

Fauna Values of Tiwest's Cooljarloo West Project Area



Wetland with samphire marsh in Cooljarloo West (M. Bamford)

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EXECUTIVE SUMMARY

Background

Tiwest Joint Venture has operated the Cooljarloo mineral sands mine since the late 1980s and is in the process of investigating expansion into an area termed Cooljarloo West, lying west of existing mine areas. Bamford Consulting Ecologists was commissioned to conduct an assessment of the potential impact of the proposed mining activities on terrestrial fauna and fauna habitats of this area, based on a site inspection and review of data collected on fauna at Cooljarloo and Falcon over a period of some 20 years. The key objectives of fauna studies are to:

- review the list of fauna expected to occur on the site based on the fauna habitats present, with a focus on investigating the likelihood of significant species being present;
- identify significant or fragile fauna habitats within the study area;
- identify any ecological processes in the study area upon which fauna may depend;
- identify general patterns of biodiversity within or adjacent to the study area, and
- identify potential impacts upon fauna and propose recommendations to minimise impacts.

Description of Project Area

The Project Area lies within the northern end of the Swan Coastal Plain Bioregion of the Interim Biogeographic Regionalisation for Australia (IBRA) classification system, although is very close to the Lesueur Sandplain Subregion of the Geraldton Sandplains Bioregion. Both the Swan and the Geraldton Bioregions fall within the Bioregion Group 1 classification of the EPA.

The desktop review and site inspection identified seven vegetation and soil associations (VSAs) that provide habitat for fauna: Banksia Low Woodland, Scrub-Heath, Low Heath on flats, Tall Heath on flats, Riparian Woodland, Samphire Wetland and Riverine Associations. The heaths, riparian woodland, samphire and Riverine associations are all linked with surface or near-surface hydrology. With the exception of the Banksia Low Woodland, the VSAs are not well-represented elsewhere on Tiwest leases, with the samphire and Riverine associations being particularly limited in extent. Overall, Cooljarloo West is distinctive for the surface hydrology effects and for the wide range of soil types present.

Fauna Assemblage

The vertebrate fauna assemblage of the Project Area may include 5 freshwater fish (2 native), 11 Frog, 56 Reptile, 157 Bird and 24 Mammal species; a total of 253 species. A total of 197 fauna species have been recorded in studies conducted for Tiwest in the nearby Cooljarloo and Falcon areas, representing 71% of the expected fauna. Species expected but not recorded may not be present or may occur only as vagrants, but studies at Cooljarloo and Falcon have found some species to be locally common at one location, but absent from another <10km away. The fauna assemblage is typical of the region the assemblage found at Cooljarloo and Falcon is considered to be representative of that expected at Cooljarloo West, with just a few species expected in one area but not the other on the basis of available habitats. For example, Cooljarloo

West lacks extensive lateritic soils but does have areas of calcareous soils not found at Cooljarloo.

Of the predicted fauna assemblage of 253 species, 12 are of high significance (Conservation Significance Level 1), being listed under legislation, eight are of moderate conservation significance (Conservation Significance Level 2), being listed as priority species by the Department of Environment and Conservation (DEC), and 11 are of local significance (Conservation Significance Level 3), because they have restricted distributions or are listed as declining species in the region. Some of the CS1 species are migratory waterbirds that may occur or have infrequently in small numbers, and thus the importance of the area to them is low.

No attempt was made to develop an expected assemblage for invertebrate fauna, but a number of significant invertebrate species are expected or have been recorded. Most notable are two or possibly three millipedes *Antichiropus* spp. that are short range endemics. One of these is known only from Cooljarloo and Falcon, and all are associated with seasonally damp environments.

Impact Assessment

Vegetation and Soil Associations. Some of the VSAs are limited in extent; notably those associated with surface hydrology. Proportional loss of these is not known but may be of concern as these are also significant for fauna, including possible SRE invertebrates.

Significant species. Impacts on the majority of significant species are expected to be low because of the small size of the proposed development and extensive similar habitat in the region. However, impacts are considered moderate for some species, notably the Woma and Western Ground Parrot that are extremely rare, not confirmed to be present but, if present, their populations would be highly significant and any adverse impact would be of concern.

Ecological Processes. Impacts associated with ecological processes are likely to be low, with main concerns related to: ongoing mortality of some significant species; increase in abundance of feral species; hydro-ecological changes (particularly surface and sub-surface hydrology, and associated VSAs); and changes in fire regimes. Note that changes in fire regimes have the potential for a positive impact. Feral predators are already controlled to some degree and this may be a further positive impact.

Patterns of Biodiversity. Several patterns of biodiversity need to be considered with respect to impacts, particularly high reptile richness in Banksia Low Woodland on sand, and high bird richness and abundance in the ecotone of woodland with heaths and Scrub-Heaths.

Management of impacts. A number of management recommendations are made, including:

- Habitat loss should be minimised (especially in the restricted VSAs).
- Impacts upon hydrology should be modelled and monitored.
- Sightings of significant species should be reported and surveys undertaken for the Western Ground Parrot.
- A precautionary approach should be taken with lighting.
- Ongoing mortality of fauna, mainly through roadkill, should be monitored.

- A fire management plan should be developed for safety and property protection, and for conservation.
- Feral species should be monitored and controlled.
- Effective rehabilitation should be undertaken.

More details on management recommendations are presented in this report.

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1 INTRODUCTION

1.1 Introduction

Tiwest Joint Venture (hereafter '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. This area comprises the exploration leases E70/2345 and E70/2346 and is termed 'Cooljarloo West', extending from south of Woolka Road north to Wongnderrah Road and therefore including areas immediately west of Falcon (see Figure 1). A detailed exploration program is planned for parts of the Cooljarloo West area and, if suitable resources are located, mining of the area may be proposed.

Bamford Consulting Ecologists was commissioned to conduct a literature review and site inspection to assess the potential impact of the proposed mining activities on terrestrial fauna and fauna habitats.

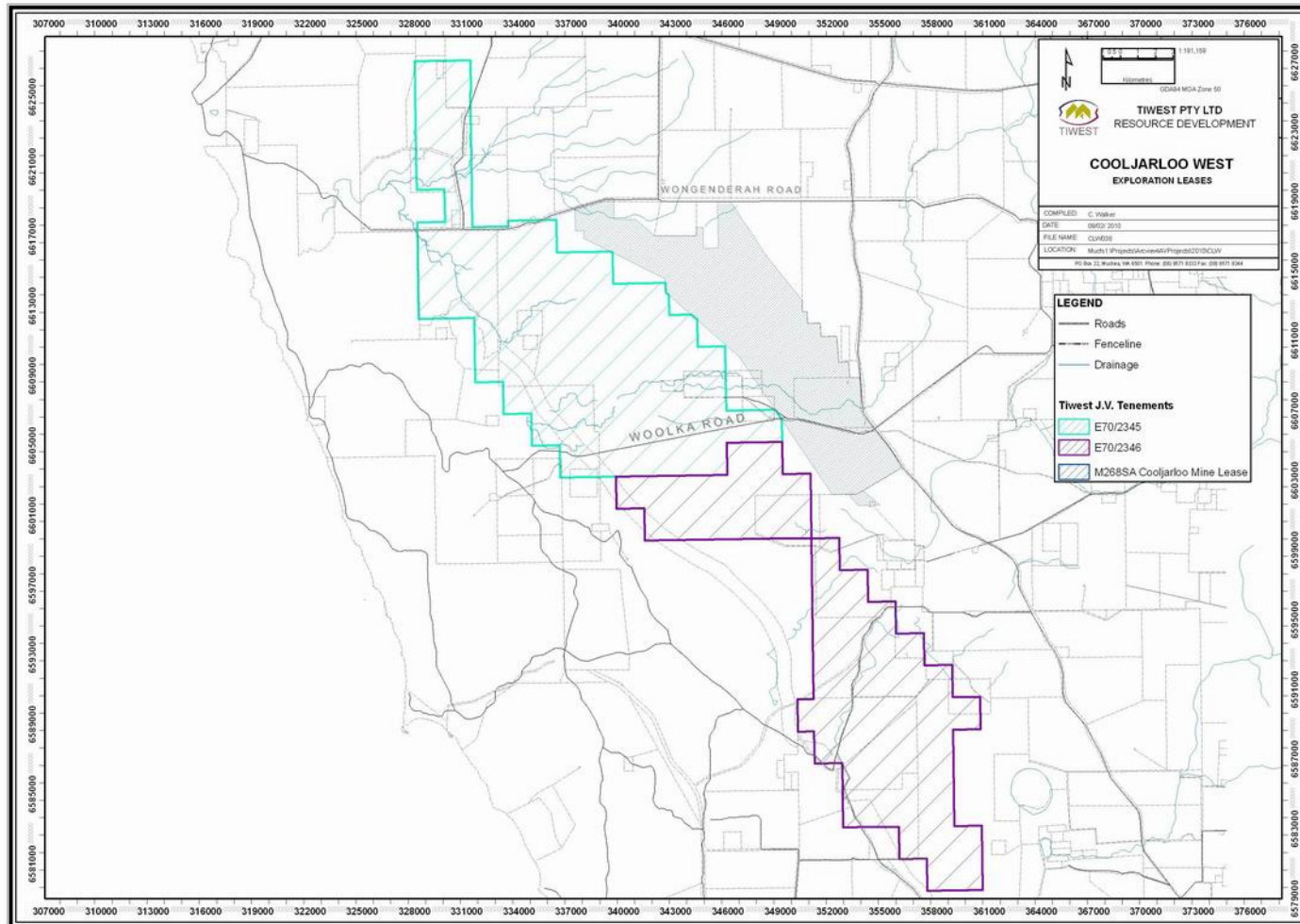
1.2 Study objectives

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. The key objectives of fauna studies are to:

- review the list of fauna expected to occur on the site based on fauna habitats present, with a focus on investigating the likelihood of significant species being present;
- identify significant or fragile fauna habitats within the study area;
- identify any ecological processes in the study area upon which fauna may depend;
- identify general patterns of biodiversity within or adjacent to the study area, and
- identify potential impacts upon fauna and propose recommendations to minimise 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 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. Tiwest leases comprising Cooljarloo West.



2 BACKGROUND

2.1 Regional description

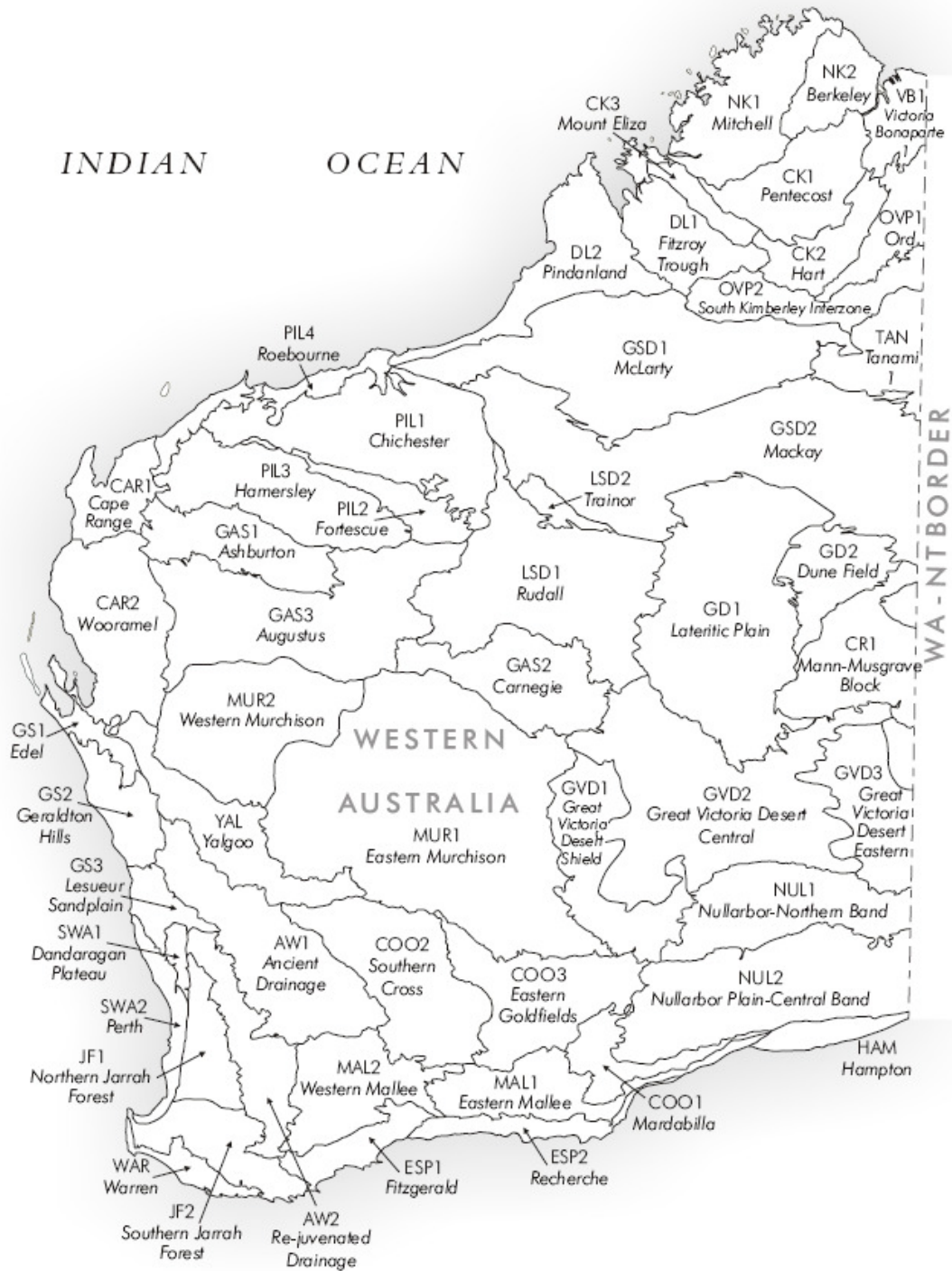
The Project Area lies within the northern end of the Swan Coastal Plain Bioregion of the Interim Biogeographic Regionalisation for Australia (IBRA) classification system (see Figure 2), although is very close to the Lesueur Sandplain Subregion of the Geraldton Sandplains Bioregion (EA 2000; McKenzie *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 (eg. 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, 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 Unallocated Crown Land, lies west of existing Tiwest operations and east of Nambung National Park, and extends from south of Woolka Road to Wongonderrah Road. The total area of exploration leases E70/2345 and E70/2346 is approximately 35 000 ha. Apart from tracks the native vegetation is intact. Much of the area consists 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 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.

