Cooljarloo West Development Envelope
Fauna Assessment

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Executive summary

Tronox (formerly Tiwest) has operated the Cooljarloo mineral sands mine since the late 1980s and is investigating mining within the area referred to as the 'Cooljarloo West Development Envelope'. Tronox is in the process of conducting an environmental impact assessment for the proposed development of Cooljarloo West and commissioned Bamford Consulting Ecologists (BCE) to undertake a fauna assessment of the Development Envelope. The project is expected to be developed within the Cooljarloo West Development Envelope also referred to as the Project Area. BCE uses an assessment process with the following components:

- The identification of **fauna values**:
    - Assemblage characteristics: uniqueness, completeness and richness;
    - Species of conservation significance;
    - Recognition of 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 fauna investigations were based on a desktop assessment and field surveys conducted in summer 2012 and winter 2013. The desktop survey (including results from previous work at Cooljarloo since 1986) identified 182 vertebrate fauna species potentially occurring in the Cooljarloo West survey area. During the field surveys 107 species were recorded. This comprised 9 frogs, 21 reptiles, 65 birds and 12 mammal species. Key **fauna values** are:

Fauna assemblage. Very rich and intact with several heath specialists and some wetland dependent species expected. Sampling indicates that the assemblage is similar to that of Cooljarloo to the east, where extensive sampling has taken place, but there are differences in the proportional representation of common species, while the gecko *Diplodactylus polyophthalmus* was recorded at Cooljarloo West, but has not been found at Cooljarloo. This gecko appears to be associated with lateritic soils withihn the Project Area.

Species of conservation significance. A range of significant species may be present. Species of note are the South-west Carpet Python, Western Ground Parrot (although probably locally extinct), Carnaby's

Black-Cockatoo, Rufous Fieldwren and Rainbow Bee-eater. Significant invertebrates are considered in a separate report. The Woma (Ramsay's Python) is historically known from the general region but has not been detected at Cooljarloo despite over two decades of field investigations. The gecko *D. polyophthalmus* can be considered locally significant as the species is poorly-known in the region. Cooljarloo West contains extensive areas of foraging habitat for the Carnaby's Black-Cockatoo but these areas appear similar to the intact habitat occurring in the surrounding landscape. No breeding habitat is present within the Project Area and the closest recorded roosting site is 3 km east of the Development Envelope.

Vegetation and Substrate Associations (VSAs). The Development Envelope is a complex mosaic of vegetation and soil types, making clear recognition of VSAs difficult. Broadly-speaking there are Riparian Woodlands, *Banksia* Woodlands and Heaths, but considerable overlap in key plant species occurs. The *Banksia* Woodlands are extensive in the Cooljarloo region, but the Low Heaths and Riparian Woodlands are not. Somewhat similar Low Heaths are present in the Falcon project area to the north. These VSAs are described below.

- Low Heath on Flats – typical plants include several species of *Hakea*, *Banksia telmatiaea* and a range of Myrtaceae. The plants are indicative of some groundwater dependence. Soils consist of a thin layer of sand over clay, and in some places a hardpan of laterite is present close to the surface. These heaths are very variable, probably due to differences in underlying geology.
- *Banksia* Woodland on Low Dunes – woodland primarily of *Banksia menziesii* and *Banksia attenuata* over a mixed shrubby understorey. These woodlands occur on slight sandy rises but in some cases the understorey includes elements from the Low Heath on Flats.
- Riparian and Riverine Woodland - woodlands associated with seasonally damp and usually clayey soils; trees include *Eucalyptus rudis*, *Banksia littoralis*, *Melaleuca priessiana* and *Melaleuca rhaphiophylla*. Riparian Woodland occurs in damp depressions and along some watercourses that lie outside the Development Envelope, such as Emu Lakes Drainage System, Mullering Brook and Frederick Smith Creek.

Patterns of biodiversity. Areas of particular significance include *Banksia* Woodland (foraging habitat for the Carnaby's Black-Cockatoo) and the groundwater-dependant dampland heath areas (supporting habitat specialist fauna with some restrictions in distribution).

Key ecological processes. Main processes currently affecting the fauna assemblage in the Development Envelope include local hydrology, fire, fauna interactions (feral predators, over-abundant native species) and weed invasion. Dieback is also considered to be a threat (although not currently present).

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1 Introduction

1.1 Introduction

Tronox (formerly Tiwest) has operated the Cooljarloo mineral sands mine since the late 1980s. Mining initially took place on farmland but the mine has expanded into areas of native vegetation within Unallocated Crown Land (UCL) both north and south of Cooljarloo Road. More recently, exploration has been conducted west of the current operational areas of the Cooljarloo and Falcon projects in an area referred to as the Cooljarloo West Development Envelope (Cooljarloo West; (see Figure 1). A detailed exploration program has been completed for the Cooljarloo West Development Envelope (Figure 2) and, feasibility studies into mining of this area are now being completed.

Tronox is in the process of conducting environmental impact assessment for this proposed development within the Cooljarloo West Development Envelope (the Project Area), and Bamford Consulting Ecologists (BCE) was commissioned by Strategen on behalf of Tronox to conduct a Fauna Assessment of the Project Area. BCE has extensive previous experience in the area, having undertaken studies at Cooljarloo/Falcon since 1986, with almost annual monitoring throughout this period to determine the fauna assemblage, patterns of distribution in relation to soil and vegetation types, response to rehabilitation, response to mulch harvesting and, coincidentally, response to fire. In 2010, an overview of fauna values of Cooljarloo West was conducted, based upon a brief site inspection and records from previous studies in the area (Bancroft and Bamford 2010). This report is based on a further review of existing information, and on field investigations specific to Cooljarloo West conducted in 2012 and 2013.

1.2 Study objectives

The objectives of fauna studies in the Environmental Impact Assessment (EIA) process are broadly to determine the fauna values of a site and the likely impacts of a proposed development. This provides government agencies with the information needed to assess the significance of impacts under state and government legislation. 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).

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.

Note that the investigations reported on here are not intended to produce a definitive list of species confirmed to be present, but are intended to provide information to allow the assessment of impacts of the proposed development upon biodiversity. Faunal assemblages are dynamic in space and time, and therefore understanding the factors such as significant species, habitat diversity and ecological processes that drive the biodiversity of a project area, and how a proposed project may interact with these factors, is considered by BCE more relevant to impact assessment than producing a detailed species list at a particular time and for a select number of locations within that project area.

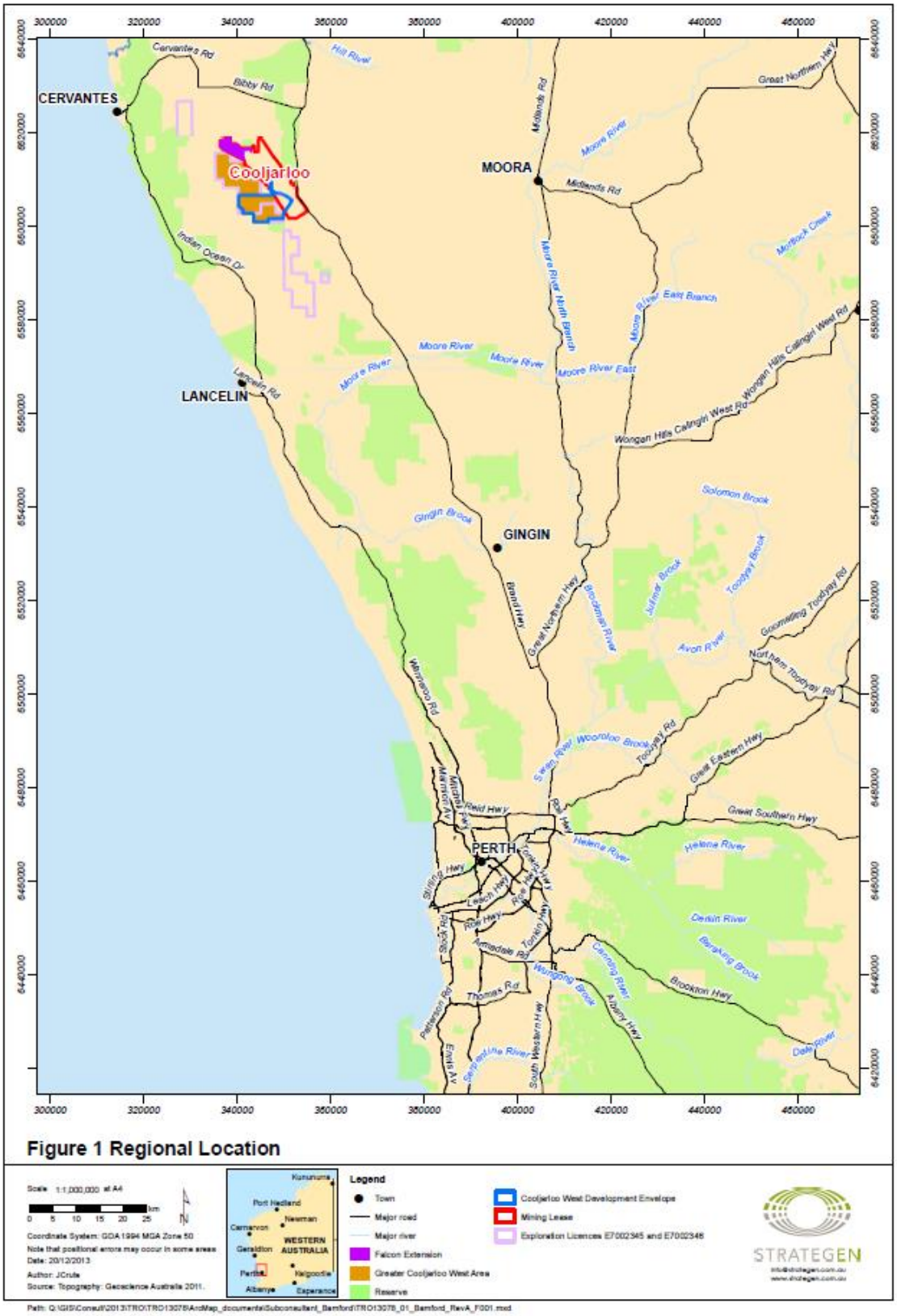

Figure 1 Regional Location

Figure 1: Location map of the Cooljarloo West Development Envelope and other areas mentioned in the text.

2 Background

2.1 Regional description

The Development Envelope lies within the northern end of the Swan Coastal Plain Bioregion of the Interim Biogeographic Regionalisation for Australia (IBRA) classification system (see Figure 2), although is very close to the Lesueur Sandplain Subregion of the Geraldton Sandplains Bioregion (EA 2000; McKenzie *et al.* 2003). Both the Swan and the Geraldton Bioregions fall within the Bioregion Group 1 classification of the EPA (2004). These are Bioregions of the South-West Botanical Province that are extensively cleared for agriculture, although in the immediate vicinity of the Project Area native vegetation is very extensive with a high representation in reserves (e.g. Nambung, Moore River, Mt Lesueur and Beekeepers). Key threatening processes are identified as:

- ongoing clearing;
- degradation of fragmented vegetation (a consequence of clearing), grazing pressure from domestic and feral species;
- feral animal control; and
- dieback (*Phytophthora* spp.), weeds and changed fire regimes (McKenzie *et al.* 2003).

The general features of these regions are summarised by McKenzie *et al.* (2003). The northern end of the Swan Bioregion is characterised by three phases of Quaternary marine sand dunes supporting *Banksia* Woodlands, with seasonal wetlands/damplands in interdunal areas and few watercourses. The Lesueur Sandplain Subregion supports heaths and shrub-heaths on sandplain overlying laterite.

2.2 Description of Project Area

The Project Area occupies UCL, and lies west of existing Tiwest operations and east of Nambung National Park. It is part of exploration leases E70/2345 and E70/2346 that cover an area of approximately 35 000 ha, and extend from south of Woolka Road to Wongonderrah Road (Figure 1). Apart from tracks the native vegetation is intact. Bancroft and Bamford (2010) described the greater Cooljarloo West area of exploration leases E70/2345 and E70/2346 as consisting …"of *Banksia* low woodlands across a landscape of stabilised sand-dunes, with some very high dunes in the west, but there are also extensive sandy flats (effectively very broad interdune swales) that support heaths and scrub-heaths, and are seasonally damp. Some seasonal wetlands within these swales support riparian woodlands of paperbarks *Melaleuca* spp., Swamp Banksia *Banksia littoralis* and Flooded Gum *Eucalyptus rudis.* In addition to low-lying areas prone to seasonal inundation, there are two drainage systems across the Project Area: a drainage line [Minyulo Brook] associated with Emu Lakes in the south (c. 351000 E, 6601000 N; WGS84), and a complex system of Mullering Brook and Frederick Smith Creek in the centre and west." The Cooljarloo West Development Envelope lies in the south-west of this greater Cooljarloo West area, between but not including the drainage systems.

Figure 2: IBRA Subregions in Western Australia. Note the project lies in SWA2, the Swan Coastal Plain Bioregion, with the approximate location indicated by the red dot

3 Methods

3.1 Overview

The methods used in these investigations are based upon the general approach to fauna investigations for impact assessment as outlined in Section 1.2 and with reference to Appendices 1 to 4. Thus, the impact assessment process involves the identification of fauna values, review of impacting processes and preparation of mitigation recommendations.

In addition, the approach to fauna impact assessment was carried out with reference to guidelines and recommendations set out by the Western Australian Environmental Protection Authority (EPA) on fauna surveys and environmental protection, and Commonwealth biodiversity legislation (EPA 2002; EPA 2004b). The EPA proposes two levels of investigation that differ in the approach to field investigations, Level 1 being a review of data and a site reconnaissance to place data into the perspective of the site, and Level 2 being a literature review and intensive field investigations (e.g. trapping and other intensive sampling). The level of assessment recommended by the EPA is determined by the size and location of the proposed disturbance, the sensitivity of the surrounding environment in which the disturbance is planned, and the availability of pre-existing data.

Due to the size and location of the proposed project, a "Level 2" fauna assessment of the Cooljarloo West area was conducted, although previous studies at Cooljarloo and Falcon just to the east mean that a lot of information on the fauna assemblage is already available. Therefore, the Level 2 investigations at Cooljarloo West included targeting of significant species and studies aimed at determining patterns of biodiversity across the landscape. The purpose of a detailed Level 2 survey is to enhance the level of knowledge at a local scale, and requires:

"One or more visit/s in each season appropriate to the bioregion and the faunal group being surveyed. Generally, maximum survey will be the season that follows the season of maximum rainfall, but there will be need to time surveys according to seasonal activity patterns of some faunal groups" (EPA 2004: 32). Two main sampling periods plus a short period to target habitat assessment for Carnaby's Black-Cockatoo more than meet this expectation.

The following approach and methods is divided into three groupings that relate to the stages and the objectives of impact assessment:

- Desktop assessment. The purpose of the desktop review is to produce a species list that can be considered to represent the vertebrate fauna assemblage of the Project Area based on unpublished and published data using a precautionary approach.
- Field investigations. The purpose of the field investigations is to gather information on this assemblage: confirm the presence of as many species as possible (with an emphasis on species of conservation significance), place the list generated by the desktop review into the context of the environment of the Project Area, collect information on the distribution and abundance of this assemblage, and develop an understanding of the Project Area's ecological processes that maintain the fauna. Note that field investigations cannot confirm the presence of an entire assemblage, or confirm the absence of a species. This requires far more work than is possible in the EIA process. For example, in an intensive trapping study, How and Dell (1990) recorded in any one year only about 70% of the vertebrate

species found over three years. In studies conducted at Cooljarloo and Falcon just to the east, Bamford (2010) has found that the vertebrate assemblage varies over time and space, meaning that even complete sampling at a set of sites only defines the assemblage of those sites at the time of sampling.

- Impact assessment. Determine how the fauna assemblage may be affected by the proposed development based on the interaction of the project with a suite of ecological and threatening processes.

The BCE approach to EIA (Appendix 1) has been developed through interpretation of the EPA's guidance Statement 56 (EPA 2004) and provides a framework for determining the appropriate level of investigation; the Cooljarloo West project is assessed against these criteria (see Table 1).

Table 1. Criteria for guidance to assess level of investigation - Assessment of Cooljarloo West proposal:

Size and scale of the proposed development.	Proposed development is relatively large in a regional context. The EPA suggests that local impact should be assessed within a radius of 15 km [of the centrepoint] of a proposal, but does not provide percentage levels and corresponding levels of significance.
Context: position relative to conservation estate and/or intact natural environments.	Project Area lies in UCL land between a number of conservation reserves.
Context: rarity of environments.	Environments are widespread except for some dampland and wetland areas that are locally unusual. These are likely to be closely linked to perched groundwater (to be confirmed by separate studies being conducted for this proposal). Upland environments are like those around Cooljarloo, but wetlands are distinctive.
Context: extent of clearing and other forms of habitat degradation in region.	Except for previous mining to east and north-east, and some clearing for agriculture, native vegetation is largely intact and virtually pristine within 10-15 km (to be confirmed by separate studies being conducted for this proposal).
Availability of existing information on fauna assemblage.	Vertebrate fauna assemblage very well documented from previous studies at sites within 5 km.
Ecological functions and processes (e.g. fire, linkage, patterns of distribution, hydrology and species interactions).	The region is ecologically complex due to the range of vegetation and soil types, potential interactions of vegetation with groundwater (to be confirmed by separate studies being conducted for this proposal), role of fire and presence of feral fauna. This has implications for the sorts of impacting processes that may result from the project.
Numbers and types of significant species.	Few significant vertebrate species present and these are mostly well-understood in the region as a result of previous studies. Vertebrate species of greatest interest are Carnaby's Black-Cockatoo, Western Ground Parrot and possibly Woma. Locally extinct mammal species are of interest if any potential for reintroduction exists. Significant invertebrates are considered in separate investigations.

Complexity of the environment.	Environment is a complex of soil and vegetation types, with soils from sand to clays varying over short distances, and relationship of vegetation with groundwater also potentially highly variable with swell and swale topography. Some seasonal and permanent wetlands present (or present nearby).
Potential for rehabilitation or similar that require monitoring.	Rehabilitation of disturbance areas back to native vegetation is expected. Tronox has developed considerable experience in post-mining rehabilitation (Strategen 2012).
Potential for cumulative impacts.	Some existing mining to east and north-east, and other tenements in region owned by other companies, therefore cumulative impacts likely.

A review against the above criteria effectively has determined that given current knowledge and risks, the present survey fshould focus on:

- Presence of unusual dampland and wetland environments that are not well-represented in Cooljarloo where previous surveys have occurred; there may be some possibility of hydrological impacts on these systems immediately adjacent to impact areas, although studies suggest that most damplands and wetlands in proximity to the mine void will be unaffected (Syrinx 2013). This suggests some sampling in dampland areas very close to potential impact sites is warranted.
- Because the potential development footprint is or may be significant and lies in a region with existing and possibly future other developments, habitat comparisons between the impact areas and the environments present nearby are warranted.
- Some significant species are present. This suggests targeted surveys should consider if these might be vulnerable to impacts from the proposal. Some of these potentially significant fauna such as SRE and subterranean fauna have been addressed by other consultants.
- Rehabilitation to a more or less natural ecosystem will be required. Therefore baseline abundance data are needed to act as a guide during monitoring; such data relate species' abundance to environment (e.g. vegetation, soils, and landforms). BCE has extensive such records from Cooljarloo and has written an outline for targeting bio-indicator species most likely to help measure the effectiveness of rehabilitation.

Areas of investigation suggested above focus on:

- Values that might be compromised by the proposal (e.g. some significant species; fauna in dampland environments close to the impact area);
- Providing information on the context of fauna values particularly through assessing nearby areas; and
- Providing information that can guide rehabilitation.

3.2 Desktop Assessment

3.2.1 Sources of information

Information on the fauna assemblage of the Project Area was drawn from a wide range of sources. These included state and federal government databases, results of regional studies and previous BCE surveys at Cooljarloo. Databases accessed were the Department of Parks and Wildlife (DPaW) NatureMap (incorporating the Western Australian Museum's FaunaBase and the DPaW Threatened and Priority Fauna Database), BirdLife Australia's Atlas Database (BA), the *Environmental Protection and Biodiversity Conservation Act 1999* (EPBC Act) Protected Matters Search Tool and the BCE database (Table 2). Information from the above sources was supplemented with species expected in the area based on general patterns of distribution. Sources of information used for these general patterns were:

- Frogs: Tyler & Doughty (2009);
- Reptiles: Storr *et al.* (1983); Storr *et al*. (1990); Storr *et al*. (1999); Storr *et al.* (2002) and Wilson & Swan (2008);
- Birds: Blakers *et al*. (1984); Johnstone and Storr (1998, 2004) and Barrett et al. (2003); and
- Mammals: Menkhorst & Knight (2001); Strahan (2004); Churchill (2008); and Van Dyck and Strahan (2008).

Table 2. Sources of information used for the desktop assessment.

Database	Type of records held on database	Area searched
NatureMap (DEC 2012)	Records in the WAM and DEC (now DPaW) databases. Includes historical data and records on Threatened and Priority species in WA.	30° 41' 47" S, 115° 22' 55" E – plus 20 km buffer
BirdLife Australia Atlas Database	Records of bird observations in Australia, 1998-2013.	Species list for one degree cell containing: 30° 41' 47" S, 115° 22' 55" E
EPBC Protected Matters	Records on matters of national environmental significance protected under the EPBC Act.	30° 41' 47" S, 115° 22' 55" E – plus 40 km buffer
BCE Cooljarloo Database	Fauna Trapping Results, bird census and other fauna observations: 1986 - 2013	All Cooljarloo lease areas surveyed by BCE

3.2.2 Previous Fauna Surveys

Information for this fauna assessment was drawn primarily from previous studies undertaken for Tiwest (now Tronox) in the Cooljarloo and Falcon areas. These studies date to 1986 and have been carried out in most years (annually since 1994), with late winter and late spring surveys involving the use of pitfall traps, funnel traps, Elliott traps, cage traps, bird censussing, bird-banding, searching, spot-lighting, trapping for bats and opportunistic observations. Work has included the collection of potential short range endemic invertebrates and sampling for freshwater fish. Much of the work has focussed on developing an understanding of patterns of distribution and environment use in relation to the colonisation of rehabilitated areas. The extent of this work means that the vertebrate fauna

assemblage has been almost completely documented, although it is notable that additions to the bird and reptile species list have been made in recent years. During the course of work at Cooljarloo and Falcon, 8084 individual small vertebrates have been caught, including 1205 frogs (8 species), 3844 reptiles (39 species) and 3035 mammals (8 species).

3.2.3 Nomenclature and taxonomy

As per the recommendations of EPA (2004a), the nomenclature and taxonomic order presented in this report are based on the Western Australian Museum's (WAM) *Checklist of the Vertebrates of Western Australia 2008*. The authorities used for each vertebrate group were: amphibians (Doughty and Maryan 2010a), reptiles (Doughty and Maryan 2010b), birds (Christidis and Boles 2008), and mammals (How *et al*. 2009). English names of species, where available, are used throughout the text; Latin species names are presented with corresponding English names in tables in the appendices.

