Endemics					
Mygalomorph	Aganippe sp.	Yes	Yes	Hardpan Mulga	Minimise Footprint	Negligible
Mygalomorph	Aname 'MYG170'	No	Yes	Calcrete, Hardpan Mulga	Minimise Footprint	Minor
Mygalomorph	Aname 'MYG212'	Yes	Yes	Calcrete Outwash, sandplain	Minimise Footprint	Minor
Mygalomorph	Barychelidae	No	Yes	Calcrete Outwash	Minimise Footprint	Insufficient data – potentially Moderate
Pseudoscorpion	Cheiridiidae	No	Yes	Calcrete	Minimise Footprint	Insufficient data – potentially Moderate
Isopod	Cubaris sp. 1	No	Yes	Calcrete	Minimise Footprint	Insufficient Data – potentially Moderate
Isopod	Cubaris sp. 2	Yes	Yes	Hardpan Mulga, sandplain	Minimise Footprint	Negligible
Chilopod	Geophilida	No	Yes	Hardpan Mulga	Minimise Footprint	Insufficient Data - Minor
Mygalomorph	Kwonkan 'MYG171	No	Yes	Hardpan Mulga	Minimise Footprint	Insufficient Data - Minor
Mygalomorph	Kwonkan 'MYG172	No	Yes	Calcrete	Minimise Footprint	Insufficient data –potentially moderate
Mygalomorph	Kwonkan 'MYG210'	Yes	Yes	Hardpan Mulga	Minimise Footprint	Negligible
Mygalomorph	Kwonkan 'MYG211'	Yes	Yes	Hardpan Mulga	Minimise Footprint	Negligible
Scorpion	Urodacus 'yeelirrie'	Yes	Yes	Hardpan Mulga	Minimise Footprint	Minor

Table 7. Summary of potential impacts upon key fauna values, including conservation significant species that are expected to occur in the survey area.

Fauna Value	Nature and Significance of Impact		Suggested Action
	Potential Impacts	Significance	
Fauna assemblage	• Increased mortality; • Loss of habitat; and • Species interactions.	Minor as impacts very localized in a regional context	• Minimise impact footprint; • Rehabilitate where possible; • Manage ongoing mortality (dust, weeds); • Minimise hydrological impacts to maintain phreatophytic VSAs
VSAs	• Loss of habitat; • Altered hydroecology; and • Habitat degradation through weed invasion or altered fire regimes.	Minor as these are widespread in the region	• Minimise footprint; • Monitor vegetation condition; • Minimise hydrological impacts to maintain phreatophytic VSAs
Significant fauna	• Increased and ongoing mortality; • Loss of habitat; and • Species interactions.	Moderate to Minor as impacts localized but consideration needed for *Aname* MYG170 and the isopod Platyarthridae/ Bathytropidae.	• Minimise footprint; • Habitat preservation – retain / manage areas of important for conservation; • Monitor important populations of conservation significant fauna; • Minimise hydrological impacts to maintain phreatophytic VSAs
Patterns of biodiversity	The most significant VSAs in terms of biodiversity are the calcrete habitats. Some SRE species were only recorded in such habitats but these also occur away from the mine footprint.	Minor as impacts localized	• Minimise footprint where possible. • Minimise hydrological impacts to maintain phreatophytic VSAs
Ecological processes	• Potential impacts on hydrology; and • Some possible impacts on fire regimes and feral predators.	Minor but changes to hydrology could be a concern.	• Management to prevent any impacts to local hydrology; and • Manage fire and feral species where necessary.

5 Conclusions

Background

Cameco commissioned BCE to carry out a review of the existing information on the invertebrate fauna of the area and to revise and update the species lists presented in the earlier reports in terms of taxonomy and changes in conservation legislation. As part of the invertebrate fauna review, information from the initial desktop assessment and survey work, conducted by ecologia (2011a, 2011b) was re-assessed to develop an updated fauna assemblage. Relevant fauna databases were re-visited and recent regional survey work was consulted (KLA, 2012; Outback Ecology, 2011; BCE, 2014).

Ecologia (2011a, 2011b) conducted a detailed assessment of the Yeelirrie project area over three parts: Part One – consisting of five field surveys within and outside the project footprint between July 2009 and January 2010. Part Two – a single field survey of three Yeelirrie Playas in February 2010 and Part Three – a targeted *Idiosoma* field survey conducted in September 2010. The ecologia surveys were conducted in accordance with Guidance Statement No. 20: Sampling of Short-range Endemic Invertebrate Fauna for Environmental Impact Assessment in Western Australia (EPA, 2009).

In 2015, BCE conducted a targeted field assessment (searching for conservation significant invertebrate species) and revisited locations where *Idiosoma* sp, had been previously found in order to determine the relationship of the species to the Shield-backed Trapdoor Spider *Idiosoma nigrum.*

Invertebrate Fauna Assemblage

A total of 42 invertebrate species was collected during the baseline surveys (ecologia, 2011a). A review of field surveys (ecologia, 2011a) and relevant databases revealed 18 conservation significant invertebrates have been recorded in the Yeelirrie area.

This includes one species listed as Vulnerable under the EPBC and Wildlife Conservation Acts, three confirmed SRE taxa and 13 species with the potential to be SRE taxa (based on the current but limited knowledge). Significantly, the Shield-backed Trapdoor Spider *Idiosoma nigrum*, (listed as Vulnerable under the EPBC and Wildlife Conservation Acts) was recorded from 17 locations by BCE in March 2015. The three SRE species were recorded by ecologia during previous surveys (a slater or isopod of the family Platyarthridae or Bathytropidae, the isopod *Pseudolaureola* sp., and the tiger beetle *Pseudotetracha helmsi*), as were the 13 species considered to be possible SREs.

The Shield-backed Trapdoor Spider appears to occur in low densities but is widespread across the Yeelirrie lease, favouring Acacia shrublands with a sandy substrate. The species appears to be absent from the grey loamy-clay soils around some calcrete areas and in the main development footprint.

The isopod *Pseudolaureola* sp. was collected from Calcrete Outwash (site T04, within the proposed mine footprint) and is thought be an undescribed species. The species is considered a relic taxon of the Gondwanan rainforest and all known species in the genus are SREs, therefore it is highly likely that this species is also a SRE (ecologia, 2011a).