Figure 2. IBRA Subregions in Western Australia. Note the project lies in SWA2: Swan Coastal Plain Bioregion.



3 METHODS

3.1 Background to Impact Assessment

Development of the project area may adversely impact upon fauna in a number of ways and some impacts upon fauna are unavoidable. Of concern are long-term, deleterious impacts upon biodiversity. These can be considered under the following categories:

- “Habitats” – “Habitats”, which are really associations of vegetation type, soil and landform (see 3.8.1), can be important for biodiversity if they are rare and support unusual species assemblages, or if they support naturally high levels of biodiversity. Impacts may therefore be significant if the impacted “habitat” is rare or biodiverse. Thus, “habitats” considers both the diversity of the environments in a project area and the patterns of distribution of fauna across those environments.
- Fauna of Conservation Significance - Impacts may be significant if species of conservation importance are affected. The assessment of conservation significance is discussed below (Section 3.1.1).
- Ecological Processes - Ecological processes are complex and can include hydrology, fire, predator/prey relationships and spatial distribution of a population (see discussion in section 5.3 below). Impacts upon ecological processes may be significant if large numbers of species or large proportions of populations are affected. Ecological processes that may be important in the assessment of impacts are discussed below (Section 3.1.2) and in Appendix 2.

3.1.1 Assessment of Conservation Significance

The conservation status of fauna species is assessed under Commonwealth and State Acts such as the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) and the Western Australian *Wildlife Conservation Act 1950*. The EPBC Act also provides protection for threatened ecological communities. The significance levels for fauna used in the EPBC Act are those recommended by the International Union for the Conservation of Nature and Natural Resources (IUCN) and reviewed by Mace and Stuart (1994). The Wildlife Conservation Act uses a set of Schedules but also classifies species using some of the IUCN categories. These categories and Schedules are described in Appendix 1.

The EPBC Act also has lists of migratory species that are recognised under international treaties such as the China Australia Migratory Bird Agreement (CAMBA), the Japan Australia Migratory Bird Agreement (JAMBA) and the Bonn Convention (The Convention on the Conservation of Migratory Species of Wild Animals). In addition, the federal Department of Environment, Water, Heritage and the Arts (DEWHA, formerly Environment Australia) has supported the publication of reports on the conservation status of most vertebrate fauna species e.g. reptiles (Cogger *et al.* 1993), birds (Garnett and Crowley 2000), monotremes and marsupials (Maxwell *et al.* 1996), rodents (Lee 1995) and bats (Duncan *et al.* 1999) These publications also use the IUCN categories, although those used by Cogger *et al.* (1993) differ in some respects as these reports pre-date Mace and Stuart’s review (1994).

In Western Australia, the Department of Environment and Conservation (DEC) has

produced a supplementary list of Priority Fauna, being species that are not considered Threatened under the *Wildlife Conservation Act* but for which the DEC feels there is cause for concern. Some Priority species, however, are also assigned to the IUCN Conservation Dependent category. Levels of Priority are described in Appendix 1. Assessments in this report are based on the most recent version of the DEC priority list (February 2009).

Fauna species included under conservation acts and/or agreements are formally protected under state or federal legislation. Species listed only as Priority by DEC, or that are included in publications such as Garnett and Crowley (2000) and Cogger *et al.* (1993), but not in State or Commonwealth Acts, are also of recognised conservation significance but are not formally protected under legislation. In addition, species that are at the limit of their distribution, those that have a very restricted range and those that occur in breeding colonies, such as some waterbirds, can be considered of conservation significance, although this level of significance has no legislative or published recognition and is based on interpretation of distribution information. The then Department of Environmental Protection (2000, now DEC) used this sort of interpretation to identify significant bird species in the Perth metropolitan area as part of Perth Bushplan (DEP, 2000).

On the basis of the above comments, three levels of conservation significance are recognised in this report:

- **Conservation Significance (CS) 1:** Species listed under State and/or Commonwealth Acts.
- **Conservation Significance (CS) 2:** Species not listed under State or Commonwealth Acts, but listed in publications on threatened fauna or as Priority species by the DEC.
- **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 may have links to preserving biodiversity at the genetic level (EPA 2002). For example, 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. Species on the edge of their range, or that are sensitive to impacts such as habitat fragmentation, may also be classed as CS3.

In addition to these conservation levels, species that have been introduced (INT) are indicated.

3.1.2 Ecological Processes and Impact Assessment

Many of the potential impacts of proposed developments upon fauna can be related to ecological processes. This is recognised under the EPBC Act, in which threatening processes are listed, and in the literature (see Appendix 2). A number of ecological processes are relevant to the proposal and can be related to the potential impacts of the project upon fauna. These are discussed below.

3.1.2.1 *Increased mortality*

Direct mortality of common species during clearing is unavoidable but can be minimised. Direct mortality of rare species, and ongoing mortality such as due to roadkill, may have a significant impact. Fragmentation of habitat can severely affect wildlife and lead to mortality through collision with vehicles (Jackson and Griffen 2000; Scheik and Jones 1999; Cleverger and Waltho 2000). Dufty (1989) suggested that the greatest cause of adult mortality in populations of Eastern Barred Bandicoots (*Perameles gunni*) was due to collisions with vehicles. Jones (2000) documented the sudden decline in a population of Eastern Quolls (*Dasyurus viverrinus*) and Tasmanian Devils (*Sarcophilus harrisii*) directly attributed to increased road mortality following the upgrade of a local road. Direct and ongoing mortality (in particular from road collisions) may be a concern for the viability of species that occur at low population densities in areas adjacent to the Project Area.

3.1.2.2 *Loss of habitat affecting population survival*

Some loss of habitat in the Project Area is inevitable but can be minimised through controls during clearing. Excessive loss of habitat can reduce the size of a population to the point where it is unsustainable or more vulnerable to other impacts. Loss of habitat has greatest impact when a large proportion of habitat is to be lost, which can occur with rare habitats or in areas with extensive previous clearing.

3.1.2.3 *Loss of habitat affecting population movements and gene flow*

Loss of habitat can affect population survival through fragmentation particularly if the affected habitat is linear and distinctive. This can occur in agricultural landscapes where remnant habitat is often linear, such as along roads, but also in substantially intact landscapes where there are distinctive habitats along watercourses or associated with geological features.

3.1.2.4 *Species interactions, including predators and over-abundant native species*

Introduced species, including the feral Cat, Fox and Rabbit may have adverse impacts upon native species, and the abundance of these species can alter during development projects. 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 Fox, and to a lesser extent the cat (Burbidge and McKenzie 1989). Introduced grazing species, such as the rabbit and domestic livestock, can also degrade habitats. Changes in the abundance of some native species can also be a concern, such as the increase in abundance of some birds, at the expense of others, due to the provision of watering points.

3.1.2.5 *Hydroecology*

Interruptions of hydroecological processes can have massive effects because they underpin primary production in ecosystems and there are specific, generally rare habitats that are hydrology-dependent. Roads and mining may alter both surface and sub-surface hydrology.

3.1.2.6 Fire

Fire is a natural feature of the environment but frequent, extensive fires may adversely impact some fauna, particularly mammals and short-range endemic species. Long-unburnt habitats are important for fauna, but some species require occasional fires, while a mosaic of fire ages may be important. For example, the conservation significant Quokka *Setonix brachyurus* requires a mosaic of recently burnt and long-unburnt refugia (Hayward *et al.* 2007).

3.1.2.7 Light and noise

Impacts of light and noise upon fauna are difficult to predict. As such, it is best to take a precautionary approach. The death of very large numbers of insects has been reported around some remote mine sites and attracts other fauna (including introduced predators), as well as presumably reducing the populations of insects in surrounding habitats. Some studies have demonstrated a decline in the abundance of some insects due to mortality around lights, although this is in fragmented landscapes where populations are already under stress (Rich and Longcore 2006). Impacts of noise on wildlife are less certain.

3.2 Impact Assessment Methodology

An assessment of the potential impacts of the project on fauna and habitat was conducted based on the results of the field surveys, desktop surveys and the past experience of the authors. The severity of impacts was quantified on the basis of predicted population change as outlined in Table 1. Population change can be the result of direct habitat loss and/or impacts upon ecological processes as discussed above.

Table 1. Assessment criteria for impacts upon fauna.

Severity of impact	Observed Impact
Minimal	No population decline
Low	Short-term population decline (recovery after end of project) within project area, no change in viability of conservation status of population
Moderate	Permanent population decline, no change in viability of conservation status of population
High	Permanent population decline resulting in change in viability or conservation status of population
Extreme	Taxon extinction

3.3 Approach to Impact Assessment

This fauna assessment was carried out with reference to guidance and position statements published by the WA Environmental Protection Authority (EPA) on fauna surveys and environmental protection, and Commonwealth biodiversity legislation (e.g. EPA 2002; EPA 2004). The level of fauna assessment required by the EPA is determined by the size and location of the proposed disturbance and the sensitivity of the surrounding environment in which the disturbance is planned. The project area lies within Bioregion Group 1 as classified by the EPA (EPA 2004) and the size of the proposed disturbance area is moderate, therefore a Level 2 Fauna Assessment

(desktop review in conjunction with a detailed survey) is required. In this, case, however, very extensive and intensive field investigations have been carried out for Tiwest over two decades in the Cooljarloo and Falcon areas, and therefore it was felt that sufficient information was available to warrant a Level 1 approach for Cooljarloo West. Falcon survey areas are within a kilometre of Cooljarloo West, with about 20km between the most westerly parts of Cooljarloo West and the most easterly sampling sites of Cooljarloo. A level 1 assessment is a desktop review and site reconnaissance. Therefore, a major component of the desktop review was existing information from previous studies for Tiwest (section 3.7), while the site reconnaissance was carried out to gain familiarity with the fauna habitats of Cooljarloo West, allowing for comparisons to be made between this area, and the areas at Cooljarloo and Falcon where intensive fauna studies have been undertaken.

3.4 Personnel

Personnel involved in this project were:

- Dr Mike Bamford (B.Sc. Hons. Ph.D.) – field assessment and report preparation;
- Mr Cameron Everard (B. Sc.) – field assessment; and
- Dr Wes Bancroft (B.Sc. Hons. Ph.D.) – report preparation.

3.5 Licences and Permits

No specific licence was required for the site visit to Cooljarloo West, as this did not involve the capture and/or handling of fauna. Field studies in the adjacent Cooljarloo and Falcon areas are conducted under DEC Regulation 17 licence number SF006980.

3.6 Nomenclature and Taxonomy

As per the recommendations of EPA (2004), the nomenclature and taxonomic order presented in this report are generally based on the Western Australian Museum's *Checklist of the Vertebrates of Western Australia*. The authorities used for each vertebrate group are: amphibians and reptiles (Aplin and Smith, 2001), birds (Christidis and Boles, 2008), and mammals (How *et al.*, 2001). Nomenclature for bat species follows Armstrong and Reardon (2006) and Van Dyck and Strahan (2008). Species designations of Churchill (2008) are not followed until formal publication of the relevant taxonomic study.

Latin and (where available) English common names are given in the species tables. English names are used in the text where possible, with Latin names used where there is no English alternative.