3.2.4 Interpretation of species lists

Species lists generated from the review of sources of information are generous as they include records drawn from a large region and possibly from environments not represented in the survey area. Therefore, some species that were returned by one or more of the data searches have been excluded because their ecology, or the environment within the survey area, meant that it was highly unlikely that these species would be present. Some are also known to be regionally extinct. The availability of extensive trapping data from Cooljarloo and Falcon means that many species returned from databases and not found are probably not present, but where uncertainty exists species returned by the desktop review process are considered to be potentially present in the survey area whether or not they were recorded during field surveys. This is because fauna are highly mobile, often seasonal and frequently cryptic. This is particularly important for significant species that are often rare and hard to find.

Interpretation of species lists generated through the desktop review included assigning an expected status within the survey area to species of conservation significance. This is particularly important for birds that may naturally be migratory or nomadic, and for some mammals that can also be mobile or irruptive. The status categories used are:

- Resident: species with a population permanently present in the survey area;
- Regular migrant or visitor: species that occur within the survey area regularly in at least moderate numbers, such as part of annual cycle;
- Irregular Visitor: species that occur within the survey area irregularly such as nomadic and irruptive species. The length of time between visitations could be decades but when the species is present, it uses the survey area in at least moderate numbers and for some time;
- Vagrant: species that occur within the survey area unpredictably, in small numbers and/or for very brief periods. Therefore, the survey area is unlikely to be of importance for the species; and
- Locally extinct: species that has not been recently recorded in the local area and therefore is almost certainly no longer present in the survey area.

3.3 Field survey

3.3.1 Overview

The field survey included several components:

- Site inspection – reconnaissance survey to select survey sites for intensive sampling and to identify the vegetation and soil associations present within the survey area;
- Intensive trapping program – replicating survey methodology previously conducted across Cooljarloo and at Falcon;
- Targeted searching for conservation significant fauna – aural surveys for the Western Ground Parrot and evening watches for Carnaby's Black-Cockatoo to determine the presence of roosts;
- Carnaby's Black-Cockatoo Habitat Assessment – an assessment of the value of Cooljarloo West area as breeding and foraging habitat for Carnaby's Black-Cockatoo;
- Opportunistic fauna observations.

3.3.2 Dates and Personnel

The field assessment was conducted over several survey periods:

- Reconnaissance Survey – 21st to 22nd September 2009;
- Intensive Trapping Survey (Phase 1) – 21st to 28th November 2012;
- Black-Cockatoo Habitat Assessment – 30th April to 4th May 2013; and
- Intensive Trapping Survey (Phase 2) – 22nd to 27th July 2013;

Personnel involved in this project were:

- Dr Mike Bamford (B.Sc. Hons. Ph.D.) – field assessments and report preparation;
- Dr Wes Bancroft (B.Sc. Hons. Ph.D.) – field assessments and report preparation;
- Mr Jeff Turpin (B.Sc.) – field assessments and report preparation;
- Mr Simon Cherriman (B.Sc. Hons.) – field assessment;
- Ms Gillian Basnett (B.Sc. M.Sc.) – field assessment;
- Mr Brendan Metcalf (B.Sc. Hons.) – field assessment;
- Mr Peter Smith (Dip. Ag.) – field assessment;
- Ms Sarah Smith (B.Sc) – field assessment;
- Mr Robert Browne-Cooper (B.Sc.) – field assessment;
- Mr Cameron Everard (B.Sc.) – field assessment (site reconnaissance) and
- Mr Daniel Panickar (B.Sc. Hons.) – field assessment.

3.3.3 Licenses and Permits

The field surveys were conducted under DEC (now DPaW) Regulation 17 (Licence to take Fauna for Scientific Purposes) licence number SF006980.

3.3.4 Vegetation and Substrate Associations

The concept of Vegetation and Substrate Associations (VSAs) is outlined in Appendix 1, and is used as a more precise and accurate term than "habitat". VSAs throughout the survey area were assessed during the desktop review and during the field investigations. Each major VSA was visited to develop

an understanding of major fauna habitat types present and to assess the likelihood of conservation significant species being present in the area. Trapping and other sampling traversed key VSAs.

3.3.5 Reconnaissance Survey

An initial site inspection and desktop review of fauna and fauna habitat in Cooljarloo West was undertaken in 2009 (Bancroft and Bamford 2010). A further inspection during November 2012 survey was conducted to select survey sites sampled during the intensive trapping program. The original site inspection of was of the greater Cooljarloo West area (see Figure 3) and found there were areas of damp heath on peaty-clay soils and several drainage systems (part of the Mullering Brook system and including Emu Lakes). There were also *Banksia* Woodlands on sand typical of elsewhere in Cooljarloo.

3.3.6 Intensive Trapping and censussing Program

Intensive trapping and censussing for fauna at Cooljarloo West replicated the sampling methodology conducted elsewhere across Cooljarloo by BCE (Bancroft and Bamford 2013). This general approach consists of sampling along transects across the landscape and thus passing continuously through vegetation and substrate types (VSAs), with sampling points spaced at about 25m intervals along the transects. This spacing allows for local patterns of variation to be detected and avoids biases that can occur if sampling points are clumped. Each point has a pitfall trap and is a bird census point. In Cooljarloo West, two transects were deployed, each of 72 sampling points spaced at 25m intervals. A total of 144 sampling points was surveyed over five consecutive nights in each of two sampling periods, 23-28/11/2012 and 22-27 July 2013 (see Figure 3 and Appendix 5 for trap locations), resulting in a total of 1440 trap-nights (720 trap-nights in each sampling period).

At Cooljarloo West, the two fauna transects were located both within and adjacent to proposed future mining footprints in order to monitor rehabilitation post mining. The transects were placed so as to pass through the mine-path, thus providing a BACI (Before After Control Impact) experimental design, with pitfall and bird census data from control sections of the transects, and from sections of the transects before mining and during rehabilitation. Transects were placed in typical and representative vegetation types – *Banksia* Woodland on sand and dampland heath on clay flats.

Pitfall traps comprised a 20L bucket used without drift fences (as such unassisted pitfalls are found to be very effective at Cooljarloo, where capture rates are high). This approach without fences removes the need to maintain drift fences and removes any possible bias that fences may introduce in rehabilitation areas, where the initially sparse vegetation may result in fences attracting animals to the trap. Sampling periods at Cooljarloo West replicated that conducted elsewhere at Cooljarloo - five nights and sampling has taken place twice a year, in late winter and late spring.

For the purposes of comparison with sampling elsewhere at Cooljarloo, there are extensive trapping records from Falcon, and several sites around both the Cooljarloo North and South Mines. Some of these investigate rehabilitation or the effects of mulch harvesting, however, while annual variation in trapping results means that data from different years cannot readily be compared. Therefore, direct comparison of trapping results relied only on data from sampling carried out at the same time as that at Cooljarloo West, and in control (i.e. undisturbed) sites. Sources of comparative data were

North Transect, South Transect and two South Mine Transects (Figure 3). These had a combined sampling effort of 910 trap-nights in each of the two sampling periods, 23-28/11/2012 and 22-27 July 2013, and therefore a total trapping effort of 1820 trap-nights. Sampling effort in the Cooljarloo control sites was therefore slightly higher than in Cooljarloo West.

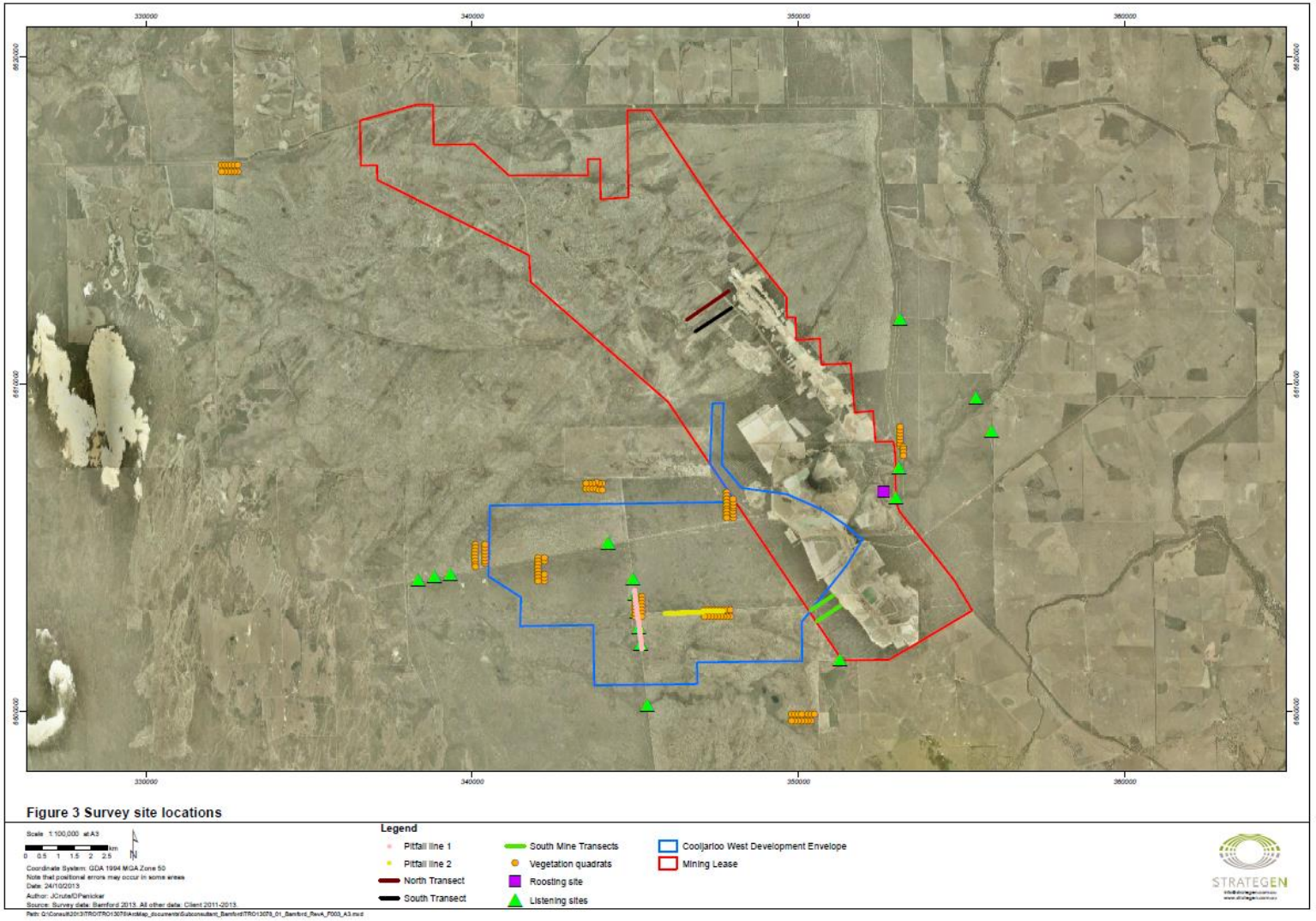

Figure 3: Locations of fauna survey sites, including those outside the Cooljarloo West Development Envelope used for reference

3.3.7 Targeted Searching for Conservation Significant Fauna

Targeted searching for conservation significant vertebrate fauna included a series of aural surveys for the Western Ground Parrot and Carnaby's Black-Cockatoo (Table 3). These two species have a high conservation significance and are species likely to be affected by the project.

Areas of low proteaceous heath were targeted for the Western Ground Parrot as this species inhabits such vegetation on the south coast. Large stands of tall trees (Eucalypt Woodland) were targeted for the Carnaby's Black-Cockatoo as potential roost sites. Flocks of several hundred regularly forage around Cooljarloo and roost sites in the local area are considered likely to occur. Breeding of this species occurs along Cataby Brook (in *Eucalyptus wandoo*) and while there is little likelihood of breeding in Cooljarloo West (lack of suitable trees), opportunistic observations were noted. Where cockatoos were recorded, the time and direction of flight was also noted. All aural surveys were conducted from at least 1 hour prior to sunset until darkness (about half an hour after sunset). There was usually only one person at each aural survey site, but occasionally two.

Table 3. Aural Surveys targeting the Western Ground Parrot and Carnaby's Black-Cockatoo.

Site	Location	Easting	Northing	Habitat	Date	Duration (minutes)
1	Cooljarloo West	339330	6604200	Low Heath	14/11/2010	90
2	Cooljarloo West	345155	6602062	Low Heath, *Banksia*	23/11/2012	90
3	Cooljarloo West	345155	6602062	Low Heath, *Banksia*	24/11/2012	90
4	Cooljarloo West	344167	6605168	Low Heath, *Banksia*	25/11/2012	90
5	Mullering NR	355907	6608563	Low Heath	23/07/2013	90
6	Emu Lakes	351262	6601593	Wetland	30/04/2013	90
7	Cooljarloo West	345368	6600201	Low Heath	30/04/2013	90
8	Cooljarloo	352987	6606535	Banksia Woodland	25/07/2013	90
9	Cooljarloo	353078	6607456	Eucalypt Woodland	24/07/2013	90
10	Cooljarloo	353110	6611996	Eucalypt Woodland	24/07/2013	90
11	Mullering NR	355446	6609576	Riverine Woodland	23/07/2013	90

Other conservation significant fauna potentially occurring at Cooljarloo West include the Woma and Carpet Python. The Woma is a rare python and has not been encountered at Cooljarloo in over 20 years. However the Carpet Python has been recorded several times at Cooljarloo, although only opportunistically. All opportunistic records of fauna were noted.

3.3.8 Opportunistic observations

At all times, observations of fauna were noted when they contributed to the accumulation of information on the fauna of the site. These included such casual observations as birds or reptiles seen while travelling through the site.

3.4 Carnaby's Black-Cockatoo Habitat Assessment

Targeted surveys for black-cockatoo activity (foraging, roosting and breeding) followed the guidelines set out by DSEWPaC (now Department of the Environment [DOTE]; 2010, 2012a,2012c, 2013). Roosting surveys are outlined above (Section 3.3.7).

3.4.1 Foraging

The potential for the Cooljarloo West area to support foraging by black-cockatoos was assessed by quantifying the density of tree species on which black-cockatoos are known to feed. This was done within the Project Area and in surrounding 'reference' vegetation, as outlined below.

Groom (2011) reviewed the literature and listed all plants known to be consumed by Carnaby's Black-Cockatoo. The tree species encountered during this survey that were also listed as a food source by Groom (2011) were: *Banksia attenuata*, *B. ilicifolia*, *B. littoralis*, *B. menziesii*, *B. prionotes*, *Eucalyptus rudis* and *E. todtiana*.

A total of 125 quadrats (each 20 x 20 m) were surveyed within the Project Area and surrounding ('reference') areas, as indicated in Table 4. Two broad vegetation types were recognised, based on the vegetation mapping of Woodman Environmental Consulting (Woodman 2013): woodland (*Banksia* Woodland) and Heath (dominated by very low, dense vegetation). Quadrats were stratified according to vegetation type and location to ensure a similar number of samples within the project and reference areas (see Table 4). For each quadrat the number of potential feed trees was recorded. In addition, the number of trees with signs of foraging by black-cockatoos (i.e. nuts or fruit with characteristic feed marks) was noted. Feed signs were ranked into the following categories, based on time since foraging took place:

- 'Recent' – feeding occurred approximately two weeks prior to the survey;
- 'Intermediate' – feeding occurred between approximately two weeks and six months prior to the survey; and
- 'Old' – feeding occurred approximately more than six months prior to the survey.

The locations of the quadrats are shown in Figure 3 and listed in Appendix 5.

Table 4. Number of survey quadrats (with total area in parentheses) in Woodland and Heath vegetation types, in the project and reference areas.

Vegetation Type	Location		
	Project Area	Reference Area	Total
Woodland	40 (1.60 ha)	47 (1.88 ha)	87 (3.48 ha)
Heath	18 (0.72 ha)	20 (0.80 ha)	38 (1.52 ha)
Total	58 (2.32 ha)	67 (2.68 ha)	125 (5.00 ha)

3.4.2 Breeding

Searching was conducted throughout Cooljarloo West and in adjacent areas for suitable breeding habitat (large trees meeting the criteria and descriptions provided by Groom 2011; Johnstone *et al.* 2011; DSEWPaC 2013). Note that searching for such habitat has been carried out in previous studies in the region for Tronox.

3.5 Survey limitations

EPA Guidance Statement 56 (EPA 2004a) outlines a number of limitations that may arise during surveying. These survey limitations are discussed in the context of the BCE fauna survey of the Project Area in Table 5.

Table 5. Survey limitations as outlined by EPA (2004).

EPA Limitation	Limitation	BCE Comment
Level of survey.	No	Level 2 (desktop study, reconnaissance survey, intensive field survey). Survey intensity was deemed adequate due to the level of survey and the number of fauna surveys previously conducted in the region.
Competency/experience of the consultant(s) carrying out the survey.	No	The authors have had extensive experience in conducting desktop reviews and site inspections.
Scope. (What faunal groups were sampled and were some sampling methods not able to be employed because of constraints?)	No	Comprehensive survey for birds, mammals, reptiles and frogs. The survey was adequate to define fauna habitats and there was abundant desktop data on the fauna assemblage in the region.
Proportion of fauna identified, recorded and/or collected.	No	All fauna observed identified.
Sources of information e.g. previously available information (whether historic or recent) as distinct from new data.	No	Sources include previous reports on the fauna of the local area (BCE database); databases (BA, DEC [DPaW], WAM, EPBC); BCE survey in nearby areas.
The proportion of the task achieved and further work.	No	Survey completed.

Timing/weather/season/cycle.	No	Surveys conducted November 2012 (warm, humid conditions), April 2013 (cool, mild) and July 2013 (wet and mild). Rainfall was recorded during both phases of trapping.
Disturbances (e.g. fire, flood, accidental human intervention etc.) which affected results of survey.	No	No disturbances affected the survey.
Intensity. (In retrospect, was the intensity adequate?)	No	Survey intensity was adequate to satisfy EPA guidelines for the area.
Completeness (e.g. was relevant area fully surveyed).	No	Desktop study covered survey area and adjacent habitats. Field surveys included all vegetation types present within survey area.
Resources (e.g. degree of expertise available in animal identification).	No	All species identified.
Remoteness and/or access problems.	No	No access problems.
Availability of contextual (e.g. biogeographic) information on the region.	No	Extensive regional information was available and was consulted.

3.6 Presentation of results for Impact Assessment

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 (now DOTE, 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. Key components to the general approach to impact assessment are addressed as follows:

Fauna values

The results of the desktop and field investigations are presented in terms of key fauna values (described in detail in Appendix 1):

- Assemblage characteristics (uniqueness, completeness and richness);
- Species of conservation significance;
- Recognition of ecotypes or vegetation/substrate associations (VSAs);
- Patterns of biodiversity across the landscape;

- Ecological processes upon which the fauna depend.

Impact assessment

The impact assessment reviews impacting processes (as described in detail in Appendix 2) with respect to the project and examines the potential effect of these impacts upon biodiversity of the project area. It 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.

3.6.1 Criteria for impact assessment

Impact assessment criteria are based on the severity of impacts on the fauna assemblage and conservation significant fauna, and were quantified on the basis of predicted population change (Table 6). Population change can be the result of direct habitat loss and/or impacts upon ecological processes.

The significance of population change is contextual. The EPA (2004) suggests that the availability of fauna habitats within a radius of 15 km 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 is rare (<5% of the landscape within a 15 km radius or within the Bioregion), whereas a low impact is where the environment is widespread (10% or more of the local landscape). Under the Ramsar Convention, a wetland that regularly supports 1% or more of a population of a waterbird species is considered to be significant. These provide some guidance for impact assessment criteria. In the following criteria (Table 6), the significance of impacts is based upon percentage population decline within a 15 km radius (effectively local impact), and upon the effect of the decline upon the conservation status of a recognised taxon (recognisably discrete genetic population, sub-species or species). Note that percentage declines can usually only be estimated on the basis of distribution of a species derived from the extent of available habitat.

Table 6. Assessment criteria of impacts upon fauna.

Impact Category	Observed Impact
Negligible	Effectively no population decline; at most few individuals impacted and any decline in population size within the normal range of annual variability.
Minor	Population decline temporary (recovery after end of project such as through rehabilitation) or permanent, but <1% within 15 km radius of centrepoint of impact area (or within bioregion if this is smaller). No change in viability or conservation status of taxon.
Moderate	Permanent population decline 1-10% within 15 km radius. No change in viability or conservation status of taxon.
Major	Permanent population decline >10% within 15 km radius. No change in viability or conservation status of taxon
Critical	Taxon extinction within 15 km and/or change in viability or conservation status of taxon.

3.7 Community comparison

The vegetation mapping of Woodman Environmental Consulting was used to categorise each pitfall/bird census point location into one of the two VSAs (see section 3.3.4): (i) heath or (ii) woodland. Fauna species captured by pitfall trapping were categorised into one of eleven broader taxa that group animals with similar ecological requirements/function: frogs (5 species), dragons (2 species), geckoes (3 species), pygopods (1 species), skinks (4 species), varanids (1 species), snakes (2 species), echidna (1 species), dunnarts (2 species), honey possum (1 species) and rodents (2 species). Similarly, bird species were grouped into one of ten broader taxa: pigeons etc. (3 species), parrots (4 species), wrens (6 species), thornbills etc. (4 species), honeyeaters (6 species), whistlers etc. (4 species), woodswallows (2 species), songlarks (1 species), silvereye (1 species), martins (1 species).

Standardised encounter rate (captures per 100 trap-nights, abundance per 100 point-counts) was calculated for each of these taxa in each of the VSAs. Data were then used to compare the communities of the two VSAs through the multivariate ANOSIM and SIMPER analyses (see section 3.8).

3.8 Data analyses

Data were investigated using graphical, univariate (single variable) and multivariate (multiple variables considered concurrently) approaches. Univariate analyses included Student's t-tests and analysis of variance. Multivariate analyses were by multivariate analysis of variance; and non-parametric tests of community similarity (e.g. ANOSIM, SIMPER). Further explanation follows, where applicable. An alpha-level of 0.05 was used to determine 'significance' (Zar 1999).

3.8.1 Student's t-tests and analysis of variance (ANOVA)

Student's *t*-tests were used to assess the difference in the mean value for a given variable between control and operations sampling sites. An F-test was used to determine whether group variances were

similar and, where this was not the case, the appropriate modification of the *t*-test was used (for elaboration see Zar 1999).

Multivariate analysis of variance (MANOVA) was used to concurrently compare multiple variables. Normality was tested using the Doornik-Hansen test (Hammer 2011; Grajales 2012) and homoscedasticity (equal variances) was assessed using a Box's M test (Hammer 2011). Where these assumptions were severely violated, a non-parametric MANOVA (NP-MANOVA, Anderson 2001) or Friedman test (for repeated measures, see Hammer 2011) was used.