Sixteen specimens of an undescribed slater genus and species from either the family Platyarthridae or Bathytropidae were collected within the project footprint, and were found within the Calcrete, Calcrete Outwash and Hardpan Mulga habitats (sites F11, T01, T02, T03, T07, T14 and T20, ecologia, 2011a). The undescribed genus from Yeelirrie is considered to be a SRE (ecologia, 2011a).

The tiger beetle (*Pseudotetracha helmsi*) was collected at three sites from the Yeelirrie Playa (YP4, YP6 and YP7). This species was previously known only from a few salt lakes located in the Murchison Bioregion and is considered a SRE.

A further 13 species have the potential to be short-range endemic fauna. However, due to the limited survey work in the region and therefore limitations on distribution, habitat and taxonomy, these species were unable to be confirmed as SREs. Additionally, some new species were described from the Yeelirrie area (e.g. *Aname*, *Kwonkan* and *Cubaris* species) and as such their distribution and SRE status is unknown. They are considered potential SRE taxa because of their biology and the fact that closely related species exhibit short-range endemism.

The Mygalomorph spider *Kwonkan moriartii* has been recorded from two locations approximately 60 km east of the project area, but as three undescribed *Kwonkan* species were found at Yeelirrie and the taxonomy of the genus *Kwonkan* is due for revision (M. Harvey pers. comm.), *K. moriartii* may not in fact occur in the region.

Vegetation and Substrate Associations (VSAs)

Eight VSAs were identified across the project area and surrounding landscape. Mixed Shrubs over Spinifex Sandplain, Hardpan Mulga, Calcrete and Calcrete Outwash dominate most of the disturbance footprint with much smaller areas of rocky breakaway also included. Biodiversity is likely to be spread across the VSAs, with the most significant areas for invertebrate fauna considered to be those associated with calcrete (Calcrete, calcrete outwash, *Eucalyptus gypsophila* woodland).

A habitat analysis by Ecologia (2011a) showed no statistically significant difference between SRE species diversity and habitat type inside and outside the project footprint. SRE species distribution depends on micro-habitats ('island' habitats) rather than broadscale habitat types. Furthermore, all of the habitat types extend beyond the proposed project footprint indicating a potential for all species to be found outside the project footprint.

Impact Assessment

Potential impacts on the general invertebrate fauna assemblage are likely to be greater in Calcrete habitats, which have a higher proportional representation in the study area. Other VSAs in the project area, such as the Mulga and Spinifex Sandplains are considered widespread. One of the dominant ecological processes currently affecting the fauna assemblage in the project area is hydrology, with other processes including fire, feral species and interactions with native species, habitat degradation due to weed invasion and connectivity. Long-unburnt habitats are likely to be important for some species, including the Shield-backed Trapdoor Spider *Idiosoma nigrum*.

Impacts upon key fauna values are mostly considered to be Minor or less, with the exception of some SRE invertebrates closely associated with the VSAs predicted to experience the highest proportional level of impact. Localised, long-term reduction in population size can be predicted for these species. Management recommendations are provided in Section 6.

6 Recommendations

Section 5 (Impact Assessment) identified several potential adverse impacts that may occur from the disturbance to the survey area. While impacts are expected to be mostly Negligible to Minor, impacts to SRE species associated with the Calcrete areas are listed as moderate because the mine footprint lies over large proportions of their habitat.

Management strategies are recommended below to reduce the potential impacts of this development on fauna species.

Loss of habitat / habitat fragmentation

- Minimise the disturbance footprint;
- Clearly delineate areas to be cleared;
- Where possible, preserve habitats that support conservation significant fauna;
- Rehabilitate any cleared areas which are not needed after construction;

Habitat Management

- Maintain the Yeelirrie lease as livestock-free as part of the site's environmental management. This would be a significant and positive step towards the management and rehabilitation of fauna habitats.
- Decommission stock watering points to reduce the availability of artificial watering points for aggressive species away from the mine area.

Species interactions

- Develop a feral animal management plan.

Hydrological changes

- Develop an understanding of the surface and sub-surface drainage and possible effects of human activities upon groundwater in order to identify the potential for hydrological changes that could potentially impact fauna habitats

Habitat degradation due to weed invasions

- Develop a weed management/hygiene plan.

Changes in fire regime

- Develop a fire management plan (which includes regard for the ecological role of fire) to preserve habitat for fire sensitive species. .

Dust, noise, light and disturbance

- Minimise the production of dust, noise and light spill; especially where these may affect adjacent bushland. Establish long-term fauna monitoring sites to assess the impacts of these to monitor trends and identify areas of concern to dictate management.

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8 Appendices

Appendix 1. Explanation of fauna values.

Fauna values are the features of a site and its fauna that contribute to biodiversity, and it is these values that are potentially at threat from a development proposal. Fauna values can be examined under the five headings outlined below. It must be stressed that these values are interdependent and should not be considered equal, but contribute to an understanding of the biodiversity of a site. Understanding fauna values provides opportunities to predict and therefore mitigate impacts.

Assemblage characteristics

Uniqueness. This refers to the combination of species present at a site. For example, a site may support an unusual assemblage that has elements from adjacent biogeographic zones, it may have species present or absent that might be otherwise expected, or it may have an assemblage that is typical of a very large region. For the purposes of impact assessment, an unusual assemblage has greater value for biodiversity than a typical assemblage.

Completeness. An assemblage may be complete (i.e. has all the species that would have been present at the time of European settlement), or it may have lost species due to a variety of factors. Note that a complete assemblage, such as on an island, may have fewer species than an incomplete assemblage (such as in a species-rich but degraded site on the mainland).

Richness. This is a measure of the number of species at a site. At a simple level, a species rich site is more valuable than a species poor site, but value is also determined, for example, by the sorts of species present.

Vegetation/substrate associations (VSAs)

VSAs combine broad vegetation types, the soils or other substrate with which they are associated, and the landform. In the context of fauna assessment, VSAs are the environments that provide habitats for fauna. The term habitat is widely used in this context, but by definition an animal's habitat is the environment that it utilises (Calver *et al.* 2009), not the environment as a whole. Habitat is a function of the animal and its ecology, rather than being a function of the environment. For example, a species may occur in eucalypt canopy or in leaf-litter on sand, and that habitat may be found in only one or in several VSAs. VSAs are not the same as vegetation types since these may not incorporate soil and landform, and recognise floristics to a degree that VSAs do not. Vegetation types may also not recognise minor but often significant (for fauna) structural differences in the environment. VSAs also do not necessarily correspond with soil types, but may reflect some of these elements.