3.7 Sources of Information for Desktop Assessment

Information for this fauna assessment was drawn primarily from previous studies undertaken for Tiwest 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 censusing, 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, 8,084 individual small vertebrates have been caught, including 1205 frogs (8 species), 3844 reptiles (39 species) and 3035 mammals (8 species).

In addition to the Tiwest Cooljarloo/Falcon records, other sources of information were:

- the Department of Environment and Conservation's (DEC) 'NatureMap'.
- the federal Department of the Environment and Water Resources (DEWR) Environment Protection and Biodiversity Conservation (EPBC) database (EPBC Protected Matters Search Tool).
- the information and species distribution maps provided by Allen *et al.* (2003), Tyler *et al.* (2000), Storr *et al.* (1983; 1990; 1999), Wilson and Swan (2003), Cogger (2000), Johnstone and Storr (1998), Strahan (1995), Menkhorst and Knight (2004) and Churchill (1998).
- the information provided by Maryan (2005).

The database searches conducted and the areas searched are shown below:

Database	Type of records held in database	Areas searched
NatureMap (DEC)	Records of fauna specimens held in the WA Museum and the DEC fauna database. Includes historical data.	30 km buffer around the point 30° 40' 15" S, 115° 19' 19" E.
Environment Protection and Biodiversity Conservation (EPBC) database - EPBC Protected Matters Search Tool (DEWR)	Records on matters protected under the EPBC Act, including threatened species and conservation estate.	30 km buffer around the point 30° 40' 15" S, 115° 19' 19" E.

Because the proposed operations within Cooljarloo West will not encounter marine systems under Commonwealth control, obligate marine animals were excluded from the results presented here.

3.8 Site inspection

The Cooljarloo West Project Area was visited by M. Bamford and C. Everard from 21st to 22nd September 2009 for a site inspection. Activities undertaken during the site inspection included:

- Site familiarisation for the recognition of vegetation and soil associations, and comparison with the Cooljarloo and Falcon areas for which detailed fauna data are available; and
- Opportunistic observations.

3.8.1 Site Familiarisation and definition of Vegetation and Soil Associations (VSAs).

This involved driving around as much of the Project Area as possible so that vegetation and soil types could be identified. Site familiarisation allows for the recognition of Vegetation and Soil Associations (VSA), which combine broad vegetation types, the soils or other substrate with which they are associated and the landform. 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 or Floristic Community Types (FCT), since these may not incorporate soil and landform, and recognise floristics to a degree that VSAs do not. Vegetation types and particularly FCTs may also not recognise minor but often significant (for fauna) structural differences in the environment.

3.8.2 Opportunistic Observations.

Opportunistic observations were made at all times when conducting the site inspection, with a focus on birds as these are the most conspicuous and readily identified fauna. Opportunistic observations thus produced a short species which, on the basis that Cooljarloo West is very similar to Cooljarloo and Falcon, would be expected to include the most common species recorded in the previously-surveyed areas. With two people in the Cooljarloo West area for all of one day and part of another, this represents approximately 20 hours of observations.

3.9 Limitations

The EPA Guidance Statement 56 (EPA 2004) outlines a number of limitations that may arise during surveying. These survey limitations are addressed below in Table 1.

Table 2. Survey limitations.

Limitation	Comment
Level of survey.	Very intensive level 2 sampling over more than two decades at adjacent site; vegetation and soils in Cooljarloo West similar to those of intensively sampled areas.
Competency/experience of the consultant(s) carrying out the survey.	The authors have had extensive experience in conducting fauna assessments, particularly in the region.
Scope (What faunal groups were sampled and were some sampling methods not able to be employed because of constraints?)	Vertebrates very effectively sampled and collection of SRE invertebrates has also taken place.
Proportion of fauna identified, recorded and/or collected.	Very high proportion of vertebrate assemblage has been identified; probably >95%.
Sources of information e.g. previously available information (whether historic or recent) as distinct from new data.	Major source from intensive surveys carried out nearby, but some databases also accessed.
The proportion of the task achieved and further work which might be needed.	Site reconnaissance complete and full access to data from nearby area.

Limitation	Comment
Timing/weather/season/cycle.	Work has been carried out across all seasons in previous studies.
Disturbances (e.g. fire, flood, accidental human intervention etc.), which affected results of survey.	No disturbances affected the survey.
Intensity (In retrospect, was the intensity adequate?)	Surveys in nearby area have been extremely intense.
Completeness (e.g. was relevant area fully surveyed).	Site reconnaissance survey complete and all key areas of Cooljarloo West visited.
Resources (e.g. degree of expertise available in animal identification to taxon level).	All vertebrates identified to species level. SRE invertebrates have been identified by the WA Museum.
Remoteness and/or access problems.	No access problems.
Availability of contextual (e.g. biogeographic) information on the region.	Extensive local but less regional data available.

The reconnaissance survey and availability of data from Cooljarloo and Falcon provide a robust dataset for the assessment of impacts of proposed developments at Cooljarloo West. The only possibly deficiencies in data are:

- SRE invertebrates, including aquatic invertebrates of the Emu Lakes system and Frederick Smith Creek, and subterranean invertebrates. Terrestrial SRE invertebrates have been sampled at Falcon and Cooljarloo but this focussed on millipedes and trapdoor spiders, and there are other groups (eg. pseudoscorpions) that may be of interest. Aquatic invertebrates were sampled in Mullering Brook in the early 1990s but not subsequently. There has been no sampling of subterranean fauna in the area.
- The Western Ground Parrot is a species of high conservation significance that can be subject to targeted sampling and this has not been done at Cooljarloo West.

4 RESULTS OF DESKTOP ASSESSMENT AND SITE INSPECTION

4.1 Vegetation/Soil Associations

The Cooljarloo West Project 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 are described below and are illustrated in Plates 1 to 12. Most of these VSAs are associated with at least seasonally damp soils; some with conditions where flooding occurs annually.

Banksia Low Woodland on stabilised sand-dunes (Plates 1 and 2). These are very extensive, with particularly tall dunes between Woolka and Wongonderrah Roads. The woodlands typically consist of *Banksia menziesii* and *Banksia attenuata*, with scattered specimens of *Eucalyptus todtiana* and *Nuytsia floribunda*. In the far west, in the region of Frederick Smith Creek, the dominant tree is *Banksia prionotes*; this is an area of low relief and slightly calcareous, even marl-rich soils. These Low Woodlands are widespread at Cooljarloo and Falcon. They encompass FCTs W2, W3, W4, W5, W6 and W7 as described by Woodman Environmental Consulting.

Scrub-Heath on undulating sands (Plate 3). Present mainly south of Woolka Road. Heaths and Scrub-Heaths are very variable in Cooljarloo West, and this sort of Scrub-Heath, is poorly represented at Cooljarloo and Falcon. The Scrub-Heath at Cooljarloo West has elements of Banksia Low Woodland and of Low Heath, but is structurally distinctive. Scrub-Heath encompasses some of the thicket and Heath FCTs recognised by Woodman Environmental Consulting, but Scrub-Heath may be included in woodland FCTs in some areas.

Low Heath on flats (Plate 4). These flats are extensive around Woolka Road and the soils were clayey-peat. At the western end of Woolka Road, these Low Heaths occur on calcareous soils with some exposed limestone. Similar Low Heaths present in Falcon but the Falcon Low Heaths have distinctive emergent *Kingia australis* that appear to be absent from the Low Heaths of Cooljarloo West. This presumably reflects a soil difference. Typical plants in this Low Heath were several species of *Hakea*, *Banksia telmatiae* and a range of Myrtaceae. The plants are indicative of some groundwater dependence. Where limestone was close to the surface, *Dryandra* (*Banksia*) *sessilis* was present, as was a small mallee eucalypt (FCT W8 according to Woodman Environmental Consulting). Other FCTs included within Low Heath are H1 and H5.

Tall Heath on flats (Plate 5 and 6). These were most extensive immediately west of Falcon and were on distinctive red-brown soils ((Plate 5). *Melaleuca lateriflora* is a major component of this association. Many of the plants are associated with wetlands and there is evidence of seasonal flooding. Little if any of this VSA occurs on Cooljarloo and Falcon. This Tall Heath includes FCTs T1 and T4 as recognised by Woodman Environmental Consulting.

Riparian Woodland (Plates 7 and 8). Woodlands associated with seasonally damp soils and occasional flooding; trees include *Eucalyptus rudis*, *Banksia littoralis*, *Melaleuca priessiana* and *Melaleuca raphiophylla*. Riparian woodland occurs in damp depressions and along some watercourses. Note that there were some locations *M. priessiana* occurred within Banksia Low Woodland, suggesting an historic decline in mesic conditions, allowing Low Woodland plants to invade what was a seasonal dampland, but with some old *M. priessiana* persisting. Very little of this riparian woodland is found on Cooljarloo and Flacon, although it is present in Wongonderrah Reserve just north of Falcon. Riparian Woodland includes some of FCTs F1, W1, W2 and T3.

Samphire wetland (Plate 9). A small seasonal wetland with samphire heath, located at 338 047E, 6 604 444N. Water was fresh. Surrounding flats supported Low Heath. There is no samphire at Cooljarloo or Falcon. This is FCT S1 as recognised by Woodman Environmental Consulting.

Riverine Associations (Plates 10, 11 and 12). The Emu Lakes Drainage System, Mullering Brook and Frederick Smith Creek had sections of flowing water and Riverine pools during the September site inspection, and supported distinctive vegetation dominated by *Melaleuca raphiophylla* over sedges. There were also submerged aquatic plants. The Emu Lakes system and Mullering Brook were similar (Plates 10 and 11), but Frederick Smith Creek (Plate 12) was deeply incised, the vegetation was sparse and the soils were a limestone marl. There are no Riverine Associations at Cooljarloo or Falcon. Riverine associations included parts of the FCTs F1, W1 and W2, with the distinction between Riparian Woodland and Riverine Associations being the presence of a watercourse with surface water present for at least several months of the year.

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 very similar in floristics and structure to those of Cooljarloo and Falcon, but all other VSAs present in Cooljarloo West are either poorly-represented or absent from Cooljarloo and Falcon. The Scrub Heath at Cooljarloo West is poorly-represented at Cooljarloo and Falcon, and was really only widespread south of Woolka Road on Cooljarloo West, the Low Heath on flats differed in some of its floristics and soils, the Tall Heath, especially with red-brown soils at the surface, appeared to occur only just west of Falcon, Riparian Woodland is limited to the margins of some wetlands in Cooljarloo and Falcon, while both Samphire and Riverine Associations are absent from Cooljarloo and Falcon. Most significantly, the VSAs that are best represented or present only in Cooljarloo West are associated with hydrological features and unusual soils.



Plate 1. Banksia Low Woodland



Plate 2. Banksia Low, Open Woodland



Plate 3. Scrub-Heath south of Woolka Road.



Plate 4. Low Heath south of Woolka Road. The scattered trees are *Nuytsia floribunda*.



Plate 5. Tall Heath on flats. Note the red-brown soil.



Plate 6. Tall Heath on flats with a flowering *Melaleuca hamulosa* and an emergent *Melaleuca raphiophylla*.



Plate 7. Riparian Woodland south of Woolka Road.



Plate 8. Riparian Woodland fringed with Tall Heath on flats of upper reaches of Frederick Smith Creek at 335 130E, 6 612 700N. Note dark, peaty-soil in foreground with flooding from recent rain.



Plate 9. Samphire wetland at 338 047E, 6 604 444N.



Plate 10. Mullering Brook at 338 000E, 6 605 367E.



Plate 11. Watercourse of the Emu Lakes system.



Plate 12. Frederick Smith Creek at 332 300E, 6 610 575N.

4.2 Vertebrate Fauna - assemblage

4.2.1 Overview

Vertebrate fauna species expected to occur in the region based upon the desktop review and those recorded during field investigations at Cooljarloo, Falcon and during the site visit to Cooljarloo West are presented in Table 4 to Table 7. Numbers of species are summarised in Table 3; of the 253 vertebrate species expected in the region based on all sources of information, 197 (71%) have been recorded by Bamford Consulting.

Table 3. Composition of vertebrate fauna assemblage expected to occur within the Project Area and recorded during the October 2009 site inspection.

Taxon	Number of species expected	Number Recorded by BCE	Significant fauna expected			Significant fauna recorded		
			CS1	CS2	CS3	CS1	CS2	CS3
Fish	5	5	-	-	2	-	-	2
Frogs	11	10	-	-	1	-	-	1
Reptiles	56	45	1	2	2	-	-	-
Birds	157	127	11	3	4	5	3	4
Mammals	24	20	-	3	2	-	2	1
Total	253	197	12	8	11	5	5	8

The assemblage reflects the high potential diversity of reptiles and birds in this region (Storr and Johnstone 1988; Maryan 2005). The faunal assemblage is likely to be 'typical' of the northern Swan Coastal Plain assemblage (e.g. Kitchener *et al.* 1978; Storr and Johnstone 1988), but with the distinct influence of wetland areas (particularly for some fish, frog and some bird species) and the close proximity of the western boundary to the coast (particularly for some reptiles).

