

**Beharra Silica Sand Project;
Detailed Assessment of Terrestrial Fauna Values**



Grey's Legless-Lizard in the Project area. Photo: W. Bancroft.

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Executive Summary

Perpetual Resources Limited (PEC) is proposing to extract high grade silica sand from an area along Mt Adams Road in the Shire of Irwin. Tetris Environmental Pty Ltd has commissioned Bamford Consulting Ecologists (BCE), to conduct Basic, Targeted and Detailed fauna assessments in the project area. This assessment provides information on the fauna values of this area, particularly for conservation significant species. It focusses on vertebrate fauna, with invertebrate investigations being carried out separately. Targeted invertebrate studies have been undertaken separately.

BCE uses a 'values and impacts' assessment process with the following components (based upon federal and state regulator guidance):

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

This report focusses on the fauna values and the review of impacting processes is being developed separately.

The project area was visited in August 2020 for a basic assessment, with targeted and detailed investigations undertaken in early December 2021, in accordance with WA Environmental Protection Authority *Technical Guidance - Terrestrial vertebrate fauna surveys for environmental impact assessment* (EPA 2020). It lies in a region where BCE has undertaken multiple Basic, Targeted and Detailed investigations, and previous studies were reviewed as part of an overall desktop assessment. Previous studies included detailed investigations in the Tronox Dongara project area, immediately to the east, and studies undertaken in the VRX Silica Arrowsmith North project area immediately to the south. Studies undertaken included a standard range of sampling techniques (such as pitfall and funnel traps, bird censusing, motion sensitive cameras, autonomous recording units). A foraging value assessment for Carnaby's Black-Cockatoo was undertaken using a scoring system developed by BCE.

Description of project area

The project area consists of a mining lease that lies alongside Yandanogo Nature Reserve and extends north and south of Mt Adams Road, although the development envelope lies south of the road. The vegetation of the survey area primarily consists of Kwongan (heath or shrubland) on sand (Vegetation

and Substrate Association (VSA) 1), with small, low-lying areas supporting a dampland shrubland (VSA 2). The survey area lies within a large region of mostly undisturbed bushland along the coastal plain, with Yandanogo Nature Reserve to the west.

Key fauna values

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

Fauna assemblage. The desktop study identified 205 vertebrate fauna species as potentially occurring in the project area: no fish, 10 frogs, 51 reptiles, 119 birds and 25 mammals. Previous BCE studies in adjacent areas have confirmed the presence of 145 species, and the current studies found 71 species in the project area. The fauna assemblage is probably typical of the Leseuer Sandplain bioregion and is thus rich in reptiles, has a bird assemblage with a large component of species that are seasonal visitors, and a small mammal assemblage with a high level of extinction.

Species of conservation significance. Three broad levels of conservation significance are used in this report:

- Conservation Significance 1 (CS1) – species listed under State or Commonwealth Acts.
- Conservation Significance 2 (CS2) – species listed as Priority by DBCA but not listed under State or Commonwealth Acts.
- Conservation Significance 3 (CS3) – species not listed under Acts or in publications but considered of at least local significance because of their pattern of distribution.

The 16 vertebrate species of conservation significance includes only six species that are expected to be resident or regular migrants/visitors to the site: Carpet Python (southwest), Black-striped Snake, Peregrine Falcon, Carnaby's Black-Cockatoo, Little Dunnart and Brush Wallaby. Of these, only the Falcon and the Black-Cockatoo are listed under legislation, and the Falcon is expected only as a visitor with the project area likely to be part of the home range of a pair that breeds nearby. Carnaby's Black-Cockatoo is notable as it is likely to be seasonally abundant in the area, there is extensive foraging habitat and there are two confirmed roosts within 10 km of the project area. There is no suitable breeding habitat either within the project area or nearby, but observations made in August 2020 suggest that breeding birds may occasionally visit the area to forage. There is a slight possibility of the Western Ground Parrot and Woma persisting in the area, but with no recent records they are probably locally extinct.

A targeted study into significant invertebrates was undertaken separately in July 2021 (Bennelongia 2022). To supplement this invertebrate work, the current study included searching for the Woollybush Bee *Hylaeus globuliferus* which would have been difficult to detect in July due to seasonal variation in activity. No bees of that genus were found.

Patterns of biodiversity.

Sampling indicates that VSA 2 (Dampland Thickets) and the transition between this and VSA 1 (Kwongan Heath) may be locally high in species richness and abundance, particularly for birds and reptiles. The low-lying thickets are also likely to be richer in significant invertebrates than high in the landscape. The kwongan represents more important foraging habitat for Carnaby's Black-Cockatoo

than the thickets. Time since and frequency of fire may be impacting on the reptile and small mammal assemblage.

Key ecological processes.

The main ecological processes which may be influencing the fauna assemblage are local hydrology, fire and feral species.

Contents

Executive Summary..... i

Contents..... i

List of Tables ii

List of Figures iii

List of Plates iv

List of Appendices iv

1 Introduction 1

 1.1 General approach to fauna impact assessment 1

 1.2 Study objectives 2

 1.3 Project area and background environmental information 2

 1.3.1 Project area 2

 1.3.2 Interim Biogeographic Regionalisation of Australia (IBRA) and landscape characteristics 2

 1.3.3 Climate information 3

 1.4 Project Description..... 3

2 Methods..... 7

 2.1 Overview 7

 2.1.1 Level of investigations..... 7

 2.1.2 Approach to investigations 8

 2.1.3 Spatial terminology 11

 2.2 Desktop assessment..... 12

 2.2.1 Sources of information..... 12

 2.2.2 Nomenclature and taxonomy 20

 2.2.3 Interpretation of species lists 20

 2.2.4 Conservation significance 21

 2.3 Field investigations 21

 2.3.1 Overview 21

 2.3.2 Personnel and permits..... 22

 2.3.3 Systematic Fauna Sampling..... 22

 2.3.4 Motion sensitive cameras..... 24

 2.3.5 Autonomous Recording Units (ARUs) 24

 2.3.6 Black-cockatoo habitat analysis 28

 2.3.7 Opportunistic collection of invertebrates..... 29

2.4	Survey limitations	29
3	Results	31
3.1	Vegetation and Substrate Associations	31
3.2	Vertebrate Fauna assemblage	36
3.2.1	Overview of fauna assemblage desktop results	36
3.2.2	Vertebrate fauna of conservation significance	40
3.2.3	Black-cockatoo habitat analysis	50
3.2.4	Invertebrates of Conservation Significance	54
3.3	Patterns of biodiversity	54
3.3.1	Overview	54
3.3.2	Pitfall and funnel trapping	55
3.3.3	Bird Censusing.....	60
3.4	Ecological processes.....	63
4	Summary of fauna values.....	64
5	References	65
6	Appendices.....	68
	Appendix 1. Explanation of fauna values.....	68
	Appendix 2. Categories used in the assessment of conservation status.....	71
	Appendix 3. Explanation of threatening processes.....	72
	Appendix 4. Ecological and threatening processes identified under legislation and in the literature.....	75
	Appendix 5. Sampling location descriptions and coordinates.....	77
	Appendix 6. Scoring system for the assessment of foraging value of vegetation for black-cockatoos. Revised 5th June 2020	80
	Appendix 7. Expected vertebrate fauna in the project area (including species now considered locally extinct).....	89
	Appendix 8. Species returned in database searches but unlikely to occur in the project area.....	102
	Appendix 9. Fauna observations made during site inspection 19-20 August 2020.....	104
	Appendix 10. Fauna observations made during field investigations, 1-10 December 2021.....	105
	Appendix 11. Results from motion-sensitive cameras set in December 2021.....	107

List of Tables

Table 1.	Assessment of site and project characteristics for level of assessment	9
Table 2.	Level of assessment suggested for the project.....	11
Table 3.	Databases searched for the desktop review; accessed January 2020.....	14

Table 4. Sources of information used for general patterns of fauna distribution..... 14

Table 5. Previous BCE surveys within c. 20 km of project area (except where noted)..... 15

Table 6. Personnel involved in the field investigations and report preparation. 22

Table 7. Systematic sampling site locations, descriptions and sampling effort. 23

Table 8. Survey limitations as outlined by EPA (2020)..... 29

Table 9. Composition of vertebrate fauna assemblage of the project area. 36

Table 10. The number of conservation significant species in each vertebrate class that are expected to occur in the project area. 41

Table 11. Conservation significant fauna species expected to occur within the project area. 41

Table 12. Foraging value of broad vegetation types for Carnaby’s Black-Cockatoo in the project area. 51

Table 13. Numbers of captures of each species along each transect. Pitfall and funnel trap captures pooled..... 56

Table 14. Comparison of numbers of captures in the Project area (December 2021) and the adjacent Tronox Dongara project area (November 2007). 57

Table 15. Numbers of records of each bird species along each transect. 60

List of Figures

Figure 1. Location of the Beharra Silica Sand Project area..... 4

Figure 2. Bioregions across Western Australia; the project area is located in the Lesueur Sandplain subregion (GES02), indicated by a red dot. 5

Figure 3. Climatic data from Green Grove, near Carnamah. 6

Figure 4. Locations of previous fauna investigations in the vicinity of the Beharra Silica Sand Project. 18

Figure 5. The relationship between the number of trapnights and the addition of species in sampling for small, terrestrial vertebrates at a range of sites. The majority of captures were in pitfalls and sampling effort similar (around 500 pitfall nights). Winter and spring at the Tronox Dongara Project are included. Results for Beharra project presented below..... 19

Figure 6. The relationship between the number of trapnights and the addition of species in sampling for small, terrestrial vertebrates at the Beharra Silica Sand Project, December 2021. The majority of captures were in pitfalls and sampling effort was 300 pitfall nights..... 19

Figure 7. The project area, indicating tracks in 2020 and 2021, and the two principle Vegetation and Substrate Associations (VSAs; described in section 3.1). 25

Figure 8. Locations of sampling sites in the Project area, Dec. 2021. Transects were numbered from north to south: thus Transect B01 in north (Map A) and Transect B04 in south (Map D). 26

Figure 9. Fire history and sampling locations 27

Figure 10. Vegetation and Substrate Associations (VSAs) of the Project area and Tronox Dongara Study Area (after Woodman 2011)..... 52

Figure 11. Locations of Carnaby’s Black-Cockatoo roost sites and of other significant fauna records in the vicinity of the project area..... 53

Figure 12. Distribution of numbers of captures per sampling location on the four transects in the Project area, Dec. 2021. Transects numbered B01 to B04 from the north. 58

Figure 13. Distribution of numbers of species trapped sampling location on the four transects in the Project area, Dec 2021. Transects numbered B01 to B04 from the north. 59

Figure 14. Distribution of bird records at sampling location on the four transects in the Project area, December 2021. Transects are numbered B01 to B04 from the north.....	61
Figure 15. Distribution of numbers of bird species at census points on the four transects in the Project area, December 2021. Transects are numbers B01 to B04 from the north.....	62

List of Plates

Plate 1. VSA 1. Kwongan Heath. <i>Banksia hookeriana</i> in flower, with <i>Banksia attenuata</i> and <i>Banksia elegans</i> to the left, and emergent <i>Banksia menziesii</i> in the background. August 2020. Last burnt 2012 (c. 9 years post fire).....	32
Plate 2. VSA 1. Kwongan Heath. <i>Banksia attenuata</i> in flower. Sampling location B21 (Transect B04). December 2021. Last burnt 2012 (c. 9 years post-fire).	32
Plate 3. VSA1. Kwongan Heath. Sampling location B52 (Transect B01). December 2021. Last burnt 2021 (c. 9 months post-fire).	33
Plate 4. VSA1. Kwongan Heath. Sampling location B19 (Transect B03). December 2021. Last burnt 2017 (c. 4 years post-fire).	33
Plate 5. VSA1. Kwongan Heath. Sampling location B41 (Transect B02). December 2021. Last burnt 2012 (c. 9 years post-fire).	34
Plate 6. VSA2. Dampland Thicket. Sampling location B12 (Transect B03). December 2021. Last burnt 2012 (c. 9 years post-fire).	34
Plate 7. VSA2. Dampland Thicket. Sampling location B53 (Transect B01). December 2021. Last burnt 2017 (c. 4 years post-fire).	35

List of Appendices

Appendix 1. Explanation of fauna values.....	68
Appendix 2. Categories used in the assessment of conservation status.....	71
Appendix 3. Explanation of threatening processes.	72
Appendix 4. Ecological and threatening processes identified under legislation and in the literature.	75
Appendix 5. Sampling location descriptions and coordinates.....	77
Appendix 6. Scoring system for the assessment of foraging value of vegetation for black-cockatoos. Revised 5th June 2020	80
Appendix 7. Expected vertebrate fauna in the project area (including species now considered locally extinct).....	89
Appendix 8. Species returned in database searches but unlikely to occur in the project area.....	102
Appendix 9. Fauna observations made during site inspection 19-20 August 2020.....	104
Appendix 10. Fauna observations made during field investigations, 1-10 December 2021.	105
Appendix 11. Results from motion-sensitive cameras set in December 2021.	107

1 Introduction

Perpetual Resources Limited is proposing to extract high grade silica sand from an area south of Mt Adams Road in the Shire of Irwin, c. 250 km north of Perth and 30 km east of Dongara (hereafter “project area”, see Figure 1). Tetris Environmental is managing environmental approvals for the project, and commissioned Bamford Consulting Ecologists (BCE) to conduct an initial Basic (*sensu* EPA 2020) assessment of fauna values (desktop review and site inspection), followed by a Targeted and Detailed survey. These investigations focussed on the vertebrate fauna assemblage; a targeted invertebrate field investigation was undertaken by Bennelongia (2022).

The approach to BCE investigations outlined below have been developed with reference to the EPA (2020) *Technical guidance - terrestrial vertebrate fauna surveys for environmental impact assessment*. The purpose of these investigations is outlined below. This report presents the results of these investigations.

1.1 General approach to fauna impact assessment

The purpose of impact assessment is to provide government agencies with the information they need to decide upon the significance of impacts of a proposed development, and to provide information to proponents to help them to develop appropriate strategies for avoiding and minimising impacts of their activities. This relies on information on the fauna assemblage and its environment, and BCE uses an approach with the following components:

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

Descriptions and background information on these values and processes can be found in Appendices 1 to 4. In particular, Appendix 1 explains and defines the fauna values, including the recognition of three classes of species of conservation significance (CS): those listed under legislation (CS1), those listed as priority by the Department of Biodiversity, Conservation and Attractions (DBCA; CS2), and those that can be considered of local or other significance, but which have no formal listing (CS3). Appendix 2 outlines the legal definitions and classes of conservation significance, Appendix 3 describes threatening processes, and Appendix 4

presents the threatening processes recognised under legislation. Not all threatening processes are relevant to the current project.

1.2 Study objectives

Based on this impact assessment process outlined above, the objectives of investigations are broadly to identify fauna values; review impacting processes with respect to these values and the proposed activity; and provide recommendations to mitigate these impacts. Key stages to meet these objectives are:

1. Conduct a literature review and searches of Commonwealth and State fauna databases to generate species list;
2. Undertake field investigations necessary to supplement information obtained from the literature and database review, and to ensure familiarity with the project area;
3. Review the list of fauna expected to occur on the site in the light of environments present;
4. Identify significant environments within the survey area;
5. Identify any ecological processes in the survey area upon which fauna may depend;
6. Identify general patterns of biodiversity within or adjacent to the survey area.

As noted above, this report presents the results of the literature review and field investigations into fauna values.

1.3 Project area and background environmental information

1.3.1 Project area

For spatial terminology (i.e. definitions of project, survey and study areas) see Section 2.1.3 below.

The proposed location for the Beharra Silica Sand Project (project area) is approximately 20 km southeast from Dongara in Western Australia as shown in Figure 1, immediately south of Mt Adams Road on mining lease M 70/1406. The lease has a total area of over 1,000 ha with a development envelope of 788 ha. Apart from Mt Adams Road and some minor tracks and small areas of disturbance from previous exploration activities, the vegetation and soils are undisturbed. The area is part of a much larger expanse of native vegetation that is connected to Yandanogo Nature reserve in the west and forms a broad corridor of native vegetation, which includes large reserves to the west and south-west such as Beekeepers' Nature Reserve. Clearing in the region for agriculture, is extensive further east of the project area.