Because VSAs provide the habitat for fauna, they are important in determining assemblage characteristics. For the purposes of impact assessment, VSAs can also provide a surrogate for detailed information on the fauna assemblage. For example, rare, relictual or restricted VSAs should automatically be considered a significant fauna value. Impacts may be significant if the VSA is rare, a

large proportion of the VSA is affected and/or the VSA supports significant fauna. The disturbance of even small amounts of habitat in a localised area can have significant impacts to fauna if rare or unusual habitats are disturbed.

Patterns of biodiversity across the landscape

This fauna value relates to how the assemblage is organised across the landscape. Generally, the fauna assemblage is not distributed evenly across the landscape or even within one VSA. There may be zones of high biodiversity such as particular environments or ecotones (transitions between VSAs). There may also be zones of low biodiversity. Impacts may be significant if a wide range of species is affected even if most of those species are not significant per se.

Species of conservation significance

Species of conservation significance are of special importance in impact assessment. The conservation status of fauna species in Australia is assessed under Commonwealth and State Acts such as the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) and the Western Australian *Wildlife Conservation Act 1950* (Wildlife Conservation Act). In addition, the Western Australian Department of Environment and Conservation (DEC) recognises priority levels, while local populations of some species may be significant even if the species as a whole has no formal recognition. Therefore, three broad levels of conservation significance can be recognised and are used for the purposes of this report, and are outlined below. A full description of the conservation significance categories, schedules and priority levels mentioned below is provided in Appendix 4.

Conservation Significance (CS) 1: Species listed under State or Commonwealth Acts.

Species listed under the EPBC Act are assigned to categories recommended by the International Union for the Conservation of Nature and Natural Resources (IUCN) and reviewed by Mace and Stuart (1994), or are listed as migratory. Migratory species are recognised under international treaties such as the China Australia Migratory Bird Agreement (CAMBA), the Japan Australia Migratory Bird Agreement (JAMBA), the Republic of South Korea Australia Migratory Bird Agreement (ROKAMBA), and/or the Convention on the Conservation of Migratory Species of Wild Animals (CMS; also referred to as the Bonn Convention). The Wildlife Conservation Act uses a series of Schedules to classify status, but also recognizes the IUCN categories and ranks species within the Schedules using the categories of Mace and Stuart (1994).

Conservation Significance (CS) 2: Species listed as Priority by the DEC but not listed under State or Commonwealth Acts.

In Western Australia, the DEC has produced a supplementary list of Priority Fauna, being species that are not considered threatened under the Wildlife Conservation Act but for which the DEC feels there is cause for concern. Some Priority species are also assigned to the Conservation Dependent category of the IUCN.

Conservation Significance (CS) 3: Species not listed under Acts or in publications, but considered of at least local significance because of their pattern of distribution.

This level of significance has no legislative or published recognition and is based on interpretation of distribution information, but is used here as it may have links to preserving biodiversity at the genetic level (EPA 2002). If a population is isolated but a subset of a widespread (common) species, then it may not be recognised as threatened, but may have unique genetic characteristics. Conservation significance is applied to allow for the preservation of genetic richness at a population level, and not just at a species level. Species on the edge of their range, or that are sensitive to impacts such as habitat fragmentation, may also be classed as CS3, as may colonies of waterbirds. The Western Australian Department of Environmental Protection, now DPaW, used this sort of interpretation to identify significant bird species in the Perth metropolitan area as part of the Perth Bushplan (DEP 2000).

Invertebrate species considered to be short range endemics (SREs) also fall within the CS3 category, as they have no legislative or published recognition and their significance is based on interpretation of distribution information. Harvey (2002) notes that the majority of species that have been classified as short-range endemics have common life history characteristics such as poor powers of dispersal or confinement to discontinuous habitats. Several groups, therefore, have particularly high instances of short-range endemic species: Gastropoda (snails and slugs), Oligochaeta (earthworms), Onychophora (velvet worms), Araneae (mygalomorph spiders), Pseudoscorpionida (pseudoscorpions), Schizomida (schizomids), Diplopoda (millipedes), Phreatoicidea (phreatoicidean crustaceans), and Decapoda (freshwater crayfish). The poor understanding of the taxonomy of many of the short-range endemic species hinders their conservation (Harvey 2002).

Introduced species

In addition to these conservation levels, species that have been introduced (INT) are indicated throughout the report. Introduced species may be important to the native fauna assemblage through effects by predation and/or competition.

Ecological processes upon which the fauna depend

These are the processes that affect and maintain fauna populations in an area and as such are very complex; for example, populations are maintained through the dynamic of mortality, survival and recruitment being more or less in balance, and these are affected by a myriad of factors. The dynamics of fauna populations in a project may be affected by processes such as fire regime, landscape patterns (such as fragmentation and/or linkage), the presence of feral species and hydrology. Impacts may be significant if processes are altered such that fauna populations are adversely affected, resulting in declines and even localised loss of species. Threatening processes as outlined below are effectively the ecological processes that can be altered to result in impacts upon fauna.

Appendix 2. Explanation of threatening processes.

Potential impacts of proposed developments upon fauna values can be related to threatening processes. This is recognised in the literature and under the EPBC Act, in which threatening processes are listed (see Appendix 5). Processes that may impact fauna values are discussed below. Rather than being independent of one another, processes are complex and often interrelated. They are the mechanisms by which fauna can be affected by development. Impacts may be significant if large numbers of species or large proportions of populations are affected.

Loss of habitat affecting population survival

Clearing for a development can lead to habitat loss for a species with a consequent decline in population size. This may be significant if the smaller population has reduced viability. Conservation significant species or species that already occur at low densities may be particularly sensitive to habitat loss affecting population survival.

Loss of habitat leading to population fragmentation

Loss of habitat can affect population movements by limiting movement of individuals throughout the landscape as a result of fragmentation. Obstructions associated with the development, such as roads, pipes and drainage channels, may also affect movement of small, terrestrial species. Fragmented populations may not be sustainable and may be sensitive to effects such as reduced gene flow.