Information on the fauna assemblage is presented below and impacts are discussed in Section 5. Tables 8 and 9 discuss and summarise information on those species recorded in or expected to occur in the Project Area that are considered to be of conservation significance. Note that all conservation significant species are discussed whether or not they were recorded during field surveys, as fauna are highly mobile, often seasonal and frequently cryptic. Therefore, the precautionary approach is taken in that if a significant species is expected to be present and suitable habitat is available, the assumption is made that the species is present or may be present within the life of the project.

4.2.2 Fish

Five freshwater fish species have been recorded in the Cooljarloo area (Table 4), with the Western Minnow and Pygmy Perth recorded in Mullering Brook, and the Swan River Goby and two introduced species found in Emu Lakes. Both Mullering Brook and Emu Lakes drain through Cooljarloo West so three species are almost certainly present. The late Dr Ray Hart observed fish, probably Western Minnows, in Wongonderrah Swamp. All the fish species recorded require permanent water, so will rely on permanent pools to survive summer, but probably disperse widely during flood conditions in late winter. Note that two native fish species found north of Perth, the Mud Minnow *Galaxiella munda* and the Black-striped Minnow *Galaxiella nigrostriata*, can survive in seasonal wetlands. The nearest known populations are in the Gingin to Muchea area, but habitats in Cooljarloo West (see plates 10, 11 and 12) look suitable for these species. They have not been included as expected because of the distance to the nearest population, and some netting during the site inspection failed to find either species, but the apparent suitability of habitat makes their presence at least remotely possible.

The Western Minnow and Western Pygmy Perth are considered to be of local conservation significance (CS3) with further information provided in Section 4.4.1. The presence of two introduced fish species in what are otherwise apparently undisturbed wetlands is disappointing and the spread of these fish should be avoided. Such impacts and management are discussed in Section 5.

Table 4. Freshwater fish that may occur in the vicinity of Cooljarloo West.

Status is assigned as described in Background. Species recorded At Cooljarloo (C), Falcon (F) and Cooljarloo West (CW) are indicated.

Species		Status	Recorded
Galaxiidae (native minnows or jollytails)			
<i>Galaxias occidentalis</i>	Western Minnow	CS3	C
Nannopercidae (pygmy perches)			
<i>Edelia vittata</i>	Western Pygmy Perch	CS3	C
Gobiidae (gobies)			
<i>Pseudogobius olorum</i>	Swan River Goby		C
Poeciliidae (livebearers)			
<i>Gambusia holbrooki</i>	Mosquitofish	INT	C
Cyprinidae (carp and allies)			
<i>Carassius auratus</i>	Goldfish	INT	C

4.2.3 Frogs

Ten species of frogs have been recorded in Cooljarloo and Falcon (Table 5), and all are almost certainly present in Cooljarloo West. Tadpoles (of one of the *Heleioporus* species) were present in Mullering Brook and Frederick Smith Creek during the site inspection, while the Poblebonk, Gunther's Toadlet and Slender Tree-Frog were observed. The one species listed as expected but not recorded, the Bleating Froglet, is probably not present as it has a distinctive call. However, it has been included on the basis of general patterns of distribution. 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 wetland created during mining and Earthworks around Cooljarloo.

The Squelching Froglet is considered to be of local conservation significance (CS3) with further information provided in Section 4.4.2.

Table 5. Amphibians that may occur in the vicinity of Cooljarloo West. Status is assigned as described in Background. Species recorded at Cooljarloo (C), Falcon (F) and Cooljarloo West (CW) are indicated.

Species		Status	Recorded
Hylidae (Tree frogs)			
<i>Litoria adelaidensis</i>	Slender Tree Frog		C, CW
<i>Litoria moorei</i>	Motorbike Frog		C
Limnodynastidae (Burrowing frogs)			
<i>Heleioporus albopunctatus</i>	Western Spotted Frog		C
<i>Heleioporus eyrei</i>	Moaning Frog		C, F
<i>Heleioporus psammophilus</i>	Sand Frog		C, F
<i>Limnodynastes dorsalis</i>	Banjo Frog, Pobblebonk		C, CW
<i>Neobatrachus pelobatoides</i>	Humming Frog		C, F
Myobatrachidae (Ground frogs)			
<i>Crinia insignifera</i>	Squelching Froglet	CS3	C, F, CW
<i>Crinia pseudinsignifera</i>	Bleating Froglet		
<i>Myobatrachus gouldii</i>	Turtle Frog		C, F
<i>Pseudophryne guentheri</i>	Günther's Toadlet		C, F, CW

4.2.4 Reptiles

Fifty-five species of reptiles occur in the region of the Project Area according to the literature (Table 6), with 43 of these recorded at Cooljarloo but only 21 at Falcon where sampling has been less intense. Species found at Cooljarloo but not Falcon are typically cryptic and/or occur at low densities, such as many of the snakes, and they are almost certainly present at both sites. However, a few species, such as the gecko *D. polyopthalmus*, occurs on lateritic slopes in the far east of Cooljarloo so is very unlikely to be found on the sandy soils of Falcon (or Cooljarloo West). 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 at Cooljarloo West during the site inspection and this lizard is usually associated with coastal, limestone-rich soils. 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 area even of 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.

Eight of the reptile species are of conservation significance: two CS1, two CS2 and four CS3. Four of these have been recorded at Cooljarloo and one at Falcon, and all should be considered as possible at Cooljarloo West. Significant reptile species are discussed in Section 4.4.3.

Table 6. Reptiles that may occur in the vicinity of Cooljarloo West. Status is assigned as described in Background. Species recorded at Cooljarloo (C), Falcon (F) and Cooljarloo West (CW) are indicated.

Species	Status	Recorded
Cheluidae (Side-necked freshwater turtles)		
<i>Chelodina oblonga</i>	Oblong Tortoise	C
Agamidae (Dragons)		
<i>Ctenophorus (Rankinia) adelaidensis</i>	Southern Heath Dragon	C F
<i>Pogona minor</i>	Western Bearded Dragon	C F
Diplodactylidae (Diplodactylid geckoes)		
<i>Crenadactylus ocellatus</i>	Clawless Gecko	
<i>Diplodactylus polyopthalmus</i>		CS3 C
<i>Lucasium alboguttatum</i>	White-spotted Ground Gecko	C F
<i>Strophurus spinigerus</i>	Soft Spiny-tailed Gecko	C F
Carphodactylidae (Carphodactylid geckoes)		
<i>Nephrurus milii</i>	Barking Gecko	
Gekkonidae (Gekkonid geckoes)		
<i>Christinus marmoratus</i>	Marbled Gecko	C F
Pygopodidae (Legless lizards)		
<i>Aprasia repens</i>	Sand-plain Worm-lizard	C
<i>Aprasia</i> sp. nov. aff. ‘fusca’		CS3
<i>Delma (Aclys) concinna</i>	Javelin Legless Lizard	C CW
<i>Delma fraseri</i>	Fraser’s Legless Lizard	C
<i>Delma grayii</i>	Gray’s Legless Lizard	C
<i>Lialis burtonis</i>	Burton’s Legless Lizard	C
<i>Pletholax gracilis</i>	Keeled Legless Lizard	C
<i>Pygopus lepidopodus</i>	Common Scaly-foot	C F
Scincidae (Skinks)		
<i>Cryptoblepharus buchananii</i>	Buchanan’s Snake-eyed Skink	C F
<i>Ctenotus australis</i>	Western Limestone Ctenotus	C
<i>Ctenotus catenifer</i>		
<i>Ctenotus fallens</i>	West Coast Ctenotus	C F, CW
<i>Ctenotus gemmula</i>	Jewelled Ctenotus	CS2 C F
<i>Ctenotus impar</i>	South-western Odd-striped Ctenotus	C

<i>Ctenotus pantherinus</i>	Leopard Ctenotus		C
<i>Cyclodomorphus celatus</i>	West Coast Slender Bluetongue		F CW
<i>Egernia kingii</i>	King's Skink		
<i>Egernia multiscutata</i>	Bull Skink		C F
<i>Egernia napoleonis</i>	Salmon-bellied Skink		C F
<i>Hemiergus quadrilineata</i>	Two-toed Earless Skink		
<i>Lerista christinae</i>	Bold-striped Lerista	CS3	F
<i>Lerista elegans</i>	West Coast Four-toed Lerista		C F
<i>Lerista lineopunctulata</i>			
<i>Lerista praepedita</i>	Western Worm Lerista		C F
<i>Menetia greyii</i>	Common Dwarf Skink		C F
<i>Morethia lineocellata</i>	Western Pale-flecked Morethia		C F
<i>Morethia obscura</i>	Dusky Morethia		C F
<i>Tiliqua occipitalis</i>	Western Blue-tongue		C
<i>Tiliqua rugosa</i>	Bobtail		C F CW
Varanidae (Monitors or goannas)			
<i>Varanus gouldii</i>	Sand Goanna		C F
<i>Varanus tristis</i>	Black-headed Monitor		
Typhlopidae (Blind snakes)			
<i>Ramphotyphlops australis</i>	Southern Blind Snake		C
Boidae (Pythons)			
<i>Antaresia stimsoni</i>	Stimson's Python		
<i>Aspidites ramsayi</i>	Woma	CS1	
<i>Morelia spilota</i>	Carpet Python	CS1	C
Elapidae (Venomous land snakes)			
<i>Brachyuropis fasciolata</i>	Narrow-banded Shovel-nosed Snake		C
<i>Brachyuropis semifasciata</i>	Southern Shovel-nosed Snake		C
<i>Demansia psammophis</i>	Yellow-faced Whip-Snake		C
<i>Echiopsis curta</i>	Bardick		C
<i>Neelaps bimaculatus</i>	Black-naped Snake		C F CW
<i>Neelaps calonotos</i>	Black-striped Snake	CS2	C
<i>Notechis scutatus</i>	Tiger Snake	CS3	
<i>Parasuta gouldii</i>	Gould's Snake		C
<i>Pseudechis australis</i>	Mulga Snake		C F
<i>Pseudonaja nuchalis</i>	Gwardar		C
<i>Simoselaps bertholdi</i>	Jan's Banded Snake		
<i>Simoselaps littoralis</i>	West Coast Banded Snake		

4.2.5 Birds

One hundred and fifty-six bird species occur in the region of the Project Area according to the literature (Table 7), of which 127 have been observed at Cooljarloo and 50 at Falcon where sampling has been less intense. During the site visit, 31 species were observed at Cooljarloo West. The total of 156 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. For example, a single juvenile White-bellied Sea-Eagle was observed at Emu Lakes, on the edge of the Cooljarloo South Mine, but the bird was probably only there for a short time and the species has never been seen again.

Bird censusing 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 censusing 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, number of species usually <5 and density <5/ha (M. Bamford and Tiwest unpubl. data). These observations at Cooljarloo suggest that the Scrub-Heath and Riparian Woodlands at Cooljarloo West are likely to be locally important for species richness and abundance.

The avifauna includes 18 species of conservation significance, most of which have been observed at Cooljarloo and/or Falcon (see Table 3). However, this list includes nine species of high conservation significance (CS1) that are almost certainly only infrequent visitors or even vagrants in the area (migratory waterbirds). Significant bird species are described in Section 4.4.4.

Table 7. Birds that may occur in the vicinity of Cooljarloo West. Status is assigned as described in Background. Species marked with a superscript ‘w’ are generally dependent on wetlands, species marked with a superscript ‘a’ are highly aerial species. Species recorded at Cooljarloo (C), Falcon (F) and Cooljarloo West (CW) are indicated. V indicates species that are probably vagrants in the general area.