1.3.2 Interim Biogeographic Regionalisation of Australia (IBRA) and landscape characteristics

The Interim Biogeographic Regionalisation of Australia (IBRA) has identified 26 bioregions in Western Australia which are further divided into subregions (DAWE 2020a) (Figure 2). Bioregions are classified on the basis of climate, geology, landforms, vegetation and fauna (Thackway and Cresswell 1995). IBRA Bioregions are affected by a range of different threatening processes and have varying levels of sensitivity to impact (EPA 2004). The project area lies within the Lesueur Sandplain subregion (GES02) of the Geraldton Sandplains bioregion, comprising coastal Aeolian and limestones of the central Perth basin overlain with shrub-heaths and rich in endemic plants. The Geraldton Sandplains bioregion falls within the Bioregion Group 1 classification (EPA 2004). Bioregions within Group 1 (South-West Botanical Province) are "extensively cleared for agriculture" and include sites of major urban developments. The bioregion has a high degree of species loss. The Lesueur subregion, however, is much less affected by clearing and habitat loss than the broader bioregion.

1.3.3 *Climate information*

The project area lies within the South-West botanical province of Western Australia's Southern climatic region. The Project Area typically has a dry, warm Mediterranean climate, with winter precipitation of 300-500 mm and 7-8 dry months per year (Beard, 1980). Average and recent (2018-2019) temperature and rainfall data from the nearest weather station (Green Grove near Carnamah; Bureau of Meteorology, 2020) are shown in Figure 3.

1.4 Project Description

The project involves extraction of high-quality silica sand which lies close to the surface. The mine area has been split into four panels, each of which have been further subdivided into 24 mine cells for scheduling silica sand extraction above the water table. Each cell is approximately 5 ha and the project expects to mine up to 4 cells each year (~20 ha per year). Silica sand is sent to the infrastructure area for processing and the final product is hauled to the Port of Geraldton via road train. Pit cells will be backfilled and progressively rehabilitated over the life of the project. The approximate total extent of the project development envelope within which mining and processing will be undertaken is shown on Figure 1.

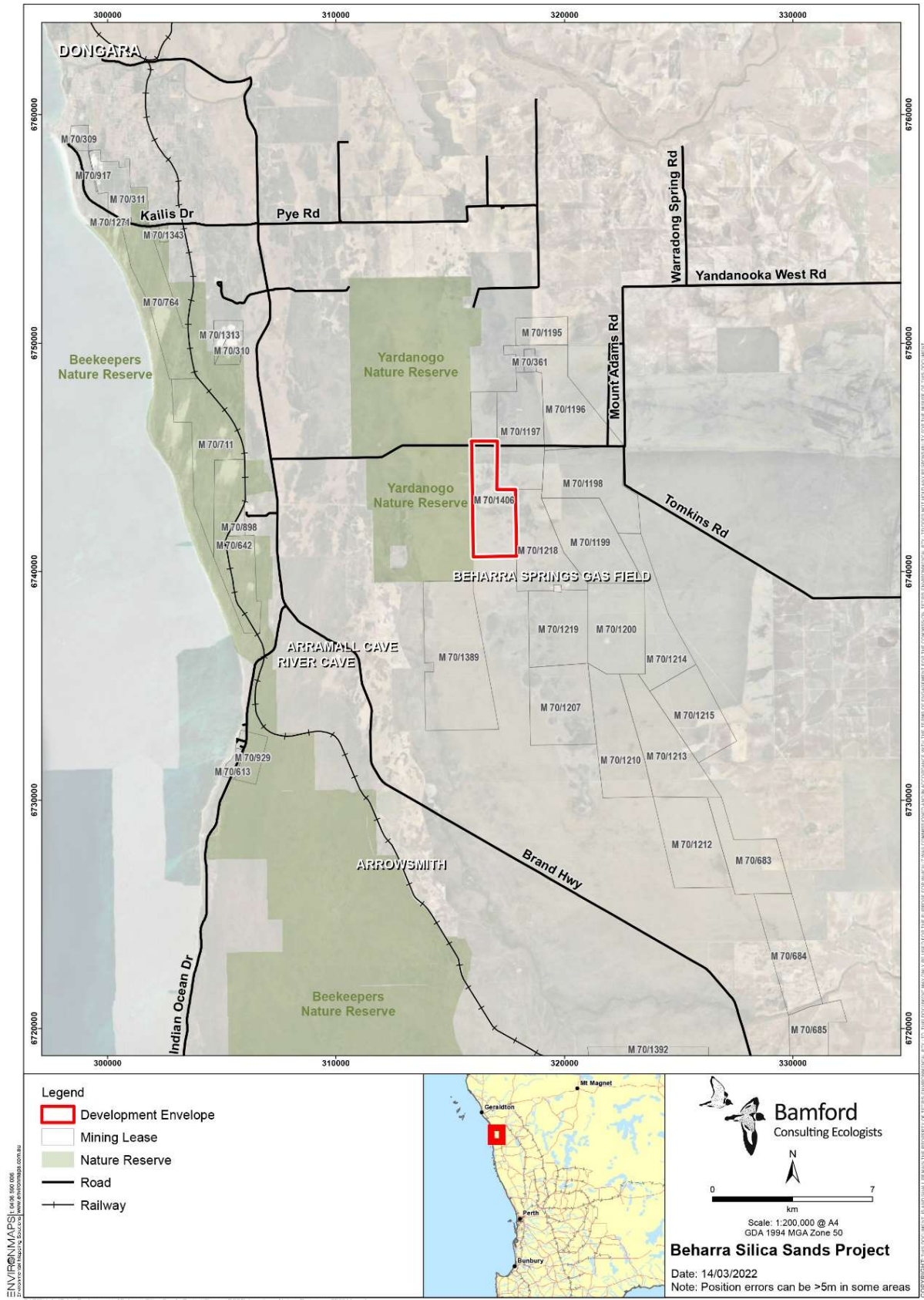


Figure 1. Location of the Beharra Silica Sand Project area.



Figure 2. Bioregions across Western Australia; the project area is located in the Lesueur Sandplain subregion (GES02), indicated by a red dot.

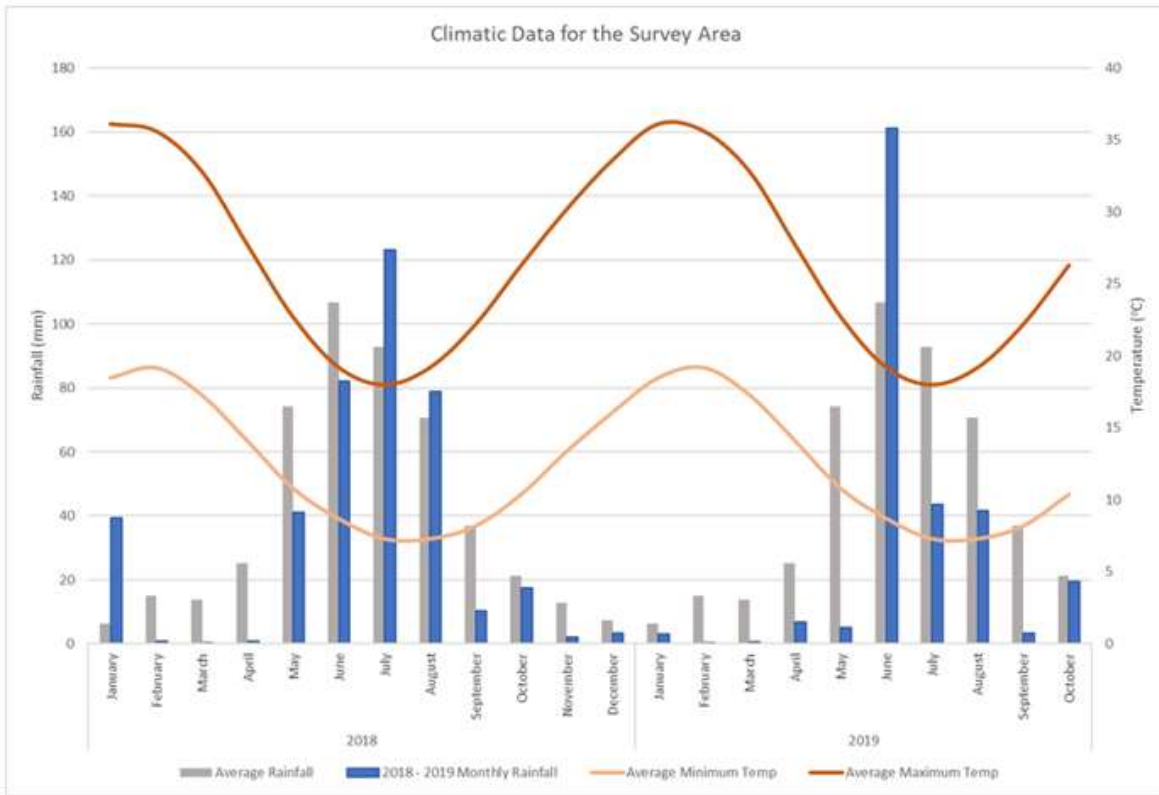


Figure 3. Climatic data from Green Grove, near Carnamah.

2 Methods

2.1 Overview

2.1.1 *Level of investigations*

The approach to terrestrial fauna assessment has been developed with reference to guidelines and recommendations set out by the Western Australian Environmental Protection Authority (EPA) on fauna surveys and environmental protection (EPA 2002, 2016b, a, 2020), and Commonwealth biodiversity legislation (DotE 2013; DSEWPaC 2013). The EPA (2020) recommends three levels of investigation that differ in their approach for field investigations:

- **Basic** – a low-intensity survey, conducted at the local scale to gather broad fauna and habitat information (formerly referred to as a Level 1). The primary objectives are to verify the overall adequacy of the desktop study, and to map and describe habitats. A basic survey can also be used to identify future survey site locations and determine site logistics and access. The results from the basic survey are used to determine whether a detailed and/or targeted survey is required. During a basic survey, opportunistic fauna observations should be made and low-intensity sampling can be used to gather data on the general faunal assemblages present. While referred to as ‘basic’, this level of survey is involved and powerful, and should be considered the primary level of assessment. Other levels of assessment (where deemed necessary) add information to inform this primary level.
- **Detailed** – a detailed survey to gather quantitative data on species, assemblages and habitats in an area (formerly referred to as Level 2). A detailed survey requires comprehensive survey design and should include at least two survey phases appropriate to the biogeographic region (bioregion). Surveys should be undertaken during the seasons of maximum activity of the relevant fauna and techniques should be selected to maximise the likelihood that the survey will detect most of the species that occur, and to provide data to enable some community analyses to be carried out.
- **Targeted** – to gather information on significant fauna and/or habitats, or to collect data where a desktop study or field survey has identified knowledge gaps. Because impacts must be placed into context, targeted surveys are not necessarily confined to potential impact areas. A targeted survey usually requires one or more site visits to detect and record significant fauna and habitats. For areas with multiple significant species there may not be a single time of year suitable to detect all species. In these cases, multiple visits, each targeting different species or groups, should be conducted.

The level of assessment recommended by the EPA (2020) is determined by geographic position, with a generic statement that detailed surveys are expected across all of the state except the Swan Coastal Plain and Jarrah Forest, but also recommending that site and project characteristics be considered. These include: survey objectives, existing available data, information required, presence of significant species, the scale and nature of the potential impacts of the proposal and the sensitivity of the surrounding environment in which the disturbance is planned (including extent of existing regional impact). The EPA (2016c) also indicates that the scale and nature of the proposal can be used to determine the appropriate level of investigations, with, for example, large scale projects requiring higher levels of investigations. This sort of advice from the EPA (2016c, 2020) provides a framework for determining the appropriate level of field investigations. Combined with some other factors based on long experience in fauna investigations for impact assessment, this framework is applied to the current project in Table 1. The results of this application are summarised in Table 2.

Although the ‘basic’ level survey is considered appropriate for the project (see Table 1 and Table 2), the more comprehensive ‘detailed’ and targeted level survey has been conducted across the project area. Tetris Environmental requested that a detailed level survey be conducted following the site inspection, in recognition of the value of additional data and as a precaution to ensure compliance with guidance (EPA 2020). Guidance for field investigations methods is provided by the (EPA 2016a, 2020) and by Bamford *et al.* (2013).”

2.1.2 Approach to investigations

The approach and methods utilised in this report are divided into two groupings that relate to the stages and the objectives of impact assessment in identifying the fauna values listed in 1.1. The two methods groupings are:

- **Desktop assessment.** The purpose of the desktop review is to produce a species list that can be considered to represent the vertebrate fauna assemblage of the project area based on unpublished and published data using a precautionary approach.
- **Field investigations.** The purpose of the initial Basic field investigations was to gather information on the vegetation and soil associations (‘habitats’) that support the fauna assemblage, which allows the output of the desktop review to be interpreted in the context of the study areas environment. The purpose of the detailed and targeted surveys was to investigate the presence of key significant species, assess the importance of the project area for these species, and to gather abundance and distribution data on the general vertebrate fauna assemblage.

Table 1. Assessment of site and project characteristics for level of assessment

Factor: site and project characteristic	Rationale for decision on level of investigations	Application to current project
Level of existing regional knowledge.	<i>Existing data reduces need for baseline survey. Similarity/uniformity of environments need to be high to extrapolate from regional knowledge</i>	Extensive regional knowledge from previous basic, detailed and targeted investigations.
Type and comprehensiveness of recent local surveys.	<i>Previous surveys, if adequate, will provide extensive baseline data and therefore reduce the need for additional baseline survey effort. Similarity/uniformity of environments need to be high to extrapolate from regional knowledge</i>	Range of studies undertaken in region and in similar landscapes, with a wide range of detection techniques (trapping, cameras, aural, searching).
Degree of existing disturbance or fragmentation at the regional scale.	<i>The type and scale of existing impacts affect the need for survey. A broadly degraded landscape may need less effort due to the likely loss of biodiversity, but a fragmented landscape may need greater effort as remaining biodiversity may be high in remnant vegetation and this can be an important value to confirm</i>	Broad landscape is intact and well-connected
Extent, distribution and significance of environments	<i>In general, rare, unusual, restricted and/or environments linked to significant species need more investigation than broad and widely-represented environments due to their likely higher significance for fauna</i>	Project area supports shrublands (kwongan) typical of the broader region and well-represented in adjacent reserves.
Significance of species likely to be present	<i>Species of conservation significance require additional effort to confirm their presence (if possible; or likelihood of presence), and the identification of habitats and processes, such as connectivity, important for them</i>	Limited range of significant species present. Desktop review suggests many significant species now locally extinct. Species that may require investigation are: Western Ground Parrot, Malleefowl. Woma and possibly Chuditch. Conservation significant invertebrates possible but addressed separately (Bennelongia 2022).
Sensitivity of the environment to the proposed action.	<i>Sensitivity is complex. Environments can be considered sensitive to impacts if the environments are restricted, fragmented or vulnerable to change such as hydrological change or any other alteration caused by the action. Off-site environments may need to be considered</i>	Low level of sensitivity as the landscapes present are broadly-represented and continuous in adjacent reserves. May be some sensitivity in low-lying areas due to interaction with groundwater.

Factor: site and project characteristic	Rationale for decision on level of investigations	Application to current project
<p>Scale and nature of impact. Geographic position.</p>	<p><i>How big is the impact; what proportion of surrounding environments will be impacted; is the impact loss or modification; will there be rehabilitation (ie is the impact a permanent change or can at least some fauna values return?); is the impact ongoing (eg long-term change to hydrology or a high proportion of the landscape altered). More information on fauna is needed in situations such as where the impact area is large or proportionally large, impacts are upon significant environments and or fauna assemblages, and where baseline data may be needed for ongoing management</i></p>	<p>The impact area is small in a regional context, due to the large reserve system nearby. Some level of rehabilitation is expected. The project area lies in Bioregion group 2, for which the EPA (2016c) suggests detailed surveys needed only for where the scale and nature of impacts are high. The Lesueur Sandplain lies north of the Swan Coastal Plain for which the EPA (2020) suggests detailed surveys are not needed, but this is based on a presumed scarcity of data outside the Swan Coastal Plain (and Jarrah Forest), whereas data are abundant from the vicinity of the project area.</p>
<p>Potential value of presence, abundance and distributional data.</p>	<p><i>There is low value in confirming the presence of common and widespread species within their known range unless this forms part of on-going monitoring such as of rehabilitation, impacts of management or to monitor on-site and/or off-site impacts. There is value where even widespread and common species are very poorly-known or where records even of such species are of conservation interest (islands, highly fragmented landscapes). There is generally high value in developing an understanding of significant species in an area. There is value if data address an ecological question (such as impact of fire).</i></p>	<p>Generally low value in obtaining distributional data as the fauna assemblage is already well-known. There is value in abundance and habitat data if rehabilitation is to be monitored. The project area has been subject to multiple prescribed fires and there may also be value in investigating impacts of these fires in the region as a separate study independent of the Project. With several other proposed developments in the vicinity, and large nature reserves where detailed abundance and habitat data could support management actions, there is a case for sampling to inform regional fire management.</p>

Table 2. Level of assessment suggested for the project.