Degradation of habitat due to weed invasion leading to population decline

Weed invasion can occur as a result of development and if this alters habitat quality, can lead to effects similar to habitat loss.

Increased mortality

Increased mortality can occur during project operations; for example from roadkill, animals striking infrastructure and entrapment in trenches. Roadkill as a cause of population decline has been documented for several medium-sized mammals in eastern Australia (Dufty 1989; Jones 2000). Increased mortality due to roadkill is often more prevalent in habitats that have been fragmented (Scheick and Jones 1999; Clevenger and Waltho 2000; Jackson and Griffin 2000).

Increased mortality of common species during development is unavoidable and may not be significant for a population. However, the cumulative impacts of increased mortality of conservation significant species or species that already occur at low densities may have a significant impact on the population.

Species interactions, including predation and competition

Changes in species interactions often occur with development. Introduced species, including the feral Cat, Red Fox and Rabbit may have adverse impacts upon native species and development can alter their abundance. In particular, some mammal species are very sensitive to introduced

predators and the decline of many mammals in Australia has been linked to predation by the Red Fox, and to a lesser extent the feral Cat (Burbidge and McKenzie 1989). Introduced grazing species, such as the Rabbit, Goat, Camel and domestic livestock, can also degrade habitats and deplete vegetation that may be a food source for other species.

Changes in the abundance of some native species at the expense of others, due to the provision of fresh watering points, can also be a concern. Harrington (2002) found the presence of artificial fresh waterpoints in the semi-arid mallee rangelands to influence the abundance and distribution of certain bird species. Common, water-dependent birds were found to out-compete some less common, water-independent species. Over-abundant native herbivores, such as kangaroos, can also adversely affect less abundant native species through competition and displacement.

Hydroecology

Interruptions of hydroecological processes can have major effects because they underpin primary production in ecosystems and there are specific, generally rare habitats that are hydrology-dependent. Fauna may be impacted by potential changes to groundwater level and chemistry and altered flow regime. These changes may alter vegetation across large areas and may lead to habitat degradation or loss. Impacts upon fauna can be widespread and major.

Changes to flow regime across the landscape may alter vegetation and may lead to habitat degradation or loss, affecting fauna. For example, Mulga has a shallow root system and relies on surface sheet flow during flood events. If surface sheet flow is impeded, Mulga can die (Kofoed 1998), which may impact on a range of fauna associated with this vegetation type.

Fire

The role of fire in the Australian environment and its importance to vertebrate fauna has been widely acknowledged (Gill *et al.* 1981; Fox 1982; Letnic *et al.* 2004; Bamford and Roberts 2003). It is also one of the factors that has contributed to the decline and local extinction of some mammal and bird species (Burbidge and McKenzie 1998). Fire is a natural feature of the environment but frequent, extensive fires may adversely impact some fauna, particularly mammals and short-range endemic species. Changes in fire regime, whether to more frequent or less frequent fires, may be significant to some fauna. Impacts of severe fire may be devastating to species already occurring at low densities or to species requiring long unburnt habitats to survive. In terms of conservation management, it is not fire *per se* but the fire regime that is important, with evidence that infrequent, extensive and intense fires adversely affect biodiversity, whereas frequent fires that cover small areas and are variable in both season and intensity can enhance biodiversity. Fire management may be considered the responsibility of managers of large tracts of land.

Dust, light, noise and vibration

Impacts of dust, light, noise and vibration upon fauna are difficult to predict. Some studies have demonstrated the impact of artificial night lighting on fauna, with lighting affecting fauna behaviour more than noise (Rich and Longcore 2006). Effects can include impacts on predator-prey interactions,

changes to mating and nesting behaviour, and increased competition and predation within and between invertebrates, frogs, birds and mammals.

The death of very large numbers of insects has been observed around some remote mine sites and attracts other fauna, notably native and introduced predators (M. Bamford pers. obs). The abundance of some insects can decline due to mortality around lights, although this has previously been recorded in fragmented landscapes where populations are already under stress (Rich and Longcore 2006). Artificial night lighting may also lead to disorientation of migratory birds. Aquatic habitats and open habitats such as grasslands and dunes may be vulnerable to light spill.

Appendix 3. Categories used in the assessment of conservation status.

IUCN categories (based on review by Mace and Stuart 1994) as used for the *Environment Protection and Biodiversity Conservation Act 1999* and the Western Australian *Wildlife Conservation Act 1950*.

Extinct	Taxa not definitely located in the wild during the past 50 years.
Extinct in the Wild	Taxa known to survive only in captivity.
Critically Endangered	Taxa facing an extremely high risk of extinction in the wild in the immediate future.
Endangered	Taxa facing a very high risk of extinction in the wild in the near future.
Vulnerable	Taxa facing a high risk of extinction in the wild in the medium-term future.
Near Threatened	Taxa that risk becoming Vulnerable in the wild.
Conservation Dependent	Taxa whose survival depends upon ongoing conservation measures. Without these measures, a conservation dependent taxon would be classed as Vulnerable or more severely threatened.
Data Deficient (Insufficiently Known)	Taxa suspected of being Rare, Vulnerable or Endangered, but whose true status cannot be determined without more information.
Least Concern.	Taxa that are not Threatened.

Schedules used in the WA *Wildlife Conservation Act 1950*

Schedule 1	Rare and Likely to become Extinct.
Schedule 2	Extinct.
Schedule 3	Migratory species listed under international treaties.
Schedule 4	Other Specially Protected Fauna

WA Department of Environment and Conservation Priority species (species not listed under the *Wildlife Conservation Act 1950*, but for which there is some concern).

Priority 1	Taxa with few, poorly known populations on threatened lands.
Priority 2	Taxa with few, poorly known populations on conservation lands; or taxa with several, poorly known populations not on conservation lands.
Priority 3	Taxa with several, poorly known populations, some on conservation lands.
Priority 4.	Taxa in need of monitoring. Taxa which are considered to have been adequately surveyed, or for which sufficient knowledge is available, and which are considered not currently threatened or in need of special protection, but could be if present circumstances change.
Priority 5	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 (IUCN Conservation Dependent).

Appendix 4. Ecological and threatening processes identified under legislation and in the literature.