3.8.2 Analysis of Similarities (ANOSIM)

Analysis of similarities (ANOSIM) is a non-parametric test of significant difference between two or more groups, based on any resemblance measure (mathematical formulae used to compute dissimilarity, distance, similarity and 'nearness' coefficients, Clarke 1993; Clarke *et al.* 2006). The resemblance measures are converted to ranks and these ranks compared using a mathematical algorithm to compute a test statistic '*R*' (ranging from -1 to 1), and to assess the statistical significance of the *R* value (thus generating a probability value, *P*). In a simplified sense, the test is based on comparing differences between groups with differences within groups. Clarke and Warwick (2001) provided a guide for interpreting the *R* values:

1: groups are mutually exclusive and dissimilar. All replicates within a group are more similar to each other than any replicates from different groups;
0: groups are similar. Replicates within a group are as similar to each other as they are to replicates from different groups; and
-1: groups are confused. All replicates within a group are more similar to replicates from different groups than they are to one another. Generally a very low negative R value indicates an error in study design or data management.

With respect to interpretation of ANOSIM results, *R* values are probably more important and informative than *P* values (the traditional focus of statistical interpretation, Clarke and Warwick 2001).

3.8.3 Similarity Percentage (SIMPER)

Similarity percentage (SIMPER) is a simple method for assessing which variables (taxa, in the Cooljarloo West analysis) are primarily responsible for an observed difference between groups of samples (Clarke 1993). SIMPER calculates the average resemblance measure between all pairs of inter-group samples and then returns this in terms of the average contribution from each of the variables (e.g. taxa). These are ranked, and the variables (e.g. taxa) that contribute most to the differences between two groups can be determined.

3.8.4 Statistical software

Statistical tests were performed using the statistiXL (Roberts and Withers 2009) or PAST (Hammer 2011) software packages.

4 Results

4.1 Vegetation and Soil Associations (VSAs – Figure 4)

The greater Cooljarloo West area is a complex landscape of tall, stabilised dunes supporting *Banksia* woodland, wetlands, watercourses, riparian woodlands and scrub-heath flats, with the soils usually sandy but in places being a heavy clayey-peat, in other places containing laterite, and with limestone exposed in some locations. This range of vegetation, landform and soils is not neatly organised but is patchy with broad areas of overlap. As a result, only broad Vegetation/Soil Associations (VSAs) can be recognised, and these contain considerable variation.

Key environments and VSAs across the greater Cooljarloo West area are described in Bancroft and Bamford (2010). Within the Cooljarloo West Development Envelope, VSAs are:

- VSA 1- Low Heath on Flats (Figures 5 and 6) – typical plants include several species of *Hakea*, *Banksia telmatiaea* and a range of Myrtaceae. The plants are indicative of some groundwater dependence. Soils consist of a thin layer of sand over clay, and in some places a hardpan of laterite is present close to the surface. These heaths are very variable probably due to differences in underlying geology.
- VSA 2 - *Banksia* Woodland on Low Dunes (Figure 7) – woodland primarily of *Banksia menziesii* and *Banksia attenuata* over a mixed shrubby understorey. These woodlands occur on slight sandy rises but in some cases the understorey includes elements from the Low Heath on Flats.
- VSA 3 - Riparian and Riverine Woodland (Figure 8) - woodlands associated with seasonally damp and usually clayey soils; trees include *Eucalyptus rudis*, *Banksia littoralis*, *Melaleuca preissiana* and *Melaleuca rhaphiophylla*. Riparian Woodland occurs in damp depressions and along some watercourses that lie outside the Project Area, such as Emu Lakes Drainage System, Mullering Brook and Frederick Smith Creek. A distinctive small wetland that supports a samphire heath lies west of Cooljarloo West, at 338 047E, 6 604 444N.

Compared with Cooljarloo and Falcon, the landforms and vegetation at Cooljarloo West are broadly similar but have some distinct differences. *Banksia* Low Woodlands occupy about half of the Cooljarloo West area and are similar in floristics and structure to those of Cooljarloo and Falcon (Woodman Environmental Consulting 2013), except there is less overlap between heath and woodland vegetation at Cooljarloo and Falcon than at Cooljarloo West. Low Heaths on Flats are present in Falcon but have some floristic (and therefore probably soil) differences compared with the Low Heaths of Cooljarloo West. Riparian Woodlands are present around some wetlands in Cooljarloo. The main three drainage lines lie outside Cooljarloo, Falcon and Cooljarloo West, but there are likely to be underlying hydrological connections. Most significantly, the features of VSAs in Cooljarloo West that are most distinctive, being the Low Heaths on flats and the overlap in plant species between these heaths and the woodlands, are related to hydrological features and unusual soils.

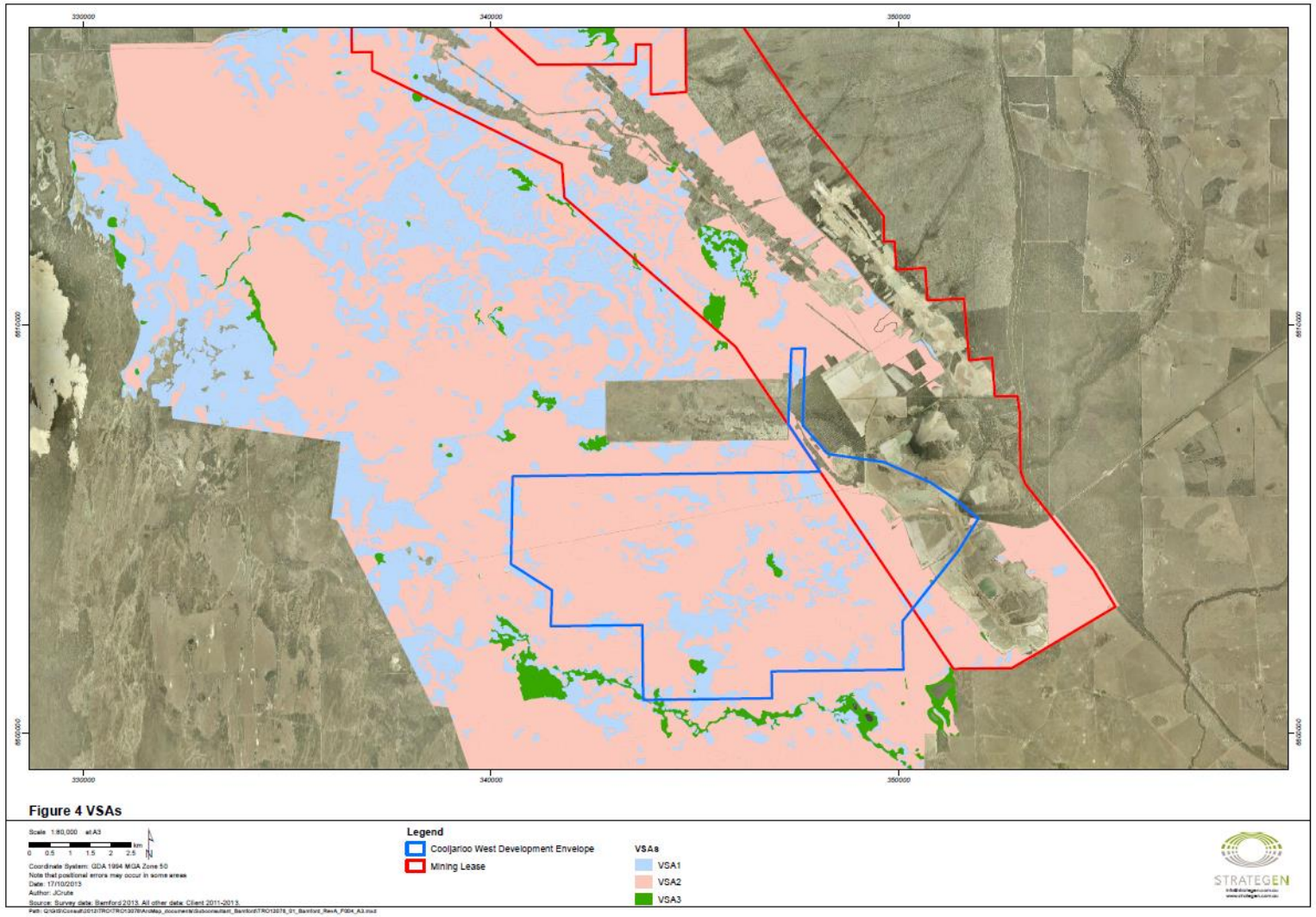

Figure 4: Distribution of VSAs based upon interpretation of vegetation mapping from Woodland Environmental Consulting (2013)

Figure 5: Low Heath on flat. Soil is sand over clay with areas of laterite

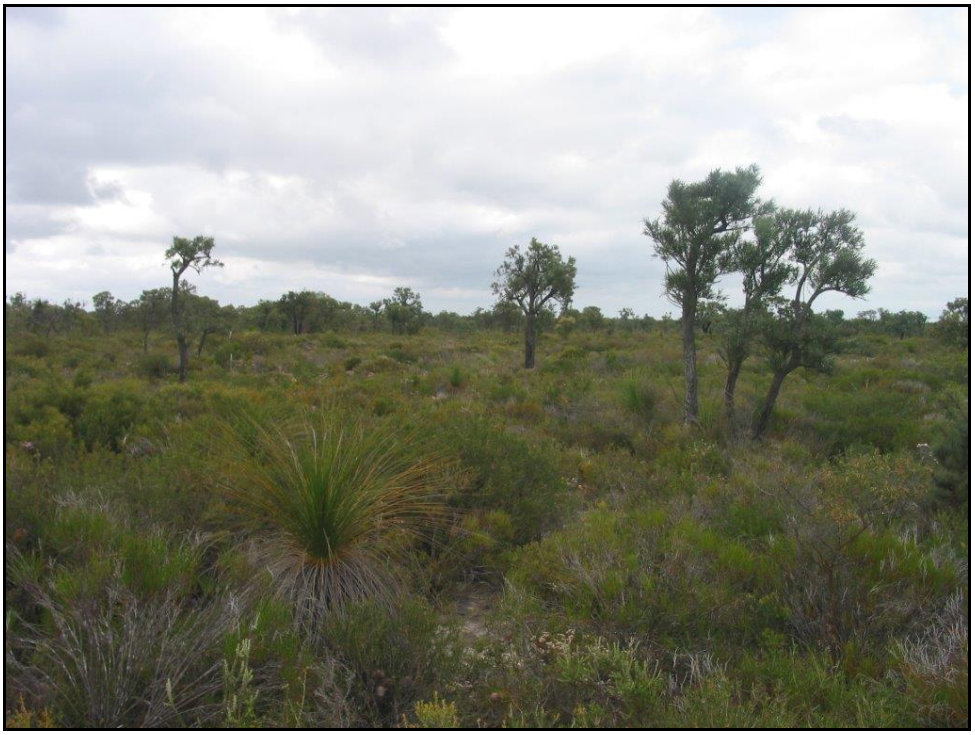

Figure 6: Low Heath on flat; scattered emergent Christmas Trees *Nuytsia floribunda.* Soil is sand over clay

Figure 7: Banksia Low Woodland on sand. Note the presence of *Banksia telmatiaea* as a component of the understorey

Figure 8: Part of the Emu Lakes drainage system, south of Cooljarloo West

4.2 Vertebrate Fauna

4.2.1 Overview of fauna assemblage

The desktop study identified 241 vertebrate fauna species as potentially occurring in the general Cooljarloo area (see Table 7 and Appendix 6): 3 native and 2 introduced fish, 10 frogs, 48 reptiles, 153 birds and 19 native and 6 introduced mammals. The majority of these have been recorded or are expected in Cooljarloo West, with the exception of many waterbird species (due to the absence of wetlands suitable for most waterbirds in the Cooljarloo West Development Envelope). Over a period of 27 years with sampling in most years, 213 species (88%) have been recorded by Bamford Consulting in the general Cooljarloo area (five fish, 10 frogs, 44 reptiles, 132 birds and 22 mammals).

The assemblage includes at least 28 vertebrate species of conservation significance (Table 7). Significant species are discussed further in Section 4.2.2.

Key features of the fauna assemblage expected in the Project Area are:

- Uniqueness: The assemblage is typical of the greater Cooljarloo area and is likely to be well-represented regionally as the sorts of environments present are widespread. During sampling carried out in 2012 and 2013, the fauna species recorded have all been previously found in Cooljarloo/Falcon.
- Completeness: The assemblage is almost complete but lacks a major component; medium sized ("critical weight range") mammals. These have declined across much of southern Australia due to factors such as predation by feral species (particularly the Red Fox) and altered fire regimes (Burbidge and McKenzie 1989). One reptile (the Woma) and several bird species (see Table 7) may also be locally extinct.
- Richness: The assemblage is rich and the Cooljarloo region in general lies in a region recognised for its high reptile species richness in particular (Maryan 2005). The assemblage is also notable for the number of small mammal species.

As a fauna value, the assemblage is almost complete and is rich, but lies in a region know to be rich in fauna biodiversity. The proportional representation of species in the sampling carried out in 2012 and 2013 is examined in Section 4.2.2 where this is compared with data from Cooljarloo and Falcon.

Table 7. Composition of vertebrate fauna assemblage expected to occur within the Cooljarloo region.

Taxon	Number of species expected in Falcon/Cooljarloo	Number of species expected in Cooljarloo West	Number of species recorded in Falcon/Cooljarloo	Number of species recorded in Cooljarloo West
Fish	5	-	5	0
Frogs	10	10	10	9
Reptiles	48	48	44	21
Birds	153	102	132	65
Mammals	25	22	22	12
Total	**241**	**182**	**213**	**107**

4.2.2 Survey Results

The Cooljarloo West trapping results are summarised in Table 8. A total of 4 frog, 13 reptile, five native mammal and one introduced mammal species were trapped along the two transects from 299 captures. Concurrent to the Cooljarloo West survey some additional sampling was conducted across Cooljarloo (North Transect, South Transect and South Mine), and results in these control sites are also presented. Across all surveys, 490 captures were recorded in summer 2012 and 194 captures in winter 2013. A significant proportion of these captures (44%) came from Cooljarloo West with 211 and 116 captures in 2012 and 2013 respectively; roughly proportional with the slightly different trapping effort at Cooljarloo West (720 trap-nights in each survey) compared with trapping effort at reference sites elsewhere in the Cooljarloo region (910 trap-nights in each survey).

Frogs

Five frog species were trapped at Cooljarloo West in 2012/2013, plus an additional four species were recorded opportunistically during the 2010 site inspection or as part of other surveys in the Cooljarloo West area (the Motorbike Frog, Slender Tree Frog, Squelching Froglet, and Gunther's Toadlet). Numbers of captures of frogs and their relative abundance were similar in Cooljarloo West compared with other Cooljarloo sites sampled concurrently, with the Moaning Frog and Sand Frog making up most captures in both areas.

Ten species of frogs have been recorded in Cooljarloo and Falcon (see Appendix 6, table 2), and all are almost certainly present in Cooljarloo West. Most of the frog species require wetlands or damplands to breed (with the exception of the Turtle Frog), but also make extensive use of woodlands throughout the remainder of the year. Several of the frog species have been found to make opportunistic use of wetlands created during mining and earthworks around Cooljarloo.

Reptiles

Thirteen reptile species were trapped at Cooljarloo West (14 species trapped across other Cooljarloo sites sampled concurrently). Including opportunistic records, 21 species were recorded at Cooljarloo West. The Spotted Stone Gecko (*Diplodactylus polyopthalmus*) was recorded at Cooljarloo West during both survey phases. This species is very rarely recorded by BCE at Cooljarloo as it typically occurs amongst the heathlands associated with the lateritic soils of the escarpment to the east. These are the first records at Cooljarloo from dampland heath on the sandplain west of the lateritic uplands, but significantly the captures occurred in an area where there is some laterisation.

There were some differences in the proportional representation of reptile species in the 2012/2013 sampling in Cooljarloo West compared with other Cooljarloo sites sampled concurrently (Table 8). For example, the Western Heath Dragon made up 47% of capture in Cooljarloo West, but only 10% at other Cooljarloo sites. This may reflect a real difference in assemblage composition related to differences in vegetation type. Species recorded at either only Cooljarloo West or only the other Cooljarloo sites were typically caught in small numbers so no conclusions about assemblage composition can be drawn from these.

Fifty-five species of reptiles occur in the region of the Project Area according to the literature, with 45 of these recorded at Cooljarloo (but only 20 at Cooljarloo West where sampling has been less intense). Species found at Cooljarloo but not Cooljarloo West are typically cryptic and/or occur at low densities, such as many of the snakes, and they are almost certainly present at both sites. All other species must be considered likely to occur at Cooljarloo West.

Two species (West Coast Slender Blue-tongue and Bold-striped Lerista) have been found at Falcon but not at Cooljarloo; both are readily found and are therefore almost certainly not present at Cooljarloo. The Slender Blue-tongue was found in the greater Cooljarloo West area during the 2010 site inspection but it was not recorded in the 2012/2013 surveys at Cooljarloo West. This lizard is usually associated with coastal, limestone-rich soils (M. Bamford pers. obs.), so would appear to be at its eastern limit of distribution in the general region and may be absent from the 2012/2013 study areas. The Bold-striped Lerista would also appear to be absent from these study areas. It appears to have a complex local pattern of distribution, as at Falcon it is present in Banksia Low Woodland on sand, while it is absent from what appears to be identical vegetation and soils at Cooljarloo.

Such local patterns of variation are likely to occur among a number of species of reptiles in the area, with the result that even species not found at Cooljarloo after 20 years could be present at Cooljarloo West. Sampling at Cooljarloo has also found that considerable variation in assemblage composition occurs even in uniform vegetation across a few hundred metres. This means that there is a relationship between species richness and sampling location even in uniform vegetation. Species richness does appear to be highest in woodland on sandy soils, reflecting the high proportion of fossorial reptile species that burrow and "swim" through the loose surface sand. The *Banksia* woodlands on sand are likely to be richest in reptiles across Cooljarloo West, with slightly damper environments with heavier

soils being relatively poor in species. However, some of the species in such areas may have restricted distributions in the region.

Mammals

Five native mammal species and one introduced species were trapped at Cooljarloo West (seven species recorded across other Cooljarloo sites sampled concurrently) and, including opportunistic records, seven native and five introduced mammals were recorded overall. During the surveys a high number of Honey Possums and House Mice were recorded in both Cooljarloo West and the other Cooljarloo Site sampled concurrently; for example the Honey Possum accounted for 56% and 38% of mammal captures at Cooljarloo West and other Cooljarloo sites respectively. The lower proportion of Honey Possums at the other Cooljarloo sites was due to few captures in winter 2013, when only four Honey Possums were caught at the other Cooljarloo sites, compared with 31 at Cooljarloo West. This reflects the mobility of Honey Possums as they move around in search of food, and the abundance of the winter flowering *Banksia telmatiaea* at Cooljarloo West. In terms of proportional representation, the small mammal samples were similar between Cooljarloo West and the other Cooljarloo sites, but the absence of the White-tailed Dunnart from Cooljarloo West (with 13 captures at other Cooljarloo sites) suggests that the species is more abundant in the latter area.

Twenty-five mammal species may occur in the Cooljarloo region according to databases and the literature (Appendix 6, table 4). The 23 mammal species recorded at Cooljarloo thus represent a high proportion of the assemblage expected, while the two bat species may well not be present. The list of mammals recorded at Cooljarloo West is smaller than that for Cooljarloo, mainly because no bat surveys have been undertaken there. However, all mammal species recorded at Cooljarloo can be expected to occur at Cooljarloo West because of the overall similarity in vegetation types.

Studies at Cooljarloo have found that the most abundant of the small mammals is the Honey Possum (1647 of a total of 3844 captures of small mammals), compared with the House Mouse (1262 captures), Noodji (749 captures), White-tailed Dunnart (106 captures), Grey-bellied Dunnart (56), Little Long-tailed Dunnart (10), Fat-tailed Dunnart (3), Echidna (3) and Moodit (18). Except for the Echidna, which rarely enters traps, these values give a fair measure of relative abundance and show that the small mammal assemblage is dominated by the nectarivorous Honey Possum and two rodents, with very small numbers of insectivorous dasyurid marsupials. The Grey Kangaroo and Brush Wallaby are the only large, native mammals seen regularly and have both been recorded in Cooljarloo West.

The small mammals vary in abundance both temporally and spatially (BCE and Tiwest unpubl. data). The Honey Possum and House Mouse peak in abundance during years of average to high rainfall, and in the case of the Honey Possum this seems to be linked to heavy flowering of *Banksia* spp. However, the Honey Possum declines in abundance after fire, whereas most other small mammal species (House Mouse, Noodji, White-tailed and Grey-bellied Dunnarts) are most abundant a few years after fire. These variations complicate patterns of distribution. It seems likely that Honey Possums move to where plants are flowering, whereas the Noodji and those dunnarts caught regularly are more or less sedentary, with captures concentrated on sandy soils. Noodji captures are concentrated in areas of heath and very open

Low Woodland but do not occur where the soil is seasonally damp, probably because the species occupies burrows.

From the observations on small mammals at Cooljarloo and Falcon, it is likely that the small mammals are widespread at Cooljarloo West, which has experienced some recent fires but also has large areas of vegetation unburnt for >10 years. Mammal abundance and richness is likely to be lowest in Low Heath and other VSAs where the soils is heavy and at least seasonally waterlogged, but such areas may support large numbers of Honey Possums when plant such as *Banksia telmatiaea* are flowering.

Table 8. Cooljarloo West Trapping Results. Other Cooljarloo refers to North Transect, South Transect and South Mine Transects, sampled at the same time. Sampling effort was 720 trap-nights in each survey at Cooljarloo West, and 910 trap-nights in each survey at other Cooljarloo sites.