- Low – a low level of additional assessment suggested by the factor. Site inspection.
- Moderate – a moderate level of additional assessment suggested by the factor. Site inspection and targeted surveys.
- High – a high level of additional assessment suggested by the factor. Site inspection, targeted and detailed surveys.

Factor: site and project characteristic	Suggested intensity of assessment
Level of existing regional knowledge.	Low
Type and comprehensiveness of recent local surveys.	Low
Degree of existing disturbance or fragmentation at the regional scale.	Low
Extent, distribution and significance of environments	Low
Significance of species likely to be present	Low/Moderate
Sensitivity of the environment to the proposed action.	Low
Scale and nature of impact.	Low
Potential value of presence, abundance and distributional data.	Moderate

2.1.3 Spatial terminology

A range of terms are used through the report to refer to the spatial environment around the proposed project, and these are defined below:

- Study area – the outermost boundary of the desktop assessment that is almost always a specified buffer distance (see Section 2.2.1 below) around the *survey area*. The study area thus encompasses the *survey area* but includes the area from which databases are sourced.
- Survey area – the *survey area* is the area to which the results of the desktop analysis are directed and/or the area within which field investigations are conducted. Note that while the term '*survey area*' is used throughout the guidance provided by EPA (2020), it does not appear to be explicitly defined and, therefore, the above definition has been developed with interpretation of both the guidance and BCE report structure.
- Project area – this may be equivalent to the *survey area* but is strictly the land over which the proponent has tenure or some control and within which on-site impacts may occur.
- Development envelope – the expected extent of land clearing and/or development.

2.2 Desktop assessment

2.2.1 Sources of information

Information on the fauna assemblage of the project area was drawn from a range of sources including databases and reports from other fauna surveys in the region. Because of multiple projects in the region, databases have been accessed for the area including the current project area on three occasions since late 2019. Databases accessed for a larger, nearby project in January 2020 are listed below (Table 3). Information from databases was supplemented with species expected in the area based on general patterns of distribution. Sources of information used for these general patterns are listed in Table 4.

BCE has conducted multiple fauna surveys in the general area between Eneabba and Dongara which have included monitoring, targeted fauna assessments and level 2 (detailed) fauna assessments. Locations of these BCE studies are indicated on Figure 4. There have also been studies by other consultants in the region, particularly for the Eneabba mineral sands mine. Species records from these studies are contained in the NatureMap database which was consulted as part of the desktop assessment. BCE also maintains a detailed database and annotated species lists for all its previous assessment (some of which pre-date NatureMap) and these were consulted for reference as part of the desktop assessment. Previous reports consulted for background information include Harris *et al.* (2008), Metcalf and Bamford (2008), Bamford (2009), Bamford (2012), Everard and Bamford (2014), Bamford *et al.* (2015), Bamford and Chuk (2015-17), Bamford and Chuk (2019), and Bamford *et al.* (2019). Some of these studies (Metcalf and Bamford 2008, Bamford 2009, 2012) were undertaken within or immediately adjacent to the project area for Tronox (formerly Tiwest Joint Venture) and included a two-season Level 2 fauna survey. In addition, a detailed survey was undertaken in the VRX Arrowsmith North project area (Immediately to the south) at the same time as the study in the Beharra Silica project area. Methods used in these previous surveys are given in Table 5.

The previous studies used a range of techniques as they were carried out for different purposes but were consistent with guidance at the time. In combination, they are consistent with current (EPA 2020) guidance in the range of techniques used; for example, motion-sensitive cameras were not used by Metcalf and Bamford (2008) but were used extensively at a nearby site by Bamford and Chuk (2015-2017). Metcalf and Bamford (2008) was the only detailed survey previously conducted within 20km of the current project area and differed from current guidance in two respects. These differences are discussed below.

Bat surveys carried out by Metcalf and Bamford (2008) were based on trapping (harp traps) rather than echolocation. Four bat species were confirmed, and the remaining species returned from databases that were not caught were probably not present, as they are woodland/forest species and thus the project area did not provide habitat. None of the species is of conservation significance and the project area was searched thoroughly for important roost sites (BCE considers that in impact assessment, understanding landscape function is more important than confirming the presence of a species).

In 2007 (Metcalf and Bamford 2008), trapping for small terrestrial vertebrates used pitfall, funnel, Elliott and cage traps; BCE would not use Elliott and/or cage traps in a site such as the project area now due to the risk to animal welfare. Cage and Elliott traps caught nothing that was not recorded by other means. Metcalf and Bamford (2008) ran traps for only five nights in winter and again in spring, which was standard at the time but the EPA (2020) now recommends trapping for seven nights. Despite this, trapping beyond five nights rarely adds additional species to the list. Figure 5 presents a simple analysis of the accumulation of species during a trapping program for several recently-sampled sites, including the Tronox Dongara Project area of

Metcalf and Bamford (2008) which is adjacent to the current project area (Figure 4) and thus provides very relevant data. Trapping ran for up to eight nights in some projects but species were rarely added after the fifth night in any project. At the Tronox Dongara site, the winter survey added no new species after the third night, and the winter sampling program yielded only two species not also recorded in spring. Both were expected and are not of conservation significance. The spring sampling program added three species on the fifth night, but the data from other projects suggests any further trapnights would have yielded little. The only species of conservation significance caught by trapping (the Black-striped Snake *Neelaps calonotos*, P3) was recorded on the fourth night; all other species recorded were expected and were not of listed conservation significance. The actual effectiveness of trapping in recording species also needs to be considered. Metcalf and Bamford (2008) recorded 33 species of small, terrestrial vertebrates (ie frogs, reptiles and small mammals). Of these, 23 species (70%) were recorded by trapping and the remaining 10 species (30%) were recorded only by hand-searching/observation.

In the other studies presented in Figure 5, from 15% to 44% of small, terrestrial vertebrates were recorded only by observation/searching (ie they were not recorded in traps). The average proportion of the small, terrestrial vertebrate assemblage recorded only by searching/observation across these projects is 30.3%. Based on these sorts of observations, the use of five nights trapping by Metcalf and Bamford (2008) is not considered to be inconsistent with the intent of the EPA (2020). It is recognised, however, that repeating the sampling in a different year and/or at slightly different locations would probably detect species not found in the 2007 sampling, and, due to annual variation and Beta diversity, might not detect some that were found in 2007 (How and Dell 1990, Bamford *et al.* 2010). The sampling for the Project provided an opportunity to make this comparison (see Section 3.3.2). Species accumulation in relation to trapping effort is presented for the current project in Figure 6. No species were added to the list after the fourth night. This was despite one of the highest numbers of individual captures BCE has ever recorded in a sampling period (nearly 400 individual captures).

Table 3. Databases searched for the desktop review; accessed January 2020.

Database	Type of records held in database	Area searched
BCE Database	Fauna recorded by BCE in the vicinity of the project area.	40 km buffer around the boundary of the project area.
Atlas of Living Australia (ALA)	Fauna records from Australian museums and conservation/research bodies, including records from BirdLife Australia's Atlas (Birdata) Database.	40 km buffer around the boundary of the project area.
NatureMap (DBCA)	Records from the Western Australian Museum (WAM) and Department of Biodiversity, Conservation and Attractions (DBCA) databases, including historical data and Threatened and Priority species in WA.	40 km buffer around the boundary of the project area.
EPBC Protected Matters Search Tool	Records on MNES protected under the EPBC Act.	40 km buffer around the boundary of the project area.

Table 4. Sources of information used for general patterns of fauna distribution.

Taxa	Sources
Fish	Morgan <i>et al.</i> (1998), Allen <i>et al.</i> (2003), Morgan <i>et al.</i> (2014), DoF (2020).
Frogs	Tyler and Doughty (2009), Anstis (2013).
Reptiles	Storr <i>et al.</i> (1983, 1990, 1999, 2002), Bush and Maryan (2011), Wilson and Swan (2017).
Birds	Johnstone and Storr (1998, 2005), Menkhorst <i>et al.</i> (2017).
Mammals	Van Dyck and Strahan (2008), Churchill (2009), Menkhorst and Knight (2011).

Table 5. Previous BCE surveys within c. 20 km of project area (except where noted).

Authors	Description	Alignment with current guidance (EPA 2020)	Limitations
Harris <i>et al.</i> 2008	Survey for threatened fauna in the Tronox My Adams project area. Hand-searching and aural surveys targeting the Millipede <i>Antichiropus</i> 'Eneabba 1' (previously found in the Mt Adams project area (Metcalf and Bamford 2008), the Phasmid-mimic Cricket <i>Phasmodes jeeba</i> (uncertainty about past records in the Mt Adams area) and Western Ground Parrot (unconfirmed but well-regarded sighting in Mt Adams area in 1992). Survey involved hand-searching and aural survey in spring 2008.	Targeted survey (<i>sensu</i> EPA 2020). Methods based on survey approaches described by Rentz (1996) for invertebrates, and based on advice from DBCA for Western Ground Parrot.	No limitations except uncertainty always surrounds surveys for rare species and absence can rarely be confirmed.
Metcalf and Bamford 2008	Basic, detailed and targeted surveys in the Tronox Mt Adams project area, including a site inspection (September 2002), and late winter and spring surveys (2007). Investigations included hand-searching for SRE invertebrates, aural surveys for Western Ground Parrot, pitfall trapping (900 trapnights), Elliott and cage trapping (240 trapnights each), bird censusing, harp-traps for bats and opportunistic observation.	A wide range of sampling techniques used as outlined by the EPA (2020). Traps were run for five nights in each survey as was standard at the time; this is discussed in Section (see also Figure 5).	No limitations. Motion-sensitive cameras were not used as is standard practice now, but were used at a nearby site by Bamford and Chuk (2015-2017).
Bamford 2009	A desktop review and site inspection carried out for Iluka from ca. Beekeepers' Road to Arrowsmith River, west of Brand Highway. Included some aural survey work for Western Ground Parrot.	Basic survey.	No limitations.
Everard and Bamford 2014	A desktop review and site inspection around and south of Eneabba for Iluka. Over 20km south of Arrowsmith North project area, but a comprehensive review of multiple fauna surveys around Eneabba across similar landscapes.	Basic survey	No limitations.
Bamford 2012	Targeted surveys for the Western Ground Parrot in the Tronox Mt Adams Project area and nearby Beekeepers' Nature Reserve. Surveys carried out in May 2008 and June 2012 with up to eight observers over up to five evenings and mornings.	Targeted survey. Methods based on advice from DBCA for Western Ground Parrot.	No limitations except uncertainty always surrounds surveys for rare species and absence can rarely be confirmed. Possible calls were heard in

Authors	Description	Alignment with current guidance (EPA 2020)	Limitations
			June 2012 but this was not followed up.
Bamford <i>et al.</i> 2015	Desktop review and site inspection of Waitsia project area for AWE; northern edge of Yandanogo Nature Reserve. Included targeted surveys for Western Ground Parrot and observations on roosting Carnaby's Black-Cockatoo.	Basic and targeted survey.	No limitations.
Bamford and Chuk 2015-2017	Use of motion-sensitive cameras (baited) to detect fauna activity along NorWest Energy drill-lines just west of Arrowsmith, targeting feral species but also appropriate for detecting significant species such as Malleefowl, Chuditch, Western Ground Parrot and Quenda. Total effort was 904 camera-nights over three years (about 10 days each autumn in 2015, 2016 and 2017). Opportunistic observations on other fauna made.	Targeted survey. Methods complement Metcalf and Bamford (2008).	No limitations.
Bamford and Chuk 2019	Desktop review and site inspection of the VRX Silica Arrowsmith South project area.	Basic survey.	No limitations.
Bancroft and Bamford 2020	Desktop review, site inspection and some targeted survey across a broad area from just east of the Arrowsmith North project area to south of Eneabba; for Beach Energy. Included an update of previous desktop reviews across this area and field investigations to confirm black-cockatoo roosts and black-cockatoo foraging habitat.	Basic and some targeted survey	No limitations.
Bamford 2020	Desktop review, site inspection and some targeted survey of the Beharra Spring Silica Project (Adams Road immediately west of Tronox project area). Targeted survey included searching for SRE invertebrates and assessing habitat for Carnaby's Black-Cockatoo.	Basic and some targeted survey	No limitations.
Bamford, Bleby and Huang 2021	Desktop review, site inspection and some targeted survey of the Strike energy West Erregulla gas field project (c. 20km east of Beharra Silica project area). Targeted survey included searching for SRE invertebrates and assessing habitat for Carnaby's Black-Cockatoo.	Basic and some targeted survey	No limitations although most of site recently burnt

Authors	Description	Alignment with current guidance (EPA 2020)	Limitations
Bamford, Chuk, McCreery and Shepherd 2022	Desktop review, site inspection, targeted and detailed survey of VRX Arrowsmith North project area, immediately south of the Beharra Silica project. Included extensive use of motion-sensitive cameras and audio-recording units.	Basic, targeted and detailed survey	No limitations

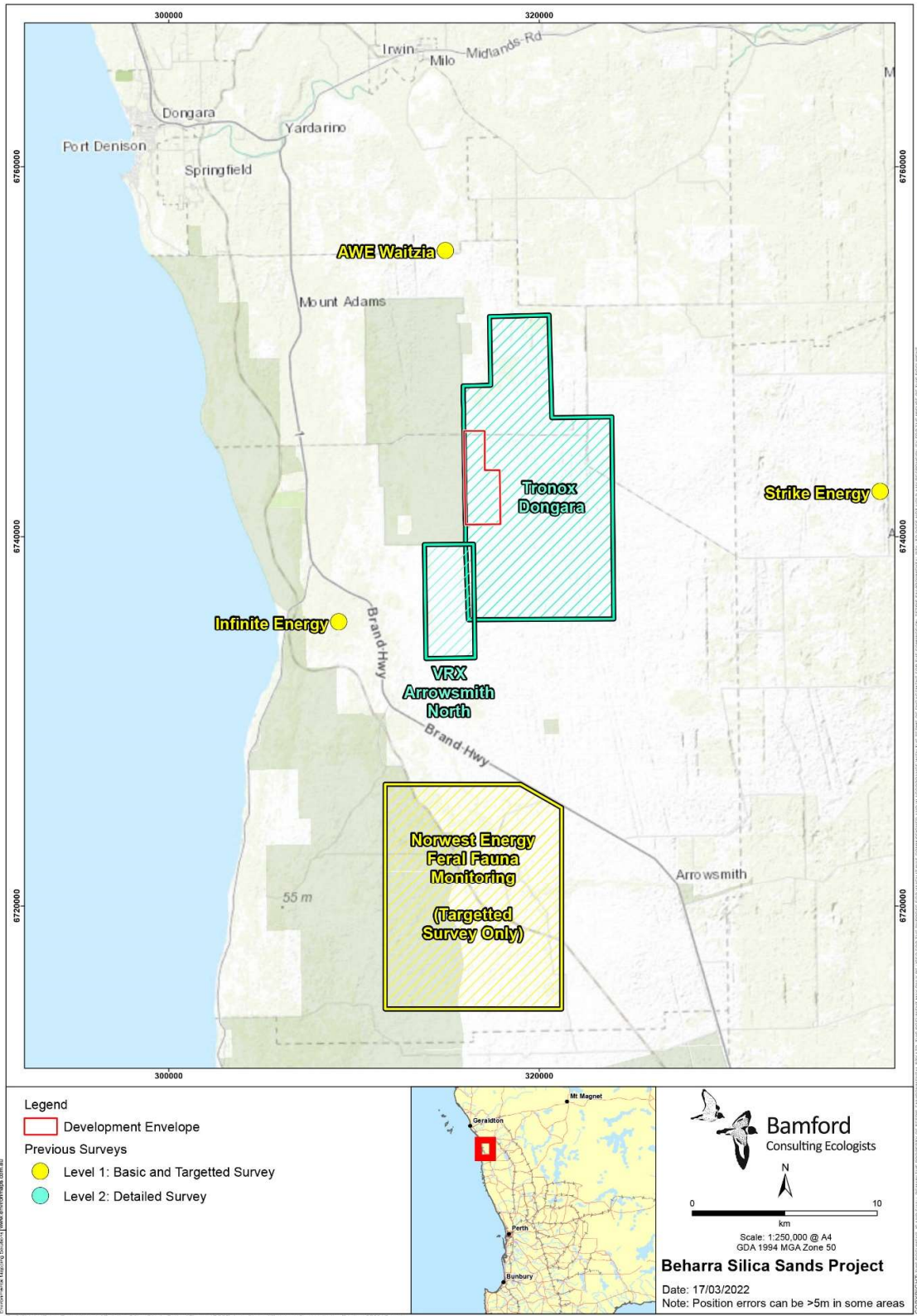


Figure 4. Locations of previous fauna investigations in the vicinity of the Beharra Silica Sand Project.