Ecological processes are processes that maintain ecosystems and biodiversity. They are important for the assessment of impacts of development proposals, because ecological processes make ecosystems sensitive to change. The issue of ecological processes, impacts and conservation of biodiversity has an extensive literature. Following are examples of the sorts of ecological processes that need to be considered.

Ecological processes relevant to the conservation of biodiversity in Australia(Soule *et al.* 2004):

- Critical species interactions (highly interactive species);
- Long distance biological movement;
- Disturbance at local and regional scales;
- Global climate change;
- Hydroecology;
- Coastal zone fluxes;
- Spatially-dependent evolutionary processes (range expansion and gene flow); and
- Geographic and temporal variation of plant productivity across Australia.

Threatening processes (EPBC Act)

Under the EPBC Act, a key threatening process is an ecological interaction that threatens or may threaten the survival, abundance or evolutionary development of a threatened species or ecological community. There are currently 20 key threatening processes listed by the federal Department of the Environment (DotE 2014b):

- Competition and land degradation by rabbits.
- Competition and land degradation by unmanaged goats.
- Dieback caused by the root-rot fungus (*Phytophthora cinnamomi*).
- Incidental catch (bycatch) of Sea Turtle during coastal otter-trawling operations within Australian waters north of 28 degrees South.
- Incidental catch (or bycatch) of seabirds during oceanic longline fishing operations.
- Infection of amphibians with chytrid fungus resulting in chytridiomycosis.
- Injury and fatality to vertebrate marine life caused by ingestion of, or entanglement in, harmful marine debris.
- Invasion of northern Australia by Gamba Grass and other introduced grasses.
- Land clearance.
- Loss and degradation of native plant and animal habitat by invasion of escaped garden plants, including aquatic plants.
- Loss of biodiversity and ecosystem integrity following invasion by the Yellow Crazy Ant (*Anoplolepis gracilipes*) on Christmas Island, Indian Ocean.
- Loss of climatic habitat caused by anthropogenic emissions of greenhouse gases.
- Novel biota and their impact on biodiversity.

- Predation by European red fox.
- Predation by exotic rats on Australian offshore islands of less than 1000 km^2 (100,000 ha).
- Predation by feral cats.
- Predation, Habitat Degradation, Competition and Disease Transmission by Feral Pigs.
- Psittacine Circoviral (beak and feather) Disease affecting endangered psittacine species.
- The biological effects, including lethal toxic ingestion, caused by Cane Toads (*Bufo marinus*).
- The reduction in the biodiversity of Australian native fauna and flora due to the red imported fire ant, *Solenopsis invicta* (fire ant).

General processes that threaten biodiversity across Australia (The National Land and Water Resources Audit):

- Vegetation clearing;
- Increasing fragmentation, loss of remnants and lack of recruitment;
- Firewood collection;
- Grazing pressure;
- Feral animals;
- Exotic weeds;
- Changed fire regimes;
- Pathogens;
- Changed hydrology—dryland salinity and salt water intrusion;
- Changed hydrology— such as altered flow regimes affecting riparian vegetation; and
- Pollution.

In addition to the above processes, DSEWPaC has produced Significant Impact Guidelines that provide criteria for the assessment of the significance of impacts. These criteria provide a framework for the assessment of significant impacts. The criteria are listed below.

- Will the proposed action lead to a long-term decrease in the size of a population?
- Will the proposed action reduce the area of occupancy of the species?
- Will the proposed action fragment an existing population?
- Will the proposed action adversely affect habitat critical to the survival of a species?
- Will the proposed action disrupt the breeding cycle of a population?
- Will the proposed action modify, destroy, remove, isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline?
- Will the proposed action result in introducing invasive species that are harmful to a critically endangered or endangered species becoming established in the endangered or critically endangered species' habitat?
- Will the proposed action introduce disease that may cause the species to decline?
- Will the proposed action interfere with the recovery of the species?

Appendix 5. Locations of Conservation Significant Fauna recorded at Yeelirrie by ecologia

Table 8. Locations of significant and SRE invertebrate fauna recorded at Yeelirrie during the BHP assessment.

Species	Easting	Northing	Habitat / Comments
Idiosoma sp.	769376	7006800	Ecologia 1, Site O04, Mulga
Idiosoma sp.	786523	6995136	Ecologia 2, Site I38, Mulga
Idiosoma sp.	774276	7001714	Ecologia 3, Site I40, Mulga
Idiosoma sp.	769375	7006800	Ecologia 4, Site I41, Mulga
Platyarthridae / Bathytropidae	789879	6989267	F11
Platyarthridae / Bathytropidae	787630	6990797	T1
Platyarthridae / Bathytropidae	787265	6990705	T2
Platyarthridae / Bathytropidae	787072	6991223	T3
Platyarthridae / Bathytropidae	788205	6990944	T7
Platyarthridae / Bathytropidae	787626	6991521	T14
Platyarthridae / Bathytropidae	787101	6991490	T20
Pseudolaureola sp.	786348	6991338	T04
Barychelidae	787756	6990644	T17
Cheiridiidae	786670	6991628	T18
Cubaris sp. 1	788205	6990944	T07
Cubaris sp. 2	769376	7006800	4
Cubaris sp. 2	774501	7005207	7
Cubaris sp. 2	775629	6996538	12
Cubaris sp. 2	793778	6996810	A7
Pseudotetracha helmsi	223407	6975321	YP4
Pseudotetracha helmsi	224835	6976047	YP6
Pseudotetracha helmsi	225769	6975531	YP7

Appendix 6. 2015 *Idiosoma* Assessment

BCE conducted as assessment of *Idiosoma* across Yeelirrie during March 2015. Fifteen areas of potential habitat were selected (using previous records, habitat and aerial imagery) and searched (by two personnel for 30 – 45 minutes) for the presence of *Idiosoma* burrows. Table 9 summarises the areas searched by BCE.

Table 9. *Idiosoma* search sites at Yeelirrie during March 2015.