Common Name	Species Name	Cooljarloo West 2012 Survey	Cooljarloo West 2013 survey	Other Cooljarloo 2012	Other Cooljarloo 2013
FROGS					
Squelching Froglet	*Crinia insignifera*				1
Moaning Frog	*Heleioporus eyrei*	38	23	21	24
Sand Frog	*Heleioporus psammophilus*	26	2	14	8
Banjo Frog, Pobblebonk	*Limnodynastes dorsalis*	7	11		1
Humming Frog	*Neobatrachus pelobatoides*		5	6	1
Turtle Frog	*Myobatrachus gouldii*		2	1	
REPTILES					
Western Heath Dragon	*Ctenophorus adelaidensis*	23		7	
Western Bearded Dragon	*Pogona minor*	3	3	9	6
Spotted Stone Gecko	*Diplodactylus polyopthalmus*	1	1		
White-spotted Ground Gecko	*Lucasium alboguttatum*	1		2	
Soft Spiny-tailed Gecko	*Strophurus spinigerus*	3		3	
Keeled Legless Lizard	*Pletholax gracilis*	1			
Common Scaly-foot	*Pygopus lepidopodus*			1	
Buchanan's Snake-eyed Skink	*Cryptoblepharus buchananii*			2	
West Coast Ctenotus	*Ctenotus fallens*	7		18	
Jewelled Ctenotus	*Ctenotus gemmula*			1	
South-western Odd-striped Ctenotus	*Ctenotus impar*			6	
Salmon-bellied Skink	*Egernia napoleonis*		1		
West Coast Four-toed Lerista	*Lerista elegans*			5	
Western Worm Lerista	*Lerista praepedita*			3	
Common Dwarf Skink	*Menetia greyii*	3		3	
Dusky Morethia	*Morethia obscura*	1		7	
Sand Goanna	*Varanus gouldii*	1		1	
Southern Blind Snake	*Ramphotyphlops australis*	3			
Gould's Snake	*Parasuta gouldii*	1			
MAMMALS					

Common Name	Species Name	Cooljarloo West 2012 Survey	Cooljarloo West 2013 survey	Other Cooljarloo 2012	Other Cooljarloo 2013
Echidna	*Tachyglossus aculeatus*	1			
Little Long-tailed Dunnart	*Sminthopsis aff. dolichura*	4		3	1
White-tailed Dunnart	*Sminthopsis granulipes*			10	3
Grey-bellied Dunnart	*Sminthopsis griseoventer*		1		1
Honey Possum	*Tarsipes rostratus*	58	31	86	4
House Mouse	*Mus musculus*	27	36	92	28
Noodji/Ash-grey Mouse	*Pseudomys albocinereus*	2		5	1
Moodit/Western Bush Rat	*Rattus fuscipes*				1
TOTAL		**211**	**116**	**306**	**80**
Species Richness	**34**	**20**	**10**	**23**	**13**

4.2.3 Bird Census

Thirty six (36) bird species were recorded along the Cooljarloo West Transects (27 species in 2012 and 18 in 2013) from 456 records (Table 9). In total 65 bird species were recorded from Cooljarloo West including opportunistic records.

The heathland specialist White-cheeked Honeyeater and Tawny-crowned Honeyeater dominated the survey records (34% and 54 % of all records in 2012 and 2013). The Southern Emu-wren, a species rarely recorded at Cooljarloo (due to a preference for dense heath) was observed to be common at Cooljarloo West amongst areas of Dampland Heath. The Dusky Woodswallow and Rufous Songlark were also particularly numerous at Cooljarloo West and may also show a preference for Dampland Heath. Interestingly, the record of the Red-capped Parrot is the first for the Cooljarloo area and represents the northern limit of the species' range.

One hundred and fifty-three bird species are expected to occur in the general Cooljarloo region according to the literature (Table 4; Appendix 6), of which 132 have been observed at Cooljarloo and 50 at Falcon where sampling has been less intense. The total of 153 species includes 46 species considered to be vagrants, most of which have been recorded at Cooljarloo. The mobility of birds means that many species can be recorded occasionally in an area which is not really suitable for them and such records are of no significance.

Bird censussing as part of studies at Cooljarloo have demonstrated that the most abundant species are nectarivores: Brown, Tawny-crowned and White-cheeked Honeyeaters make up 51% of 2566 bird census records, with the Brown Honeyeater alone accounting for 32% of records (M. Bamford and Tiwest unpubl. data). The nectarivores forage on a range of plants, but focus on the several species of *Banksia* present in the area. These *Banksia* species occur in the *Banksia* Low Woodland but also in the heaths and scrub-heaths.

The nectarivores are generally observed where-ever suitable food-plants are flowering, but the Tawny-crowned Honeyeater is largely restricted to heath and the most open of the woodland, while there are other species found only in certain vegetation types. For example, the Southern Emu-wren, White-winged Fairy-wren and Rufous Fieldwren occur only in Low Heath, including early rehabilitation, while the White-breasted Robin and White-browed Scrubwren occur only in scrub-heath and dense, riparian vegetation. Overall, species richness and density tends to be highest on the transition between Low Woodland and scrub-heath or low heath that lies low in the landscape, and particularly where there are riparian elements to the vegetation. The highest species richness and overall density found during bird censussing at Cooljarloo occurs in an area of Riparian Woodland, scrub-heath and adjacent *Banksia* Low Woodland where typical sandy soils on a slope are juxtaposed with a seasonally inundated flat supporting Low Heath on heavier soils. In a single bird survey area of 3ha, the number of species observed regularly exceeded 10, with overall density of about 10 birds/ha. In comparison, in Low Woodland and Low Heath, the number of species is usually <5 and density <5/ha (M. Bamford and Tiwest unpubl. data). These observations at Cooljarloo suggest that the margins of *Banksia* Woodlands and Low Heaths may be important for bird richness and diversity.

Table 9. Cooljarloo West Bird Census Results.

Common Name	Species Name	Total Records Summer 2012 Survey	Total Records Winter 2013 survey
Emu	*Dromaius novaehollandiae*		1
Crested Pigeon	*Ocyphaps lophotes*	3	
Button-quail sp.	*Turnix sp.*		2
Galah	*Eolophus roseicapillus*	2	
Australian Ringneck	*Barnardius zonarius*	2	
Red-capped Parrot	*Purpureicephalus spurius*		2
Elegant Parrot	*Neophema elegans*		13
Horsfield's Bronze-Cuckoo	*Chalcites basalis*	2	1
Splendid Fairy-wren	*Malurus splendens*	12	
White-winged Fairy-wren	*Malurus leucopterus*	2	
Variegated Fairy-wren	*Malurus lamberti*	2	
Southern Emu-wren	*Stipiturus malachurus*	22	
Fairy-wren sp.	*Malurus sp.*	3	
White-browed Scrubwren	*Sericornis frontalis*	1	
Rufous Fieldwren	*Calamanthus campestris*	3	
Western Gerygone	*Gerygone fusca*		1
Yellow-rumped Thornbill	*Acanthiza chrysorrhoa*		5
Western Thornbill	*Acanthiza inornata*	20	
Striated Pardalote	*Pardalotus striatus*		2
White-fronted Honeyeater	*Purnella albifrons*	2	
Western Wattlebird	*Anthochaera lunulata*	2	3
Red Wattlebird	*Anthochaera carunculata*	1	1
Tawny-crowned Honeyeater	*Glyciphila melanops*	10	50

Common Name	Species Name	Total Records Summer 2012 Survey	Total Records Winter 2013 survey
Brown Honeyeater	*Lichmera indistincta*	35	10
White-cheeked Honeyeater	*Phylidonyris niger*	81	52
Varied Sittella	*Daphoenositta chrysoptera*	3	
Black-faced Cuckoo-shrike	*Coracina novaehollandiae*	1	7
White-winged Triller	*Lalage sueurii*	4	
Rufous Whistler	*Pachycephala rufiventris*	7	
Crested Bellbird	*Oreoica gutturalis*	4	
Black-faced Woodswallow	*Artamus cinereus*	2	4
Dusky Woodswallow	*Artamus cyanopterus*		29
Willie Wagtail	*Rhipidura leucophrys*	5	
Rufous Songlark	*Cincloramphus mathewsi*	33	
Silvereye	*Zosterops lateralis*	3	1
Tree Martin	*Petrochelidon nigricans*		5
Total		**267**	**189**

4.2.4 Fauna community comparisons of the VSAs

The average capture rates of the pitfall-trapped taxon categories (explained in section 3.7) are shown in Figure 9.

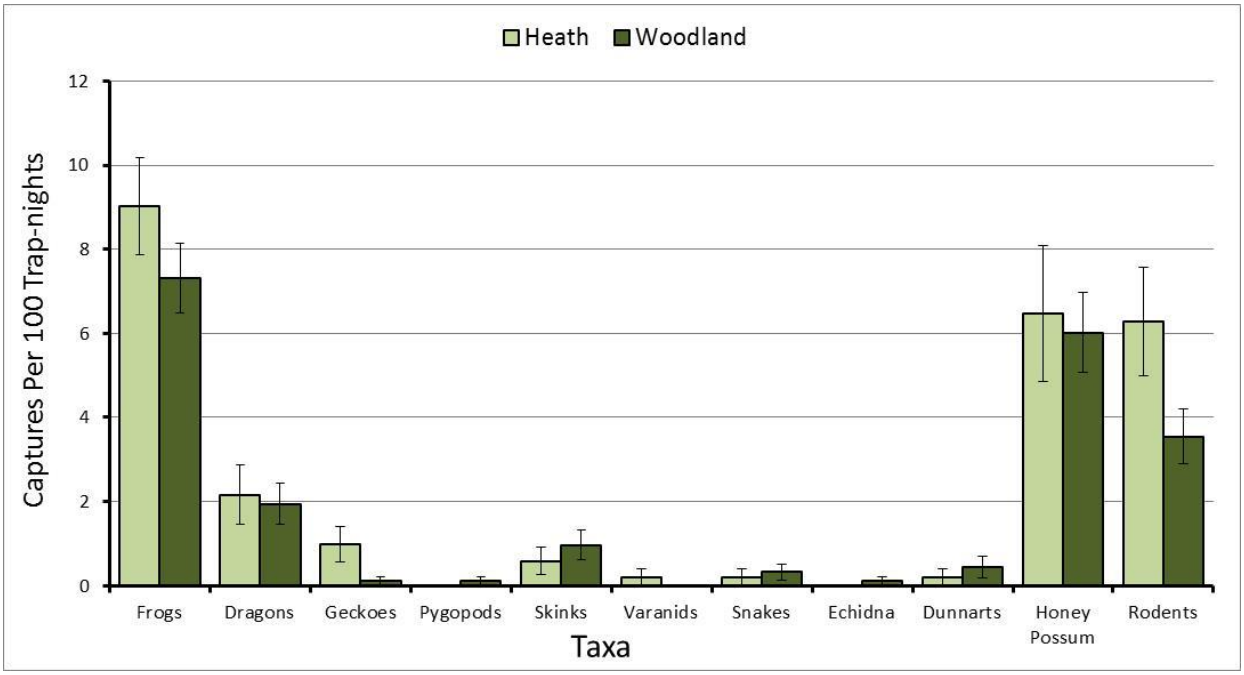

Figure 9. Mean (± SE) standardised capture rates (captures per 100 trap-nights) for taxa recorded in the heath and woodland VSAs.

The pitfall-trapped fauna communities of the heath and woodland VSAs were very similar (ANOSIM, *R* = -0.014), with no statistically significant difference between them (ANOSIM, *P* = 0.714). Nevertheless, the taxa that contributed to any (non-significant) differences were investigated with SIMPER. The three taxa that contributed most to the differences were frogs, honey possum and rodents (all more abundant in heath and all contributing to >22% of the differences). This can also be seen, graphically, in Figure 9. The reasons for the preference for heath by these taxa are likely to be different for each. The heath VSA generally occurred in the lower-lying clay/loam soils landscape; thus the location at which rainwater naturally pools and, therefore, a point of congregation for frogs dependent on this resource. The diversity and density of flowering plants appeared to be higher in the heath VSA and it is probable that this supports an increased density of some fauna through the provision of nectar (for honey possums) and seed (for rodents) resources. The House Mouse, responsible for almost all rodent captures, typically favours slightly mesic (and therefore usually low-lying) environments in the Cooljarloo area,

The average standardised abundances of the bird taxon categories (explained in section 3.7) are shown in Figure 10.

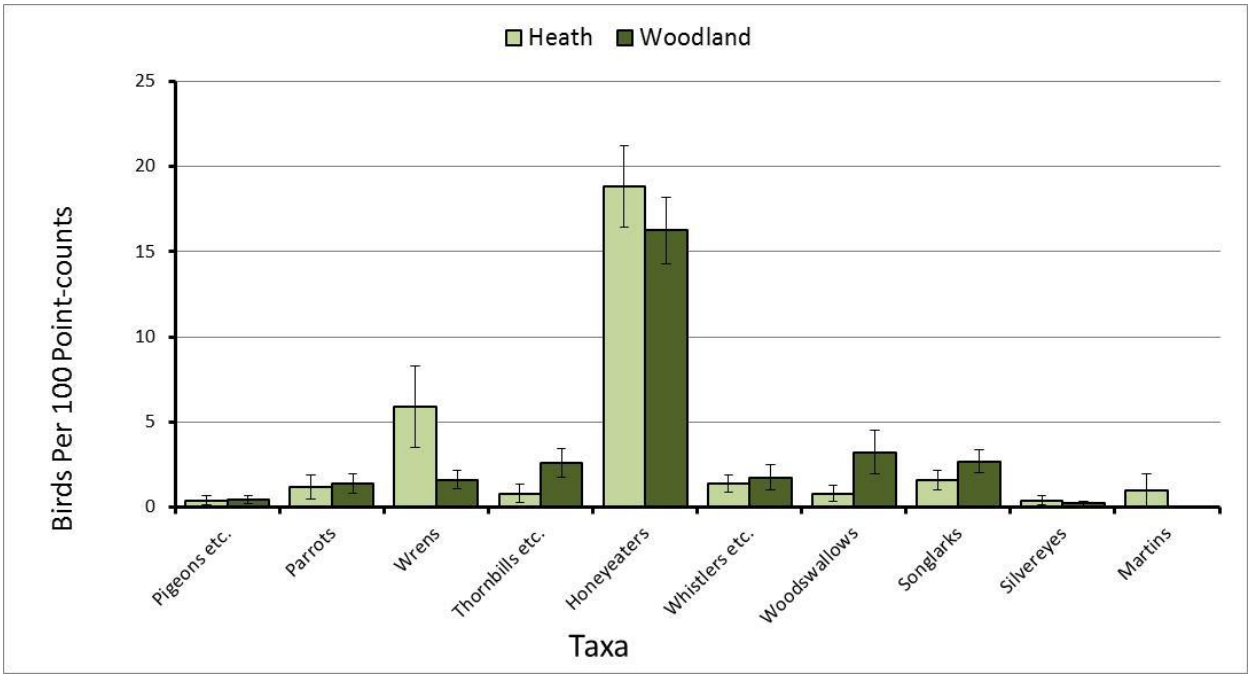

Figure 10. Mean (± SE) standardised abundance (birds per 100 point-counts) for taxa recorded in the heath and woodland VSAs.

The avifauna communities of the heath and woodland VSAs were very similar (ANOSIM, *R* = -0.020), with no statistically significant difference between them (ANOSIM, *P* = 0.834). Nevertheless, as for the pitfall data, the bird taxa that contributed to any (non-significant) differences were investigated with SIMPER. The three taxa that contributed most to the differences were honeyeaters, wrens and songlarks (the first two more abundant in heath, songlarks more abundant in the woodland, and all contributing to >9% of the differences). Givem the diversity of flowering plants, the heath propbably provides greater

foraging resources (nectar) for the honeyeaters and, structurally, suits the wren taxa (that show a preference for low, dense vegetation). The preference of songlarks to use open areas (between trees) in the woodland explains their greater abundance in this VSA.

4.2.5 Species of conservation significance

Details on species of conservation significance recorded or expected to occur at Cooljarloo West are summarised in Table 10. Included in the assemblage of significant fauna are two freshwater fish, one frog, five reptile, 18 bird and five mammal species. Seven species of conservation significance were recorded at Cooljarloo West:

1. Spotted Stone Gecko (*Diplodactylus polyophthalmus,* CS3);
2. Rainbow Bee-eater (*Merops ornatus*, CS1);
3. Carnaby's Black-Cockatoo (*Calyptorhynchus latirostris*, CS1);
4. Rufous Fieldwren (*Calamanthus campestris montanellus*, CS2);
5. Crested Bellbird (*Oreoica gutturalis gutturalis*, CS2);
6. Southern Emu-wren (*Stipiturus malachurus*, CS3);
7. Brush Wallaby (*Macropus irma*, CS2);

Further information on species that might be present, including observations from the field surveys, is presented below. Note that species extinct in the region and that may have been present on the basis of broad patterns of distribution have not been included in the following descriptions except where there are some recent records within about a 50 km radius, suggesting that the species may still be regionally present even if not currently present at Cooljarloo West.

4.2.6 Fish

Conservation Significance Level 3

Western Minnow *Galaxias occidentalis*

Western Pygmy Perch *Edelia vittata*

Both these species are endemic to the South-West and are close to the northern limit of their range in Mullering Brook, with the populations probably being small and isolated. Although unlikely to occur in Cooljarloo West itself, they are present in nearby wetlands and could be exposed to indirect impacts.

4.2.7 Frogs

Conservation Significance Level 3

Squelching Froglet *Crinia insignifera*

The Squelching Froglet occurs only on the Swan Coastal Plain as far south as Busselton but is abundant within its range. The population in the Cooljarloo area is of significance as it is the extreme northern extent of the species' range and actually represents a range extension from Gingin, with the most northerly WA Museum records from that area (Tyler *et al.* 2000). It is possible that literature records of the Bleating Froglet *C. pseudinsignifera*, not recorded during Cooljarloo surveys, actually refer to the Squelching Froglet.

4.2.8 Reptiles

Conservation Significance Level 1

South-West Carpet Python *Morelia spilota imbricata*

This large snake is listed under Schedule 4 (Other Specially Protected Fauna) of the WA Wildlife Conservation Act and as Priority 4 by the DPaW. It occurs in the general region, with a specimen recently run over on Brand Highway between the two Cataby Roadhouses and several found in the Cooljarloo North Mine area over two decades. One individual was recorded during the Cooljarloo surveys in 2012 from the Falcon area (active during warm humid conditions). It is almost certainly present in Cooljarloo West. There is some indication of more recent sightings in response to fox control. It is vulnerable to clearing operations and to roadkill because it is large and slow-moving. Personnel need to be aware of the significance of this snake so it is not inadvertently killed.

Woma *Aspidites ramsayi* (South-West)

This large snake is listed under Schedule 4 (Other Specially Protected Fauna) of the WA Wildlife Conservation Act and as Priority 1 by the DPaW. It may locally extinct in the Project Area, but there were several specimens seen in the Badgingarra/Watheroo region in the 1980s, so there is a possibility that it persists. It may have been impacted by foxes, so the fox control sponsored by Tiwest / Tronox may allow remnant populations to recover. It is vulnerable to clearing operations and to roadkill

because it is large and slow-moving, and personnel need to be aware of the significance of this snake so it is not inadvertently killed.

Conservation Significance Level 2

Jewelled Ctenotus *Ctenotus gemmula*

The Jewelled Ctenotus is listed as Priority 3 by the DPAW and has been recorded in *Banksia* Low Woodland on sandplain at both Cooljarloo and Falcon. Its distribution is very patchy. There is extensive suitable habitat in Cooljarloo West so it is almost certainly present.

Black-striped Snake *Neelaps calonotos*

This small snake is listed as Priority 3 by the DPaW and has been recorded in *Banksia* Low Woodland on sandplain at Cooljarloo. It has not been found at Falcon but is a cryptic species; there is suitable habitat at Falcon and at Cooljarloo West so it is almost certainly present.

Conservation Significance Level 3

Bold-striped Lerista *Lerista christinae*

This small, fossorial skink has a patchy distribution from Perth to the Mt Adams area inland from Dongara, and in all sampling for Tiwest (now Tronox) around the Cooljarloo/Falcon operations, has been recorded only in *Banksia* Low Woodland at Falcon. It possibly occurs in woodland close to the transition with Low Heath on seasonally damp flats. It was not recorded at Cooljarloo West but given the patchiness of its local distribution it may be present.

Speckled Stone Gecko *Diplodactylus polyophthalmus*

This gecko appears to have a patchy distribution on the coastal plain north of Perth and was suspected of representing a species complex. This has recently been resolved (Doughty and Oliver 2013), and the population in the Cooljarloo area has been confirmed as *D. polyophthalmus* at the northern limit of its range. At Cooljarloo it occurs mainly in the heath on laterite to the east, with the Cooljarloo West records unexpected, but associated with small areas of laterisation.

4.2.9 Birds

Conservation Significance Level 1.

Migratory species: Fork-tailed Swift, Eastern Great Egret, Common Sandpiper, Common Greenshank, Red-necked Stint, Sharp-tailed Sandpiper, Rainbow Bee-eater.

With the exception of the Swift and the Bee-eater, these are waterbirds that can be expected only as vagrants or otherwise in very small numbers. For example, a single Common Sandpiper was observed regularly on the Cooljarloo South Mine dredge pond when this was adjacent to Cooljarloo Road in the late 1990s and early 2000s. Suitable wetlands are not present in Cooljarloo West but do occur nearby (e.g. Emu Lakes).

The Fork-tailed Swift is almost entirely aerial when in Australia and while not yet recorded during the studies for Tronox, it is likely to be an intermittent visitor. Being an aerial species it is little-affected by regionally small areas of ground disturbance.

The Rainbow Bee-eater is seen regularly in spring and summer at Cooljarloo and Falcon and breeds in the area. It is actually attracted by ground disturbance, often digging its nest-burrows in low banks around disturbed areas. It was recorded during the Cooljarloo West surveys and is almost certainly a regular breeding visitor to the area. While of high conservation significance, it is widespread and often favours disturbed environments.

Peregrine Falcon *Falco peregrinus*

The Peregrine Falcon is classified as Specially Protected Fauna under Schedule 4 of the *Wildlife Conservation Act*. This species is widespread in a range of environments across Australia but is often associated with cliff-lines or scattered tall trees which provide it with nest sites. It has not been observed at Cooljarloo or Falcon although there was an early (1991), unsubstantiated report by a member of staff. Despite this, it could be a vagrant in the Cooljarloo West area.

Carnaby's Black-Cockatoo *Calyptorhynchus latirostris*

Listed as Endangered under the EPBC Act and the *WA Wildlife Conservation Act 1950*, Carnaby's Black-Cockatoo is common around Cooljarloo and Falcon, with non-breeding flocks seen. Observations have been recorded opportunistically on every field trip since 1986, and a consistent pattern has emerged. Numbers tend to be high in winter, with regular counts of 250-300 birds (August 2008, 2011, 2012 and July 2013). These are likely to be birds dispersing north towards breeding grounds. Counts in late spring/summer are usually much lower (<50 birds), but there are records of 150 in November 2003 and 100 in December 2008.

The species is known to breed in the hollows of large trees along Cataby Brook, just south of Cooljarloo, and there is potential breeding habitat (large Marri trees) along Mullering Brook east of the Brand Highway (Figure 11). This species was recorded from Cooljarloo West and is likely to be a regular foraging visitor in large numbers. There do not appear to be any large trees suitable for nesting or roosting, however a large roost (at least 100 birds) was recorded outside the Project Area during July 2013 near Mullering Brook (352617E, 6606727N). This is on Mullering Farm and the birds were roosting in trees planted by Tronox. Carnaby's Black-Cockatoo forages largely on the seeds of Proteaceae, particularly *Banksia* spp. Detailed assessments of the value of foraging habitat in Cooljarloo West were undertaken and are presented below (Section 4.4).