Species		Status	Recorded
Casuariidae (Cassowaries and emus)			
<i>Dromaius novaehollandiae</i>	Emu		C, F
Phasianidae (Pheasants and allies)			
<i>Coturnix pectoralis</i>	Stubble Quail		C
Anatidae (Ducks and allies)			
<i>Biziura lobata</i>	Musk Duck ^w	V	C
<i>Cygnus atratus</i>	Black Swan ^w	V	C
<i>Tadorna tadornoides</i>	Australian Shelduck ^w		C
<i>Chenonetta jubata</i>	Australian Wood Duck ^w		C
<i>Malacorhynchus membranaceus</i>	Pink-eared Duck ^w	V	
<i>Anas rhynchotis</i>	Australasian Shoveler ^w	V	C
<i>Anas gracilis</i>	Grey Teal ^w		C
<i>Anas castanea</i>	Chestnut Teal ^w	V	C
<i>Anas superciliosa</i>	Pacific Black Duck ^w		C, F
<i>Aythya australis</i>	Hardhead ^w	V	C
<i>Oxyura australis</i>	Blue-billed Duck ^w	V	C
Podicipedidae (Grebes)			
<i>Tachybaptus novaehollandiae</i>	Australasian Grebe ^w		C
<i>Poliiocephalus poliocephalus</i>	Hoary-headed Grebe ^w		C
Columbidae (Pigeons and doves)			
<i>Columba livia</i>	Rock Dove/Feral Pigeon	INT, V	
<i>Streptopelia senegalensis</i>	Laughing Dove	INT, V	C
<i>Phaps chalcoptera</i>	Common Bronzewing		C, F, CW
<i>Phaps elegans</i>	Brush Bronzewing		C, CW
<i>Ocyphaps lophotes</i>	Crested Pigeon		C, F
Podargidae (Australian frogmouths)			
<i>Podargus strigoides</i>	Tawny Frogmouth		C
Eurostopodidae (Eared-nightjars)			
<i>Eurostopodus argus</i>	Spotted Nightjar		C
Aegothelidae (Owlet-nightjars)			
<i>Aegotheles cristatus</i>	Australian Owlet-nightjar		
Apodidae (Typical swifts)			
<i>Apus pacificus</i>	Fork-tailed Swift ^a	CS1	
Anhingidae (Darters)			
<i>Anhinga novaehollandiae</i>	Australasian Darter ^w	V	C
Phalacrocoracidae (Cormorants)			
<i>Microcarbo melanoleucos</i>	Little Pied Cormorant ^w		C
<i>Phalacrocorax sulcirostris</i>	Little Black Cormorant ^w	V	C
Pelicanidae (Pelican)			
<i>Pelecanus conspicillatus</i>	Australian Pelican ^w	V	C
Ardeidae (Herons, bitterns and egrets)			
<i>Ardea pacifica</i>	White-necked Heron ^w		C

<i>Ardea modesta</i>	Eastern Great Egret ^w	CS1	
<i>Egretta novaehollandiae</i>	White-faced Heron ^w		C
<i>Egretta garzetta</i>	Little Egret ^w	V	
<i>Nycticorax caledonicus</i>	Nankeen Night Heron ^w		C
Threskiornithidae (Ibises and spoonbills)			
<i>Threskiornis molucca</i>	Australian White Ibis		
<i>Threskiornis spinicollis</i>	Straw-necked Ibis		C
<i>Platalea flavipes</i>	Yellow-billed Spoonbill ^w	V	C
Accipitridae (Osprey, hawks and eagles)			
<i>Elanus axillaris</i>	Black-shouldered Kite		C
<i>Lophoictinia isura</i>	Square-tailed Kite	CS3	C, F
<i>Haliaeetus leucogaster</i>	White-bellied Sea-Eagle	CS1, V	C
<i>Haliastur sphenurus</i>	Whistling Kite		C
<i>Accipiter fasciatus</i>	Brown Goshawk		C
<i>Accipiter cirrocephalus</i>	Collared Sparrowhawk		C
<i>Circus assimilis</i>	Spotted Harrier		C
<i>Circus approximans</i>	Swamp Harrier		C
<i>Aquila audax</i>	Wedge-tailed Eagle		C, F
<i>Hieraaetus morphnoides</i>	Little Eagle		C
Falconidae (Falcons)			
<i>Falco cenchroides</i>	Nankeen Kestrel		C, F, CW
<i>Falco berigora</i>	Brown Falcon		C, F, CW
<i>Falco longipennis</i>	Australian Hobby		C
<i>Falco peregrinus</i>	Peregrine Falcon	CS1, V	
Rallidae (Rails, gallinules and coots)			
<i>Porphyrio porphyrio</i>	Purple Swamphen ^w		C
<i>Gallirallus philippensis</i>	Buff-banded Rail ^w	V	C
<i>Porzana pusilla</i>	Baillon's Crake ^w	V	
<i>Porzana fluminea</i>	Australian Spotted Crake ^w	V	
<i>Porzana tabuensis</i>	Spotless Crake ^w	V	
<i>Tribonyx ventralis</i>	Black-tailed Native-hen	V	C
<i>Fulica atra</i>	Eurasian Coot ^w		C
Otididae (Bustards)			
<i>Ardeotis australis</i>	Australian Bustard	CS2, V	C
Recurvirostridae (Stilts and avocets)			
<i>Himantopus himantopus</i>	Black-winged Stilt ^w		C
<i>Recurvirostra novaehollandiae</i>	Red-necked Avocet ^w		
<i>Cladorhynchus leucocephalus</i>	Banded Stilt ^w	V	
Charadriidae (Lapwings, plovers and dotterels)			
<i>Charadrius ruficapillus</i>	Red-capped Plover ^w	V	C
<i>Elseyornis melanops</i>	Black-fronted Dotterel ^w	V	C
<i>Erythrogonys cinctus</i>	Red-kneed Dotterel ^w	V	
<i>Vanellus tricolor</i>	Banded Lapwing	V	C
Scolopacidae (Curlews, godwits, snipe, sandpipers and allies)			
<i>Actitis hypoleucos</i>	Common Sandpiper ^w	CS1, V	C
<i>Tringa nebularia</i>	Common Greenshank ^w	CS1, V	
<i>Calidris ruficollis</i>	Red-necked Stint ^w	CS1, V	
<i>Calidris acuminata</i>	Sharp-tailed Sandpiper ^w	CS1, V	
Turnicidae (Button-quails)			
<i>Turnix varius</i>	Painted Button-quail		C, F

<i>Turnix velox</i>	Little Button-quail	V	C
Cacatuidae (Cockatoos)			
<i>Calyptorhynchus latirostris</i>	Carnaby's Black-Cockatoo	CS1	C, F
<i>Eolophus roseicapillus</i>	Galah		C, F, CW
<i>Cacatua pastinator</i>	Western Corella		C
<i>Cacatua sanguinea</i>	Little Corella	V	
<i>Nymphicus hollandicus</i>	Cockatiel	V	
Psittacidae (Parrots)			
<i>Glossopsitta porphyrocephala</i>	Purple-crowned Lorikeet	V	Cataby
<i>Polytelis anthopeplus</i>	Regent Parrot	V	C, F
<i>Barnardius zonarius</i>	Australian Ringneck		C, F
<i>Purpureicephalus spurius</i>	Red-capped Parrot	V	Cataby
<i>Melopsittacus undulatus</i>	Budgerigar	V	C
<i>Neophema elegans</i>	Elegant Parrot		C, F
<i>Pezoporus wallicus</i>	Ground Parrot	CS1	
Cuculidae (Old world cuckoos)			
<i>Chalcites basalis</i>	Horsfield's Bronze-Cuckoo		C, F, CW
<i>Chalcites osculans</i>	Black-eared Cuckoo	V	
<i>Chalcites lucidus</i>	Shining Bronze-Cuckoo		C, CW
<i>Cacomantis pallidus</i>	Pallid Cuckoo		C, CW
<i>Cacomantis flabelliformis</i>	Fan-tailed Cuckoo		C, CW
Strigidae (Hawk owls)			
<i>Ninox novaeseelandiae</i>	Southern Boobook		C, F
Tytonidae (Barn owls)			
<i>Tyto javanica</i>	Eastern Barn Owl		
Halcyonidae (Tree kingfishers)			
<i>Dacelo novaeguineae</i>	Laughing Kookaburra	INT	C
<i>Todiramphus pyrrhopygius</i>	Red-backed Kingfisher	V	C
<i>Todiramphus sanctus</i>	Sacred Kingfisher		C
Meropidae (Bee-eaters)			
<i>Merops ornatus</i>	Rainbow Bee-eater	CS1	C
Maluridae (Fairy-wrens, emu-wrens and grasswrens)			
<i>Malurus splendens</i>	Splendid Fairy-wren		C, F, CW
<i>Malurus leucopterus</i>	White-winged Fairy-wren		C, F, CW
<i>Malurus lamberti</i>	Variiegated Fairy-wren		C, F, CW
<i>Malurus pulcherrimus</i>	Blue-breasted Fairy-wren		
<i>Stipiturus malachurus</i>	Southern Emu-wren	CS3	C, F
Acanthizidae (Australasian warblers)			
<i>Sericornis frontalis</i>	White-browed Scrubwren		C, CW
<i>Calamanthus campestris</i>	Rufous Fieldwren	CS2	C, F, CW
<i>Smicrornis brevirostris</i>	Weebill		C
<i>Gerygone fusca</i>	Western Gerygone		C, CW
<i>Acanthiza chrysorrhoa</i>	Yellow-rumped Thornbill		C, F, CW
<i>Acanthiza inornata</i>	Western Thornbill		C, F
<i>Acanthiza apicalis</i>	Inland Thornbill		C
Pardalotidae (Pardalotes)			
<i>Pardalotus punctatus</i>	Spotted Pardalote		C
<i>Pardalotus striatus</i>	Striated Pardalote		C
Meliphagidae (Honeyeaters)			
<i>Acanthorhynchus superciliosus</i>	Western Spinebill		C, F

<i>Certhionyx variegatus</i>	Pied Honeyeater	V	C, F
<i>Lichenostomus virescens</i>	Singing Honeyeater		C, F
<i>Manorina flavigula</i>	Yellow-throated Miner		C
<i>Anthochaera lunulata</i>	Western Wattlebird		C, F, CW
<i>Anthochaera carunculata</i>	Red Wattlebird		C, F
<i>Epthianura tricolor</i>	Crimson Chat	V	C
<i>Epthianura albifrons</i>	White-fronted Chat		C
<i>Sugomel niger</i>	Black Honeyeater		C, F
<i>Glyciphila melanops</i>	Tawny-crowned Honeyeater		C, F, CW
<i>Lichmera indistincta</i>	Brown Honeyeater		C, F, CW
<i>Phylidonyris novaehollandiae</i>	New Holland Honeyeater		C, CW
<i>Phylidonyris niger</i>	White-cheeked Honeyeater		C, F, CW
<i>Melithreptus brevirostris</i>	Brown-headed Honeyeater		C
Neosittidae (Sitellas)			
<i>Daphoenositta chrysoptera</i>	Varied Sittella		C, F, CW
Campephagidae (Cuckoo-shrikes and trillers)			
<i>Coracina maxima</i>	Ground Cuckoo-shrike	V	C
<i>Coracina novaehollandiae</i>	Black-faced Cuckoo-shrike		C, F, CW
<i>Lalage sueurii</i>	White-winged Triller		C, F
Pachycephalidae (Whistlers, shrike-thrushes and allies)			
<i>Pachycephala rufiventris</i>	Rufous Whistler		C, F, CW
<i>Colluricincla harmonica</i>	Grey Shrike-thrush		C, F, CW
<i>Oreoica gutturalis</i>	Crested Bellbird	CS2	C, F, CW
Artamidae (Woodswallows, butcherbirds and currawongs)			
<i>Artamus personatus</i>	Masked Woodswallow	V	C
<i>Artamus cinereus</i>	Black-faced Woodswallow		C, F, CW
<i>Artamus cyanopterus</i>	Dusky Woodswallow		C, F
<i>Cracticus torquatus</i>	Grey Butcherbird		C, F, CW
<i>Cracticus nigrogularis</i>	Pied Butcherbird		C
<i>Cracticus tibicen</i>	Australian Magpie		C, F
Rhipiduridae (Fantails)			
<i>Rhipidura albiscapa</i>	Grey Fantail		C, F, CW
<i>Rhipidura leucophrys</i>	Willie Wagtail		C, F, CW
Corvidae (Crows and allies)			
<i>Corvus coronoides</i>	Australian Raven		C, F, CW
<i>Corvus bennetti</i>	Little Crow	V	Cataby
Monarchidae (Flycatchers, monarchs and magpie-lark)			
<i>Myiagra inquieta</i>	Restless Flycatcher	V	
<i>Grallina cyanoleuca</i>	Magpie-lark		C, F
Petroicidae (Robins)			
<i>Petroica boodang</i>	Scarlet Robin	CS3	C
<i>Petroica goodenovii</i>	Red-capped Robin		C
<i>Melanodryas cucullata</i>	Hooded Robin		C, F
<i>Eopsaltria georgiana</i>	White-breasted Robin	CS3	C
Megaluridae (Grassbirds)			
<i>Cincloramphus mathewsi</i>	Rufous Songlark		C
<i>Cincloramphus cruralis</i>	Brown Songlark		C
Timaliidae (White-eyes)			
<i>Zosterops lateralis</i>	Silvereye		C, F, CW
Hirundinidae (Swallows and martins)			

<i>Cheramoeca leucosterna</i>	White-backed Swallow		C
<i>Hirundo neoxena</i>	Welcome Swallow		C, F
<i>Petrochelidon nigricans</i>	Tree Martin		C, F
<i>Petrochelidon ariel</i>	Fairy Martin		
Nectariniidae (Sunbirds and allies)			
<i>Dicaeum hirundinaceum</i>	Mistletoebird		C
Estrildidae (Finches)			
<i>Taeniopygia guttata</i>	Zebra Finch	V	C
Motacillidae (Old world wagtails and pipits)			
<i>Anthus novaeseelandiae</i>	Australasian Pipit		C

4.2.6 Mammals

Twenty-four mammal species occur in the region of the Project Area according to the literature (Table 8), and a further 10 species are locally extinct (Table 9). The 20 mammal species recorded at Cooljarloo thus represent a high proportion of the assemblage expected, while the two bat species and one introduced rodent not recorded may well not be present. The list of mammals recorded at Falcon is smaller than that for Cooljarloo, mainly because no bat surveys have been undertaken there. All mammal species recorded at Cooljarloo can be expected to occur at Cooljarloo West. The status of the two bat species and rodent not recorded at Cooljarloo but known from the general region is uncertain, but it has to be assumed they occur in Cooljarloo West.