Site	Easting	Northing	Habitat	*I. nigrum*	Search
1	769375	7006800	Acacia shrubland on sandy rise over calcrete	Yes	45 mins
2	774223	7001691	Mulga on sandy loam adjacent to calcrete rise	Yes	45
3	773922	7001355	Mulga on sandy, calcrete rise	Yes	30
4	783913	6993534	E. gypsophila woodland on clayey-loam soil	No	45
5a	789576	6994524	Acacia shrubland over spinifex on sandy loam	No	45
5b	786523	6995136	Acacia shrubland over spinifex on sandy loam	Yes	45
6	792060	7005141	Rocky slope with acacia shrubland	No	45
7	792934	7004910	Barr Smith Range	No	30
8	790502	7005086	Mulga woodland on sandy loam	Yes	30
9	797374	6991419	Calcrete rise with scattered Acacia	No	30
10	782740	6992566	Mulga and spinifex on sandy loam	No	30
11	796309	6990620	Acacia over spinifex on sandy loam	No	30
12	216389	6997422	Mulga over spinifex on sandy loam	Yes	30
13	215232	6997399	Acacia over spinifex on sandy loam	No	30
14	216117	7002307	Tall mulga over mixed shrubs on sandy-clay-loam	Yes	30
15	216112	7003282	Dense Mulga Woodland on Barr Smith Range	No	30

A total of 17 Idiosoma burrows was recorded across Yeelirrie (see Tables 10 and 11, Figure 6). When burrows were located, the use of a burrowscope enabled the status of the burrow to be verified (active vs inactive) and allow for species verification (*Idiosoma nigrum* due to the appearance of a thickened and highly corrugated abdomen and the tendency for the species to exhibit phragmosis). To confirm the species identification, two individuals were collected and forwarded to Phoenix Environmental for genetic analysis (see Appendix 7). The analysis of genetic sequences (with reference specimens from the region – Jack Hills and Boolardy) confirmed the species identification as *Idiosoma nigrum* (Phoenix Environmental, 2015). The closest recorded of *Idiosoma nigrum* to Yeelirrie come from Weld Range and Jack Hills, approximately 200km to the west (DPaW, 2015).

The identification of *Idiosoma nigrum* from Yeelirrie is significant as the species is listed under both the EPBC and WA Wildlife Conservation Acts (Vulnerable). This determination also differs from the previous Yeelirrie invertebrate study (which recognised the species as *Idiosoma* sp. and not *I. nigrum*). However, genetic analysis was not previously conducted during this determination. The

2015 genetic sequence data obtained from both Yeelirrie spiders was also well within current accepted divergence thresholds for Mygalomorph spiders in Western Australia.

Idiosoma nigrum occurs at Yeelirrie in apparently much lower densities than those observed elsewhere. BCE has recorded 50 - 400 spiders per hectare in suitable habitat on banded ironstone ridges of the Midwest (Hinge Fauna Assessment, BCE. 2011). However, at Yeelirrie densities appear to be much lower, with typically only one or two spiders recorded across a number of hectares. At Yeelirrie, the spider does not appear to form matriarchal clusters, which is perhaps an artefact of low recruitment rates.

Idiosoma nigrum constructs an elaborate burrow with a leaf litter and silk door, with leaf and twig trip-lines fanning out from the centre of the front of the burrow rim (Gray 2014, see Table 10). At Yeelirrie, *I. nigrum* appears to favour Acacia shrublands (with or without spinifex) on red, sandy-loam soil both on plains, sandy rises and slopes. In favoured areas, the soil is sandy and friable to depth of at least 30cm, and lacks the clay layer or hardpan that is common across much of the site. *I. nigrum* appears to be absent from the grey loamy-clay soils around some calcrete areas and in the main development footprint. Spiders also appear absent from shallow, rocky soils of the Barr-Smith Range.

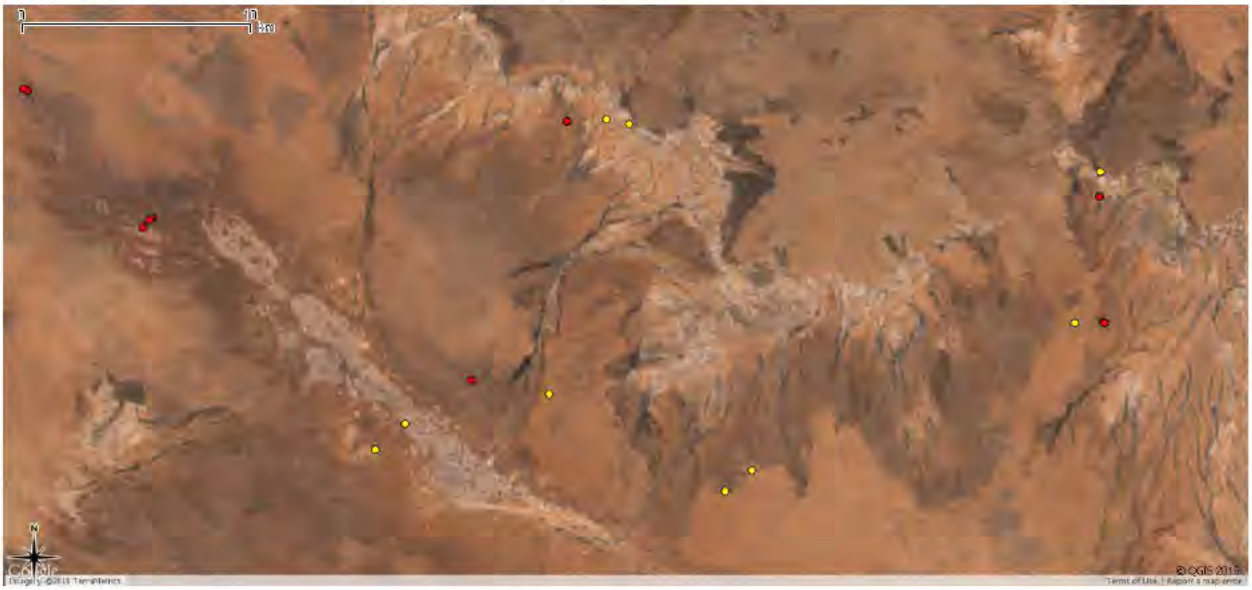
An additional mygalomorph spider was recorded during the Idiosoma assessment. Anidiops represents a genus of widespread spiders which similarly construct leave decorated burrows with a trap door. Aniodiops is considered a widespread group and is not currently known to exhibit short-range endemism (see Appendix 7).