Western Ground Parrot *Pezoporus flaviventris*

Listed as Critically Endangered under the EPBC Act and as Critically Endangered under the WA *Wildlife Conservation Act,* the range of the Western Ground Parrot once extended from north of Perth to Esperance, but the species was until recently considered to be restricted to Waychinicup, Fitzgerald River and Cape Arid National Parks where the population is <150 individuals. In the last 10 years, however, there have been several unconfirmed sightings in the Jurien/Leeman/Badgingarra/Mt Adams

area, including one report near the intersection of Wongonderrah Road and Brand Highway, just north of Cooljarloo, and one between Cervantes and Jurien, west of Cooljarloo West. The Western Ground Parrot occurs in Low Heath and is sensitive to fire regime changes and introduced predators. Some suitable vegetation is present in Cooljarloo West but repeated surveys using techniques recommended by DPaW (Section 3.3.7) have failed to locate the species in the area.

Conservation Significance Level 2.

Australian Bustard *Ardeotis australis*

The Australian Bustard is listed as Priority 4 by the DPaW and Near Threatened by Garnett and Crowley (2000). This species is a large, ground-dwelling bird known to occur in open or lightly-wooded country in Australia (extinct in south-eastern Australia) and southern New Guinea. It is nomadic and may range over very large areas, largely dependent on rainfall and hence food availability. It appears to be a summer visitor to the Cooljarloo area, as one or two birds were seen in most years when summer surveys were carried out in the late 1980s and early 1990s. It is therefore likely to be an occasional summer visitor in small numbers to Cooljarloo West.

Rufous Fieldwren *Calamanthus campestris montanellus*

The Wheatbelt sub-species of the Rufous Fieldwren is listed as Priority 4 by the DPaW because it has lost much of its habitat due to clearing for agriculture. It is common in Low Heaths of Cooljarloo and Falcon, both on seasonally damp flats and on the laterite slopes in the east. It was observed in Low Heath at Cooljarloo West.

Crested Bellbird *Oreoica gutturalis gutturalis*

The Wheatbelt sub-species of the Crested Bellbird is listed as Priority 4 by the DPaW because it has lost much of its habitat due to clearing for agriculture. It is common in *Banksia* Low Woodland of Cooljarloo and Falcon, and was observed in Low Woodland at Cooljarloo West.

Conservation Significance Level 3.

The Square-tailed Kite, Southern Emu-wren, Scarlet Robin and White-breasted Robin are of local conservation significance and all have declined in areas of clearing and development, such as around Perth (DEP 2000). The Square-tailed Kite is an uncommon bird of prey that is a winter visitor in small numbers to the Low Heaths of Cooljarloo and Falcon. It probably also forages over the Low Heaths of Cooljarloo West. The Southern Emu-wren is also an uncommon species and seems to occur in only small numbers in Low Heaths of Cooljarloo and Falcon. Its presence in the region was not confirmed until 2005 and it was recorded at Cooljarloo West. The Scarlet Robin is at the northern extreme of its range at Cooljarloo and was recorded only in the mid-1990s, in an area of rehabilitation that was effectively an open woodland of eucalypts. It would appear to be only a vagrant in the area naturally, and that would also apply to Cooljarloo West. In contrast, the White-breasted Robin is locally common but restricted to Scrub-Heaths and other dense vegetation around damplands and wetlands. It has been recorded only at Cooljarloo but this includes records around Emu Lake, so it is probably present in suitable vegetation at Cooljarloo West.

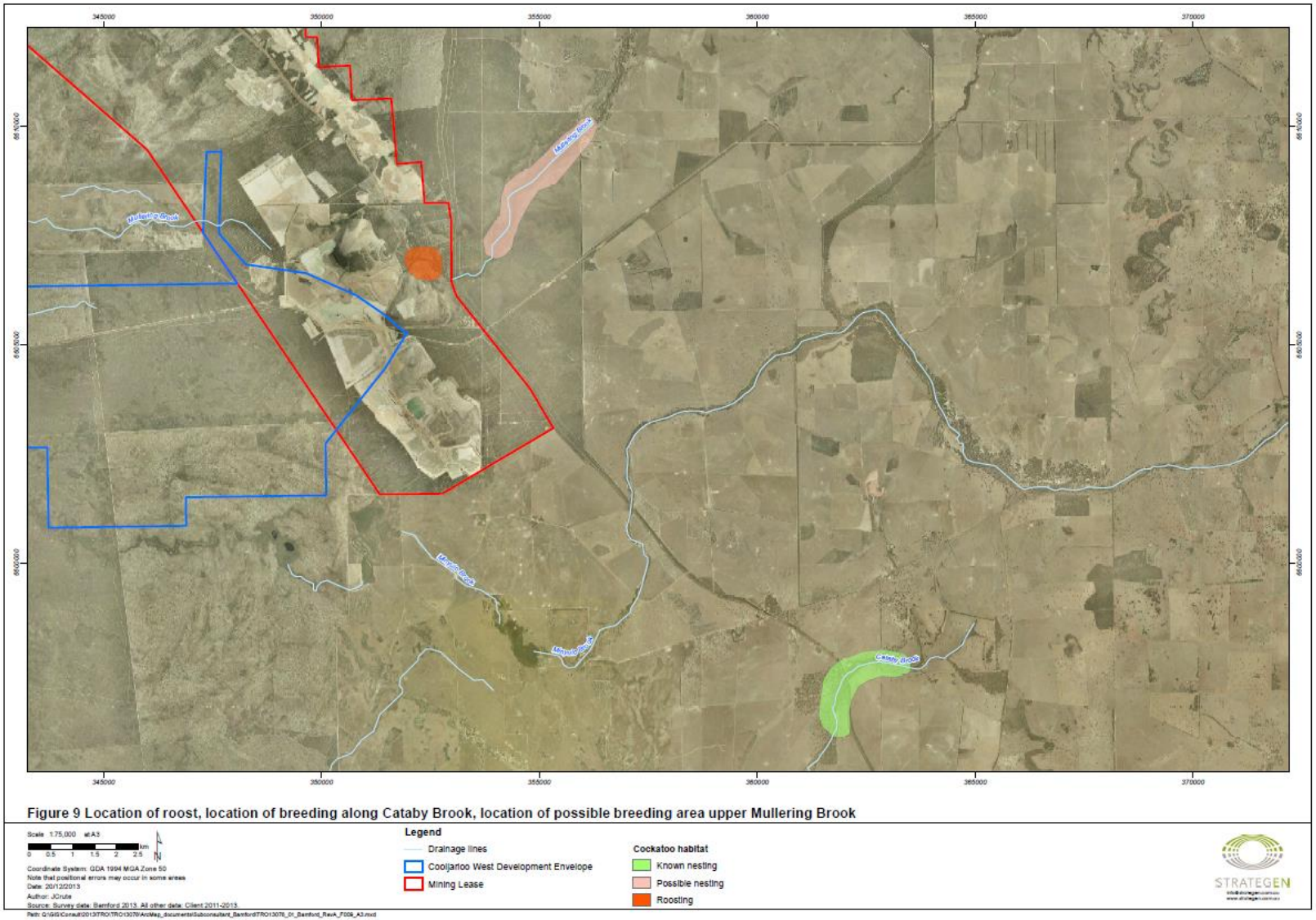

Figure 11. Carnaby's Black-Cockatoo; locations of roost, breeding area along Cataby Brook and possible breeding area Mullering Brook east.

4.2.10 Mammals

Conservation Significance Level 2

Quenda *Isoodon obesulus*

Listed as Priority 5 by the DPaW and is of concern because of a great contraction in range due to fox predation and clearing of habitat. A translocated population is being established in Nambung National Park, near Cervantes, and if this population is successful it could spread eastward through Cooljarloo West, where dense vegetation around damplands and wetlands provides ideal habitat. Currently the species is considered locally extinct in the greater Cooljarloo area.

Tammar *Macropus eugenii*

Listed as Priority 5 by the DPAW and is of concern because of a great contraction in range due to fox predation and clearing of habitat. A translocated population is being established in Nambung National Park, near Cervantes, and an animal seen in dense, riparian vegetation at Cooljarloo in December 2006 was probably one of these specimens. Otherwise the species is considered locally extinct in the greater Cooljarloo area.

Brush Wallaby *Macropus irma*

Listed as Priority 5 by the DPAW and is of concern because of a contraction in range due to fox predation and clearing of habitat. The Brush Wallaby is still seen regularly around Cooljarloo and Falcon, and was recorded from Cooljarloo West. Sightings appear to be more regular since fox control was implemented in the region. The Brush Wallaby favours dense, moderately low vegetation such as the understorey in Low Woodland and Scrub-Heath.

Conservation Significance Level 3

The Brushtail Possum and Western Freetail Bat both appear to be uncommon in the region. The Possum has contracted in range and while still common in parts of the South-West, it once occurred across much on the Murchison and Goldfields. There is a population around Dandaragan and one record (a roadkill) near the mine offices of Tronox (early 1990s). There appears to be no resident possums around Cooljarloo and Falcon, but the species may be an occasional visitor and has the potential to recolonise the area as a result of fox control. The Western Freetail-Bat (*Mormopterus* sp. 4, population O) is part of a complex under taxonomic review. The status and distribution of the taxon that may be present in the Cooljarloo area is unknown.

Table 10. Conservation status of significant fauna species expected to occur (based on desktop review and field investigations). See Appendix 2 for explanation of status codes.

Common Name	Species Name	Conservation Status			Recorded at Cooljarloo	Recorded at Cooljarloo West	Expected status in Project Area
		CS1	CS2	CS3			
FISH							
Western Minnow	*Galaxias occidentalis*			CS3	X		Resident / Temporary Resident
Pygmy Perch	*Edelia vittata*			CS3	X		Resident / Temporary Resident
FROGS							
Squelching Froglet	*Crinia insignifera*			CS3	X		Resident
REPTILES							
Jewelled Ctenotus	*Ctenotus gemmula*		P3		X		Resident
Woma, Ramsay`s Python	*Aspidites ramsayi*	S1, S4	P1				Probably locally extinct
Black-striped Snake	*Neelaps calonotos*		P3		X		Resident
Carpet Python	*Morelia spilota*	S4	P4		X		Resident
Speckled Stone Gecko	*Diplodactylus polyophthalmus*			CS3	X	X	Resident
Bold-striped Lerista	*Lerista christinae*			CS3	X		Resident
BIRDS							
Carnaby's Black-Cockatoo	*Calyptorhynchus latirostris*	En, S1			X	X	Regular visitor
Peregrine Falcon	*Falco peregrinus*	S4					Irregular visitor
Fork-tailed Swift	*Apus pacificus*	Mig, S3					Irregular visitor
Rainbow Bee-eater	*Merops ornatus*	Mig, S3			X	X	Regular visitor
Migratory Waterbirds	See Scolopacidae in Appendix 6	Mig, S3			X		Irregular visitors
Western Ground Parrot	*Pezoporus flaviventris*	Cr, Mig					Possible resident but may be locally extinct
Australian Bustard	*Ardeotis australis*		P4		X		Irregular visitor
Rufous Fieldwren	*Calamanthus campestris*		P4		X	X	Resident

Common Name	Species Name	Conservation Status			Recorded at Cooljarloo	Recorded at Cooljarloo West	Expected status in Project Area
		CS1	CS2	CS3			
Crested Bellbird	*Oreoica gutturalis*		P4		X	X	Irregular visitor
Square-tailed Kite	*Lophoictinia isura*			CS3	X		Regular visitor
Southern Emu-wren	*Stipiturus malachurus*			CS3	X	X	Resident
Scarlet Robin	*Petroica multicolor*			CS3	X		Resident
White-breasted Robin	*Eopsaltria georgiana*			CS3	X		Resident
Mammals							
Chuditch	*Dasyurus geoffroii*	Vul, S1					Locally extinct
Tammar Wallaby	*Macropus eugenii*		P5		X		Probably locally extinct[1]
Brush Wallaby	*Macropus irma*		P4		X	X	Resident
Quenda	*Isoodon obesulus*		P5				Locally extinct
Brushtail Possum	*Trichosurus vulpecula*			CS3	X		Irregular visitor
Western Freetail-Bat	*Mormopterus sp 4.*			CS3	X		Irregular visitor

1. Single specimen observed in 2006 was probably an animal released in Nambung National Park as part of a trial relocation project and no further sightings have been made.

4.3 Summary of species of conservation significance

Significant species expected to occur within the Project Area include two freshwater fish, one frog, six reptile, 13 bird and six mammal species. Of greatest interest, because it is of high level of conservation significance and may be present regularly, is the Carnaby's Black-Cockatoo (extensive evidence of foraging and visits the Project Area in large numbers to forage). There is however, no evidence of roosting sites or of individuals roosting within the Project Area. The Western Ground Parrot would be of great interest if present, but surveys have failed to detect it, while other species that are present or almost certainly present are regionally common and occur at low densities, with the result that relatively small areas of impact are of low significance (e.g. Crested Bellbird, Rufous Fieldwren, Brush Wallaby).

4.4 Black-Cockatoo values of Cooljarloo West

4.4.1 Potential foraging value

It is apparent that there is considerable variation in tree density and community composition in *Banksia* Woodland, both in the general Cooljarloo West area and also throughout the extent of this vegetation type. *Banksia* Woodland may vary from diverse areas (with multiple tree species) with high tree densities and a closed canopy to monocultures (of a single tree species) with a low tree density and a very open canopy. As a result, the value of *Banksia* Woodland to black-cockatoos, with respect to the provision of food, may also vary widely. The foraging value of the Cooljarloo West area was assessed relative to the surrounding lands. Distinction was made between two vegetation types: banksia woodland (VSA 2) and heath (VSA 1).

On average, there were 374 ± 41SE potential forage trees per hectare in the woodland of the Project Area, this was just over half the density of reference sites (711 ± 77SE potential forage trees per hectare). The average density of each forage species is shown in Figure 12. The most common species were *Banksia attenuata* and *B. menziesii*, together making up greater than 92% of all potential forage trees counted.

The overall difference in density between the project and reference area woodland was statistically significant (MANOVA, $F_{6,80} = 5.65$, $P < 0.001$) and attributable to the individual densities of *B. attenuata*, *B. ilicifolia*, *B. menziesii* and *Eucalyptus todtiana* (individual ANOVAs, $F_{1,85} > 4.14$, $P < 0.045$). This can also be seen, graphically, in Figure 12. There was no statistical difference in the densities of *B. prionotes* and *E. rudis* in the woodland of the control and reference areas.

On average, there were 74 ± 35SE potential forage trees per hectare in the heath of the Project Area and 16 ± 7SE potential forage trees per hectare in the reference area heath. Individual species densities are shown in Figure 12. There was no significant statisfical difference in the potential forage tree density of the Project Area and reference heath (MANOVA, $F_{5,32} = 0.88$, $P = 0.508$). Densities of another species, *Banksia telmatiaea*, were not calculated as there was no evidence of foraging on the fruit of his low shrub that is widespread in heaths at Cooljarloo West and elsewhere in the region. However, the Black-Cockatoos occasionally target the flowers of this species in winter, presumably extracting nectar. This sort of foraging was very patchy. In winter 2013 there was an area of over 1ha where most inflorescences had been torn apart, but in the same period there was no such foraging evidence on the same species at Cooljarloo West.

Banksia woodland provides more potential foraging trees than heath, and is the more widespread VSA. Across the area mapped in Figure 4, there is an area of 23055 ha of Banskia woodland (VSA 2), of which 3693 ha (16%) lie within the Cooljlaroo West Development Envelope.

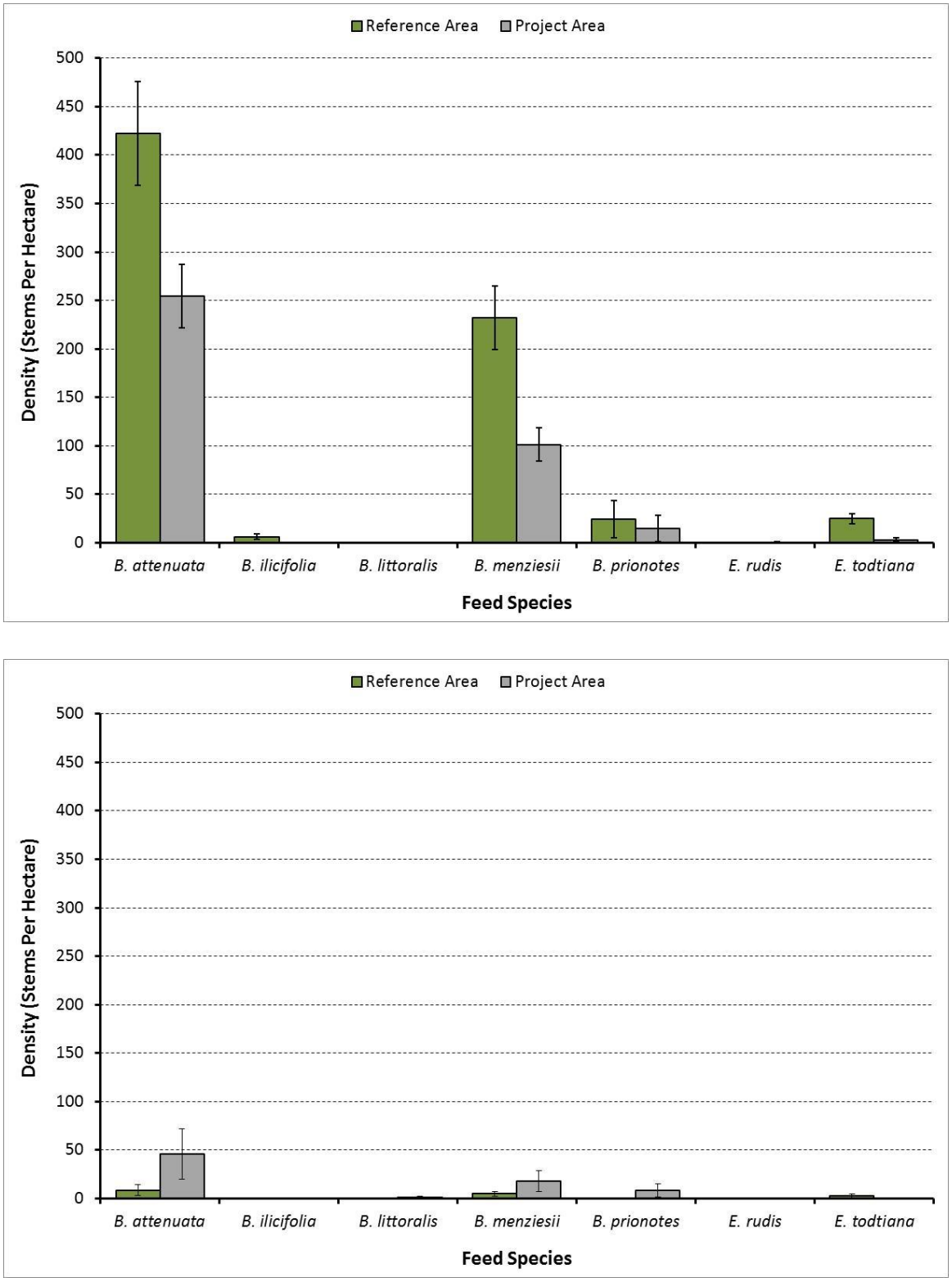

Figure 12: Average (± standard error) density of potential black-cockatoo forage trees in woodland (top graph) and heath (bottom graph) within the reference (green bars) and project (grey bars) areas

4.4.2 Actual foraging activity

Approximately 10-12% of trees in *Banksia* Woodland in the Cooljarloo West region had been foraged by black-cockatoos. The percentage of trees (for woodland sites only) that had evidence of foraging by black-cockatoos is shown for the project and reference areas in Table 11. There was no significant difference in the average density of actual foraged trees of the project (41.9 ± 7.6SE trees per hectare) and reference (52.7 ± 8.6SE trees per hectare) areas (Students t-test, t_{85} = 0.921, P = 0.360).

The average density of each age-class of foraged trees in the woodland is shown in Figure 13. There was no significant difference in the density of each age-class of actual forage trees in project and reference areas (MANOVA, $F_{3,83}$ = 1.255, P =0.295).

Four tree species had signs of black-cockatoo feeding, with foraging evidence found mostly under *B. attenuata* (72% of all foraged trees; all data pooled), and *B. menziesii* (25%), *B. prionotes* (1%) and *E. todtiana* (2%) making up the remainder. The average density of each species of foraged tree in the woodland is shown for project and reference areas in Figure 14. There was no significant difference in the use of tree for foraging at these sites (MANOVA, $F_{4,82}$ = 2.117, P =0.086).

The most important conclusion from these data is that while the density of primary foraging plants in woodland (*B. attenuata* and *B. menziesii*) is significantly lower at Cooljarloo West than in reference areas elsewhere in the Cooljarloo region, the actual intensity of foraging on an area basis is the same (i.e. it is independent of tree density, at least within the range of tree densities found across the sites).

Table 11. Percentage of trees that had evidence of black-cockatoo foraging in woodland within the project and reference areas.