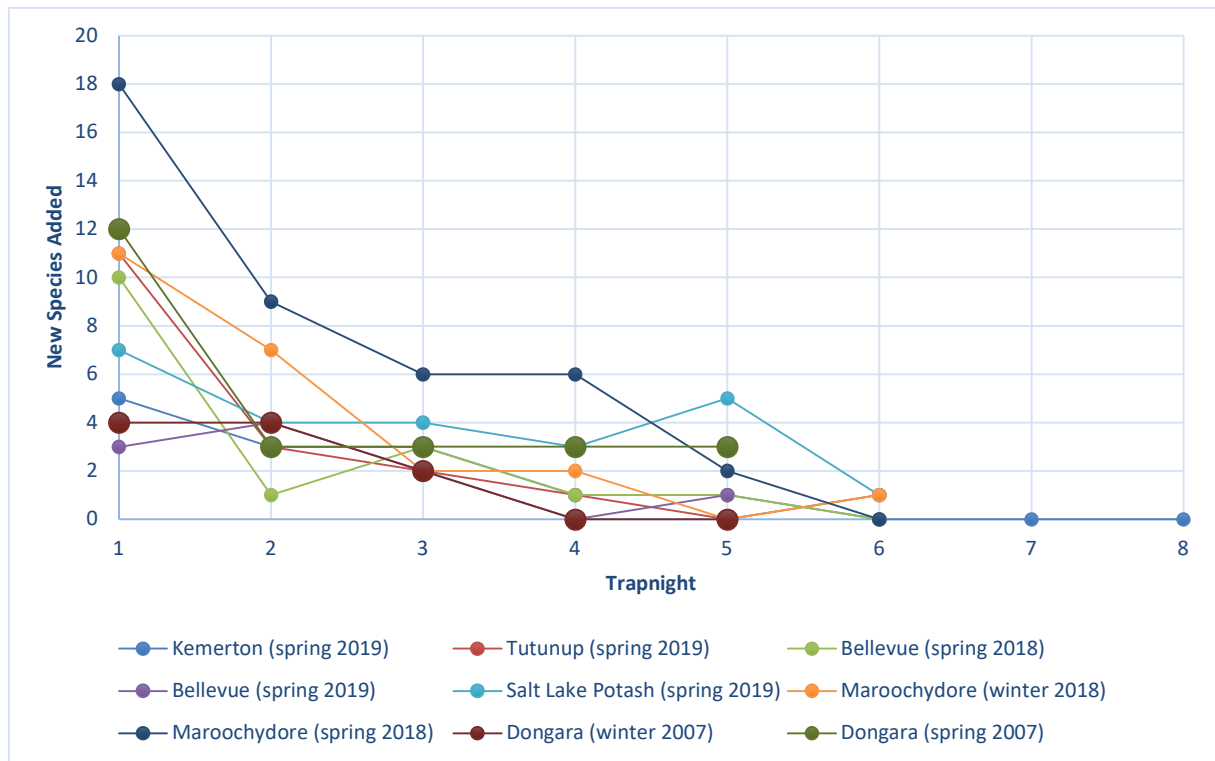


Figure 5. The relationship between the number of trapnights and the addition of species in sampling for small, terrestrial vertebrates at a range of sites. The majority of captures were in pitfalls and sampling effort similar (around 500 pitfall nights). Winter and spring at the Tronox Dongara Project are included. Results for Beharra project presented below.

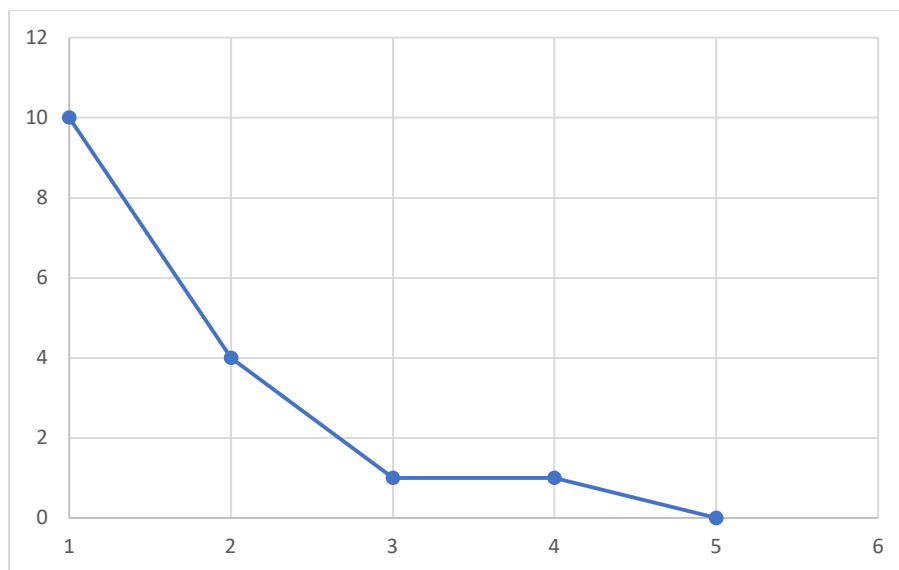


Figure 6. The relationship between the number of trapnights and the addition of species in sampling for small, terrestrial vertebrates at the Beharra Silica Sand Project, December 2021. The majority of captures were in pitfalls and sampling effort was 300 pitfall nights.

2.2.2 Nomenclature and taxonomy

As per the recommendations of the EPA (2004), the nomenclature and taxonomic order presented in this report are generally based on the Western Australian Museum's (WAM) Checklist of the Fauna of Western Australia 2018. The authorities used for each vertebrate group were: fish (Morgan *et al.* 2014), frogs (Doughty *et al.* 2019a), reptiles (Doughty *et al.* 2019b), birds (BirdLife Australia 2019), and mammals (Travouillon 2019). In some cases, more widely-recognised names and naming conventions have been followed, particularly for birds where there are national and international naming conventions in place (e.g. the BirdLife Australia working list of names for Australian Birds). This includes the consistent use of the group name "Black-Cockatoo" for all species of Black-Cockatoos. English common names of species, where available, are used throughout the text; Latin names are presented with corresponding English names in tables in the appendices.

2.2.3 Interpretation of species lists

Species lists generated from the review of sources of information are generous as they include records drawn from a large region and possibly from environments not represented in the project area. Therefore, some species that were returned by one or more of the database and literature searches have been excluded because their ecology, or the environment within the project area, determine that it is highly unlikely that these species will be present. Such species can include, for example, seabirds that might occur as extremely rare vagrants at a terrestrial, inland site, but for which the site is of no importance. Species returned from the databases and not excluded on the basis of ecology or environment are therefore considered potentially present or expected to be present in the project area at least occasionally, whether or not they were recorded during field surveys, and whether or not the project area is likely to be important for them. These are referred to as 'expected' species (they can also be considered as 'likely to occur'). This list of expected species is therefore subject to interpretation by assigning each a predicted status in the project area. The status categories used are:

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

These status categories make it possible to distinguish between vagrant species, which may be recorded at any time but for which the site is not important in a conservation sense, and species which use the site in other ways but for which the site is important at least occasionally. This is particularly useful for birds that may naturally be migratory or nomadic, and for some mammals that can also be mobile or irruptive, and further recognises that even the most detailed field survey can fail to record species which will be present at times. The status categories are assigned conservatively based on the precautionary principle. For example, a lizard known from the general area is assumed to be a resident

unless there is very good evidence the site will not support it, and even then, it may be classed as a vagrant rather than assumed to be absent if the site might support dispersing individuals. It must be stressed that these status categories are predictions only and that often very intensive sampling would be required to confirm a species' status. The results of the database searches were reviewed and interpreted, and obvious errors and out of date taxonomic names were deleted.

2.2.4 Conservation significance

All expected species were assessed for conservation significance as detailed in Appendix 1. Three broad levels of conservation significance are used in this report:

- Conservation Significance 1 (CS1) – species listed under State or Commonwealth Acts such as the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) and the Western Australian *Biodiversity Conservation Act 2016* (BC Act);
- Conservation Significance 2 (CS2) – species listed as Priority by DBCA but not listed under State or Commonwealth Acts; and
- Conservation Significance 3 (CS3) – species not listed under Acts or in publications, but considered of at least local significance because of their pattern of distribution.

See Appendix 1 for an expanded discussion of these categories and Appendix 2 for a description of the categories used in the legislation (EPBC and BC Acts) and by the DBCA.

2.3 Field investigations

2.3.1 Overview

A basic survey and site inspection of the project area was carried out on 19th and 20th August 2020 by Dr Mike Bamford and Tetris Environmental. The aim of the site visit was to familiarise the consultant with the environments that provide habitat for fauna, and in particular to assess the area's importance for Black-Cockatoos, which are key species of conservation significance in the region. Representative parts of the project area were walked to assess the vegetation and visit key Floristic Community Types (FCTs) recorded by Woodman Environmental (2011), and locations of interest were recorded, including evidence of Black-Cockatoo foraging. Opportunistic observations on fauna in general were made. Tracks followed in August 2020 and in the subsequent December 2021 field trip are illustrated in Figure 7. The basic survey was followed by a detailed and targeted survey carried out from 1-10 December 2021. This survey incorporated a range of survey techniques summarised below and described in further detail in Sections 2.3.1 to 2.3.7.

- Identification of VSAs;
- Systematic sampling transects;
 - Pitfall trapping
 - Funnel traps
 - Bird censusing
- Black-Cockatoo foraging habitat assessment;
- Motion sensitive cameras;
- Autonomous recording units (ARUs) for both bats and the Western Ground Parrot;
- Opportunistic invertebrate collection, and
- Opportunistic observations.

2.3.2 Personnel and permits

Personnel involved in the field investigations and report preparation (including desktop review) are listed in Table 6. The field investigations were carried out under Regulation 27 permit No BA27000568.

Table 6. Personnel involved in the field investigations and report preparation.

Personnel	EIA Experience (years)	Field Investigations		Report Preparation
		Trip 1 (Aug 2020)	Trip 2 (Dec 2021)	
Dr Mike Bamford <i>BSc, Hons (Biology), PhD (Biology)</i>	40	+		+
Dr Wes Bancroft <i>BSc (Zoology/Microbiology), Hons (Zoology), PhD (Zoology)</i>	24		+	+
Mr Andy McCreery <i>BSc. (Wildlife and Cons. Biol.)</i>	10		+	
Dr Jamie Wadey <i>BSc, Hons (Biology), PhD (Biology)</i>	2		+	
Ms Eliza-Joyce Mellersh <i>(Wildlife and Cons. Biol.)</i>	4		+	
Ms Rhiannon de Visser <i>BSc. (Zool.)</i>	1		+	
Mr James Hesford <i>BSc (Env. Sci. and Biol.) (Tetris Environmental)</i>	23	+		
Mr Marcus Radford <i>BSc (Biol.) (Tetris Environmental)</i>	3	+		

2.3.3 Systematic Fauna Sampling

Systematic fauna sampling was based on four transects of trap and census points; transects are described in Table 7 and details of locations are given in Appendix 5. Sampling locations are mapped on Figure 8. The transects consisted of either 10 or 20 sampling points spaced approximately 20 metres apart, with a total of 60 sampling points. An additional transect of 20 sampling points was located just to the south of the project area, in a similar landscape. This was sampled as part of a separate project but provides some comparative and off-site data. Each sampling point had a pitfall trap (pitfall) and there was a funnel trap at about every third location. Usage of funnel traps was limited by the weather conditions. The trap layout consisted of one 20 litre bucket with three fences (each 1.2 metres in length) extending radially from the bucket to allow fauna to fall into the pit when following the fence line. The fences were 1.2 m in length where there was no funnel trap, but where there was a funnel, one fence was 3 m in length with the funnel half way along this length.

Weather conditions were hot to extremely hot with maxima towards the end of the field trip over 40 °C. As a result, funnel traps were disabled for the hottest part of the day on some days, while traps were checked twice each morning. The first trap round was completed by about 9am, and

the second trap round took place from 10:30 am to 12 noon. This was to ensure that animals caught after the early morning trap round were not in traps through the hottest part of the day, as that is when most mortality occurs. Traps were run for five nights as species return had declined to zero (Figure 6) and there was increasing concern with trapping during extreme weather conditions. The total trapping effort was 300 pitfall nights and 75 funnel-trap nights. Site locations, descriptions and trapping effort are displayed in Table 7 and Figure 8. Photos of sites are presented on Plates 1 to 7 and fire history across the Project area in Figure 9 (Note: the whole area was burnt in 1991 and this fire is not shown to maintain clarity of the map).

Bird census surveys were carried out during each pitfall check, so there were effectively 10 or 20 bird census points on each transect, depending on the number of sampling points on a transect. Birds were identified visually and acoustically within 25 m of each sampling point. Censusing was carried out five times at each point, so there were 300 census events in total, with birds censused along each transect five times (ie 20 transect census events).

Table 7. Systematic sampling site locations, descriptions and sampling effort.

Location codes	Transect description	Environment	Sampling effort
Transect B01. Locations B51 to B60	10 pitfalls, 3 funnels and 10 census points Set 3/12/21 Collected 8/12/21	Kwongan on sand across valley (B51 to B54 and B56 to B60) with <i>Melaleuca</i> damp land on dark grey loam from B54 to B56. Most burnt in autumn 2021 but unburnt patches from B56 to B57, and around B59. Fire history: 1991, 2002, 2021.	50 pitfall trap nights, 15 funnel nights and 5 bird surveys
Transect B02. Locations B41 to B50	10 pitfalls, 2 funnels and 10 census points Set 2/12/21 Collected 7/12/21	Kwongan on sandplain with <i>Banksia attenuata</i> and occasional <i>Banksia elegans</i> over <i>Conospermum</i> , <i>Verticordia</i> and <i>Beaufortia</i> . Sand is pale grey to creamy-white. Last burnt in 2017. Fire history 1991, 2012.	50 pitfall trap nights, 10 funnel nights and 5 bird surveys
Transect B03. Locations B01 to B20	20 pitfalls, 5 funnels and 20 census points. Set 2/12/21 Collected 7/12/21	Kwongan on sandplain with a slight dip into <i>Acacia</i> tall shrubland on a dark grey loam soil from pitfalls 6 to 11. Kwongan of <i>Banksia attenuata</i> and very occasional emergent <i>Banksia menziesii</i> over <i>Conospermum</i> , <i>Verticordia</i> and <i>Beaufortia</i> . Sand is very pale grey. Last burnt 2012 except for B17 to B20 which are on the edge of an area burnt 2017 (The fire history dataset layer 2017 is based on DBCA target burn area, actual burn area further east). Recently burnt area has low shrubland of <i>Acacia</i> with regenerating <i>Banksia</i> . Fire history: 1991, 2012, 2017(part).	100 pitfall trap nights, 25 funnel nights and 5 bird surveys

Location codes	Transect description	Environment	Sampling effort
Transect B04. Locations B21 to B40	20 pitfalls, 5 funnels and 20 census points Set 2/12/21 Collected 7/12/21	Kwongan on sandplain with <i>Banksia attenuata</i> , occasional <i>Banksia hookeriana</i> and very occasional <i>Banksia elegans</i> over <i>Conospermum</i> , <i>Verticordia</i> and <i>Beaufortia</i> . Scattered emergent <i>Banksia menziesii</i> to 3 m. Sand is a pale grey to creamy white. Last burnt 2012. Fire history: 1972, 1991, 2012.	100 pitfall trap nights, 25 funnel nights and 5 bird surveys

2.3.4 Motion sensitive cameras

Five motion sensitive cameras were set up in the Project area, with a further five cameras set at nearby locations to the south. These additional cameras were set in dense vegetation close to extensive riparian areas. A non-reward lure was used to attract fauna in the form of bait tubes filled with universal bait (peanut paste, rolled oats, sardines and tuna oil). Bait tubes were placed into the camera view and attached to a solid object and cameras were positioned in areas selected to maximise fauna detection, such as on the edges of thickets of dense vegetation. Fauna targeted with the cameras were species such as the Chuditch that are probably locally extinct, but where there exists a slight possibility that they persist. Cameras were set on 2nd December and collected on 10th December, giving a total camera effort of 40 camera nights. Locations of cameras set in the Project area are illustrated on Figure 8, and details of all cameras are given in Appendix 5.