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), 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.

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 occupiers 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 telmatiae* are flowering.

The mammal assemblage includes only four species of conservation significance (see Table 3), none of which is of high significance. The extinct mammals include several that are of high conservation significance. Significant mammal species are described in Section 4.4.5.

Table 8. Mammals that may occur in the vicinity of Cooljarloo West. Status is assigned as described in Background. Species recorded at Cooljarloo (C), Falcon (F) and Cooljarloo West (CW) are indicated.

Species		Status	Recorded
Tachyglossidae (Echidnas)			
<i>Tachyglossus aculeatus</i>	Echidna		C, F, CW
Dasyuridae (Dasyurids)			
<i>Sminthopsis crassicaudata</i>	Fat-tailed Dunnart		C
<i>Sminthopsis griseoventer</i>	Grey-bellied Dunnart		C, F
<i>Sminthopsis granulipes</i>	White-tailed Dunnart		C, F
Peramelidae (Bandicoots)			
<i>Isoodon obesulus</i>	Southern Brown Bandicoot, Quenda	CS2	
Macropodidae (Kangaroos, wallabies and tree kangaroos)			
<i>Macropus eugenii</i>	Tammar, Tammar Wallaby	CS2	C
<i>Macropus fuliginosus</i>	Western Grey Kangaroo		C, F, CW
<i>Macropus irma</i>	Brush Wallaby	CS2	C, F
Phalangeridae (Brushtail possums)			
<i>Trichosurus vulpecula</i>	Brushtail Possum	CS3	C
Tarsipedidae (Honey Possum)			
<i>Tarsipes rostratus</i>	Honey Possum		C, F
Vespertilionidae (Vespertilionid bats)			
<i>Chalinolobus gouldii</i>	Gould's Wattled Bat		C
<i>Chalinolobus morio</i>	Chocolate Wattled Bat		
<i>Nyctophilus geoffroyi</i>	Lesser Long-eared Bat		C
<i>Nyctophilus timoriensis</i>	Greater Long-eared Bat		C
<i>Vespadelus regulus</i>	Southern Forest Bat		C
Molossidae (Freetail bats)			
<i>Mormopterus</i> sp. (Species 4, population O)	Western Freetail-bat	CS3	
<i>Tadarida australis</i>	White-striped Freetail-bat		C
Muridae (Rats and mice)			
<i>Mus musculus</i>	House Mouse	INT	C, F
<i>Pseudomys albocinereus</i>	Ash-grey Mouse or Noodji		C, F
<i>Rattus fuscipes</i>	Western Bush Rat or Moodit		C
<i>Rattus rattus</i>	Black Rat	INT	
Leporidae (Rabbits and hares)			
<i>Oryctolagus cuniculus</i>	Rabbit	INT	C, F
Canidae (Dogs and foxes)			

<i>Vulpes vulpes</i>	Red Fox	INT	C, F
Felidae (Cats)			
<i>Felis catus</i>	Cat	INT	C, F

Table 9. Species considered to be extinct in the vicinity of Cooljarloo West.

Burhinidae (Stone-curlews)		
<i>Burhinus grallarius</i>	Bush Stone-curlew	
Cinclosomatidae (Quail-thrushes and allies)		
<i>Psophodes nigrogularis</i>	Western Whipbird	
Dasyuridae (Dasyurids)		
<i>Dasyurus geoffroii</i>	Chuditch	
<i>Parantechinus apicalis</i>	Dibbler	
Peramelidae (Bandicoots)		
<i>Peremeles bougainville</i>	Western Barred Bandicoot, Marl	
Thylacomyidae (Bilbies)		
<i>Macrotis lagotis</i>	Bilby	
Potoroidae (Potoroos and bettongs)		
<i>Bettongia lesueur</i>	Burrowing Bettong, Boodie	
<i>Bettongia penicillata</i>	Brush-tailed Bettong, Woylie	
<i>Potorous platyops</i>	Broad-faced Potoroo	
Rodentia (Rats and mice)		
<i>Pseudomys fieldi</i>	Shark Bay Mouse	
<i>Pseudomys occidentalis</i>	Western Mouse	
<i>Pseudomys shortridgeii</i>	Heath Rat	

4.3 Invertebrate Fauna - assemblage

Invertebrates in general are beyond the scope of environmental impact assessment because there are so many species and their taxonomy is so poorly understood, but it is possible to focus on species of listed conservation significance and a small range of invertebrate taxa that are short-range endemics (SREs). Harvey (2002) notes that the majority of invertebrate species that have been classified as short-range endemics have common life history characteristics such as limited capacity for dispersal or confinement to discontinuous habitats. Several invertebrate groups, therefore, have particularly high instances of short-range endemic species: Gastropoda (snails and slugs), Oligochaeta (earthworms), Onychophora (velvet worms), Araneae (mygalomorph spiders), Schizomida (schizomids; spider-like arachnids), Diplopoda (millipedes), Phreatoicidea (phreatoicidean crustaceans), and Decapoda (freshwater crayfish).

Cooljarloo West lacks relictual environments/discontinuous habitats of the sort associated with SRE invertebrate species, as even the wetlands are parts of extensive, interconnected systems. However, Cooljarloo West is notable for the extent of mesic environments compared with Cooljarloo and Falcon.

Invertebrate sampling at Cooljarloo and Falcon has targeted species that might be of listed conservation significance, and species that might be SREs. In addition, species of listed conservation significance are included in the DEC Threatened Fauna database. Aquatic macro-invertebrates were also sampled in Mullering Brook in the early 1990s (Streamtech 1991, 1992), and sampling for invertebrates in woodland was carried out in the early 1990s. This found greater abundance and species richness close to wetlands than in *Banksia* Low Woodland. Significant invertebrate species are discussed in Section 4.4.6.

4.4 Vertebrate and Invertebrate Fauna – species of conservation significance

Details on species of conservation significance are discussed below, and are summarised in Table 10. Impacts upon these species are considered in Section 5.

4.4.1 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.

4.4.2 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, not recorded during Cooljarloo surveys, actually refer to the Squelching Froglet.

4.4.3 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 DEC. 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. 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 DEC. It is probably 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 may be allowing 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 DEC and has been recorded in Banksia Low Woodland on sandplain at both Cooljarloo and Falcon. 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 DEC 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.

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 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 is likely to be present in Cooljarloo West.

Speckled Stone Gecko

Diplodactylus polyopthalmus

This gecko appears to have a patchy distribution on the coastal plain north of Perth, and populations in the Cataby to Mt Lesueur area are under taxonomic review. Around Cooljarloo it is known only from the lateritic escarpment that supports very low heath. It is unlikely to occur in Cooljarloo West.

Legless lizard

Aprasia sp. nov. aff. '*fusca*'

This small legless-lizard is currently undescribed and is known only from sandplains near Geraldton, but Maryan (2005) suggest it may be more widespread. Its status in the area of Tiwest operations is unknown but the only member of the genus recorded has been the widespread *Aprasia repens*. However, members of this genus are cryptic and fossorial and only three specimens have been caught at Cooljarloo over 20 years. This suggests that a second member of the genus could be present. Furthermore, *A. repens* appears most abundant in sandy soils around the margins of seasonal wetlands (M. Bamford, unpubl. data) and such habitat is more widespread at Cooljarloo West than either Cooljarloo or Falcon.

Tiger Snake

Notechis scutatus

There are a few records of the Tiger Snake in the Jurien area and the population appears to be isolated, with no other records north of Gingin. This apparently small, isolated population may extend to some of the dense, wetland-associated vegetation of Cooljarloo West.

4.4.4 Birds

Conservation Significance Level 1.

Migratory species: Fork-tailed Swift, Eastern Great Egret, White-bellied Sea-Eagle, 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. Although natural wetlands are more extensive in Cooljarloo West than at Cooljarloo or Falcon, they are not the sort of open wetlands with extensive shallows that would attract large numbers of these migratory waterbirds.

The Fork-tailed Swift is almost entirely aerial when in Australia and while not yet recorded during the studies for Tiwest, 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 breeds in the area. It is actually attracted by ground disturbance, often digging its nest-burrows in low banks around disturbed areas. It is almost certainly a regular visitor to Cooljarloo West.

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 and WA *Wildlife Conservation Acts*, Carnaby's Black-Cockatoo is common around Cooljarloo and Falcon, with non-breeding flocks seen regularly and occasionally containing 500 birds. The species also breeds in the hollows of large trees along Cataby Brook, just south of Cooljarloo. It is likely to be a regular foraging visitor in large numbers to Cooljarloo West but there did not appear to be any large trees suitable for nesting. Carnaby's Black-Cockatoo forages largely on the seeds of Proteaceae, particularly *Banksia* spp.

Western Ground Parrot

Pezoporus wallicus flaviventris

Listed as 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. Recent DNA analyses suggest that the Western Ground Parrot should be considered a full species (A.H. Burbidge pers. comm.), distinct from the

moderately common Eastern Ground Parrot. This makes the survival of the taxon of particular importance. 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.

Conservation Significance Level 2.

Australian Bustard

Ardeotis australis

The Australian Bustard is listed as Priority 4 by the DEC 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 DEC 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 DEC 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. 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 throughout Cooljarloo West.

4.4.5 Mammals

Conservation Significance Level 2

Quenda*Isoodon obesulus*

Listed as Priority 5 by the DEC 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 will probably spread eastward through Cooljarloo West, where dense vegetation around damplands and wetlands provides ideal habitat.

Tammar*Macropus eugenii*

Listed as Priority 5 by the DEC 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.

Brush Wallaby*Macropus irma*

Listed as Priority 5 by the DEC 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 is almost certainly present at 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 Tiwest (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 Tiwest Cooljarloo area is unknown.

4.4.6 InvertebratesConservation Significance Level 2**Phasmid-mimic Cricket***Phasmodes jeeba*

Listed as Priority 2 by the DEC and known from only two locations between Jurien and Dongara (Rentz 1993). Searching for this species has been undertaken at Cooljarloo, in the Mt Adams Road area and near Eneabba (M. Bamford unpubl. data), but only the widespread *Phasmodes ranitiformis* has been found. Habitat photographs presented by Rentz (1993) illustrate coastal heath unlike the heaths of Cooljarloo West.

Scorpion-fly*Austromerope poultoni*

Listed as Priority 2 by the DEC but according to Fathfull *et al.* (1985), this species is most abundant in moist areas of forests in the south-west, such as around Boddington. Despite this, *A. poultoni* is listed for the general area on the DEC threatened Fauna

database. If present in Cooljarloo West, it could be expected in seasonally damp areas close to wetlands.

Conservation Significance Level 3

Several species of millipedes have been collected at Cooljarloo/Falcon and at least some of these are SREs, as follows:

Antichiropus sp. nov. 'cooljarloo' (Paradoxosomatidae). An undescribed millipede known only from specimens collected in August 2006 in *Banksia* Low Woodland near Dump 1, near the North Mine and at Falcon. Likely to be present in similar vegetation at Cooljarloo West. This is almost certainly an SRE but the extent of its distribution is unknown.

Antichiropus Eneabba 2 (Paradoxosomatidae). A millipede previously known only from the Eneabba area. Specimens collected in August 2009 in *Banksia* Low Woodland along North Transect, near the Cooljarloo North Mine, from a low-lying and seasonally damp area. Likely to be present in a similar environment at Cooljarloo West. Although the Cooljarloo record increases the known range of this species, the WA Museum considers it to be an SRE.

Antichiropus whistleri (Paradoxosomatidae). Specimens collected in August 2009 in *Banksia* Low Woodland along North Transect, near the Cooljarloo North Mine. Likely to be present in similar vegetation at Cooljarloo West. The WA Museum advises that this is not an SRE species.

Podykipus sp. (Iulomorphidae). A single specimen collected in August 2006 from *Banksia* low woodland at Falcon. The genus *Podykipus* is restricted to south-western Australia, but the taxonomy is poorly resolved as many new species have been detected. The taxonomic status of the Cooljarloo is uncertain (M. Harvey, WA Museum, pers. comm.) and therefore this may be an SRE species.

Table 10. Conservation status of significant fauna species expected to occur in the Project Area. See Appendix 2 for explanation of status codes.