Location	Age of Foraging Signs			
	Recent	Intermediate	Old	Any
Project Area	0.0 0.00%	2.4 ± 1.08%	11.8 ± 2.46%	11.8 ± 2.46%
Reference Area	1.4 ± 0.67%	1.7 ± 0.58%	9.2 ± 2.16%	10.7 ± 2.17%

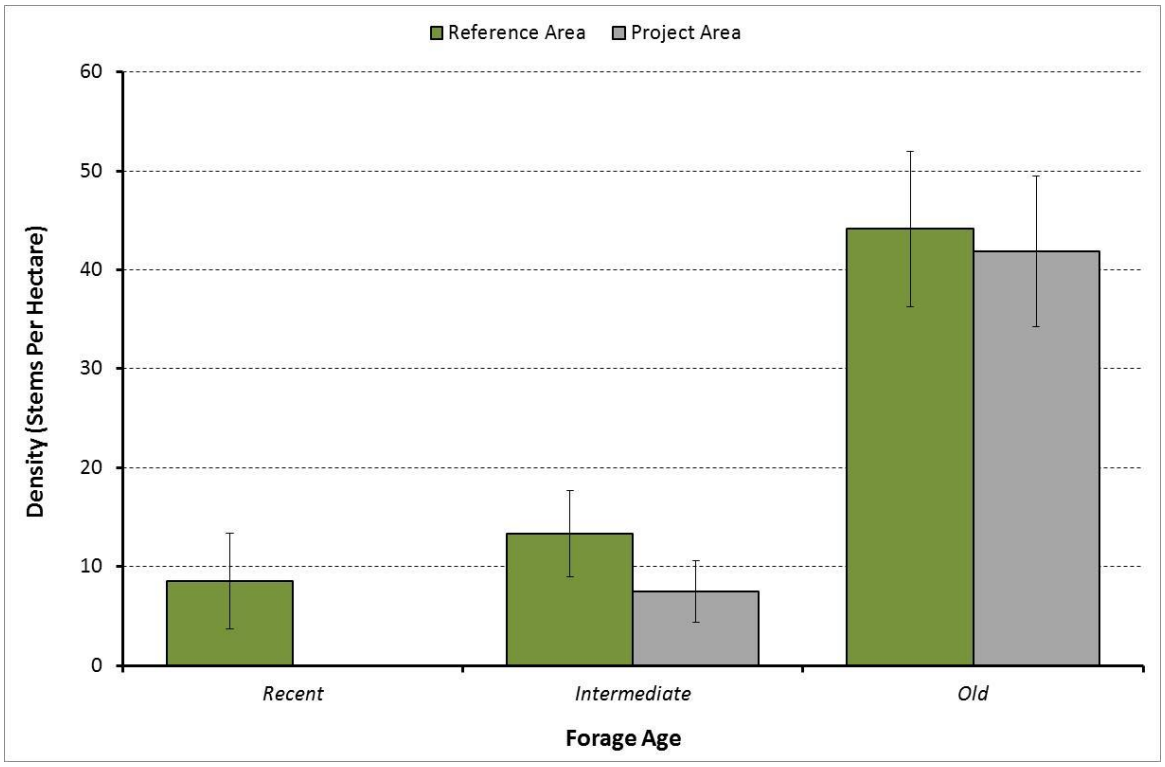

Figure 13: Average (± standard error) density of each age-class of actual black-cockatoo forage trees in woodland within the reference (green bars) and project (grey bars) areas

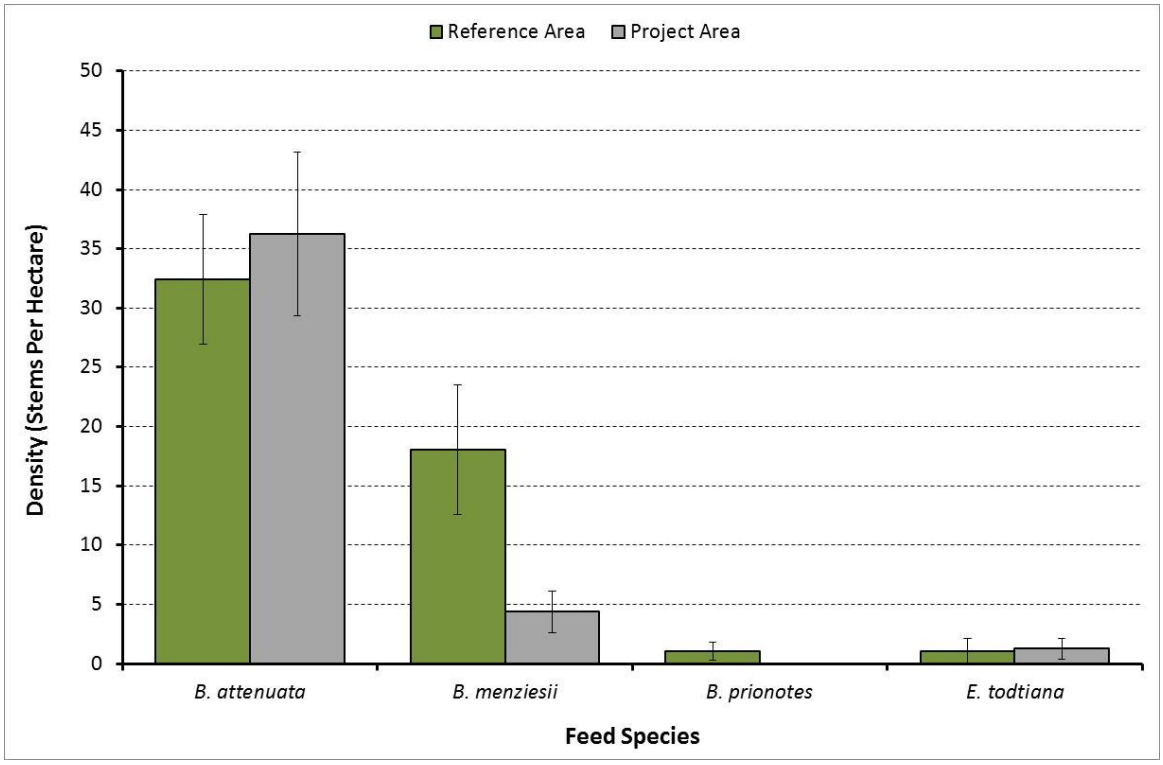

Figure 14: Average (± standard error) density of each species of actual black-cockatoo forage trees in woodland within the reference (green bars) and project (grey bars) areas

4.4.3 Conclusions

In the *Banksia* Woodland and heath of the Cooljarloo West area there was considerable variation in the density of potential black-cockatoo foraging trees. Woodland within the proposed Cooljarloo West Project Area had a significantly lower potential forage-tree density than surrounding reference areas. The woodland was dominated by two potential feed species: *B. attenuata*, and *B. menziesii*. For heath vegetation, the potential forage-tree density was similar in both the project and reference areas.

Despite the greater potential feeding resource in the control sites, both the project and reference areas had a similar density of trees with actual evidence of black-cockatoo foraging. The majority of foraging was on *B. attenuata*. The similar density of actual foraging despite the difference in tree density is probably an artefact of the birds' behaviour, as they tend to move quickly through an area while foraging. They may therefore be able to re-visit areas of high tree density more often, although it is not clear if this is the case. On the basis of density of foraging trees, the woodlands of the Cooljarloo West area are of similar value for black-cockatoos as nearby woodlands even where these have a higher density of potential forage trees. Higgins (1999, citing work by Dr. D. Saunders) reports that breeding Carnaby's Black-Cockatoos will forage up to 12.1 km from their nest, so the Cooljarloo West area is probably outside the foraging range from known nesting sites.

No roosting activity was recorded in the area, and the Project Area did not support the tree species known to be used by black-cockatoos for breeding. However, a large Carnaby's Black-Cockatoo roost was recorded outside the Project Area during July 2013 near Mullering Brook (352617E, 6606727N). Over 100 individuals were estimated to be using the roost over consecutive nights. The roost was situated adjacent to Mullering Brook and included both native *Eucalyptus rudis* trees (along the brook) and planted Eucalypts within Mullering Farm. It is highly likely that birds roosting in this area forage at Cooljarloo West, only 3 km to the west.

4.5 Patterns of biodiversity

Patterns of biodiversity can be interpreted from information on significant species and the characteristics of the VSAs described above, although intensive field investigations are required to provide detailed information. Analysis of long-term records from Cooljarloo (Bamford *et al.* 2010) found that patterns of distribution of individual species were complex and varied over time. Patterns relevant to impact assessment are:

- Fauna assemblage at Cooljarloo West has a similar composition to that found at Cooljarloo (see Table 8); however, Cooljarloo West does include some sandplain heath specialist species.
- Some heath specialist species (such as the Southern Emuwren, Whitewinged Fairy-wren, Rufous Fieldwren and the Spotted Stone Gecko *Diplodactylus polyopthalmus*) are likely to be restricted to the Heath on flats (see Figure 4).
- *Banksia* Woodland is more likely to support Carnaby's Black-Cockatoo (Secton 4.4.2) and some other species of conservation significance.
- Riverine associations that are outside areas of direct impact are likely to support wetland-dependent species and also a suite of thicket-dependent species such as White-browed Scrubwren and White-breasted Robin.
- Reptile species richness appears to be highest in woodland on sandy soils, reflecting the high proportion of fossorial reptile species that burrow and "swim" through the loose surface sand. The *Banksia* woodlands on sand are likely to be richest in reptiles across Cooljarloo West, with slightly damper environments with heavier soils being relatively poor in species. However, some of the species in such areas may have restricted distributions in the region.
- The small mammal assemblage is dominated by the nectarivorous Honey Possum and two rodents (one introduced), with very small numbers of insectivorous dasyurid marsupials. Mammal abundance and richness is likely to be lowest in Heath where the soils is heavy and at least seasonally waterlogged, but such areas may support large numbers of Honey Possums when plants such as *Banksia telmatiaea* are flowering.
- Overall, bird species richness and density tends to be highest on the transition between Low Woodland and scrub-heath or Low Heath that lies low in the landscape, and particularly where there are riparian elements to the vegetation.

4.6 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. Environments are widespread but the vegetation differs in some ways from elsewhere in the Cooljarloo region, probably due to distinctive underlying geology and the nature of the watertable; to be resolved from separate studies commissioned by Tronox. Some of the vegetation may be groundwater-dependent.

Fire. The heaths and low woodlands of the northern sandplains are prone to fire and while appropriate fire regimes can benefit biodiversity, inappropriate regimes can lead to a loss of biodiversity. Long-term studies at Cooljarloo have found some reptile species have been encouraged by repeated fires, and mammals such as the Noodji or Ashy-grey Mouse are only abundant around 3-8 years after fire (Bamford *et al.* 2010).

Feral predators and interactions with over-abundant native species. The fauna assemblage of the Project Area has already been impacted by feral species (loss of a major component of the mammal fauna), and several feral species are likely to be present. Human activity has the potential to alter the abundance of feral species. Current fox baiting supported by Tronox has resulted in an anecdotal increase in sightings of the Echidna, Gould's Goanna and Carpet Python.

Habitat degradation due to weed invasion. The Project Area currently has low levels of weed invasion. Disturbing the area, particularly with the movement of equipment and vehicles along roads, raises the potential for weed invasion into the adjacent areas that are currently in very good condition. This risk would include the threat from dieback fungus.

4.7 Summary of fauna values

Fauna values within the Project Area can be summarised as follows:

Fauna assemblage. Very rich and intact with several heath specialists. Generally similar in composition and proportional representation to other areas in the Cooljarloo region where sampling has been undertaken, but with some difference related to factors such as the large area of Heath and the presence of distinct soil types.

Species of conservation significance. A range of significant species may be present. Species of note are the South-west Carpet Python, Western Ground Parrot (although probably locally extinct), Carnaby's Black-Cockatoo, Rufous Fieldwren and Rainbow Bee-eater. Cooljarloo West contains extensive areas of foraging habitat for Carnaby's Black-Cockatoo, but these areas appear similar to the intact habitat occurring in the surrounding landscape. There is no breeding or roosting habitat for Carnaby's Black-Cockatoo in Cooljarloo West, with the nearest roost 3 km east of the Project Area.

Vegetation and Substrate Associations. Three VSAs were identified across the Project Area with the Low Heath on Flats considered locally unusual and possibly closely linked to groundwater. These VSAs include:

- Low Heath on Flats– these occur on distinctive sand over clay and sometimes laterite soils, and are not well-represented in the general Cooljarloo area.
- *Banksia* woodland on Low Dunes– woodlands typical of the Cooljarloo area, but notable in Cooljarloo West is the understorey includes elements from the Low Heath on Flats.
- Riparian and Riverine Woodland– woodlands associated with seasonally damp depressions and along some watercourses that lie outside the Project Area, but possibly within the range of indirect impacts.

Patterns of biodiversity. Areas of particular significance include *Banksia* Woodland (foraging habitat for the Carnaby's Black Cockatoos) and the dampland heath areas (supporting habitat specialist fauna with some restrictions in distribution).

Key ecological processes. Main processes currently affecting the fauna assemblage in the Project Area include local hydrology, fire, fauna interactions (feral predators), weed invasion and *Phytophthora* dieback.

5 Recommendations

This report has identified the fauna assemblage, significant species, and vegetation and substrate associations occurring within the Project Area, as well as patterns of biodiversity and ecological processes important for ecosystem function. The following recommendations are designed to reduce potential adverse impacts that may occur from the proposed development within the Project Area. While potential impacts are expected to be mostly minor, any reduction in impacts is desirable. The EPBC Act-listed Carnaby's Black - Cockatoo may require special consideration. Management strategies are recommended below to reduce the potential impacts of this development on fauna species.

Loss of habitat

- Minimise vegetation clearing;
- Minimise the disturbance footprint;
- Clearly delineate areas to be cleared;
- Rehabilitate all disturbed areas upon the completion of mining activities. Special attention should be made to rehabilitate foraging habitat for Carnaby's Black-Cockatoo.

Species interactions

- Discourage the presence of feral species, particularly the feral cat and fox, by the use of appropriate waste management procedures.
- Consider expanding the current fox control program.

Hydrological changes

- Develop an understanding of the surface and sub-surface drainage and possible effects of drilling and mining upon groundwater in order to identify the potential for hydrological changes that could potentially impact (degrade) fauna habitats.

Habitat degradation due to weed invasions

- Develop a weed management/hygiene plan; including for dieback.

Changes in fire regime

- Develop a fire management plan (which includes regard for the ecological role of fire).

Dust, noise, light and disturbance

- Minimise the production of dust, noise and light spill.

Impact upon Carnaby's Black-Cockatoo

Loss of quality foraging habitat is unavoidable. While there is extensive foraging habitat outside impact areas, referral guidelines from DSEWPaC (now DOTE) (2011) recommend referral if >1ha of quality foraging habitat is impacted (noting referral occurred in May 2013).

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7 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 Parks and Wildlife (DPaW) 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 3.

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 DPAW but not listed under State or Commonwealth Acts.

In Western Australia, the DPAW has produced a supplementary list of Priority Fauna, being species that are not considered threatened under the Wildlife Conservation Act but for which the DPAW 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 4). 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 feral cats (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 Parka and Wildlife 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 19 key threatening processes listed by the federal Department of Sustainability, Environment, Water, Population and Communities (DSEWPaC 2011):

- Competition and land degradation by feral/unmanaged Goats (*Capra hircus*);
- Competition and land degradation by feral Rabbits (*Oryctolagus cuniculus*);
- Dieback caused by the root-rot fungus (*Phytophthora cinnamomi*);
- Incidental catch (bycatch) of Sea Turtles 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;
- Predation by exotic rats on Australian offshore islands of less than 1000 km2 (100 000 ha);
- Predation by feral Cats (*Felis catus*);

- Predation by the European Red Fox (*Vulpes vulpes*);
- Predation, Habitat Degradation, Competition and Disease Transmission by Feral Pigs (*Sus scrofa*);
- Psittacine Circoviral (beak and feather) Disease affecting endangered psittacine species;
- The biological effects, including lethal toxic ingestion, caused by Cane Toads (*Bufo marinus*); and
- The reduction in the biodiversity of Australian native fauna and flora due to the imported Red Fire Ant, *Solenopsis invicta*.

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. Fauna Sampling Locations.

Locations of Pitfall Traps

PitfallDescription	PitfallCode	Easting	Northing
Cooljarloo West Line 01 Pit 01	C101	345196	6601905
Cooljarloo West Line 01 Pit 02	C102	345190	6601928
Cooljarloo West Line 01 Pit 03	C103	345188	6601952
Cooljarloo West Line 01 Pit 04	C104	345184	6601980
Cooljarloo West Line 01 Pit 05	C105	345182	6602002
Cooljarloo West Line 01 Pit 06	C106	345180	6602036
Cooljarloo West Line 01 Pit 07	C107	345173	6602051
Cooljarloo West Line 01 Pit 08	C108	345174	6602082
Cooljarloo West Line 01 Pit 09	C109	345173	6602101
Cooljarloo West Line 01 Pit 10	C110	345174	6602132
Cooljarloo West Line 01 Pit 11	C111	345169	6602156
Cooljarloo West Line 01 Pit 12	C112	345164	6602182
Cooljarloo West Line 01 Pit 13	C113	345162	6602225
Cooljarloo West Line 01 Pit 14	C114	345160	6602247
Cooljarloo West Line 01 Pit 15	C115	345156	6602269
Cooljarloo West Line 01 Pit 16	C116	345153	6602292
Cooljarloo West Line 01 Pit 17	C117	345146	6602318
Cooljarloo West Line 01 Pit 18	C118	345147	6602335
Cooljarloo West Line 01 Pit 19	C119	345142	6602362
Cooljarloo West Line 01 Pit 20	C120	345140	6602385
Cooljarloo West Line 01 Pit 21	C121	345134	6602412
Cooljarloo West Line 01 Pit 22	C122	345137	6602437
Cooljarloo West Line 01 Pit 23	C123	345132	6602458
Cooljarloo West Line 01 Pit 24	C124	345128	6602484
Cooljarloo West Line 01 Pit 25	C125	345125	6602512
Cooljarloo West Line 01 Pit 26	C126	345123	6602539
Cooljarloo West Line 01 Pit 27	C127	345119	6602563
Cooljarloo West Line 01 Pit 28	C128	345113	6602591
Cooljarloo West Line 01 Pit 29	C129	345111	6602615
Cooljarloo West Line 01 Pit 30	C130	345108	6602641
Cooljarloo West Line 01 Pit 31	C131	345108	6602666
Cooljarloo West Line 01 Pit 32	C132	345112	6602692
Cooljarloo West Line 01 Pit 33	C133	345112	6602722
Cooljarloo West Line 01 Pit 34	C134	345115	6602754
Cooljarloo West Line 01 Pit 35	C135	345105	6602780
Cooljarloo West Line 01 Pit 36	C136	345092	6602808
Cooljarloo West Line 01 Pit 37	C137	345078	6602834
Cooljarloo West Line 01 Pit 38	C138	345084	6602858
Cooljarloo West Line 01 Pit 39	C139	345085	6602879

PitfallDescription	PitfallCode	Easting	Northing
Cooljarloo West Line 01 Pit 40	C140	345084	6602908
Cooljarloo West Line 01 Pit 41	C141	345079	6602938
Cooljarloo West Line 01 Pit 42	C142	345075	6602962
Cooljarloo West Line 01 Pit 43	C143	345066	6602996
Cooljarloo West Line 01 Pit 44	C144	345054	6603026
Cooljarloo West Line 01 Pit 45	C145	345054	6603050
Cooljarloo West Line 01 Pit 46	C146	345057	6603077
Cooljarloo West Line 01 Pit 47	C147	345055	6603103
Cooljarloo West Line 01 Pit 48	C148	345052	6603129
Cooljarloo West Line 01 Pit 49	C149	345047	6603157
Cooljarloo West Line 01 Pit 50	C150	345045	6603179
Cooljarloo West Line 01 Pit 51	C151	345043	6603200
Cooljarloo West Line 01 Pit 52	C152	345040	6603220
Cooljarloo West Line 01 Pit 53	C153	345036	6603245
Cooljarloo West Line 01 Pit 54	C154	345033	6603278
Cooljarloo West Line 01 Pit 55	C155	345026	6603295
Cooljarloo West Line 01 Pit 56	C156	345024	6603317
Cooljarloo West Line 01 Pit 57	C157	345019	6603339
Cooljarloo West Line 01 Pit 58	C158	345013	6603366
Cooljarloo West Line 01 Pit 59	C159	345009	6603394
Cooljarloo West Line 01 Pit 60	C160	345007	6603421
Cooljarloo West Line 01 Pit 61	C161	345009	6603447
Cooljarloo West Line 01 Pit 62	C162	345003	6603471
Cooljarloo West Line 01 Pit 63	C163	344999	6603494
Cooljarloo West Line 01 Pit 64	C164	344993	6603517
Cooljarloo West Line 01 Pit 65	C165	344997	6603545
Cooljarloo West Line 01 Pit 66	C166	344991	6603570
Cooljarloo West Line 01 Pit 67	C167	344988	6603591
Cooljarloo West Line 01 Pit 68	C168	344983	6603620
Cooljarloo West Line 01 Pit 69	C169	344981	6603640
Cooljarloo West Line 01 Pit 70	C170	344977	6603670
Cooljarloo West Line 01 Pit 71	C171	344976	6603687
Cooljarloo West Line 01 Pit 72	C172	344972	6603715
Cooljarloo West Line 02 Pit 01	C201	345915	6602993
Cooljarloo West Line 02 Pit 02	C202	345948	6602991
Cooljarloo West Line 02 Pit 03	C203	345972	6602996
Cooljarloo West Line 02 Pit 04	C204	346001	6602996
Cooljarloo West Line 02 Pit 05	C205	346029	6602996
Cooljarloo West Line 02 Pit 06	C206	346053	6602989
Cooljarloo West Line 02 Pit 07	C207	346079	6602997
Cooljarloo West Line 02 Pit 08	C208	346101	6603002
Cooljarloo West Line 02 Pit 09	C209	346123	6603003
Cooljarloo West Line 02 Pit 10	C210	346139	6603008

PitfallDescription	PitfallCode	Easting	Northing
Cooljarloo West Line 02 Pit 11	C211	346160	6603007
Cooljarloo West Line 02 Pit 12	C212	346189	6603011
Cooljarloo West Line 02 Pit 13	C213	346220	6603016
Cooljarloo West Line 02 Pit 14	C214	346244	6603012
Cooljarloo West Line 02 Pit 15	C215	346264	6603014
Cooljarloo West Line 02 Pit 16	C216	346290	6603012
Cooljarloo West Line 02 Pit 17	C217	346321	6603012
Cooljarloo West Line 02 Pit 18	C218	346346	6603014
Cooljarloo West Line 02 Pit 19	C219	346374	6603015
Cooljarloo West Line 02 Pit 20	C220	346398	6603012
Cooljarloo West Line 02 Pit 21	C221	346422	6603020
Cooljarloo West Line 02 Pit 22	C222	346442	6603019
Cooljarloo West Line 02 Pit 23	C223	346469	6603023
Cooljarloo West Line 02 Pit 24	C224	346494	6603019
Cooljarloo West Line 02 Pit 25	C225	346521	6603026
Cooljarloo West Line 02 Pit 26	C226	346548	6603027
Cooljarloo West Line 02 Pit 27	C227	346566	6603029
Cooljarloo West Line 02 Pit 28	C228	346595	6603028
Cooljarloo West Line 02 Pit 29	C229	346620	6603029
Cooljarloo West Line 02 Pit 30	C230	346644	6603028
Cooljarloo West Line 02 Pit 31	C231	346669	6603030
Cooljarloo West Line 02 Pit 32	C232	346694	6603031
Cooljarloo West Line 02 Pit 33	C233	346723	6603033
Cooljarloo West Line 02 Pit 34	C234	346747	6603037
Cooljarloo West Line 02 Pit 35	C235	346777	6603029
Cooljarloo West Line 02 Pit 36	C236	346810	6603029
Cooljarloo West Line 02 Pit 37	C237	346839	6603022
Cooljarloo West Line 02 Pit 38	C238	346862	6603035
Cooljarloo West Line 02 Pit 39	C239	346887	6603033
Cooljarloo West Line 02 Pit 40	C240	346912	6603038
Cooljarloo West Line 02 Pit 41	C241	346939	6603035
Cooljarloo West Line 02 Pit 42	C242	346964	6603037
Cooljarloo West Line 02 Pit 43	C243	346989	6603037
Cooljarloo West Line 02 Pit 44	C244	347006	6603045
Cooljarloo West Line 02 Pit 45	C245	347025	6603051
Cooljarloo West Line 02 Pit 46	C246	347048	6603057
Cooljarloo West Line 02 Pit 47	C247	347067	6603053
Cooljarloo West Line 02 Pit 48	C248	347099	6603057
Cooljarloo West Line 02 Pit 49	C249	347116	6603055
Cooljarloo West Line 02 Pit 50	C250	347142	6603057
Cooljarloo West Line 02 Pit 51	C251	347172	6603057
Cooljarloo West Line 02 Pit 52	C252	347196	6603058
Cooljarloo West Line 02 Pit 53	C253	347226	6603057