Camera results were recorded as events to give a measure of the abundance/activity of each species. An event is one or more images of an animal judged to be taken as part of one visit to the camera. For example, there might be 10 photographs taken of a Brush Wallaby taken over a period of five minutes. A separate event (i.e. visit) is therefore considered to occur if a period of more than c. five minutes elapses before the next photograph is taken.

2.3.5 Autonomous Recording Units (ARUs)

Four Song Meters (SM2s) (Wildlife Acoustics Ltd) were set in the Project area, with a further two SMs and four Audiomoths set just to the south. The detectors were set to record bird calls to target the Western Ground Parrot. Recorders were not set to detect bats, as bats had previously been surveyed nearby and the bat assemblage is not expected to include species of conservation significance as the area is out of the range of significant bats known from the South-West region (Metcalf and Bamford 2008). Units were set to record for one hour after sunset and one hour before sunrise, which are the key calling periods for the Western Ground Parrot, and operated from 4th to 10th December (nights of 4th to 9th December; therefore 24 unit-nights in the Beharra project area. Locations of ARUs set in the Project area are illustrated on Figure 8, and details of all ARUs are given in Appendix 5.

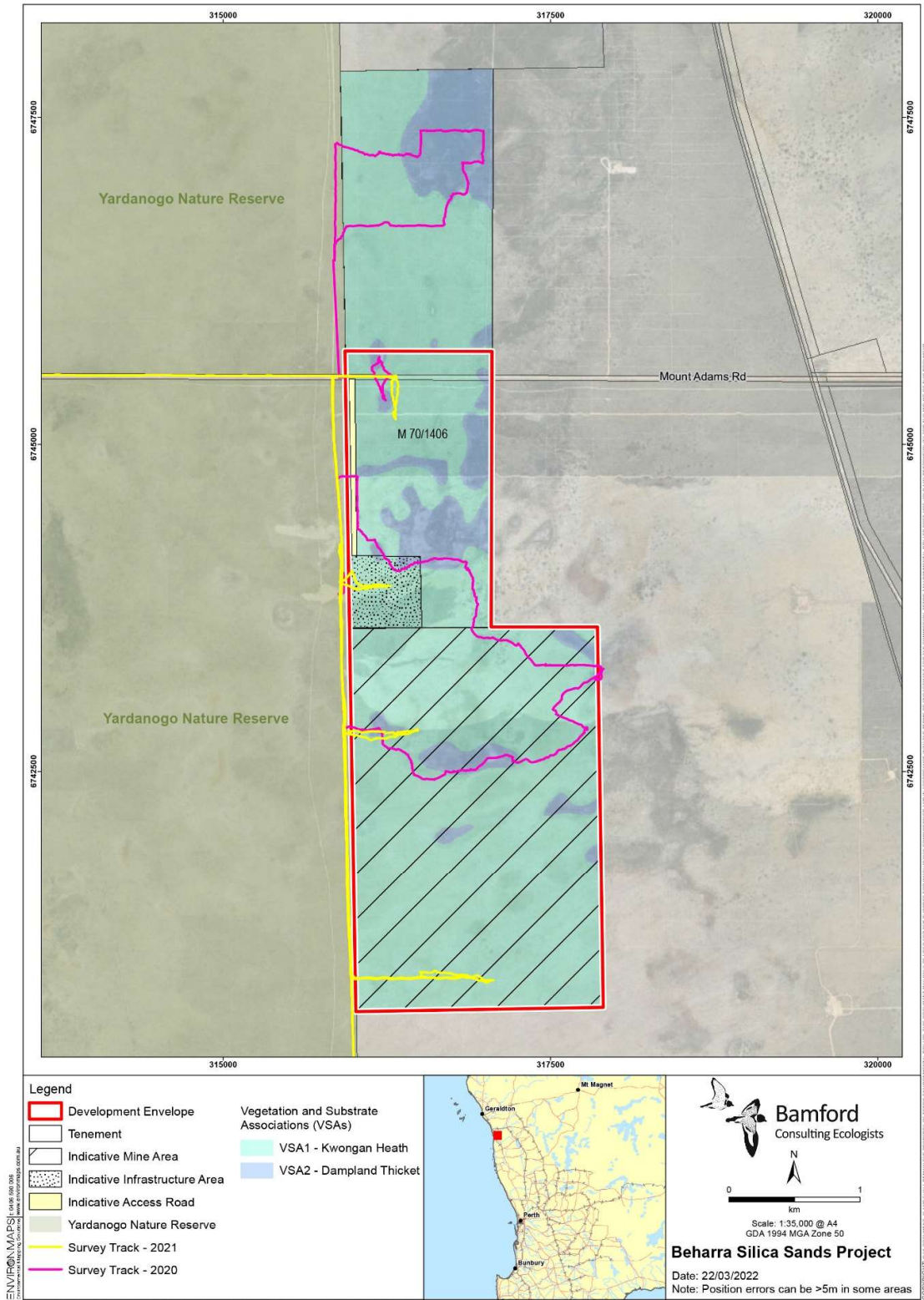


Figure 7. The project area, indicating tracks in 2020 and 2021, and the two principle Vegetation and Substrate Associations (VSAs; described in section 3.1).

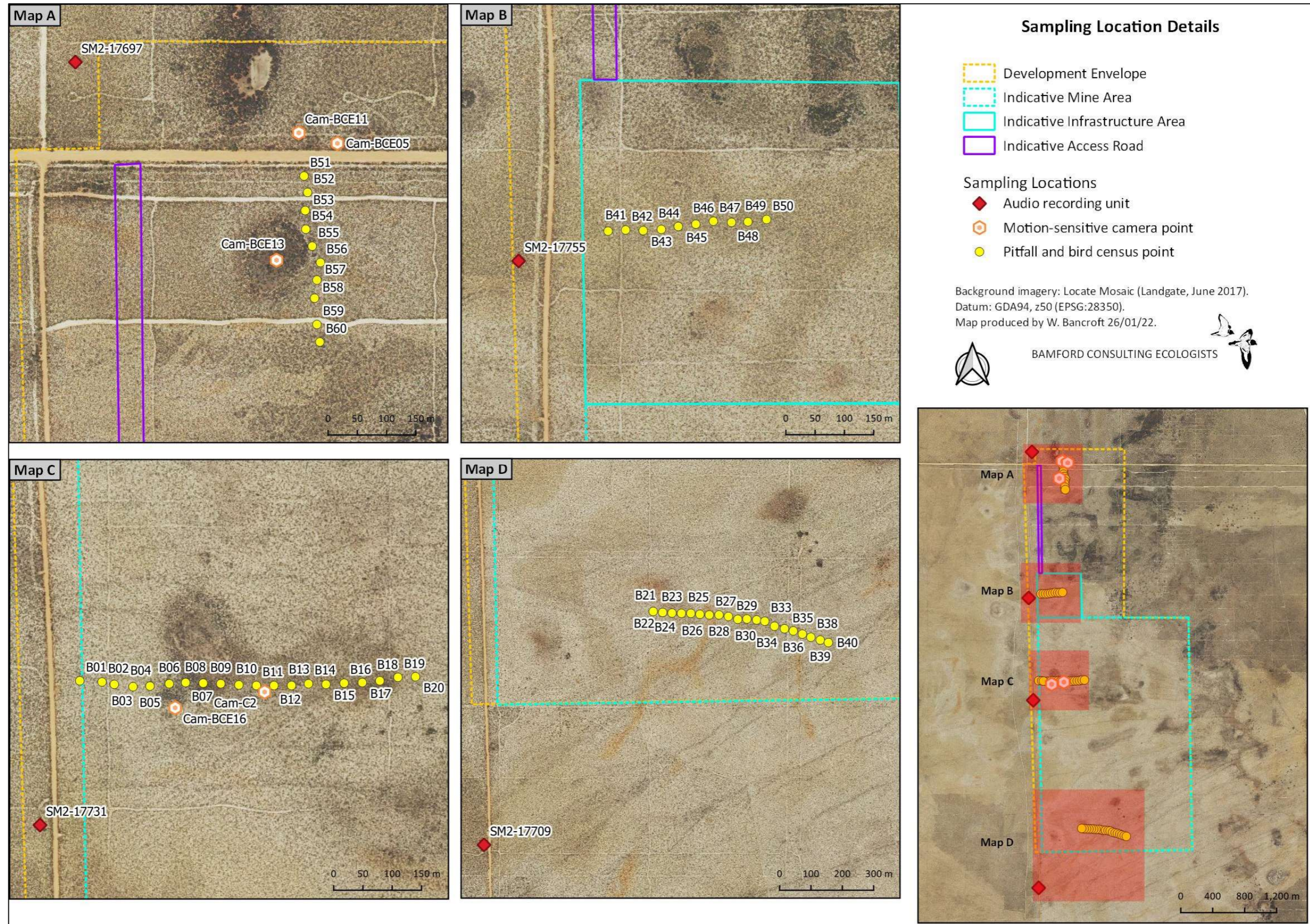


Figure 8. Locations of sampling sites in the Project area, Dec. 2021. Transects were numbered from north to south: thus Transect B01 in north (Map A) and Transect B04 in south (Map D).

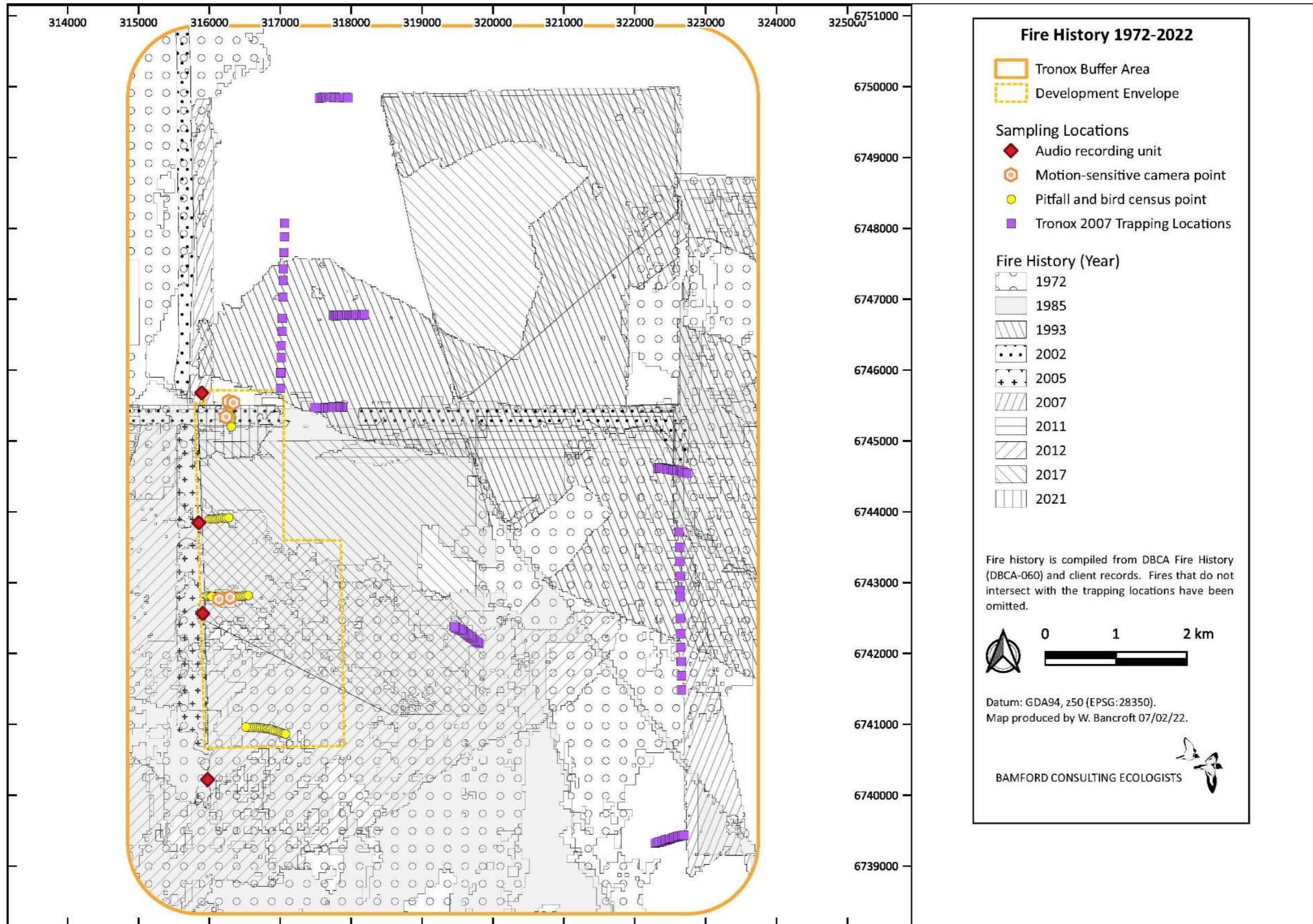


Figure 9. Fire history and sampling locations

2.3.6

2.3.6.1 *Black-cockatoo habitat analysis*

2.3.6.2 *Guidelines*

The Department of Agriculture, Water and the Environment (DAWE; formerly the Department of the Environment and Energy and the Department of Sustainability, Environment, Water, Population and Communities) provides guidelines for the referral of actions that may result in impact to black-cockatoos. The survey and analysis reported here have been conducted with strong reference to both the existing guidelines (DSEWPaC 2012) as well as the recently revised draft guidelines (DEE 2017). In addition, survey methodology followed the recommendations listed on the DAWE's Species Profile and Threats Database (DAWE 2020b).

Ecological values for black-cockatoos within the site were based on the definitions of breeding, foraging and roosting habitat as per the EPBC Act referral guidelines for black-cockatoos (DSEWPaC 2012), with foraging and nesting values assessed using systems developed by Bamford Consulting.

It should be noted that the only threatened species of black-cockatoo likely to occur within the project area is Carnaby's Black-Cockatoo (*Calyptorhynchus latirostris*), and that the subspecies of Red-tailed Black-Cockatoo (*Calyptorhynchus banksii escondidus*, the Inland Red-tailed Black-Cockatoo) present in the general area is not listed under state or federal legislation. The field investigations were therefore limited to the former.

2.3.6.3 *Breeding tree assessment*

The project area's suitability for breeding was assessed by checking for large, potentially hollow-bearing trees that may facilitate breeding by black-cockatoos (sensu DAWE 2020b).

2.3.6.4 *Foraging habitat assessment*

For foraging value for black-cockatoos, the site was assessed by inspecting the vegetation and reviewing vegetation descriptions, and calculating a foraging score as outlined in Appendix 6. The size of the project area precluded detailed inspections of all areas of native vegetation, however all vegetation types (FCTs) were traversed. The foraging score provides a numerical value that reflects the significance of vegetation as foraging habitat for black-cockatoos, and this numerical value is designed to provide the sort of information needed by the DAWE to assess impact significance and potential offset requirements. The foraging score of the vegetation depends upon the type, density and condition of trees and shrubs in an area, and can be influenced by the context such as the availability of foraging habitat nearby.

The foraging score is based on three components, as detailed in Appendix 6. These three components are drawn from the DAWE offset calculator, with the scoring approach developed by BCE:

- A score out of six for the vegetation composition, condition and structure.
- A score out of three for the context of the site.
- A score out of one for species density.

The foraging score can thus be assigned a value out of six, based upon site vegetation characteristics, or out of 10 if context and species density are also considered. The score out of 10 is calculated only for vegetation of at least Low to Moderate foraging value (vegetation characteristics score of ≥ 3). Vegetation with No, Negligible or Low foraging value is effectively assigned context and species density scores of '0' because the context and species density are of little relevance if the vegetation does not support regular foraging by the birds. A different score out of 10 can be assigned to different vegetation types.

2.3.6.5 Roosting habitat assessment

Vegetation was assessed for roosting habitat potential based on tree species present and on the occurrence of local confirmed or potential roosting sites (based upon previous records from BCE and the 'Great Cocky Count' (Peck *et al.* 2016; DBCA 2020).