Table 10. Photos of *Idiosoma nigrum* burrows and their habitat.

Table 11. Locations of *Idiosoma nigrum* burrows recorded by BCE during 2015 (total 17 burrows recorded).

Species	Easting	Northing	Habitat	Comments
I. nigrum	769375	7006800	Acacia shrubland on sandy rise over calcrete	2 burrows, specimen collected
I. nigrum	769517	7006741	Acacia shrubland on sandy rise over calcrete	3 burrows, specimen collected
I. nigrum	769516	7006754	Acacia shrubland on sandy rise over calcrete	1 burrow
I. nigrum	774223	7001691	Mulga on sandy loam adjacent to calcrete rise	2 burrows
I. nigrum	774253	7001688	Mulga on sandy loam adjacent to calcrete rise	1 burrow
I. nigrum	774156	7001639	Mulga on sandy loam adjacent to calcrete rise	1 burrow
I. nigrum	773922	7001355	Mulga on sandy, calcrete rise	1 burrow
I. nigrum	786523	6995136	Acacia shrubland over spinifex on sandy loam	1 burrow
I. nigrum	790502	7005086	Mulga woodland on sandy loam	1 burrow
I. nigrum	216380	6997475	Mulga over spinifex on sandy-loam plain	2 burrows
I. nigrum	216389	6997422	Mulga over spinifex on sandy-loam plain	1 burrow
I. nigrum	216117	7002307	Tall Mulga on heavy sandy-loam	1 burrow

Figure 6. *Idiosoma nigrum* recorded at Yeelirrie. Note: records include red circles (species present) and yellow circles (survey site – species not located).



Appendix 7. Phoenix Invertebrate Report.

PHOENIX
ENVIRONMENTAL SCIENCES

Identification and assessment of short-range endemism of invertebrates from Yeelirrie, Western Australia

Prepared for Bamford Consulting Pty Ltd

March 2015

Taxonomic Report

Identification and assessment of short-range endemism of invertebrates from the Yeelirrie, Western Australia

Prepared for Bamford Consulting Pty Ltd

Taxonomic Report

Authors: Volker Framenau

Date: 27 March 2015

Submitted to: Mike Bamford

Chain of authorship and review			
Name	Task	Version	Date
Volker Framenau	Draft for client comments	1.0	27 March 2015

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1 BACKGROUND

Short-range endemics are organisms with a naturally narrow distribution range, in Western Australian nominally less than 10,000 km^2 (EPA 2009; Harvey 2002). There are uncertainties in determining the range-restrictions of many invertebrates in Western Australia due to lack of surveys, lack of taxonomic resolutions within target taxa and problems in identifying certain life stages. The WA Museum has introduced a three-tier system to account for these uncertainties, confirmed and potential SREs in addition to widespread species (Western Australian Museum 2013).

2 SCOPE OF WORKS

In March 2015, Phoenix Environmental Sciences Pty Ltd (Phoenix) was commissioned by Dalcon Environmental Pty Ltd (on behalf of Bamford Consulting Pty Ltd) to identify terrestrial invertebrates collected at Yeelirrie, Western Australia. The scope of works included molecular identification (COI barcoding) of two specimens of the mygalomorph spider genus *Idiosoma* in the family Idiopidae.

3 METHODS

Specimens were identified by V.W. Framenau and the molecular work conducted at the molecular laboratory of the School of Animal Biology, University of Western Australia. Spider taxonomy follows the World Spider Catalog (2014), that of beetles Anichtchenko (2007–2005).

4 RESULTS

The material submitted included at least three widespread species (Table 4-1 and Table 4-2). *Idiosoma nigrum* is conservation significant bot at Federal and State level.

Table 4-1 Taxonomy and SRE categories of invertebrate species identified from the Yeelirrie

Order	Family	Species	SRE Category (see Appendix 1)
Araneae (Mygalomorphae)	Idiopidae	*Anidiops* sp. indet.	Widespread
	Idiopidae	*Idiosoma nigrum* Main, 1952	Widespread, (Vulnerable (EPBC), Schedule 1 (WA Act)
Coleoptera	Carabidae	*Megacephala corpulenta* Horn, 1907	Widespread

Table 4-2 Identification of SRE target invertebrate from the Wilga Project Area

Field no.	WAM registration	Family	Genus and species	♂♂	♀♀	Juv.	Total
BCE1	T135961	Idiopidae	*Idiosoma nigrum*		1		**1**
BCE2	T135962	Idiopidae	*Idiosoma nigrum*		1		**1**
BCE3	T135963	Idiopidae	*Anidiops* sp. indet.			1	**1**
BCE4	T135964	Idiopidae	*Anidiops* sp. indet.		1		**1**
BCE5	TBA	Carabidae	*Megacephala*	1			
Total:				**1**	**3**	**1**	**5**

4.1 *ANIDIOPS* SP. INDET.

Currently two species of Anidiops are described from Western Australia, *A. manstridgei* and *A. villosus* (Framenau 2014; Main 1985) Pedipalp morphology of both species suggests these to belong to different genera and although not published in the scientific literature, the latter species is often reported as representing a different genus, *Gaius*. *Anidiops* and *Gaius* females can be separated mainly by size with *Gaius* specimens being considerably larger. Spiders in both genera construct leave decorated burrows with a trapdoor. The burrow also includes a 'sock', i.e. the lower section of silk lining has a collar-like structure that the spider can retract to provide a false bottom, presumably serving as anti-predatory mechanism (Main 1985). *Anidiops* (incl. *Gaius*) have generally fairly wide distributions and not considered to have many, if any, SREs.

The two specimens submitted, a female and a small juvenile, cannot be identified to species level and associated with morphotypes at the WA Museum. Based on the distribution patterns in the genus, they are considered widespread.

4.2 *IDIOSOMA NIGRUM* (SHIELD-BACKED TRAPDOOR SPIDER)

The idiopid genus *Idiosoma* differs from *Aganippe* by a truncated abdomen in females that has deep corrugations and short and stout spines (Main 1952, 1985). The abdominal sigillae are generally situated on the truncated back of the abdomen, in contrast to Aganippe in which the sigillae are situated dorsally. Spiders plug their burrow with the truncated abdomen, which neatly fits into a constriction in the upper parts of the burrow (Main 2003). Three species of *Idiosoma* are currently described from Australia, all are WA endemics (Framenau 2014): *Idiosoma sigillatum* and *I. hirsutum* are known from the Perth coastal plain and *I. nigrum*, the Shield-back Trapdoor Spider, occurs from the northern Avon Wheatbelt into the Midwest . However, a number of undescribed species of Idiosoma are known from the collection of the WA Museum.