PitfallDescription	PitfallCode	Easting	Northing
Cooljarloo West Line 02 Pit 54	C254	347246	6603059
Cooljarloo West Line 02 Pit 55	C255	347275	6603063
Cooljarloo West Line 02 Pit 56	C256	347305	6603058
Cooljarloo West Line 02 Pit 57	C257	347329	6603058
Cooljarloo West Line 02 Pit 58	C258	347350	6603059
Cooljarloo West Line 02 Pit 59	C259	347378	6603062
Cooljarloo West Line 02 Pit 60	C260	347399	6603068
Cooljarloo West Line 02 Pit 61	C261	347424	6603066
Cooljarloo West Line 02 Pit 62	C262	347464	6603066
Cooljarloo West Line 02 Pit 63	C263	347484	6603068
Cooljarloo West Line 02 Pit 64	C264	347504	6603070
Cooljarloo West Line 02 Pit 65	C265	347524	6603073
Cooljarloo West Line 02 Pit 66	C266	347544	6603075
Cooljarloo West Line 02 Pit 67	C267	347564	6603077
Cooljarloo West Line 02 Pit 68	C268	347564	6603079
Cooljarloo West Line 02 Pit 69	C269	347584	6603081
Cooljarloo West Line 02 Pit 70	C270	347604	6603083
Cooljarloo West Line 02 Pit 71	C271	347624	6603085
Cooljarloo West Line 02 Pit 72	C272	347644	6603087

Locations of Black-Cockatoo Foraging Quadrats

Site	Quadrat	Vegetation Type	Location	Centroid Easting	Centroid Northing
Cooljarloo Road	82	Heath	Control	343989	6606990
Cooljarloo Road	83	Heath	Control	343889	6606989
Cooljarloo Road	84	Heath	Control	343789	6606992
Cooljarloo Road	85	Heath	Control	343687	6606990
Cooljarloo Road	86	Heath	Control	343587	6606990
Cooljarloo Road	87	Heath	Control	343492	6606985
Cooljarloo Road	88	Woodland	Control	343489	6606790
Cooljarloo Road	89	Woodland	Control	343588	6606790
Cooljarloo Road	90	Woodland	Control	343689	6606790
Cooljarloo Road	91	Woodland	Control	343789	6606789
Cooljarloo Road	92	Woodland	Control	343888	6606787
Cooljarloo Road	93	Woodland	Control	343988	6606761
Woolka Road 02	51	Woodland	Mine Lease	342012	6604689
Woolka Road 02	52	Woodland	Mine Lease	342011	6604588
Woolka Road 02	53	Woodland	Mine Lease	342012	6604490
Woolka Road 02	54	Woodland	Mine Lease	342009	6604389
Woolka Road 02	55	Woodland	Mine Lease	342013	6604289
Woolka Road 02	56	Woodland	Mine Lease	342015	6604190
Woolka Road 02	57	Woodland	Mine Lease	342013	6604091

Site	Quadrat	Vegetation Type	Location	Centroid Easting	Centroid Northing
Woolka Road 02	58	Woodland	Mine Lease	342013	6603989
Woolka Road 02	59	Woodland	Mine Lease	342210	6603987
Woolka Road 02	60	Woodland	Mine Lease	342210	6604091
Woolka Road 02	61	Woodland	Mine Lease	342210	6604192
Woolka Road 02	65	Woodland	Mine Lease	342212	6604591
Woolka Road 02	66	Woodland	Mine Lease	342211	6604690
Wongonderrah Road	105	Woodland	Control	332310	6616690
Wongonderrah Road	106	Woodland	Control	332409	6616690
Wongonderrah Road	107	Woodland	Control	332510	6616690
Wongonderrah Road	108	Woodland	Control	332610	6616690
Wongonderrah Road	109	Woodland	Control	332709	6616690
Wongonderrah Road	110	Woodland	Control	332810	6616690
Wongonderrah Road	111	Woodland	Control	332809	6616489
Wongonderrah Road	112	Woodland	Control	332709	6616489
Wongonderrah Road	113	Woodland	Control	332610	6616489
Wongonderrah Road	114	Woodland	Control	332509	6616490
Wongonderrah Road	115	Woodland	Control	332410	6616490
Wongonderrah Road	116	Woodland	Control	332309	6616490
Mining Lease (Pitfall Line N-S)	1	Woodland	Mine Lease	344990	6602910
Mining Lease (Pitfall Line N-S)	2	Woodland	Mine Lease	344990	6603011
Mining Lease (Pitfall Line N-S)	3	Woodland	Mine Lease	344989	6603109
Mining Lease (Pitfall Line N-S)	4	Woodland	Mine Lease	344988	6603209
Mining Lease (Pitfall Line N-S)	5	Woodland	Mine Lease	344989	6603309
Mining Lease (Pitfall Line N-S)	6	Woodland	Mine Lease	344991	6603411
Mining Lease (Pitfall Line N-S)	7	Woodland	Mine Lease	344990	6603509
Mining Lease (Pitfall Line N-S)	8	Woodland	Mine Lease	345189	6603511
Mining Lease (Pitfall Line N-S)	9	Woodland	Mine Lease	345188	6603407
Mining Lease (Pitfall Line N-S)	10	Heath	Mine Lease	345189	6603308
Mining Lease (Pitfall Line N-S)	11	Heath	Mine Lease	345188	6603211
Mining Lease (Pitfall Line N-S)	12	Heath	Mine Lease	345189	6603110
Mining Lease (Pitfall Line N-S)	13	Heath	Mine Lease	345189	6603009
Mining Lease (Pitfall Line N-S)	14	Heath	Mine Lease	345188	6602910
Woolka Road 01	33	Heath	Mine Lease	347989	6605911
Woolka Road 01	34	Heath	Mine Lease	347990	6606010
Woolka Road 01	35	Heath	Mine Lease	347988	6606112
Woolka Road 01	36	Woodland	Mine Lease	347993	6606217
Woolka Road 01	37	Woodland	Mine Lease	347989	6606311
Woolka Road 01	38	Woodland	Mine Lease	347990	6606410
Woolka Road 01	39	Heath	Mine Lease	347987	6606512
Woolka Road 01	42	Woodland	Control	347792	6606711
Woolka Road 01	43	Woodland	Control	347790	6606608
Woolka Road 01	44	Woodland	Control	347790	6606511
Woolka Road 01	45	Woodland	Mine Lease	347790	6606411

Site	Quadrat	Vegetation Type	Location	Centroid Easting	Centroid Northing
Woolka Road 01	46	Heath	Mine Lease	347789	6606311
Woolka Road 01	47	Heath	Mine Lease	347788	6606208
Woolka Road 01	48	Heath	Mine Lease	347788	6606111
Woolka Road 01	49	Heath	Mine Lease	347787	6606009
Woolka Road 01	50	Heath	Mine Lease	347787	6605908
Woolka Road 03	67	Heath	Control	340389	6604511
Woolka Road 03	68	Heath	Control	340391	6604609
Woolka Road 03	69	Heath	Control	340390	6604710
Woolka Road 03	70	Heath	Control	340388	6604809
Woolka Road 03	71	Heath	Control	340388	6604908
Woolka Road 03	72	Heath	Control	340388	6605010
Woolka Road 03	73	Heath	Control	340389	6605110
Woolka Road 03	74	Woodland	Control	340089	6605110
Woolka Road 03	75	Woodland	Control	340088	6605012
Woolka Road 03	76	Woodland	Control	340087	6604909
Woolka Road 03	77	Woodland	Control	340086	6604812
Woolka Road 03	78	Woodland	Control	340086	6604711
Woolka Road 03	79	Woodland	Control	340086	6604611
Woolka Road 03	80	Woodland	Control	340090	6604509
Woolka Road 03	81	Woodland	Control	340088	6604410
Emu Lakes area	117	Heath	Control	350391	6599709
Emu Lakes area	118	Heath	Control	350291	6599711
Emu Lakes area	119	Heath	Control	350189	6599711
Emu Lakes area	120	Heath	Control	350089	6599710
Emu Lakes area	121	Heath	Control	349991	6599712
Emu Lakes area	122	Heath	Control	349890	6599709
Emu Lakes area	123	Heath	Control	349787	6599711
Emu Lakes area	124	Woodland	Control	349789	6599913
Emu Lakes area	125	Woodland	Control	349889	6599910
Emu Lakes area	126	Woodland	Control	349988	6599908
Emu Lakes area	127	Woodland	Control	350089	6599909
Emu Lakes area	128	Woodland	Control	350288	6599908
Emu Lakes area	129	Woodland	Control	350389	6599908
Emu Lakes area	130	Woodland	Control	350489	6599909
Mining Lease (Pitfall Line E-W)	15	Woodland	Mine Lease	347109	6603110
Mining Lease (Pitfall Line E-W)	16	Woodland	Mine Lease	347209	6603109
Mining Lease (Pitfall Line E-W)	17	Woodland	Mine Lease	347310	6603109
Mining Lease (Pitfall Line E-W)	18	Woodland	Mine Lease	347410	6603110
Mining Lease (Pitfall Line E-W)	19	Woodland	Mine Lease	347509	6603110
Mining Lease (Pitfall Line E-W)	20	Woodland	Mine Lease	347612	6603111
Mining Lease (Pitfall Line E-W)	21	Woodland	Mine Lease	347712	6603110
Mining Lease (Pitfall Line E-W)	22	Heath	Mine Lease	347809	6603112
Mining Lease (Pitfall Line E-W)	23	Woodland	Mine Lease	347911	6603109

Site	Quadrat	Vegetation Type	Location	Centroid Easting	Centroid Northing
Mining Lease (Pitfall Line E-W)	24	Heath	Mine Lease	347911	6602911
Mining Lease (Pitfall Line E-W)	25	Heath	Mine Lease	347811	6602910
Mining Lease (Pitfall Line E-W)	26	Woodland	Mine Lease	347709	6602910
Mining Lease (Pitfall Line E-W)	27	Woodland	Mine Lease	347609	6602910
Mining Lease (Pitfall Line E-W)	28	Woodland	Mine Lease	347512	6602912
Mining Lease (Pitfall Line E-W)	29	Woodland	Mine Lease	347413	6602913
Mining Lease (Pitfall Line E-W)	30	Heath	Mine Lease	347314	6602911
Mining Lease (Pitfall Line E-W)	31	Woodland	Mine Lease	347210	6602911
Mining Lease (Pitfall Line E-W)	32	Woodland	Mine Lease	347113	6602913
Brand Highway	94	Woodland	Control	353110	6608110
Brand Highway	95	Woodland	Control	353109	6608210
Brand Highway	96	Woodland	Control	353109	6608310
Brand Highway	97	Woodland	Control	353110	6608410
Brand Highway	98	Woodland	Control	353110	6608510
Brand Highway	99	Woodland	Control	353109	6608610
Brand Highway	100	Woodland	Control	353109	6608710
Brand Highway	101	Woodland	Control	353209	6608109
Brand Highway	102	Woodland	Control	353209	6608009
Brand Highway	103	Woodland	Control	353210	6607909
Brand Highway	104	Woodland	Control	353210	6607809

Appendix 6. Fauna recorded or expected to occur in the Cooljarloo West Development Envelope (Tables 1 to 5).

These lists are derived from the results of database and literature searches, and from previous field surveys conducted in the Falcon/Cooljarloo area by BCE. Sources of information are:

- BA = Birdlife Australia Database: searched August, 2013 (Birds Australia 2013);
- E = EPBC Protected Matters Search Tool: searched August 2013 (EPBC database 2013);
- N = NatureMap Database: searched August, 2013 (Department of Environment and Conservation 2013);
- BCE = species recorded at Cooljarloo during BCE field surveys (1986 to 2013) outside the Cooljarloo West area;
- CW rec = species recorded during BCE field investigations in Cooljarloo West, 2010, 202 and/or 2013. .

The species listed are those recorded and/or expected in the general Falcon/Cooljarloo area, with those expected and/or recorded in Cooljarloo West indicated in the far right column (CW rec/exp). Status refers to conservation significance as outlined in Appendix 1. Species returned from databases that are not expected in the general Falcon/Cooljarloo area due to lack of suitable habitat, local extinction or database errors are listed in Appendix 7.

Table 1. Freshwater fish assemblage of the Falcon/Cooljarloo region, indicating those recorded/expected in Cooljarloo West.

Common Name	Species Name	Status	E	N	BCE	CW rec	CW rec/exp
Galaxiidae							
Western Minnow	Galaxias occidentalis	CS3			X		
Nannopercidae							
Western Pygmy Perch	Edelia vittata	CS3			X		
Gobiidae							
Swan River Goby	Pseudogobius olorum				X		
Poeciliidae							
Mosquitofish	Gambusia holbrooki	INT			X		
Cyprinidae							
Goldfish	Carassius auratus	INT			X		
Total number of species	**5**		0	0	5	0	0

Table 2. Frog assemblage of the Falcon/Cooljarloo region, indicating those recorded/expected in Cooljarloo West.

Common Name	Species Name	Status	E	N	BCE	CW rec	CW rec/exp
HYLIDAE							
Motorbike Frog	*Litoria moorei*			X	+	X	**X**
Slender Tree Frog	*Litoria adelaidensis*				+	X	**X**
MYOBATRACHIDAE							
Squelching Froglet	*Crinia insignifera*	CS3		X	+	X	**X**
Turtle Frog	*Myobatrachus gouldii*			X	+	X	**X**
Günther`s Toadlet	*Pseudophryne guentheri*			X	+	X	**X**
LIMNODYNASTIDAE							
Western Spotted Frog	*Heleioporus albopunctatus*				+		**X**
Moaning Frog	*Heleioporus eyrei*			X	+	X	**X**
Sand Frog	*Heleioporus psammophilus*				+	X	**X**
Banjo Frog, Pobblebonk	*Limnodynastes dorsalis*			X	+	X	**X**
Humming Frog	*Neobatrachus pelobatoides*			X	+	X	**X**
Total number of species	**10**			8	10	9	10

Table 3. Reptile assemblage of the Falcon/Cooljarloo region, indicating those recorded/expected in Cooljarloo West.

Common Name	Species Name	Status	E	N	BCE	CW rec	CW rec/exp
CHELUIDAE							
Oblong Tortoise	*Chelodina colliei (oblonga)*				+		**X**
AGAMIDAE							
Western Heath Dragon	*Ctenophorus adelaidensis*			X	+	X	**X**
Western Bearded Dragon	*Pogona minor*			X	+	X	**X**
DIPLODACTYLIDAE							
Clawless Gecko	*Crenadactylus ocellatus*				+		**X**
Spotted Stone Gecko	*Diplodactylus polyophthalmus*	CS3			+	X	**X**
White-spotted Ground Gecko	*Lucasium alboguttatum*			X	+	X	**X**
Soft Spiny-tailed Gecko	*Strophurus spinigerus*			X	+	X	**X**
GEKKONIDAE							
Marbled Gecko	*Christinus marmoratus*			X	+		**X**

Common Name	Species Name	Status	E	N	BCE	CW rec	CW rec/exp
PYGOPODIDAE							
Sand-plain Worm-lizard	*Aprasia repens*				+		**X**
Javelin Legless Lizard	*Delma concinna*			X	+	X	**X**
Fraser's Delma	*Delma fraseri*			X	+		**X**
Gray's Legless Lizard	*Delma grayii*				+		**X**
Burton's Legless Lizard	*Lialis burtonis*				+	X	**X**
Keeled Legless Lizard	*Pletholax gracilis*			X	+	X	**X**
Common Scaly-foot	*Pygopus lepidopodus*				+		**X**
SCINCIDAE							
Fence Skink	*Cryptoblepharus buchananii*			X	+	X	**X**
Western Limestone Ctenotus	*Ctenotus australis*			X	+		**X**
West Coast Ctenotus	*Ctenotus fallens*			X	+	X	**X**
Jewelled Ctenotus	*Ctenotus gemmula*	CS2		X	+		**X**
South-western Odd-striped Ctenotus	*Ctenotus impar*			X	+		**X**
Leopard Ctenotus	*Ctenotus pantherinus*				+		**X**
West Coast Slender Bluetongue	*Cyclodomorphus celatus*				+	X	**X**
Bull Skink	*Egernia multiscutata*			X	+		**X**
Salmon-bellied Skink	*Egernia napoleonis*			X	+	X	**X**
Bold-striped Lerista	*Lerista christinae*	CS3			+		**X**
West Coast Lerista	*Lerista elegans*			X	+		**X**
Western Worm Lerista	*Lerista praepedita*			X	+		**X**
Common Dwarf Skink	*Menetia greyii*				+	X	**X**
Western Pale-flecked Morethia	*Morethia lineoocellata*			X	+		**X**
Southern Pale-flecked Morethia	*Morethia obscura*			X	+	X	**X**
Western Blue-tongue	*Tiliqua occipitalis*				+		**X**
Bobtail	*Tiliqua rugosa*			X	+	X	**X**
VARANIDAE							
Sand Goanna	*Varanus gouldii*				+	X	**X**
Black-headed Monitor	*Varanus tristis*						**X**
TYPHLOPIDAE							
Southern Blind Snake	*Ramphotyphlops australis*			X	+	X	**X**
Beaked Blind Snake	*Ramphotyphlops waitii*						**X**

Common Name	Species Name	Status	E	N	BCE	CW rec	CW rec/exp
BOIDAE							
Woma, Ramsay`s Python	*Aspidites ramsayi*	CS1					**X?**
Carpet Python	*Morelia spilota*	CS1			+		**X**
ELAPIDAE							
Narrow-banded Snake	*Brachyurophis fasciolata*				+		**X**
Shovel-nosed Snake	*Brachyurophis semifasciata*				+		**X**
Yellow-faced Whipsnake	*Demansia psammophis*				+	X	**X**
Bardick	*Echiopsis curta*			X	+		**X**
Black-striped Snake	*Neelaps calonotos*	CS2		X	+		**X**
Black-naped Snake	*Neelaps bimaculatus*				+	X	**X**
Gould`s Snake	*Parasuta gouldii*			X	+	X	**X**
Mulga Snake	*Pseudechis australis*			X	+	X	**X**
Gwardar	*Pseudonaja nuchalis*				+		**X**
Jan`s Banded Snake	*Simoselaps bertholdi*						**X**
Total Number of Species	**48**	**CS=6**		**27**	**44**	**21**	**48**

Table 4. Bird assemblage of the Falcon/Cooljarloo region, indicating those recorded/expected in Cooljarloo West.

Common Name	Species Name	Status	E	BA	BCE	CW rec	CW rec/exp
CASUARIIDAE							
Emu	*Dromaius novaehollandiae*			X	+	X	**X**
PHASIANIDAE							
Stubble Quail	*Coturnix pectoralis*			X	+		**X**
ANATIDAE							
Black Swan	*Cygnus atratus*			X	+		
Australian Shelduck	*Tadorna tadornoides*			X	+		
Pacific Black Duck	*Anas superciliosus*			X	+		
Grey Teal	*Anas gibberifrons*			X	+		
Chestnut Teal	*Anas castanea*			X	+		
Australasian Shoveler	*Anas rhynchotis*			X	+		
Pink-eared Duck	*Malacorhynchus membranaceus*			X			
Hardhead	*Aythya australis*			X	+		
Australian Wood Duck	*Chenonetta jubata*			X	+		
Musk Duck	*Biziura lobata*			X	+		
Blue-billed Duck	*Oxyura australis*			X	+		
PODICEPIDIDAE							
Hoary-headed Grebe	*Poliocephalus poliocephalus*			X	+		
Australasian Grebe	*Tachybaptus novaehollandiae*			X	+		

Common Name	Species Name	Status	E	BA	BCE	CW rec	CW rec/exp
COLUMBIDAE							
Rock Dove/Feral Pigeon	*Columba livia*	Int		X			
Crested Pigeon	*Ocyphaps lophotes*			X	+	X	**X**
Common Bronzewing	*Phaps chalcoptera*			X	+	X	**X**
Brush Bronzewing	*Phaps elegans*			X	+	X	**X**
Laughing Dove	*Streptopelia senegalensis*	Int		X	+		
PODARGIDAE							
Tawny Frogmouth	*Podargus strigoides*			X	+		**X**
CAPRIMULGIDAE							
Spotted Nightjar	*Eurostopodus argus*			X	+		**X**
APODIDAE							
Fork-tailed Swift	*Apus pacificus*	CS1		X			**X**
ANHINGIDAE							
Darter	*Anhinga melanogaster*			X	+		
PHALACROCORACIDAE							
Little Black Cormorant	*Phalacrocorax sulcirostris*			X	+		
Little Pied Cormorant	*Phalacrocorax melanoleucos*			X	+		
ARDEIDAE							
White-faced Heron	*Egretta novaehollandiae*			X	+		**X**
Little Egret	*Egretta garzetta*			X			
White-necked Heron	*Ardea pacifica*			X	+		**X**
Great Egret	*Egretta modesta*	CS1		X			
Nankeen Night-Heron	*Nycticorax caledonicus*			X	+		
PLATALEIDAE							
Australian White Ibis	*Threskiornis molucca*			X			
Straw-necked Ibis	*Threskiornis spinicollis*			X	+		**X**
Yellow-billed Spoonbill	*Platalea flavipes*			X	+		
TURNICIDAE							
Painted Button-quail	*Turnix varia*			X	+		**X**
Little Button-quail	*Turnix velox*			X	+	X	**X**
ACCIPITRIDAE							
White-bellied Sea-Eagle	*Haliaeetus leucogaster*				+		
Collared Sparrowhawk	*Accipiter cirrhocephalus*			X	+		**X**
Brown Goshawk	*Accipiter fasciatus*			X	+		**X**
Wedge-tailed Eagle	*Aquila audax*			X	+	X	**X**
Swamp Harrier	*Circus approximans*			X	+		
Spotted Harrier	*Circus assimilis*			X	+		**X**
Black-shouldered Kite	*Elanus axillaris*			X	+	X	**X**
Whistling Kite	*Haliastur sphenurus*			X	+	X	**X**
Little Eagle	*Hieraaetus morphnoides*			X	+	X	**X**
Square-tailed Kite	*Lophoictinia isura*	CS3		X	+		**X**
FALCONIDAE							