2.3.7 Opportunistic collection of invertebrates

Targeted studies on invertebrates were undertaken by Bennelongia (2022) but opportunistic collection and observations were carried out as part of this survey. This included collecting invertebrates caught in pitfalls if they were considered to be potentially of taxonomic interest, such as trapdoor spiders, and searching for trapdoor spider burrows when carrying out work such as pitfall digging. Searching was also carried out for native bees of the genus *Hylaeus* as these are distinctively black and yellow, often fly around flowering shrubs, and are active in late spring/early summer. This searching was directed particularly at the Woollybush Bee *Hylaeus globuliferus* which is of high conservation significance. It is most active in summer, whereas the Bennelongia (2022) field investigations took place in July (when many other significant invertebrates are best-sampled).

2.4 Survey limitations

The EPA's technical guidance for terrestrial fauna surveys (EPA 2020) outlines a number of limitations that may arise during field investigations for Environmental Impact Assessment (EIA). These survey limitations are discussed in the context of the BCE investigation of the project area in Table 8.

Table 8. Survey limitations as outlined by EPA (2020).

EPA Survey Limitations	BCE Comment
Availability of data and information.	Abundant information from regional studies and databases (Table 5).
Competency/experience of the survey team, including experience in the bioregion surveyed.	Field and reporting personnel have extensive experience in the region and with fauna investigations for impact assessment (Table 6).
Scope of the survey, e.g. were faunal groups excluded from the survey.	The investigations focused on terrestrial vertebrate fauna and fauna values, including significant species. Scope was to target information on significant species and to provide an indicative assemblage based upon databases. No groups excluded except invertebrates not recognised as significant.

EPA Survey Limitations	BCE Comment
Timing, weather and season.	Not a limitation, except maxima were very high in the December 2021 survey period and the decision was made to remove traps after five nights. However, numbers of captures were very high and no species were added after the fourth night of trapping.
Disturbance that may have affected results, e.g. Fire, flood.	Multiple recent fires are likely to have affected the fauna assemblage, with about eight fires somewhere across the project area in the last 50 years.
The proportion of fauna identified, recorded or collected.	All fauna recorded were identified. The actual proportion of fauna species present that were recorded is uncertain and this issue is discussed above.
Adequacy of the survey intensity and proportion of survey achieved, e.g. The extent to which the area was surveyed.	The project area was well-covered in the site inspection and detailed investigations.
Access problems.	No access problems and therefore not a limitation.
Problems with data and analysis, including sampling biases.	NA

3 Results

3.1 Vegetation and Substrate Associations

The project area reflects major components of the Lesueur Sandplain Subregion and the vegetation has been described by Woodman Environmental (2009, 2011 and 2021). The entire project area and surrounds consists largely of Kwongan Heath and associated shrublands typical of the subregion, with small low-lying areas subject to seasonally damp conditions. The project area lies alongside the Tronox mineral sands Dongara Project area, which was intensively studied for flora (Woodman Environmental 2009, 2011 and 2021; Strategen 2012) and fauna (by BCE; see references) in the period 2008 to 2012. The flora studies extended into what is now the Beharra project area and Floristic Community Types (FCTs) have been identified and mapped. The FCTs were reviewed to assist in defining Vegetation and Substrate Associations (VSAs) in the field that provide habitat for fauna. This involves combining FCTs that are separated on some floristic characteristics but are broadly similar in key plant species, structure and substrate. On this basis, the five FCTs described in the project area by Woodman Environmental can be grouped into two broad VSAs:

- **VSA 1 – Kwongan Heath.** Kwongan shrubland on sandy soils more or less high in the landscape and with several banksia species prominent (*Banksia attenuata*, *Banksia hookeriana*, *Banksia menziesii* and in some areas *Banksia elegans*). Plates 1 to 5 illustrate VSA 1 with a range of fire ages.
- **VSA 2 – Dampland Thicket.** Thickets on heavier soils subject to winter waterlogging low in the landscape, usually with *Banksia leptophylla* and *Acacia* sp.. Often with patches of a low *Verticordia* sp.. Illustrated Plates 6 and 7.

Mapping of the VSAs was extended beyond the project area using the Woodman Environmental dataset for the Tronox Dongara Project. The distribution of these two VSAs is illustrated in Figure 10.



Plate 1. VSA 1. Kwongan Heath. *Banksia hookeriana* in flower, with *Banksia attenuata* and *Banksia elegans* to the left, and emergent *Banksia menziesii* in the background. August 2020. Last burnt 2012 (c. 9 years post fire).



Plate 2. VSA 1. Kwongan Heath. *Banksia attenuata* in flower. Sampling location B21 (Transect B04). December 2021. Last burnt 2012 (c. 9 years post-fire).



Plate 3. VSA1. Kwongan Heath. Sampling location B52 (Transect B01). December 2021. Last burnt 2021 (c. 9 months post-fire).



Plate 4. VSA1. Kwongan Heath. Sampling location B19 (Transect B03). December 2021. Last burnt 2017 (c. 4 years post-fire).



Plate 5. VSA1. Kwongan Heath. Sampling location B41 (Transect B02). December 2021. Last burnt 2012 (c. 9 years post-fire).



Plate 6. VSA2. Dampland Thicket. Sampling location B12 (Transect B03). December 2021. Last burnt 2012 (c. 9 years post-fire).



Plate 7. VSA2. Dampland Thicket. Sampling location B53 (Transect B01). December 2021. Last burnt 2017 (c. 4 years post-fire).

3.2 Vertebrate Fauna assemblage

3.2.1 Overview of fauna assemblage desktop results

The desktop study identified 205 vertebrate fauna species as expected (likely to occur) in the project area currently: 10 frogs, 51 reptiles, 119 birds and 25 mammals. This includes three introduced birds and nine introduced mammals, but no introduced frogs or reptiles. A further 16 species are considered to be locally extinct. All species, including those considered locally extinct, are listed in Appendix 7. Species returned from the database searches but which are considered not likely to occur in the project area are presented in Appendix 8. Seventy-one species were recorded in field investigations in the project area, and 145 species have been recorded by BCE in studies in adjacent areas for Tronox (Metcalf and Bamford 2008) and VRX Silica (Bamford *et al.* 2021). Recorded species are indicated in Appendix 7 and sampling results are presented and discussed in Section 3.3.2. Appendix 9 and Appendix 10 provide annotated species lists of fauna observations in the August 2020 and December 2021 field trips.

The project area may support 16 species of conservation significance, discussed in Section 3.2.2 below. The composition of the overall vertebrate fauna assemblage is summarised in Table 9 and discussed below.

Table 9. Composition of vertebrate fauna assemblage of the project area.

Recorded species are those observed during the field investigations in August 2020 and December 2021. Locally extinct species are not included in totals.

Taxon	Number of species likely to occur (Expected)	Recorded species regional (BCE)	Recorded Species (project area)	Number of species in each status category				
				Resident	Regular migrant or visitor	Irregular visitor	Vagrant	Locally extinct
Frogs	10	10	2	7	0	3	0	0
Reptiles	51	39	17	50	0	0	1	1
Birds	119							
Native	116	77	44	35	43	22	9	3
Introduced	3	1	0	0	1	0	2	
Mammals	25							
Native	16	12	4	11	3	0	2	12
Introduced	9	6	4	4	1	3	1	0
Total	205	145	71	110	48	28	15	15

Frogs

The ten frog species expected to occur in the project area consist mostly of burrowing species which rely on seasonal flooding for breeding, and these are considered to be resident. They disperse widely from wetlands outside the breeding season, with the Turtle Frog being entirely terrestrial. An additional three species (Motorbike Frog, Slender Tree-Frog and Squelching Froglet) are more closely associated with wetlands and are considered to be irregular visitors only. All ten frogs species have been recorded by BCE within about 15 km of the project area (20 km for the three wetland-dependent species), with the Moaning Frog, Banjo Frog, Humming Frog, Turtle Frog and Crawling Toadlet recorded in the adjacent Tronox lease area in 2007/2008 (Metcalf and Bamford 2008).

Of the ten frog species likely to occur in the project area, only two (the Turtle Frog and Crawling Toadlet) were recorded, with the Crawling Toadlet found breeding in near-roadside pools along Mt Adams Road in 2020 and the Turtle Frog detected on recording units. The Moaning Frog was found in the VRX lease immediately south of the project area in December 2021. No frog species likely to occur is of conservation significance and all are wide-spread in the northern sandplains.

With the exception of the artificial roadside hollow where Crawling Toadlets were breeding, it is unclear if any of the damplands within the project area ever contain sufficient water for frogs to breed in them regularly. Extensive areas of damplands occur outside the development area (to the north and south west) (Figure 10).

Reptiles

All of the 51 reptile species expected to occur in the project area would do so as residents, with the exception of the Long-necked Tortoise; this may be present in the nearby Arrowsmith River (c. 10km to the south) and individuals could be occasional visitors. Studies in the region by BCE have confirmed the presence of 39 reptile species, with 29 species recorded by Metcalf and Bamford (2008) across two surveys in the adjacent Tronox lease.

The current study recorded 17 species, 14 by trapping and three by searching/observations. Three of the 17 were not found in the nearby Tronox lease, while 13 found in the Tronox lease were not detected in the Beharra project area (Metcalf and Bamford 2008).

Detection of reptile species is subject to much variability. For example, the Tronox lease is closer to gravelly and other heavy soils of the low escarpment to the east, and several of the species not found at the Beharra site (such as the Leopard Ctenotus) are associated with such heavier soils. Likewise, the burrowing skink *Lerista planiventralis* was found only in the very sandy soils of the Beharra project area and not in the Tronox lease. The same suite of reptiles was trapped on the VRX lease (to the south rather than the east) as on the Beharra project area. The lack of gravelly soils, wetlands and limestone at the surface at the Beharra project area, as found further west, means that while 51 reptile species were returned from databases and are considered likely to be present, the reptile assemblage of the project area may be smaller than this.

The Lesueur Sandplains IBRA subregion and, more broadly, the mid-west coast of Western Australia is recognised for its high reptile richness and large numbers of species that are at their distributional limits (Maryan 2005). A feature of this assemblage is likely to be differences in assemblage

composition across short distances related to slight differences in soil and vegetation, and this may account for the difference between the Tronox and Beharra areas. Almost all species are widespread but a few have somewhat restricted distributions, including the gecko *Diplodactylus ornatus* that was found in the Beharra area. The only reptile of listed conservation significance, the Woma, was not recorded at the project area and may be locally extinct, as discussed below. Another reptile of conservation significance returned from databases, the Western Spiny-tailed Skink, is not considered to be present due to a lack of suitable habitat (large trees).

Birds

The bird assemblage of 116 native species has more species considered to be regular visitors (43) than considered to be residents (35), which reflects an important feature of the landscape with respect to birds. Many species are nectarivores so visit seasonally when food is available, while other species (i.e. inland birds) move towards the coast on a seasonal basis. Such visitations can be intermittent, so 22 species are considered to be irregular visitors. The remaining species are considered to be vagrants. In such a dynamic avian assemblage the number of species present at any one time can vary enormously. For example, in a 30-year study between Cataby and Badgingarra, the Black Honeyeater was absent most years, but approximately one year in ten it was among the most abundant of nectarivores (M. Bamford unpubl. data). Similarly, the White-fronted Honeyeater, Pied Honeyeater, Red-backed Kingfisher, Masked Woodswallow and Budgerigar have each been recorded on fewer than five occasions in the 30-year study north of Cataby; the White-fronted Honeyeater was present and quite abundant in the Beharra project area during the August 2020 site inspection, but was not present in December 2021. Other vagrant species were not present during the Beharra visits, as is typical for vagrant species.

Metcalf and Bamford (2008) recorded 70 species across two surveys in the Tronox lease just to the east of the Beharra project area, while in the two visits to the Beharra lease (August 2020 and December 2021), 44 species were recorded, including one species, the Painted Button-quail, recorded only on camera (Appendix 11).

The Beharra project area lacks the environmental variability of the Tronox lease. Despite this, eight species recorded at Beharra were not recorded in the Tronox area. Bird species listed as vagrants are generally species that occur more to the east, in wheatbelt woodlands, but may occasionally visit the woodlands and kwongan of the Geraldton sandplains. Waterbirds were returned from the databases and even observed not far from the project area, such as on Arrowsmith Lake about 10 m to the south-south-west, but they are excluded even though they may very occasionally fly over the area.

Three species are considered to be locally extinct (Western Ground Parrot, Bush Stone-curlew and Western Whipbird), although there are occasional unconfirmed reports that the parrot persists in the general region (further discussed below). A few species of conservation significance may be present, most notably Carnaby's Black-Cockatoo. It is possible that a sub-species of Red-tailed Black-Cockatoo, the Inland Red-tailed Black-Cockatoo (*Calyptorhynchus banksia escondidus*), may visit the project area occasionally. One specimen was seen along Brand Highway during the December 2021 survey. It must be stressed that this sub-species is not of conservation significance.

Mammals

The mammal assemblage is depauperate, with just 16 native species known generally from the area, of which 12 have been recorded in regional BCE surveys (eg Metcalf and Bamford 2008, Bamford and Chuk 2015-2017), and just four recorded in the project area. This included a feral Cat recorded on a camera (Appendix 11). A further 12 species are locally extinct due to predation by introduced predators, habitat destruction and changing fire regimes. Metcalf and Bamford (2008) recorded many more mammal species, including four bat species, all of which are common and widespread. Bats were not surveyed in the current study, with the project area lacking important features, such as large trees or caves, for roosting, and furthermore none of the expected species of conservation significance.

The Honey Possum was not detected in the Project area, but was recorded in the Tronox Project Area to the east (Metcalf and Bamford 2008), and in the VRX Project Area to the south (Bamford 2022). Sampling was more than adequate to detect the Honey Possum, so presumably it may be present in such low numbers as to be undetectable. It is naturally very variable in abundance and is also sensitive to too-frequent fires, with much of the Beharra project area burnt repeatedly since the early 1990s. The implications of this fire regime are discussed below (Section 3.3.2).

Four Dunnart species may occur in the project area (Appendix 7), two of which have moderately restricted distributions on the coastal sandplains:

- The White-tailed Dunnart has been recorded at the project area, as well as within the Tronox lease (Metcalf and Bamford 2008) and in the VRX lease (Bamford 2022). Its range extends along the west-coast from Kalbarri to Mooliabeenee (near Gingin).
- The 'Little Dunnart', although not recorded at the project area, was recorded nearby at the Tronox lease (Metcalf and Bamford 2008). The Little Dunnart is a currently unrecognised taxon, similar to the Little Long-tailed Dunnart (*Sminthopsis dolichura*), but with a shorter tail being same length as head and body rather than noticeably longer, known from the vicinity of the project area, north of Cataby, Mooliabeenee and just north of Muchea (M. Bamford unpubl. records). Specimens have been lodged with the WA Museum (1984 from Mooliabeenee and 2018 from near Cataby) and have been DNA tested. They are virtually identical to *S. dolichura* on DNA but morphologically distinct based on tail length, and the museum noted that DNA tests are not conclusive (K. Travouillon, pers. comm.). Apparently there are no immediate plans to review the taxonomy of *Sminthopsis* but BCE considers it important that the 'Little Dunnart' should be recognised as a distinct taxon even while undescribed.

Of the extant mammal assemblage, the Brush Wallaby is of conservation significance and is expected to be resident. Two other significant mammal (Rakali and Brushtail Possum) species are possibly present. These three significant mammals are discussed below.

Key features of the fauna assemblage expected in the project area are:

- **Uniqueness:** The assemblage is likely to be typical of the coastal belt of the Geraldton Sandplains bioregion, but this overall assemblage is unusual and has a limited distribution on the coastal sandplain from just north of Perth to around Dongara. There are also different assemblages within the bioregion because many species have distributions that either overlap

with only part of the bioregion or have distributions that are smaller than the bioregion. The representation of the assemblage is therefore likely to be patchy cross the landscape.

- **Completeness:** The assemblage of species from the project area is missing over a third of its original mammal species, and probably three bird and one reptile species. There is also extensive species decline due to agricultural clearing in the region.
- **Richness:** The assemblage is likely to vary annually and seasonally according to climatic conditions, but lies in a region of high biodiversity, particularly for reptiles.

3.2.2 *Vertebrate fauna of conservation significance*

Because of the high level of local extinction, particularly among mammals, the vertebrate assemblage of the project area includes only 16 vertebrate species of conservation significance, and two of these may also be locally extinct (Table 10 and Table 11). These species of conservation significance are also indicated in the complete species list (Appendix 7). Note that wholly marine species of conservation significance returned from databases, and particularly the Protected Matters Search Tool, are not considered here. They are included in Appendix 8.