Table 10. CONSERVATION STATUS		CS1				CS2	CS3
COMMON NAME	LATIN NAME	EPBC	WA Act	JAMBA	CAMBA		
FISH							
Western Minnow	<i>Galaxias occidentalis</i>						+
Pygmy Perch	<i>Edelia vittata</i>						+
FROGS							
Squelching Froglet	<i>Crinia insignifera</i>						+
REPTILES							
South West Carpet Python	<i>Morelia spilota imbricata</i>		Sch 4			P4	
Woma	<i>Aspidites ramsayi</i>		Sch 4			P1	
Black-striped Snake	<i>Neelaps calonotos</i>					P3	
Jewelled Ctenotus	<i>Ctenotus gemmula</i>					P3	
Speckled Stone Gecko	<i>Diplodactylus polyophthalmus</i>						+
Tiger Snake	<i>Notechis scutatus</i>						+
Bold-striped Lerista	<i>Lerista christinae</i>						+
Legless-lizard	<i>Aprasia</i> sp. nov. aff. 'fusca'						+
BIRDS							
Carnaby's Black-Cockatoo	<i>Calyptorhynchus latirostris</i>	End	Sch 1				
Peregrine Falcon	<i>Falco peregrinus</i>		Sch 4				
Fork-tailed Swift	<i>Apus pacificus</i>	MIG		+	+		

Table 10. CONSERVATION STATUS		CS1				CS2	CS3
COMMON NAME	LATIN NAME	EPBC	WA Act	JAMBA	CAMBA		
Rainbow Bee-eater	<i>Merops ornatus</i>	MIG		+	+		
Migratory waterbirds		MIG		+	+		
Western Ground Parrot	<i>Pezoropus walliculus flaviventris</i>	End	Sch 1				
Australian Bustard	<i>Ardeotis australis</i>					P4	
Rufous Fieldwren	<i>Calamanthus campestris montanellus</i>					P4	
Crested Bellbird	<i>Oreoica gutturalis gutturalis</i>					P4	
Square-tailed Kite	<i>Lophoictinia isura</i>						+
Southern Emu-wren	<i>Stipiturus malachurus</i>						+
Scarlet Robin	<i>Petroica multicolor</i>						+
White-breasted Robin	<i>Eopsaltria georgiana</i>						+
MAMMALS							
Brush Wallaby	<i>Macropus irma</i>					P4	
Quenda	<i>Isodon obesulus</i>					P5	
Tammar	<i>Macropus eugenii</i>					P5	
Brushtail Possum	<i>Trichosurus vulpecula</i>						+
Western Freetail Bat	<i>Mormopterus</i> sp. 4, Population O						+
INVERTEBRATES							
Phasmid-mimic Cricket	<i>Phasmodes jeeba</i>					P2	
Scorpion Fly	<i>Austromerope poultoni</i>					P2	
Millipedes: <i>Antichiropus</i> sp. nov. "Cooljarloo, <i>Antichiropus</i> Eneabba 2 and possibly <i>Podykipus</i> sp.							+

5 IMPACT ASSESSMENT

Developments such as that proposed by Tiwest for the Cooljarloo West area can impact upon fauna in a number of ways. For example:

- Loss of habitat (clearing);
- Fragmentation of habitat;
- Obstructions (e.g. pipes on ground, roads) to the movements of terrestrial fauna;
- Impacts to surface and groundwater flows (through vegetation clearing, interception of the ground water table and dewatering);
- Introduction of permanent water storages;
- Death/injury of fauna during clearing, grading and impacts with vehicles/machinery;
- Disturbance of fauna in nearby areas from light, blasting vibrations, noise, dust and even personnel feeding selected species; and
- Changes in the abundance of feral species.

Some impacts upon fauna are unavoidable. Of concern are long-term, deleterious impacts upon biodiversity. These are discussed below under the following categories:

- VSAs. Impacts may be significant if the VSA is rare, a large proportion of the VSA is affected and/or the VSA supports significant fauna.
- Significant fauna. Impacts may be significant if species of conservation importance are affected.
- Processes. Ecological processes are complex and can include hydrology, fire, predator/prey relationships and spatial distribution of a population (see discussion below). Impacts upon ecological processes may be significant if large numbers of species or large proportions of populations are affected.
- Patterns of biodiversity. Species are not distributed evenly across the landscape or even within one VSA. There may be zones of high biodiversity such as particular VSAs or ecotones (transitions between VSAs).

Table 12 summarises impacts upon fauna according to criteria set out in the EPA Guidance Statement No. 56.

5.1 Vegetation and Soil Associations (VSA)

The main VSAs in the Project Area are described in Section 4.1 (above). The extent and impact on each VSA type can be summarised as follows:

1. Banksia Low Woodland on stabilised sand-dunes.
 - Representation. Very extensive within Project Area and within region.
 - Conservation Significance for Fauna. Supports a rich fauna with some significant species. The banksias are key food source for nectarivorous birds, the Honey Possum and Carnaby's Black-Cockatoo. Reptiles very species rich.
 - Impact. Some loss of this VSA will occur.
 - Impact Assessment. Impact low because of small area of impact compared with local and regional representation of the VSA.
2. Scrub-Heath on undulating sands.

- Representation. Restricted distribution within the Project Area and regionally, but this VSA is difficult to define.
- Conservation Significance for Fauna. Faunal assemblage probably similar to that of Banksia Low Woodland, but may be more insectivorous bird species such as the Splendid-Fairy-wren and Whiter-browed Scrubwren, and probably higher bird densities and bird species richness overall.
- Impact. Some loss of this VSA will occur and it may be sensitive to hydrological changes.
- Impact Assessment. Impact moderate because of the restricted distribution of this VSA and sensitivity to hydrological changes.

3. Low Heath on flats.

- Representation. Extensive in the south and west of the Project Area, and quite variable. Similar low heaths on Falcon differ floristically.
- Conservation Significance for Fauna. Probably less species rich than the Low Woodlands and Scrub-Heaths, but some species, such as the Southern Emu-wren, mostly confined to Low Heath. The Low Heath may also be seasonally important for nectarivorous species, while Carnaby's Black-Cockatoo feeds on *Banksia telmatiae* that occurs in the Low Heath. The Low Heath is seasonally damp and was where the millipedes *Antichiropus whistleri* and *Antichiropus Eneabba 2* were found (in Cooljarloo).
- Impact. Some loss of this VSA will occur and it is very likely to be sensitive to hydrological changes.
- Impact Assessment. Impact moderate because of the restricted distribution of this VSA and sensitivity to hydrological changes.

4. Tall Heath on flats.

- Representation. Very limited and fragmented in distribution, with small patches just west of Falcon. Limited elsewhere in the Project Area and at Cooljarloo and Falcon. Seems to occur on flats where surface water occurs in some years.
- Conservation Significance for Fauna. Supports a range of insectivorous bird species with locally restricted distributions (eg White-breasted Robin) and probably also supports some of the SRE invertebrates. .
- Impact. Not known if there will be direct impact upon this VSA, but it is very likely to be sensitive to hydrological changes.
- Impact Assessment. Impact moderate because of the restricted distribution of this VSA and sensitivity to hydrological changes.

5. Riparian Woodland.

- Representation. Very limited in distribution to the main drainage lines, and a distinctive feature of the Project Area that is poorly represented regionally.

- Conservation Significance for Fauna. High species richness and abundance of birds but probably lower abundance of reptiles and small mammals than the Banksia Low Woodlands. Probably also supports some of the SRE invertebrates.
- Impact. Not known if there will be direct impact upon this VSA, but it is very likely to be sensitive to hydrological changes.
- Impact Assessment. Impact moderate because of the restricted distribution of this VSA and sensitivity to hydrological changes.

6. Samphire wetland.

- Representation. A single site of only a few hectares in the west of Cooljarloo West. No other freshwater samphire wetlands known in region.
- Conservation Significance for Fauna. Probably low species richness and abundance but potentially supports SRE invertebrates
- Impact. Not known if there will be direct impact upon this VSA, but it is very likely to be sensitive to hydrological changes.
- Impact Assessment. Impact moderate because of the restricted distribution of this VSA and sensitivity to hydrological changes.

7. Riverine Associations.

- Representation. Represented by the Emu Lakes Drainage System, Mullering Brook and Frederick Smith Creek. These extend out of the Project Area but are in good condition and associated with extensive seasonally-flooded flats within Cooljarloo West.
- Conservation Significance for Fauna. Almost certainly locally and regionally important for fauna associated with wetlands including freshwater fish, frogs, birds (including small numbers of waterbirds) and probably SRE invertebrates.
- Impact. Not known if there will be direct impact upon this VSA, but it is very likely to be sensitive to hydrological changes.
- Impact Assessment. Impact moderate because of the restricted distribution of this VSA and sensitivity to hydrological changes.

Impacts upon Vegetation and Soil Associations are variable but a consistent pattern is for VSAs associated with hydrological processes to be considered sensitive, because they tend to be limited in extent, support unusual fauna assemblages and may be affected by hydrological change. Hydrological processes are discussed further in Section 5.3.5.

5.2 Conservation Significant Fauna

The desktop review found that 34 significant vertebrate species may occur in the vicinity of the Project Area, consisting of: two freshwater fish; one frog, eight reptiles, 18 birds and five mammals. In addition there may be five SRE invertebrates present, although it should be recognised that invertebrate surveys are incomplete and that complete invertebrate surveys even just for potential SRE species are massive

undertakings. Information on these species is presented above (Section 4.4, see also Table 10), and impacts are summarised in Table 11.

Impacts on the majority of significant species are expected to be low (Table 11) because the species is considered unlikely to occur in Cooljarloo West, occurs only in small numbers, or because the habitat is extensive. Impacts on a number of species are considered potentially moderate, however, including: Western Minnow, Pygmy-perch, Carpet Python, Woma, Tiger Snake, Western Ground Parrot, White-breasted Robin and SRE millipedes. While habitat loss is a concern for these (and other) species, the sources of impact of greatest concern for these significant species are hydrological change (Minnow, Pygmy-perch, Tiger Snake, Robin, millipedes), feral predators (Carpet Python, Woma, Ground Parrot) and fire (Ground Parrot, Robin). The two species of greatest concern are the Woma and Ground Parrot. Both may be extinct in the area but there are fairly recent records nearby and in broadly similar environments (Woma in 1980s near Badgingarra Maryan 2003, and Ground Parrot near Leeman in January 2010). If present, populations of these two species would be highly significant. Direct impacts of Tiwest's proposal for Cooljarloo West would be slight unless there was direct mortality during clearing, but changes in feral predator abundance and the fire regime would be important for these populations. The Woma is difficult to survey for but the Ground Parrot can be surveyed aurally. If either species were found in the area, Tiwest could assist in their conservation management.

Table 11. Impacts upon fauna species of conservation significance occurring or likely to occur in the Project Area.

Species Name	Nature and significance of likely impact		Action required
	Nature of impact	Significance	
FISH			
Western Minnow	Change in wetland hydrology and introduction of feral fish	Moderate (species restricted in distribution)	Minimise hydrological impacts. Feral fish should not be introduced and existing wetlands should not be linked (some already contain feral species)
Western Pygmy-perch	Change in wetland hydrology and introduction of feral fish	Moderate (species restricted in distribution)	Minimise hydrological impacts. Feral fish should not be introduced and existing wetlands should not be linked (some already contain feral species)
FROGS			
Squelching Froglet	Change in wetland hydrology	Low (species may not be present)	Minimise hydrological impacts
REPTILES			
South-West Carpet Python	Potential loss of habitat and disturbance. Potential for impacts from introduced predators. Roadkill possible.	Moderate (species very likely to be present)	Minimise habitat loss. Education of personnel involved in clearing so that if pythons are found, they can be translocated. Control of domestic animals to reduce predation. Feral predator control (current)
Woma	Potential loss of habitat and disturbance. Potential for impacts from introduced predators. Roadkill possible.	Moderate (presence of this species would be very important because of regional decline)	Minimise habitat loss. Education of personnel involved in clearing so that if pythons are found, they can be translocated. Control of domestic animals to reduce predation. Feral predator control (current). Sightings of this species should be recorded and reported to the DEC. Photograph specimens.
Black-striped Snake	Potential loss of habitat.	Low (species likely to be present but habitat very extensive)	Minimise habitat loss.