Idiosoma nigrum is a medium-sized trapdoor spider; females grow up to 30 mm in body length with dark brown to black colouration and a distinctive, rugose abdominal cuticle. The trapdoor of the burrow is constructed with a characteristic fan ('moustache') of twigs attached to the burrow rim. Burrow construction and decoration are similar to that of other idiopid genera such as *Anidiops* and *Aganippe*; however, the burrow of *I. nigrum* has a constriction in its upper part where spiders plug the burrow with their truncated abdomen.

The Shield-backed Trapdoor Spider is listed as Vulnerable under the Federal Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act) and is on Schedule 1 of the Western Australian Wildlife Conservation Act 1950 (WC Act).

Two *Idiosoma* females were submitted for molecular identification based on the cytochrome C oxidase subunit 1 (COI) (Čandek & Kuntner 2015; Castalanelli *et al.* 2014; Lopardo & Uhl 2014). The standard primers LCO and HCO where used for amplification (Folmer *et al.* 1994). The resulting sequences were 645 base pairs long.

The sequence data were compared with those of reference specimens of *I. nigrum* from Jack Hills and Boolardy Station (Table 4-1). Sequence divergence of the Yeelirrie spiders to these specimens was less than 9.0%, currently considered the species level cut-off for mygalomorph spiders in WA, including in the Idiopidae (Castalanelli *et al.* 2014). Based on our current understanding, the specimens from Yeelirrie represent I. nigrum.

4.2.1 Sequence data (COI) for *Idiosoma nigrum* from Yeelirrie

WAM T135961

GTATATTATTTTAGGGGTATGGTCTGCTATGTTTGGTACTGCAATGAGAGTTGTTATTCGAACAGAATTAG
GCCAGGTTGGGAGATTGTTATTGGATGATCATTTATATAATGTGGTGGTTACTGTTCATGCTTTGGTGATA
ATTTTTTTTATAGTGATGCCTATTATGATTGGGGGATTTGGAAATTGGTTGGTTCCTTTGATGCTAGGGGC
GCCTGATATGGCATTTCCTCGTATGAATAATTTGAGATTTTGGTTGTTACCTTCTTCTTTGTTTTTTTTAG
TAGTTTCTTCTCTAATAGGGGTGGGTGTTGGGGCTGGATGAACTATTTATCCTCCTTTGTCTTCTGGTATT
GGTCATAGTGGGGGAGGTATGGATTTCGTTATTTTCTCTTTACATTTGGCTGGAGCTTCTTCTATTATGGG
TGCTATTAATTTTATTTCTACTATTATCAATATACGATCTGAGGGAATAGTGTTTGAGCGTGTTCCTTTGT
TTGTGTGGTCTGTAATAGTTACTGCGGTTTTATTGTTGTTATCGCTTCCTGTTTTAGCTGGGGCTGTTACT
ATACTTTTGACTGATCGTAATTTTAATACTTCTTTTTTTGATCCTGCTGGTGGGGGTGATCCTGTTTTGTT
TCAGCA

WAM T135962

GTATATTATTTTAGGGGTATGGTCTGCTATGTTTGGTACTGCAATGAGAGTTGTTATTCGAACAGAATTAG
GCCAGGTTGGGAGATTGTTATTGGATGATCATTTATATAATGTGGTGGTTACTGTTCATGCTTTGGTGATA
ATTTTTTTTATAGTGATGCCTATTATGATTGGGGGATTTGGAAATTGGTTGGTTCCTTTGATGCTAGGGGC
GCCTGATATGGCATTTCCTCGTATGAATAATTTGAGATTTTGGTTGTTACCTTCTTCTTTGTTTTTTTTAG
TAGTTTCTTCTCTAATAGGGGTGGGTGTTGGGGCTGGATGAACTATTTATCCTCCTTTGTCTTCTGGTATT
GGTCATAGTGGGGGAGGTATGGATTTCGTTATTTTCTCTTTACATTTGGCTGGAGCTTCTTCTATTATGGG
TGCTATTAATTTTATTTCTACTATTATCAATATACGATCTGAGGGAATAGTGTTTGAGCGAGTTCCTTTGT
TTGTGTGGTCTGTAATAGTTACTGCGGTTTTATTGTTGTTATCGCTTCCTGTTTTAGCTGGGGCTGTTACT
ATACTTTTGACTGATCGTAATTTTAATACTTCTTTTTTTGATCCTGCTGGTGGGGGTGATCCTGTTTTGTT
TCAGCA

4.3 *MEGACEPHALA CORPULENTA*

The Australian tiger beetles in the genus *Megacephala* have most recently been revised by (McCairns *et al.* 1997). The genus is considered pantropical although some authors restrict it to African species (Pearson & Vogler 2001). *Megacephala* are nocturnal. In Australia, they can be found at coastal tidal flats and sandy riverbanks, but a number of species are specialised hunters on dry salt lakes (Pearson & Vogler 2001).

Megacephala corpulenta is a metallic green tiger beetle with a bronze sheen. The species has been mainly been found on salt lakes, between Wongan Hills in the northern Avon Wheatbelt in the south-west to Karara Well in the north-east (McCairns *et al.* 1997).

Table 4-3 COI sequence divergence of *Idiosoma nigrum* from Yeelirrie compared to reference specimens from Jack Hills and Boolardy Station

		Jack Hills			Boolardy Station			Yeelirrie	
		PES9293	PES9296	PES9295	PES17895	PES17896	PES17899	WAM T135961	WAM T135962
Jack Hills	PES9293		0.3	0.5	6	6	6	7	7.1
	PES9296			0.8	6.4	6.4	6.4	7.3	7.4
	PES9295				5.9	5.9	5.9	6.8	7
Boolardy Station	PES17895					0	0	8.1	8.2
	PES17896						0	8.1	8.2
	PES17899							8.1	8.2
Yeelirrie	WAM T135961								0.2
	WAM T135962								

4

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