A full explanation of the three levels of conservation significance used here is provided in Appendix 1 but, in summary, species classed as CS1 are those listed under legislation (EPBC Act and BC Act), while those classed as CS2 are listed as Priority by DBCA, but not listed under legislation. The CS3 class is more subjective, but includes locally significant species that have declined extensively in an area due to natural or human-induced impacts, and species that occur at the edge of their range. This makes their presence in the project area significant as populations on the edge of a species' range are often less abundant and more vulnerable to extinction than populations at the centre of the range (Curnutt *et al.* 1996). Species of conservation significance are discussed below. This discussion includes two species believed to be recently locally extinct, the Woma and the Western Ground Parrot.

Table 10. The number of conservation significant species in each vertebrate class that are expected to occur in the project area.

See Appendix 1 for full explanation of Conservation Significance (CS) levels: CS1 = listed under WA State and/or Commonwealth legislation; CS2 = listed as Priority by DBCA; CS3 = considered locally significant.

CLASS	CONSERVATION SIGNIFICANCE			
	CS1	CS2	CS3	Total
Frogs	0	0	0	0
Reptiles	0	2	1	3
Birds	5	0	5	10
Mammals	0	1	2	3
Total	5	3	8	16

Table 11. Conservation significant fauna species expected to occur within the project area.

Species are listed in taxonomic order.

CS1, CS2, CS3 = (summary) levels of conservation significance (see Appendix 1).

EPBC Act listings: E = Endangered, V = Vulnerable, M = Migratory (see Appendix 2).

WA Biodiversity Conservation Act 2016 listings: S1 to S7 = Schedules 1 to 7 (see Appendix 2).

DBCA Priority species: P1 to P4 = Priority 1 to 4 (see Appendix 2).

LS = considered by BCE to be of local significance (see Appendix 1).

SPECIES	COMMON NAME	CONSERVATION SIGNIFICANCE	EXPECTED OCCURRENCE
<i>Morelia spilota imbricata</i>	Carpet Python (southwest)	CS3 (LS)	Resident
<i>Aspidites ramsayi</i>	Woma	CS2 (P1)	Locally extinct?
<i>Neelaps calonotos</i>	Black-striped Snake	CS2 (P3)	Resident
<i>Leipoa ocellata</i>	Malleefowl	CS1 (V,S3)	Irregular visitor
<i>Apus pacificus</i>	Fork-tailed Swift	CS1 (M,S5)	Irregular visitor
<i>Falco peregrinus</i>	Peregrine Falcon	CS1 (S7)	Irregular visitor
<i>Calyptorhynchus latirostris</i>	Carnaby's Black-Cockatoo	CS1 (E,S2)	Regular migrant
<i>Pezoporos flaviventris</i>	Western Ground Parrot	CS1 (Cr. S1)	Locally Extinct?
<i>Merops ornatus</i>	Rainbow Bee-eater	CS3 (LS)	Regular migrant
<i>Calamanthus campestris</i>	Rufous Fieldwren	CS3 (LS)	Resident
<i>Calamanthus cautus</i>	Shy Heathwren	CS3 (LS)	Regular visitor
<i>Pomatostomus superciliosus</i>	White-browed Babbler	CS3 (LS)	Vagrant
<i>Oreica gutturalis</i>	Crested Bellbird	CS3 (LS)	Resident
<i>Trichosurus vulpecula</i>	Brush-tail Possum	CS3	Vagrant
<i>Notamacropus irma</i>	Brush Wallaby	CS2 (P4)	Resident
<i>Hydromys chrysogaster</i>	Rakali (water-rat)	CS2 (P4)	Vagrant

Species recorded in the Beharra project area indicated in bold.

3.2.2.1 Conservation Significance 1

Malleefowl

Conservation status:	Vulnerable; Schedule 3. Has declined in range due to habitat clearing and fragmentation, and probably impacts of feral predators.
Distribution and habitat:	Semi-arid woodlands and shrublands across southern Australia.
Ecology:	Occurs single or in pairs with an unusual breeding system based upon incubation of eggs in a mound. Terrestrial but can fly strongly, and feeds on a range of plant and animal materials.
Expected occurrence:	Irregular Visitor. Occasionally recorded in the general area and the WA Museum has reported breeding (mounds) in the general region, but details are not available. There is no indication that there is a resident, breeding population in the project area, with no evidence of the species found during the multiple visits to the project area or nearby despite the tracks and mounds being distinctive and conspicuous. The Beharra project area, and the nearby VRX Arrowsmith North project area to the south, were both subject to intensive searches for rare flora, with personnel at c. 20 m spacing across each area, and no mounds were encountered (botanists were familiar with mounds of the species). The project was also intensively searched for matters of heritage significance by traditional owners using human transects of similar spacing, no mounds or birds were found. Much of the vegetation may be too low as the Malleefowl usually occurs in woodlands and tall shrublands.

Fork-tailed Swift

Conservation status:	Migratory; Schedule 5. Considered to be significant because it is migratory and subject to international conservation agreements.
Distribution and habitat:	The swift is a largely aerial species of unpredictable occurrence in Western Australia. There are scattered records from the south coast, widespread in coastal and subcoastal areas between Augusta and Carnarvon, scattered along the coast from south-west Pilbara to the north and east Kimberley region. Sparsely scattered inland records, especially in the Wheatbelt, but more common in the north and north-west Gascoyne Region, north through much of the Pilbara Region, and the south and east Kimberley (Higgins 1999; DAWE 2020a). Aerial, usually flying from as low as one metre to in excess of 300 m above the ground.

Ecology:	A diurnal, aerial insectivore, this species often forages along the edge of low pressure systems in flocks of ten to 1000 birds (Higgins 1999; DAWE 2020a). Breeds in Siberia (April to July) and spends the non-breeding season (October to mid-April) in Australia. Being aerial, it is effectively independent of terrestrial ecosystems when in Australia.
Expected occurrence:	Irregular visitor. A flock of about 10 birds was observed high over Dongara on 7 th December 2021, during the field trip, and was possibly part of a much larger group of birds moving across the landscape. Flocks may pass over the project area briefly at intervals of a year or more.

Peregrine Falcon

Conservation status:	Schedule 7. Only listed under the BC Act.
Distribution and habitat:	More or less cosmopolitan including Australia (Menkhorst <i>et al.</i> 2017). This species occurs in a variety of environments but is usually reliant on cliff faces or tall trees for nesting (Debus 2019).
Ecology:	A highly adept aerial predator that predominantly forages on birds, although will also occasionally take invertebrates, fish, reptiles and mammals (Debus 2019). Mostly diurnal or crepuscular.
Expected occurrence:	Irregular visitor. The project area may be part of the foraging range of a pair. It is unlikely to breed in the project area due to the lack of suitable nesting sites such as cliff faces, large tree hollows and large nests of other birds, although there are large trees around the drainage systems to the east and south of the project area, and shallow rivers lined with tall trees in the broader region.

Western Ground Parrot

Conservation status:	Critically Endangered; Schedule 1. Of very high significance and has suffered a catastrophic decline in range and abundance with the only confirmed population numbering about 150 birds in the Cape Arid region east of Esperance. The decline in range is due to a combination of factors, but broad-scale fire (as opposed to patchy fires that provide a range of fire-age vegetation) and feral predators (possibly feral Cats in particular) are of key concern.
Distribution and habitat:	Formerly widespread in near-coastal shrublands of the south-west, including in the Kwongan Heaths north of Perth. Thus a species primarily of VSA 1.

Ecology:	A terrestrial and ground-nesting parrot that feeds on a range of plant materials; however can fly well. Calls before dawn and after sunset, and conspicuous activity correspondingly often crepuscular. Favours long-unburnt vegetation but will forage in recently-burnt areas.
Expected occurrence:	Possibly locally extinct with no recent confirmed records north of Perth. However, there are accounts of the Western Ground Parrot persisting in this region, including a fairly reliable sighting in 1992 of an adult male and an immature bird. The sighting was very close to the project area, less than 5 km to the south-east. In 2008 and 2012 targeted Ground Parrot surveys were undertaken in the areas surrounding the project area in the former Tronox leases to the east and Beekeepers NR to the west and south (Bamford 2008, Bamford 2012). The surveys involved several people listening for calls of the Parrot during the times before sunrise and after sunset, when the species is most vocal. In 2012, one and two note calls were heard from two individuals that were possibly from the Western Ground Parrot. However, given the full song was not heard, the species could not be confirmed. Whilst not confirmed, it is a possibility that the species does persist in the general area. The aural record was in close proximity to the project area -c 10km to the south-east. Both 1992 and 2012 records were in areas of Kwongan shrubland. ARUs set in October 2019 in the VRX project area did not detect the species. The six ARUs set in December 2021 across the Project area and VRX project areas (Figure 8) also did not detect the species. The project area and much of the surrounding landscape has been subject to multiple fires in recent years, so if the species was present in 1992 and 2012, it may now have disappeared.

Carnaby’s Black-Cockatoo

Conservation status:	Endangered; Schedule 2. Of significance because of population decline due largely to clearing of breeding habitat in the Wheatbelt and foraging habitat in the non-breeding range near the coast.
Distribution and habitat:	Endemic to the South-West, roughly south of a line Kalbarri to west of Esperance, but the range has contracted from the Wheatbelt in the last 50 years. Breeds in eucalypt woodlands but forages in eucalypt woodlands and proteaceous woodlands and heaths.
Ecology:	A granivore that also feeds on insect larvae, the species is migratory with inland breeding habitat (c. July to December) and more coastal non-breeding habitat, but movements are incomplete and some birds are beginning to breed in the former non-breeding range near the coast. The project area is in a region where the breeding and non-breeding ranges overlap. Often forms large flocks in the non-breeding season and roosts in traditional locations; usually locally large trees close to water. Proteaceous woodlands and heaths are important during the breeding and non-breeding seasons.

Expected occurrence: A regular visitor to the project area with records from the Project area in August 2020 (14 birds observed just south of Mt Adams Road and foraging signs abundant); also regularly recorded during other work in the broader region. The foraging signs were banksias (*B. attenuata* (seeds and beetle larvae in the infructescences), *B. hookeriana* (flowers) and *B. leptophylla* (flowers)) throughout. Not recorded during the December 2021 field studies but up to 80 at once seen along the Brand Highway to the west in the same period. The project area provides foraging habitat of proteaceous and myrtaceous shrubland primarily in VSA 1, however roosting and breeding habitat is not present due to the lack of suitable trees. There is nesting habitat approximately 10 km south of the project area in River Gums along the Arrowsmith River, and roosting locations are known to the north, west and south-west. This species is discussed in detail in Section 3.2.3.

3.2.2.2 Conservation Significance 2

Woma

Conservation status: Priority 1 (southern population). Cogger *et al.* (1993) classified the south-western population as Endangered, whilst Maryan (2005) suggested it may be critically endangered given the rarity of recent sightings. The southern population of the Woma has declined across much of its range, probably due to clearing and predation by feral predators (Maryan 2005). The northern population, found across much of the Great Sandy and Little Sandy Deserts, appears to be secure.

Distribution and habitat: Formerly found across the dry heathlands and woodlands of the South-West, from Shark Bay to the Great Victoria Desert, but now greatly reduced in this region. Usually associated with sandy soils.

Ecology: A terrestrial predator of small to medium-sized vertebrates in heathlands, woodlands and spinifex hummock grasslands on sand. Often nocturnal but occasionally encountered during daylight hours.

Expected occurrence: Probably locally extinct. It was not returned from databases for the region of the project area, but there are records from Kwongan Heath on sand at Badgingarra, Watheroo (1989) and Marchagee (1986; B. Maryan pers. comm.). It was almost certainly a former resident in the project area and while probably locally extinct, there is a slight chance it persists in the area. If present at very low densities, the species would be almost undetectable.

Black-striped Snake

Conservation status:	Priority 3. The Black-striped Snake has a naturally limited distribution and a large part of its range lies within areas affected by agricultural and/or urban development.
Distribution and habitat:	Confined to the coastal plain between Mandurah and Dongara; sandy soils of heaths and woodlands. Bush <i>et al.</i> (2007) suggest that the Dongara population is isolated as at the time there was only a single record from that area, but the Metcalf and Bamford (2008) record of the species from the Tronox Lease suggests it is more widespread in the north of its range. The possibility that the northern population is isolated is supported by the lack of records in the Eneabba area, where extensive fauna surveys have been undertaken. This is despite there being suitable environments between Cooljarloo ((about 120km south of Arrowsmith and where the species has been recorded by BCE) and the Dongara/Arrowsmith region. The Metcalf and Bamford (2008) specimen was found at (50J) 317862mE, 6749842mN in kwongan shrubland on sand like much of that in the current project area..
Ecology:	A fossorial species that probably feeds on small lizards. Often found by hand-searching through loose, sandy soil.
Expected occurrence:	Resident and presumably widespread in the project area in VSA 1.

Brush Wallaby

Conservation status:	Priority 4. The Brush Wallaby is widespread in the South-West but has declined due to habitat loss (clearing for agriculture and urban development) and may also be affected by Fox predation.
Distribution and habitat:	Endemic to the South-West more or less south of line from Geraldton to Esperance, although it has disappeared from much of the Wheatbelt due to clearing. Occurs in a wide range of vegetation types from Eucalypt Woodland to Banksia Woodland, Shrublands and Kwongan. The Brush Wallaby is encountered consistently in Kwongan Heath and low woodlands from Cataby to Dongara (M. Bamford pers. obs.). Metcalf and Bamford (2008) saw one animal in the Tronox Dongara Project at (50J) 322500mE, 6744600mN.
Ecology:	Based on detailed radio-tracking study in Banksia Woodland in Whiteman Park (Bamford and Bamford 1999): a largely solitary species that browses on shrubs and bushes; rarely on grass. Rarely drinks free-standing water and rarely ventures from dense vegetation. Individuals occupy home ranges of up to c. 10ha; larger in males than females and those of females overlap.
Expected occurrence:	Resident and presumably widespread in the project area; may favour taller vegetation on the margins of VSA2.

Rakali

Conservation status:	Priority 4. In the South-West the Rakali has declined due to wetland degradation (clearing and salination).
Distribution and habitat:	The Rakali is semi-aquatic and occurs in permanent and reliably seasonal waterways around Australia. In some areas it also occurs along marine coastlines. In the South-West it occurs along major rivers and in large wetland systems where the native riparian vegetation is more or less intact.
Ecology:	A semi-aquatic predator of freshwater crustaceans and other large aquatic invertebrates, fish, ducklings and probably young tortoises. It favours permanent water (lakes, streams and rivers) but will move into seasonal wetlands.
Expected occurrence:	Vagrant. The species may occur occasionally along the Arrowsmith River and other rivers in the region, so dispersing individuals may at times move through the project area.

3.2.2.3 Conservation Significance 3

South-West Carpet Python

Conservation status:	Previously considered Priority 4 but has since been delisted. The sub-species has declined due to land-clearing and predation by feral species. It is considered CS3 as these threatening processes remain, and where Fox control is implemented the pythons becomes noticeably more abundant (M. Bamford pers obs.)
Distribution and habitat:	Occurs across southern WA from near Shark Bay to the southern edge of the Nullarbor Plain; in a wide range of environments from forest to woodlands and coastal shrublands. It has also been recorded in shrubland in a rehabilitated sand-mine (M. Bamford pers obs.). It is often associated with areas with rocks or logs that provide shelter.
Ecology:	A usually nocturnal predator of vertebrates and in particular mammals.
Expected occurrence:	Resident. While a difficult species to detect, it is seen regularly in Woodlands and Kwongan between Cataby and Badgingarra (Brand Highway) and along Indian Ocean Drive north of Jurien (M. Bamford pers. obs.).

Rainbow Bee-eater

Conservation status:	This species was recently removed from the Migratory list of the EPBC Act and Schedule 5 of the WA BC Act. Despite this, it is a migrant in the South-West. Part of its conservation interest is related to its selection of breeding sites, as it is likely to breed along the edges of clearings and tracks, and thus may place itself at risk of mortality. It has been recorded regularly in the project area and nearby.
Distribution and habitat:	Occurs across mainland Australia and parts of Indonesia; a summer-breeding migrant in the south. In the South-West it arrives in October and departs in January/February. Favours fairly open vegetation types including parkland clearing and constructs nesting burrows in sandy to sandy-loam soils, often in the open.
Ecology:	An aerial insectivore that forages by 'sallying' from a perch. Eats a wide range of insects and not just bees. Often seen in loose flocks on migration and may breed in loose colonies or singly. Tends to be faithful to breeding sites but will also move if a site gets too overgrown or is destroyed. Will also colonise new areas and has been known to nest in piles of earth on construction sites.
Expected occurrence:	Regular visitor. Can be expected to arrive in October and depart in February. Will breed where there are areas of suitable sparse vegetation on sand. The species may be particularly abundant during migration periods as birds pass through.