Species Name	Nature and significance of likely impact		Action required
	Nature of impact	Significance	
Jewelled Ctenotus	Potential loss of habitat.	Low (species may be present but habitat very extensive).	Minimise habitat loss.
Speckled Stone-Gecko	Potential loss of habitat.	Low. (species may be present but habitat very extensive).	Minimise habitat loss.
Tiger Snake	Potential loss of habitat. Hydrological impacts upon vegetation and wetlands/damplands. Roadkill possible.	Moderate (species may occur in restricted VSA).	Minimise habitat loss. Education of personnel so that snakes aren't deliberately killed. Sightings of this species should be recorded and reported to the DEC. Photograph specimens.
Bold-striped Lerista	Potential loss of habitat.	Low (if present species probably widespread in extensive VSA).	Minimise habitat loss.
Legless-lizard <i>Aprasia affusca</i>	Potential loss of habitat.	Low (if present species probably widespread in extensive VSA).	Minimise habitat loss.
BIRDS			
Carnaby's Black-Cockatoo	Potential loss of foraging habitat. Nesting habitat unlikely to be affected	Moderate (species present regularly in large numbers but foraging habitat is very extensive).	Minimise loss of foraging habitat and include food plants (<i>Banksia</i> spp. in rehabilitation).
Peregrine Falcon	Potential loss of habitat.	Low (unlikely to depend on habitat within project area).	Minimise disturbance footprint. Avoid disturbance to hollow bearing Tuart trees.
Fork-tailed Swift	None	None (aerial species).	None.
Rainbow Bee-eater	Potential loss of habitat and impact on breeding sites during earthworks.	Low (a migratory species but widespread and opportunistic in habitat usage, including of disturbed environments).	Nesting may occur along roads and grading of road verges during the spring breeding period could be avoided.
Migratory waterbirds	None	None (numbers too low to be significant)	None.
Western Ground Parrot	Some loss of habitat, change in fire	Moderate to high (if species present, the	Minimise habitat loss, establish fire management

Species Name	Nature and significance of likely impact		Action required
	Nature of impact	Significance	
	regime, changes in the abundance of feral species.	population would be highly significant and probably very small, so any impacts of great concern).	and control and monitor feral predators. If species found, instigate monitoring programme.
Australian Bustard	Some loss of habitat	None (species only an irregular visitor in small numbers and habitat used is extensive)	None.
Rufous Fieldwren	Some loss of habitat, changes in fire regime	Low (species present in heaths but this VSA is widespread and created during rehabilitation)	Minimise habitat loss and introduce fire management. Create suitable habitat during rehabilitation
Crested Bellbird	Some loss of habitat, changes in fire regime	Low (species present in woodland but this VSA is widespread)	Minimise habitat loss and introduce fire management. Create suitable habitat during rehabilitation
Square-tailed Kite	Some loss of habitat	Low (species forages mainly over heaths which are widespread and created during rehabilitation)	Minimise habitat loss.
Southern Emu-wren	Some loss of habitat, changes in fire regime	Low (species present in heaths but this VSA is widespread and created during rehabilitation)	Minimise habitat loss and introduce fire management. Create suitable habitat during rehabilitation
Scarlet Robin	Possibly some loss of habitat	Low (species only known as a vagrant and then only recorded in acacia/eucalypt plantation)	None.
White-breasted Robin	Some loss of habitat, changes in fire regime, hydrological impacts	Moderate (species restricted to thickets around damplands and wetlands which are limited in extent)	Minimise habitat loss and introduce fire management. Avoid hydrological impacts. Create suitable habitat during rehabilitation
MAMMALS			
Brush Wallaby	Loss of habitat, changes in fire regime and impacts from feral predators. Roadkill possible.	Low (Species almost certainly present but widespread).	Minimise habitat loss and control feral predators.

Species Name	Nature and significance of likely impact		Action required
	Nature of impact	Significance	
Quenda	Loss of habitat, changes in fire regime and impacts from feral predators. Roadkill possible. Hydrological changes could affect dampland vegetation.	Low (species probably not present).	Minimise habitat loss and control feral predators. Avoid hydrological changes.
Tammar	Loss of habitat, changes in fire regime and impacts from feral predators. Roadkill possible. Hydrological changes could affect dampland vegetation.	Low (species probably not present).	Minimise habitat loss and control feral predators. Avoid hydrological changes
Brushtail Possum	Loss of habitat, changes in fire regime and impacts from feral predators. Roadkill possible.	Low (species probably not present as only one record in over 20 years).	Minimise habitat loss and control feral predators.
Western Freetail Bat	Loss of habitat.	Low (species may not be present but, if present, likely to be dispersed widely).	None.
Phasmid-mimic Cricket	Loss of habitat and changes in fire regime	Low (species probably not present)	Minimise habitat loss
Scorpion Fly	Loss of habitat and changes in fire regime	Low (species probably not present)	Minimise habitat loss
Millipedes: <i>Antichiropus</i> sp. nov. "Cooljarloo, <i>Antichiropus</i> Eneabba 2 and possibly <i>Podykipus</i> sp.	Loss of habitat and hydrological changes	Moderate (at least two and possibly three species; all appear dependent on seasonally damp conditions on flats)	Minimise habitat loss and hydrological changes

5.3 Ecological Processes

Many of the potential impacts of proposed developments upon fauna can be related to ecological processes, and this is recognised under the EPBC Act, in which threatening processes are listed, and in the literature (see Appendix 2). A number of ecological processes can be related to the impacts upon fauna of the project, and these are discussed below. In general, impacts associated with ecological processes are likely to be low, with main concerns being:

- Changes in abundance of feral predators;
- Hydro-ecological changes, with drainage systems of particular significance; and
- Changes in fire regimes (this has the potential to have a positive impact through a fire management programme across the area).

5.3.1 *Increased mortality*

Increased mortality is inevitable during clearing operations and from ongoing activities, such as roadkill due to animals being struck by vehicles, or birds striking powerlines. The greatest concern is with species of conservation significance that occur or may occur in very low numbers. These include the Woma and Western Ground Parrot. The Brush Wallaby is also sensitive to roadkill but appears moderately abundant in the region; its population can probably cope with some increase in mortality due to roadkill, but it is more sensitive to predation by feral species (discussed below).

5.3.2 *Loss of habitat affecting population survival*

Some loss of habitat is inevitable but can be minimised through controls during clearing. Rehabilitation of disturbed areas may also be implemented. Of greatest concern are VSAs that are small in area and sensitive to impacts from hydrological changes, such as riparian woodland and wetland associations. Some fauna species (eg. freshwater fish, some frogs breed only in major pools, some birds) may be restricted to these VSAs, so loss of a proportion of these VSAs could result in significant population declines.

5.3.3 *Loss of habitat affecting population movements and gene flow*

The proposed disturbance area is within a region with no other development and while some VSAs are very extensive, linear VSAs (associated with drainage systems) and their associated fauna may be vulnerable to fragmentation.

5.3.4 *Species interactions, including predators and other feral species*

Feral species are a major conservation concern in general. Foxes and Cats have been implicated in the local decline and/or extinction of several mammal species (eg. Quenda, Tammar), and may be responsible for the decline of the Woma, Carpet Python and Ground Parrot. Control of Foxes is already taking place in the region (sponsored by Tiwest), but there are anecdotal reports that this can lead to an increase in the abundance of feral Cats. Clearing, ground disturbance and other human activities within natural areas can attract Foxes and Cats, with some evidence from fauna studies at Cooljarloo that both species forage around the margins of active mine areas; this evidence includes reports from mining staff and a fall in mammal capture rates on long-term monitoring sites as mining approached these sites (unpubl. data

Bamford Consulting and Tiwest). Feral fish are already present in some wetlands. Management of feral fauna should be considered as part of the Cooljarloo West project.

5.3.5 Hydroecology

Interruptions of hydroecological processes are a concern as the Cooljarloo West area has a range of hydrology-dependent VSAs from the Low Heath on seasonally damp flats to seasonal drainage lines that have some permanent pools. Management of hydrological impacts will need to be examined.

5.3.6 Fire

Changes in the fire regime (frequency, intensity, extent and season) in the Project Area have almost certainly affected the vegetation and the fauna, and the fire regime is of ongoing importance in this sort of environment. For example, the Ground Parrot is sensitive to overly frequent or extensive fires, and studies conducted in Cooljarloo have demonstrated that species such as the Honey Possum are reduced in abundance for several years after fire. There is potential for some conservation benefit through increased fire management in the Project Area and surrounds.

5.3.7 Light, noise and disturbance

The proposed development will introduce light, noise and other sources of disturbance to an area where there is currently very little human activity. Impacts under such circumstances are poorly documented and therefore a precautionary approach is recommended. This can include minimising light spill and using lights with wavelengths that are demonstrated not to attract fauna.

5.4 Patterns of Biodiversity

Patterns of biodiversity are complex but there are several patterns identified from the ongoing work carried out by Bamford consulting and Tiwest at Cooljarloo and Falcon that need to be considered with respect to impacts at Cooljarloo West. For example:

- Banksia low woodlands on sandy soils of stabilised dunes are very rich in reptiles.
- Ecotones around wetlands, where the banksia low woodland is dense, scrub-heaths are present and there is a great richness in vegetation floristics and structure over short distances tend to be very rich in bird species.
- Falcon and probably Cooljarloo West have some reptile species not recorded at Cooljarloo; possibly a reflection of more limestone-rich soils.
- The woodlands around Fred Smith Creek are distinctive from woodlands elsewhere and have distinctive soils. The vertebrate assemblage may be slightly different from elsewhere, and the invertebrate assemblage is very likely to be distinctive.

6 MANAGEMENT AND MONITORING RECOMMENDATIONS

Section 5 (Impact Assessment) identifies the sorts of adverse impacts that can be expected, and provides a number of actions for their minimisation. These are summarised below.

Habitat loss. A concern for a number of species, including some of conservation significance. Of greatest concern is loss of restricted VSAs such as Tall Heath on Flats, Scrub-Heath and VSAs associated with wetlands. Habitat loss should be minimised through strict clearing controls, using existing tracks where available and avoiding clearing during exploration; crushing down vegetation rather than clearing it enables rapid regeneration.

Habitat fragmentation. Roads, trenches and pipelines are barriers for terrestrial fauna and the effects of such barriers should be minimised where possible. For example, water and slurry pipelines can have simple underpasses to allow the passage of terrestrial fauna such as Honey Possums.

Monitoring of significant species. Sightings of significant species should be reported, requiring personnel education. Surveys should be taken for the Western Ground Parrot, as the presence of this species would be highly important.

Altered hydrology in Low Heath, Tall Heath, Samphire, Riparian Woodland and Riverine Associations. These VSAs may be affected by changed surface and sub-surface hydrology. Possible impacts should be modelled and monitored.

Disturbance. A precautionary approach should be taken with lighting.

Ongoing mortality. Sources of ongoing mortality include roadkill, striking infrastructure and destruction of nests close to areas of activity (eg. Rainbow Bee-eater). Roadkill may be of greatest concern as it can affect significant species such as the Carpet Python. Reduced speeds at night and personnel education may assist in reducing roadkill. Rainbow Bee-eaters may nest on road verges in late spring and earthworks along road verges can be avoided during this period.

Fire. Fire is an important factor in the terrestrial ecology of the region and needs to be managed, both for safety and property protection, and for conservation. A fire management plan needs to be developed, and provides the opportunity for some conservation benefits. Some of the significant species are greatly affected by fire and could benefit from improved fire management.

Feral species. Introduced species such as Fox and Feral Cat are a concern for several species of high conservation significance and current controls should be maintained. These controls may not adequately address cats and this should be investigated. Baiting on the margins of mine areas is suggested as there appears to be a concentration of feral predators in such areas. Deliberate or inadvertent encouragement of feral species should be avoided. This includes avoiding spreading the feral fish that are already present in the Emu Lakes system.

Rehabilitation. This can be effective in the sandy landscapes with good topsoil management and soil profile reconstruction. Use of mulch in rehabilitation is beneficial, but mulch-harvesting can impact upon fauna for several years. Leaving un-mulched strips in harvested areas is recommended.

Table 12. The potential impacts to fauna of the proposal as assessed following the guidance of the EPA's Guidance Statement No. 56. (Terrestrial fauna surveys for environmental impact assessment in Western Australia, EPA 2004).

Factor	Impact and explanation
Degree of habitat degradation or clearing within the local area or region.	Low (project lies within of a region of continuous habitat with very little existing disturbance)
Size/scale of proposal/impact.	High (>50ha of remnant native vegetation may be disturbed - Bioregion Group 1).
Rarity of vegetation and landforms.	Low to moderate (impacted vegetation and landforms are extensive in sub-region but wetland areas may be restricted and impacted).
Refugia.	Moderate (Vegetation types, soils and landforms are generally widespread but dampland and wetland areas are refugia.
Fauna protected under international agreements or treaties, Specially Protected or Priority Fauna.	Moderate (faunal assemblage includes species of high conservation significance but impacts on these species are mostly expected to be low).
Size of remnant and condition/intactness of habitat and faunal assemblage.	Low (project area and surrounds comprises intact native vegetation)
Ecological linkage.	Low (vegetation types in project area are largely continuous)
Heterogeneity or complexity of the habitat and faunal assemblage.	Moderate(project area has a moderate habitat heterogeneity)

7 REFERENCES

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8 APPENDICES

Appendix 1. Categories used in the assessment of conservation status.

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

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

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

Appendix 2. Ecological processes.

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 in Impact Assessment.

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 (1999), 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 17 key threatening processes listed by the federal Department of the Environment, Water, Heritage and the Arts).

- 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;
- Land clearance;
- 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*);
- The reduction in the biodiversity of Australian native fauna and flora due to the red imported fire ant, *Solenopsis invicta*.

(Taken from <http://www.environment.gov.au/cgi-bin/sprat/public/publicgetkeythreats.pl> , viewed on the 10th November 2009)