Common Name	Species Name	Status	E	BA	BCE	CW rec	CW rec/exp
Brown Falcon	*Falco berigora*			X	+	X	**X**
Nankeen Kestrel	*Falco cenchroides*			X	+	X	**X**
Australian Hobby	*Falco longipennis*			X	+		**X**
Peregrine Falcon	*Falco peregrinus*	CS1		X			**X**
RALLIDAE							
Buff-banded Rail	*Rallus philippensis*			X	+		
Baillon's Crake	*Porzana pusilla*						
Spotless Crake	*Porzana tabuensis*			X			
Australian Crake	*Porzana fluminea*						
Purple Swamphen	*Porphyrio porphyrio*			X	+		
Black-tailed Native-hen	*Tribonyx ventralis*			X	+	X	**X**
Eurasian Coot	*Fulica atra*			X	+		
OTIDAE							
Australian Bustard	*Ardeotis australis*	CS2		X	+		**X**
RECURVIROSTRIDAE							
Black-winged Stilt	*Himantopus himantopus*			X	+		
Banded Stilt	*Cladorhynchus leucocephalus*			X			
Red-necked Avocet	*Recurvirostra novaehollandiae*			X			
CHARADRIIDAE							
Red-capped Plover	*Charadrius ruficapillus*			X	+		
Black-fronted Dotterel	*Elseyornis melanops*			X	+		
Red-kneed Dotterel	*Erythrogonys cinctus*			X			
Banded Lapwing	*Vanellus tricolor*			X	+	X	**X**
SCOLOPACIDAE							
Common Greenshank	*Tringa nebularia*	CS1		X			
Common Sandpiper	*Tringa hypoleucos*	CS1		X	+		
Red-necked Stint	*Calidris ruficollis*	CS1		X			
Sharp-tailed Sandpiper	*Calidris acuminata*	CS1		X			
CACATUIDAE							
Carnaby`s Black-Cockatoo	*Calyptorhynchus latirostris*	CS1		X	+	X	**X**
Western Corella	*Cacatua pastinator*			X	+	X	**X**
Little Corella	*Cacatua sanguinea*			X			
Galah	*Eolophus roseicapilla*			X	+	X	**X**
Cockatiel	*Nymphicus hollandicus*			X			
PSITTACIDAE							
Purple-crowned Lorikeet	*Glossopsitta porphyrocephala*			X	+		**X**
Australian Ringneck	*Barnardius zonarius*			X	+	X	**X**
Regent Parrot	*Polytelis anthopeplus*			X	+	X	**X**
Red-capped Parrot	*Purpureicephalus spurius*			X	+	X	**X**
Budgerigar	*Melopsittacus undulatus*			X	+		**X**
Elegant Parrot	*Neophema elegans*				+	X	**X**
Western Ground Parrot	*Pezoporus flaviventris*	CS1					**X?**

Common Name	Species Name	Status	E	BA	BCE	CW rec	CW rec/exp
CUCULIDAE							
Fan-tailed Cuckoo	*Cacomantis flabelliformis*			X	+	X	**X**
Pallid Cuckoo	*Cacomantis pallidus*			X	+	X	**X**
Shining Bronze-Cuckoo	*Chalcites lucidus*			X	+	X	**X**
Horsfield's Bronze-Cuckoo	*Chrysococcyx basalis*			X	+	X	**X**
STRIGIDAE							
Southern Boobook	*Ninox novaeseelandiae*			X	+	X	**X**
TYTONIDAE							
Eastern Barn Owl	*Tyto javanica*			X			**X**
HALCYONIDAE							
Laughing Kookaburra	*Dacelo novaeguineae*	Int		X	+		
Red-backed Kingfisher	*Todiramphus pyrrhopygia*				+		**X**
Sacred Kingfisher	*Todiramphus sanctus*			X	+		**X**
MEROPIDAE							
Rainbow Bee-eater	*Merops ornatus*	CS1		X	+	X	**X**
MALURIDAE							
Variegated Fairy-wren	*Malurus lamberti*			X	+	X	**X**
White-winged Fairy-wren	*Malurus leucopterus*			X	+	X	**X**
Splendid Fairy-wren	*Malurus splendens*			X	+	X	**X**
Southern Emu-wren	*Stipiturus malachurus*	CS3			+	X	**X**
PARDALOTIDAE							
White-browed Scrubwren	*Sericornis frontalis*			X	+	X	**X**
Rufous Fieldwren	*Calamanthus campestris*	CS2		X	+	X	**X**
Weebill	*Smicrornis brevirostris*			X	+		
Western Gerygone	*Gerygone fusca*			X	+	X	**X**
Inland Thornbill	*Acanthiza apicalis*			X	+		**X**
Yellow-rumped Thornbill	*Acanthiza chrysorrhoa*			X	+	X	**X**
Western Thornbill	*Acanthiza inornata*			X	+	X	**X**
Spotted Pardalote	*Pardalotus punctatus*			X	+		
Striated Pardalote	*Pardalotus striatus*			X	+	X	**X**
MELIPHAGIDAE							
Red Wattlebird	*Anthochaera carunculata*			X	+	X	**X**
Western Wattlebird	*Anthochaera lunulata*			X	+	X	**X**
Western Spinebill	*Acanthorhynchus superciliosus*			X	+	X	**X**
Black Honeyeater	*Certhionyx niger*				+	X	**X**
Pied Honeyeater	*Certhionyx variegatus*				+		**X**
White-fronted Chat	*Epthianura albifrons*			X	+		**X**
Crimson Chat	*Epthianura tricolor*			X	+		**X**
Singing Honeyeater	*Lichenostomus virescens*			X	+	X	**X**
Brown Honeyeater	*Lichmera indistincta*			X	+	X	**X**
Yellow-throated Miner	*Manorina flavigula*			X	+		**X**
Brown-headed Honeyeater	*Melithreptus brevirostris*			X	+	X	**X**

Common Name	Species Name	Status	E	BA	BCE	CW rec	CW rec/exp
White-fronted Honeyeater	*Phylidonyris albifrons*				+	X	**X**
Tawny-crowned Honeyeater	*Phylidonyris melanops*			X	+	X	**X**
White-cheeked Honeyeater	*Phylidonyris nigra*			X	+	X	**X**
New Holland Honeyeater	*Phylidonyris novaehollandiae*			X	+	X	**X**
PETROICIDAE							
Hooded Robin	*Melanodryas cucullata*			X	+		**X**
Red-capped Robin	*Petroica goodenovii*			X	+		**X**
Scarlet Robin	*Petroica boodang*	CS3		X	+		**X**
White-breasted Robin	*Eopsaltria georgiana*	CS3		X	+		**X**
NEOSITTIDAE							
Varied Sittella	*Daphoenositta chrysoptera*			X	+	X	**X**
PACHYCEPHALIDAE							
Grey Shrike-thrush	*Colluricincla harmonica*			X	+	X	**X**
Crested Bellbird	*Oreoica gutturalis*	CS2		X	+	X	**X**
Rufous Whistler	*Pachycephala rufiventris*			X	+	X	**X**
Golden Whistler	*Pachycephala pectoralis*			X	+		
DICRURIDAE							
Restless Flycatcher	*Myiagra inquieta*			X			
Magpie-lark	*Grallina cyanoleuca*			X	+		**X**
Grey Fantail	*Rhipidura fuliginosa*			X	+	X	**X**
Willie Wagtail	*Rhipidura leucophrys*			X	+	X	**X**
CAMPEPHAGIDAE							
Ground Cuckoo-shrike	*Coracina maxima*				+		
Black-faced Cuckoo-shrike	*Coracina novaehollandiae*			X	+	X	**X**
White-winged Triller	*Lalage sueurii*			X	+	X	**X**
ARTAMIDAE							
Black-faced Woodswallow	*Artamus cinereus*			X	+	X	**X**
Dusky Woodswallow	*Artamus cyanopterus*			X	+	X	**X**
Masked Woodswallow	*Artamus personatus*			X	+	X	**X**
Grey Butcherbird	*Cracticus torquatus*			X	+	X	**X**
Pied Butcherbird	*Cracticus nigrogularis*			X	+		
Australian Magpie	*Gymnorhina tibicen*			X	+	X	**X**
CORVIDAE							
Australian Raven	*Corvus coronoides*			X	+	X	**X**
Little Crow	*Corvus bennetti*			X	+		**X**
MOTACILIDAE							
Australasian Pipit	*Anthus novaeseelandiae*			X	+	X	**X**
PASSERIDAE							
Zebra Finch	*Taeniopygia guttata*			X	+		**X**
DICAEIDAE							
Mistletoebird	*Dicaeum hirundinaceum*			X	+		**X**

HIRUNDINIDAE							
White-backed Swallow	*Cheramoeca leucosternum*			X	+		**X**
Fairy Martin	*Hirundo ariel*			X	+		**X**
Welcome Swallow	*Hirundo neoxena*			X	+		**X**
Tree Martin	*Hirundo nigricans*			X	+	X	**X**
SYLVIIDAE							
Brown Songlark	*Cinclorhamphus cruralis*			X	+		
Rufous Songlark	*Cinclorhamphus mathewsi*			X	+	X	**X**
ZOSTEROPIDAE							
Silvereye	*Zosterops lateralis*			X	+	X	**X**
Total Number of Species	**153**	**CS = 17 Int = 3**		**149**	**132**	**65**	**102**

Table 5. Mammals expected to occur and recorded in the Cooljarloow West survey area.

Common Name	Species Name	Status	E	N	BCE	CW rec	CW rec/exp
TACHYGLOSSIDAE							
Echidna	*Tachyglossus aculeatus*			X	+	X	**X**
DASYURIDAE							
Fat-tailed Dunnart	*Sminthopsis crassicaudata*				+		**X**
Little Long-tailed Dunnart	*Sminthopsis aff. dolichura*			X	+	X	**X**
White-tailed Dunnart	*Sminthopsis granulipes*			X	+		**X**
Grey-bellied Dunnart	*Sminthopsis griseoventer*			X	+	X	**X**
MACROPODIDAE							
Tammer Wallaby	*Macropus eugenii*	CS2			+		
Western Grey Kangaroo	*Macropus fuliginosus*			X	+	X	**X**
Brush Wallaby	*Macropus irma*	CS2		X	+	X	**X**
PHALANGERIDAE							
Brushtail Possum	*Trichosurus vulpecula*	CS3			+		
TARSIPEDIDAE							
Honey Possum	*Tarsipes rostratus*			X	+	X	**X**
VESPERTILIONIDAE							
Gould`s Wattled Bat	*Chalinolobus gouldii*				+		**X**
Chocolate Wattled Bat	*Chalinolobus morio*						**X**
Lesser Long-eared Bat	*Nyctophilus geoffroyi*			X	+		**X**
Greater Long-eared Bat	*Nyctophilus timoriensis*				+		**X**
Southern Forest Bat	*Vespadelus regulus*			X	+		**X**

MOLOSSIDAE							
Western Freetail-bat	*Mormopterus sp. 4.*	CS3					
White-striped Freetail-bat	*Tadarida australis*				+		**X**
MURIDAE							
House Mouse	*Mus musculus*	Int		X	+	X	**X**
Ash-grey Mouse, Noodji	*Pseudomys albocinereus*			X	+	X	**X**
Western Bush Rat	*Rattus fuscipes*			X	+		**X**
Black Rat	*Rattus rattus*	Int			+		**X**
LEPORIDAE							
Rabbit	*Oryctolagus cuniculus*	Int			+	X	**X**
CANIDAE							
Dog	*Canis lupus*	Int				X	**X**
Red Fox	*Vulpes vulpes*	Int			+	X	**X**
FELIDAE							
Cat	*Felis catus*	Int			+	X	**X**
Total Number of Species	**25 (19 Native, 6 Introduced species)**	**CS = 4 Int = 6**	**0**	**12**	**22**	**12**	**22**

Appendix 7. Fauna returned from database reviews but not expected in the Falcon/Cooljarloo area or in Cooljarloo West.

Sources of information are:

- BA = Birds Australia Database (Birds Australia 2013);
- E = EPBC Protected Matters Search Tool (EPBC 2013);
- N = NatureMap Database: searched August, 2013; (Department of Environment and Conservation2013).
- Some species are included on the basis of the general literature.

The absence of these species is based upon to lack of suitable habitat, local extinction or database errors. In addition, the extensive field investigations in the Falcon/Cooljarloo area means that conspicuous species that have not been found can be assumed to be absent.

Common Name	Species Name	Status	E	N
MYOBATRACHIDAE				
Bleating Froglet	*Crinia pseudinsignifera*			X
CARPHDACTYLIDAE				
Barking Gecko	*Underwoodisaurus milii*			
PYGOPODIDAE				
Aprasia sp.	*Aprasia sp. nov. aff fusca*			X
SCINCIDAE				
Chain-striped South-west Ctenotus	*Ctenotus catenifer*			
King's Skink	*Egernia kingii*			
Two-toed Earless Skink	*Hemiergis quadrilineata*			
South-western Lerista	*Lerista distinguenda*			
Dotted-line Robust Slider	*Lerista lineopunctulata*			X
BOIDAE				
Stimson`s Python	*Antaresia stimsoni*			
ELAPIDAE				
Tiger Snake	*Notechis scutatus*			
West Coast Banded Snake	*Simoselaps littoralis*			
PHASIANIDAE				
Brown Quail	*Coturnix ypsilophora*			X
ANATIDAE				
Freckled Duck	*Stictonetta naevosa*			
BURHINIDAE				
Bush Stone-curlew	*Burhinus grallarius*	CS2		
AEGOTHELIDAE				
Australian Owlet-nightjar	*Aegotheles cristatus*			X

PHALACROCORACIDAE				
Great Cormorant	*Phalacrocorax carbo*			X
Pied Cormorant	*Phalacrocorax varius*			X
CUCULIDAE				
Black-eared Cuckoo	*Chalcites osculans*			X
MALURIDAE				
Blue-breasted Fairy-wren	*Malurus pulcherrimus*			X
MELIPHAGIDAE				
Spiny-cheeked Honeyeater	*Acanthagenys rufogularis*			X
PERAMELIDAE				
Quenda	*Isoodon obesulus*	CS2		
Mala or Western Barred Bandicoot	*Perameles bougainville*	CS1		
DASYURIDAE				
Chuditch	*Dasyurus geoffforii*	CS1		
MACROPODIDAE				
Banded Hare-Wallaby	*Lagostrophus fasciatus*	CS1		
MURIDAE				
Djoongarri or Shark Bay Mouse	*Pseudomys fieldii*	CS1		

Appendix 7. Vegetation Descriptions along the Cooljarloo West Transects; vegetation cover values are estimated % cover within a 5m radius of each pitfall.

Pitfall Location	Vegetation Cover (m)						Banksia Species Present			
	Litter	0-.25	25-50	50-1	1.0-2.0	2+	B. attenuata	B. menziesii	B. telmatiae	B. Ilicifolia
1.01	30	20	25	10	<1	0	0	0	+	0
1.02	25	20	20	20	5	<1	0	0	+	0
1.03	20	15	15	15	<1	0	0	0	0	0
1.04	20	15	10	10	2	0	0	0	0	0
1.05	20	15	15	10	2	0	0	0	0	0
1.06	20	20	30	10	5	0	0	0	0	0
1.07	20	20	30	15	5	1	0	0	0	0
1.08	25	20	20	10	1	0	0	0	++	0
1.09	20	15	15	5	1	2	0	0	++	0
1.10	30	25	40	40	15	5	0	0	++	0
1.11	25	25	15	10	5	2	2	0	+	0
1.12	40	25	30	25	15	10	13	0	+	0
1.13	15	25	20	10	5	0	1	1	0	0
1.14	80	20	20	15	10	10	16	7	0	0
1.15	60	30	35	20	10	5	15	12	+	0
1.16	65	40	35	20	15	10	17	0	0	0
1.17	15	25	30	10	5	5	6	0	0	0
1.18	20	20	30	15	5	3	1	2	0	0
1.19	30	20	30	20	5	10	5	0	0	0
1.20	40	30	25	20	20	10	3	0	0	0
1.21	30	30	20	10	1	0	4	0	0	0
1.22	15	25	40	10	5	0	0	0	0	0
1.23	25	25	50	15	1	0	0	0	+	0
1.24	20	20	40	10	5	1	0	0	+	0
1.25										
1.26										
1.27										
1.28										
1.29										
1.30										
1.31										
1.32										
1.33										
1.34										
1.35										
1.36										
1.37	70	65	40	15	5	0		0	+	0
1.38	70	60	30	15	5	0		0	+	0
1.39	70	70	65	50	10	0		0	+	0
1.4	65	60	50	20	10	1	3	5	+	0
1.41	55	45	35	15	10	1	1	2	+	0
1.42	70	65	50	40	15	10	6	2	+	0
1.43	55	60	35	20	20	5	8	7	0	0
1.44	70	65	40	30	15	5	8	1	0	0

Pitfall Location	Vegetation Cover (m)						Banksia Species Present			
	Litter	0-.25	25-50	50-1	1.0-2.0	2+	B. attenuata	B. menziesii	B. telmatiae	B. Ilicifolia
1.45	60	60	50	40	10	1	7	3	0	1
1.46	65	50	45	40	15	1	4	0	0	0
1.47	60	50	45	20	20	5	6	0	0	0
1.48	60	40	40	30	10	5	0	0	0	0
1.49	80	50	40	20	10	10	5	3	0	0
1.50	70	50	30	30	20	20	1	0	0	0
1.51	70	60	60	40	10	5	0	0	0	0
1.52	70	60	50	40	15	5	0	0	0	0
1.53	60	60	50	40	10	0	3	0	0	0
1.54	60	60	50	30	10	0	0	0	0	0
1.55	70	50	30	10	5	0	0	0	0	0
1.56	80	60	60	60	5	0	0	0	0	0
1.57	60	70	50	30	5	0	0	0	0	0
1.58	80	70	70	50	30	10	22	2	0	0
1.59	80	60	50	40	40	30	5	0	0	0
1.60	80	80	70	50	40	30	23	2	0	0
1.61	90	70	50	40	20	30	15	5	0	0
1.62	80	70	70	40	30	20	17	8	0	0
1.63	70	70	60	40	40	10	18	11	0	0
1.64	70	60	30	40	30	10	29	7	0	0
1.65	90	70	60	40	10	30	14	11	0	1
1.66	60	50	40	20	20	5	21	10	0	3
1.67	60	50	40	30	20	5	22	8	0	3
1.68	70	60	40	30	10	10	21	7	0	3
1.69	60	40	30	30	20	5	18	3	0	2
1.70	60	50	60	40	20	5	24	6	0	1
1.71	70	60	40	40	10	10	26	9	0	4
1.72	60	50	50	50	30	10	18	20	0	2
2.01	90	90	80	20	0	0	0	0	++	0
2.02	80	80	70	20	0	0	0	0	+	0
2.03	70	60	50	15	5	5	0	0	+	0
2.04	70	65	60	50	<5	0	0	0	0	0
2.05	80	70	60	30	5	<5	0	0	+	0
2.06	70	65	50	50	<5	0	0	0	+	0
2.07	90	80	75	60	5	<5	0	0	+	0
2.08	80	75	70	60	10	<5	0	0	+	0
2.09	90	85	80	70	10	0	0	0	0	0
2.10	90	80	75	60	20	5	0	0	0	0
2.11	80	70	60	30	10	<5	1	3	0	0
2.12	90	80	60	20	10	5	7	5	+	0
2.13	80	80	50	40	<5	<5	0	1	++	0
2.14	90	85	85	70	30	5	2	6	++	0
2.15	90	85	80	70	40	5	0	5	+	0
2.16	80	70	65	60	5	<5	0	1	0	0
2.17	80	80	75	60	10	<5	0	1	0	0
2.18	90	80	70	20	<5	<5	0	0	0	0

Pitfall Location	Vegetation Cover (m)						Banksia Species Present			
	Litter	0-.25	25-50	50-1	1.0-2.0	2+	B. attenuata	B. menziesii	B. telmatiae	B. Ilicifolia
2.19	80	75	70	50	5	<5	0	0	+	0
2.20	70	65	50	5	<5	<5	0	0	0	0
2.21	70	70	50	30	5	<5	4	0	+	0
2.22	70	70	60	50	35	10	8	3	+	0
2.23	80	75	75	65	50	20	10	1	++	0
2.24	70	70	60	60	30	10	3	20	+	0
2.25	80	80	70	70	40	10	4	15	++	0
2.26	70	65	60	55	40	10	0	0	++	0
2.27	80	75	70	70	20	10	0	1	++	0
2.28	60	50	50	40	15	<5	3	4	++	0
2.29	80	75	70	60	40	25	5	18	++	0
2.30	90	85	85	80	15	5	0	14	++	0
2.31	80	75	70	65	5	<5	0	1	++	0
2.32	90	80	50	40	30	20	9	4	++	0
2.33	95	80	80	80	60	10	0	25	++	0
2.34	90	70	70	60	20	5	0	4	++	0
2.35	70	70	60	50	5	<5	0	4	++	0
2.36	90	70	90	60	5	<5	0	0	++	0
2.37	70	50	50	30	30	20	3	2	+	0
2.38	80	80	70	40	20	5	0	0	+	0
2.39	90	70	70	30	30	30	0	1	+	0
2.40	70	70	70	50	5	0	0	0	+	0
2.41	70	70	60	50	5	<5	0	0	+	0
2.42	90	90	70	70	5	0	0	0	++	0
2.43	70	60	60	30	20	5	2	0	+	0
2.44	80	70	70	60	25	5	1	0	+	0
2.45	70	70	50	30	20	0	2	0	0	0
2.46	80	50	50	5	15	20	5	0	0	0
2.47	50	50	40	30	25	20	1	0	0	0
2.48	60	60	50	15	0	0	1	0	0	0
2.49	95	70	50	15	30	50	12	13	0	0
2.50	80	80	70	10	0	0	0	0	0	0
2.51	70	60	50	20	10	10	0	0	0	0
2.52	80	40	30	10	0	0	0	0	0	0
2.53	90	70	60	5	5	0	1	0	0	0
2.54	70	60	50	5	0	0	1	0	0	0
2.55	90	70	60	15	16	10	1	0	0	0
2.56	70	60	60	30	15	15	2	0	0	0
2.57	60	50	30	10	5	0	0	0	0	0
2.58	70	70	60	20	5	<5	0	0	0	0
2.59	70	70	60	5	0	0	0	0	0	0
2.60	80	60	30	10	0	0	0	0	0	0
2.61	70	50	50	10	20	5	3	1	0	0
2.62	40	30	30	15	10	5	1	0	0	0
2.63	80	70	70	30	10	5	0	1	0	0
2.64	50	30	20	15	20	20	4	3	0	0

Pitfall Location	Vegetation Cover (m)						Banksia Species Present			
	Litter	0-.25	25-50	50-1	1.0-2.0	2+	B. attenuata	B. menziesii	B. telmatiae	B. Ilicifolia
2.65	60	60	30	10	5	<5	6	1	0	0
2.66	60	40	30	5	5	<5	0	0	0	0
2.67	80	70	70	20	25	10	10	4	0	0
2.68	70	60	50	5	10	10	1	0	0	0
2.69	50	40	35	5	0	0	2	0	0	0
2.70	60	60	40	10	5	0	2	0	+	0
2.71	40	40	25	30	20	15	6	0	+	0
2.72	50	40	30	10	20	10	5	1	+	0