Rufous Fieldwren, Shy Heathwren, White-browed Babbler and Crested Bellbird

Conservation status:	These species were formerly listed as Priority 4 (thus CS2) due to massive declines as a result of habitat loss across the Wheatbelt. Considered of local conservation significance as these declines have happened and are probably ongoing in some cases as remnant vegetation degrades, and the project area is on the edge of the Wheatbelt.
Distribution and habitat:	These four species occur broadly across southern Australia and in the South-West are found in semi-arid heaths and woodlands, hence their susceptibility to clearing in the Wheatbelt. The Rufous Fieldwren occurs in very low heath (VSA 1) and will also move into areas following fire and during minesite rehabilitation, moving out as the vegetation gets dense and tall (M. Bamford pers obs.). The Shy Heathwren favours denser, taller vegetation, often in thickets, such as VSA 2. The White-browed Babbler usually occurs in tall and moderately open shrubland with scattered thickets. The Crested Bellbird is the most Catholic in environmental preference, occurring in low heaths and Kwongan to open tall shrublands and scattered trees over spinifex.

Ecology: Insectivores that forage over the ground and low vegetation; the babbler will also search under loose bark. Mostly sedentary but will move if the environment changes, such as the Fieldwren moving as vegetation structure alters with time since fire or rehabilitation.

Expected occurrence: The Rufous Fieldwren and Crested Bellbird are expected as residents and both have been recorded in the project area and nearby. The Shy Heathwren was observed about 5 km to the south in September 2019 (Bamford *et al.* 2022) and was in a dense thicket around a damland. Such vegetation is limited in distribution in the Project area and therefore the species is expected as a regular visitor rather than a resident. The Babbler is expected only as a Vagrant visitor as it is readily detected so would have been recorded if present. Most of the vegetation may be too low and dense for it. However, with records from databases, there would appear to be resident birds nearby.

Brushtail Possum

Conservation status: Although widespread in the South-West, the Brushtail Possum has disappeared from parts of its range due to habitat loss and feral predators. It would formerly have occurred in the project area and, while it may be locally extinct, it may persist in areas of large trees around the drainage system that lie to the east, west and south. Scats that might have been of this species were found in this area of large trees in November 2018, but identity was uncertain. Relictual populations are known from locations such as Dandaragan and Goomalling, and such populations are of local significance.

Distribution and habitat: Patchily distributed (formerly widespread) across the South-West. Usually in woodland and forest with large trees.

Ecology: An arboreal omnivore, nocturnal and shelters in tree hollows during the day.

Expected occurrence: Vagrant or may be locally extinct, but the species does persist in some areas of the South-West despite extensive clearing. While much of the project area is probably not suitable for resident animals due to the general absence of large trees, individuals may disperse through. Scats possibly of this species were found by BCE personnel in November 2018, amongst large trees c. 10km east of the project area.

3.2.3 Black-cockatoo habitat analysis

Carnaby's Black-Cockatoo is a species of high conservation significance that was recorded during the August 2020 site inspection (foraging signs present and several small flocks of birds seen; Appendix 9), and a flock was seen nearby (along Brand Highway to west) in December 2021. It is therefore of particular importance to understand how the species uses the landscape. This is examined with respect to breeding, foraging and roosting habitat below. The area is important for foraging by non-breeding birds and there are several major roosts in the region as discussed below.

3.2.3.1 Breeding tree assessment

The project area supports no large trees so provides no breeding habitat. However, there may be large trees that could support breeding in the general area, with scattered large trees along the Arrowsmith River to the south and Irwin River to the north, and large trees around seasonal wetlands to the east. Some of these trees are within c. 10 km of the project area. Saunders and Dawson (2017) found that adults foraged on average 1.4 km from their nests at Coomallo Creek (range 0 to 7.1 km), while Saunders (1980) found adults foraged on average 2.5 km from their nests (range 0.6 to 12 km) where the foraging habitat was more fragmented. While such distances suggest foraging in the project area would mainly involve non-breeding birds, on 20th August 2020 a group of eight birds feeding on flowers of *B. hookeriana* included only one male. There were two pairs nearby. As August is within the breeding season, this imbalance suggests that other males may have been on nests; if so, these nests would probably have been in locations such as along the Arrowsmith River, about 10 km to the south. Early in the breeding season, females incubate at night and males incubate during the day.

3.2.3.2 Foraging habitat assessment

As outlined in Section 3.1, there are two VSAs in the project area. VSA 1 is Kwongan Heath (covering most of the project area), while VSA 2 is Dampland Thickets. These two broad units are assigned foraging values for Carnaby's Black-Cockatoo value based upon vegetation characteristics, context and species density as described in Appendix 6. The foraging values are summarised in Table 12. VSA 1 (Kwongan Heath) receives a vegetation characteristics score of 4 (out of 6), while VSA 2 (Dampland Thickets) receive a characteristics score of 2. This is based largely on the density of banksias. Kwongan receive a context score of 1 (out of 3) as the project area does not have breeding very close by but there is extensive clearing nearby, and a species density score of 1 (out of 1). Dampland Thicket receives a context score of only 1 to adjust for the variability in banksia density across this vegetation type. It also receives a species density score of 1. Birds were observed in the Kwongan Heath during the site inspection, and there was abundant foraging evidence in the Kwongan Heath and some in the Dampland Thickets. This gives Kwongan Heath a total score of 6 (out of 10) and Dampland Thickets a total score of 4. These scores are considered low-moderate (4) and moderate-high (6) foraging values.

3.2.3.3 Roosting habitat assessment

There is no roosting habitat within the project area, as Carnaby's Black-Cockatoo usually roost in the tallest trees in a region and there are no tall trees within the project area; but there are tall trees within about 10 km. Three roosts have been found in the region by BCE: one along the Arrowsmith River at 317663mE 6723633mS, where 300+ birds were seen on 15th June 2016 (Bamford and Chuk 2017), one in large trees around a wetland near the north-eastern boundary of Yandanogo Nature Reserve at 316325mE 6752399mS, where 500+ birds were seen in April 2015 (M. Bamford pers. obs.), and one just east of the Brand Highway in tall trees around a wetland at as: 310350mE, 6735200mN,

where about 80 birds were roosting on 6th December 2021. In addition to these roosts, several have been identified in the region as part of the Great Cocky Count. All known roosts are mapped on Figure 11 and three are within about 12 km of the project area. There are also more distant (>30 km) roost sites identified as part of the Great Cocky Count, and there are likely to be roosts that have not been recorded.

Table 12. Foraging value of broad vegetation types for Carnaby's Black-Cockatoo in the project area.

Vegetation description	Vegetation characteristics (6)	Context (3)	Species Density (1)	Total (10)
VSA 1; Kwongan Heath and similar	4	1	1	6 (moderate to high)
VSA 2; Dampland Thickets	2	1	1	4 (low to moderate)

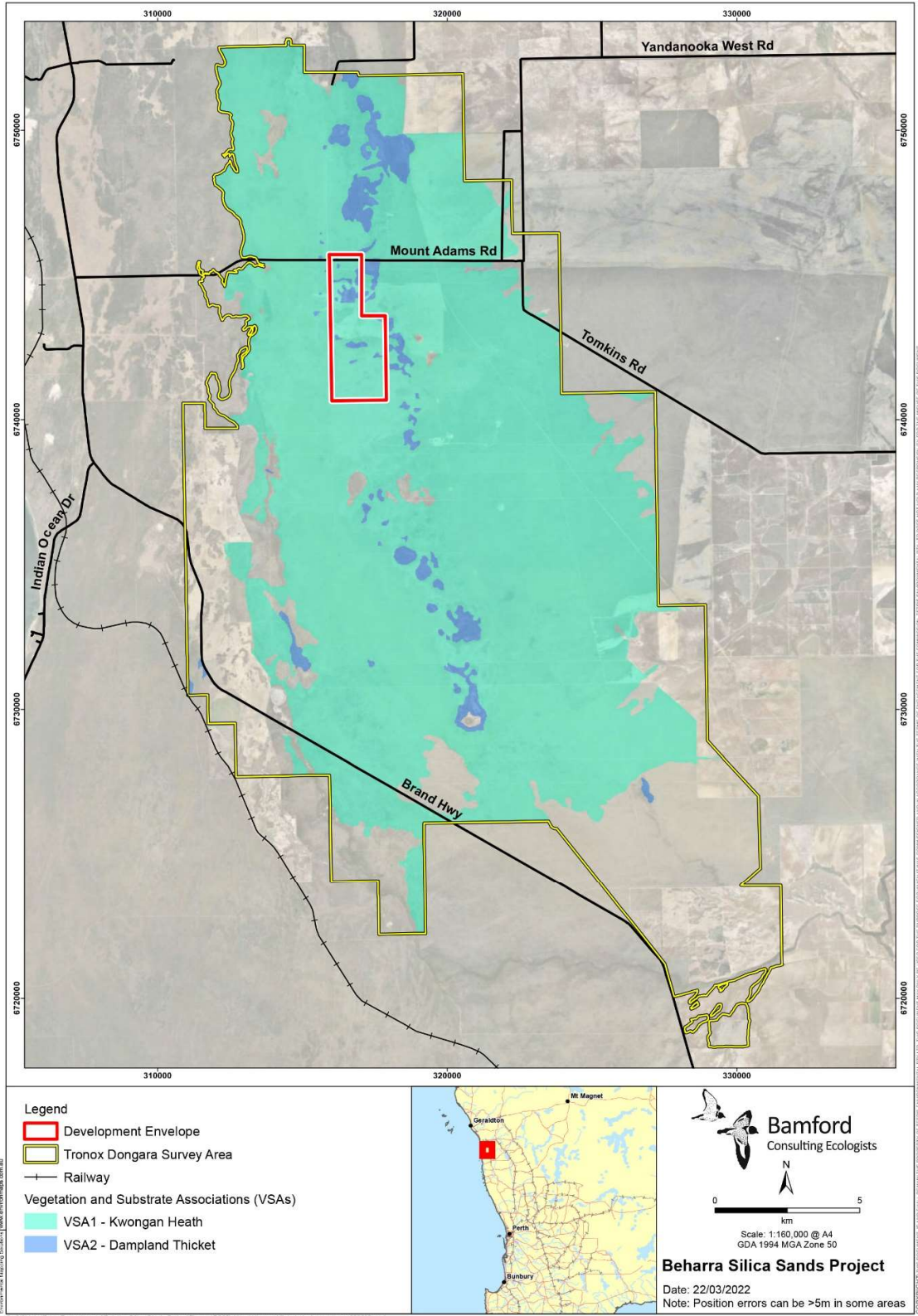


Figure 10. Vegetation and Substrate Associations (VSAs) of the Project area and Tronox Dongara Study Area (after Woodman 2011).

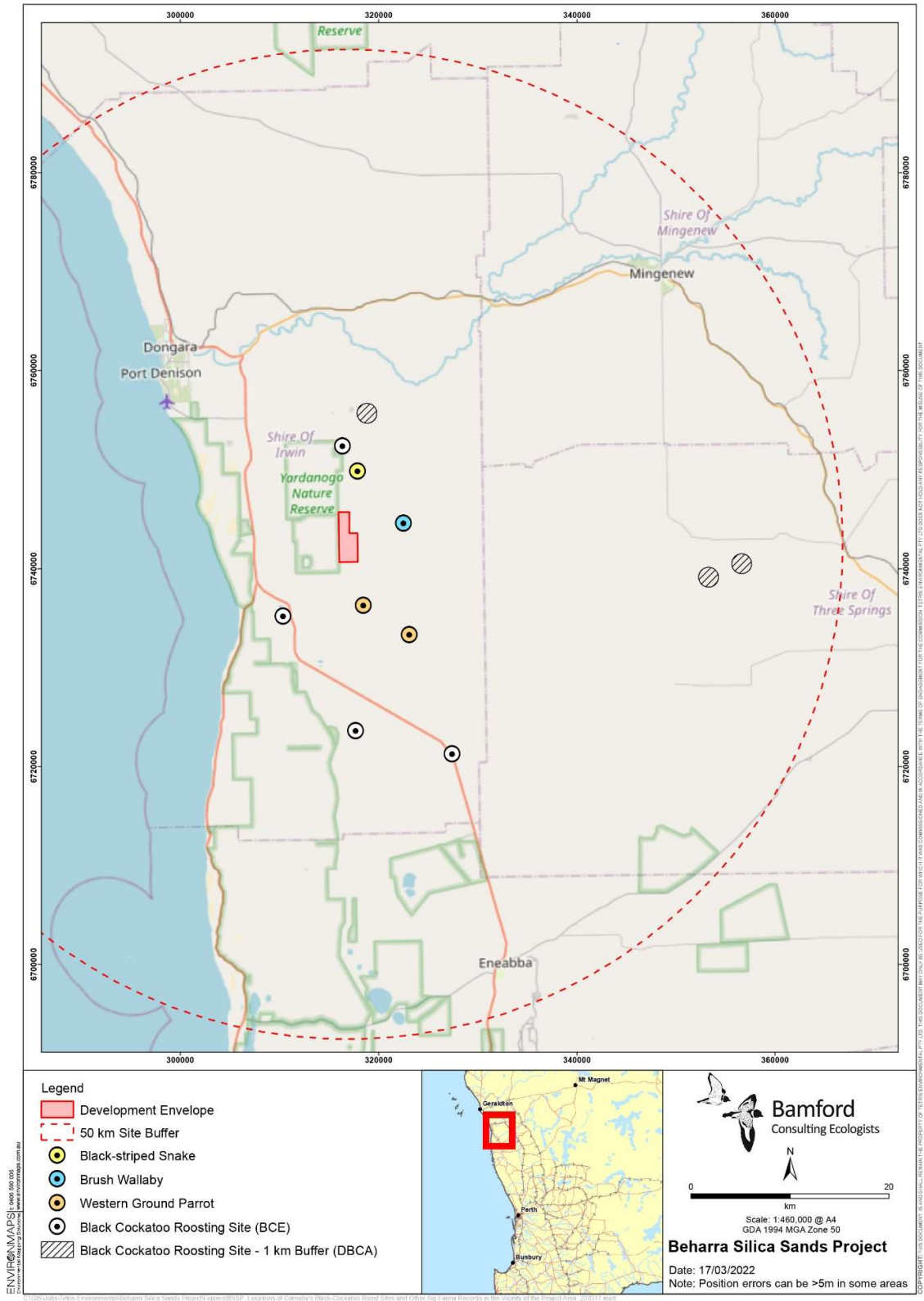


Figure 11. Locations of Carnaby’s Black-Cockatoo roost sites and of other significant fauna records in the vicinity of the project area.

3.2.4 Invertebrates of Conservation Significance

Investigations into the invertebrate assemblage, and particularly species of conservation significance (listed under legislation, priority or thought to be Short Range Endemics SREs), was carried out by Bennelongia (2022). Opportunistic investigations carried out in December 2021 by BCE resulted in the collection of four trapdoor spiders. These were identified by Bennelongia (on behalf of BCE 2021) as three male *Kwonkan* sp., and a female Anamidae could not be identified to species but possibly also a *Kwonkan*. It could not be confirmed if these were SREs or not, but no significant *Kwonkan* sp. is listed for the region.

Despite more or less continuous scanning of flowering shrubs between checking pitfall traps, no native bees of the genus *Hylaeus* were observed. The intention of watching for these bees was to check for the presence of the Woollybush Bee *Hylaeus globuliferus* (Priority 3). It cannot be concluded to be absent, but the nearest record in DBCA and WA Museum databases is from 30 km south-south-east of the project area.

3.3 Patterns of biodiversity

3.3.1 Overview

Investigating patterns of biodiversity can be complex and are often beyond the scope even of comprehensive field investigations, but it is possible to draw some general conclusions based upon the different landscapes in the project area, the previous studies that have taken place in the vicinity and the field investigations conducted in 2021.

All the vertebrate species recorded by trapping and censusing were expected to be present based upon past records and interpretation of the environment, and the majority had previously been recorded by Metcalf and Bamford (2008) in the Tronox Dongara project area immediately to the east, and in the VRX Arrowsmith area to the south (in 2021). Just three reptile and 13 bird species recorded during in the Project area had not been detected by Metcalf and Bamford (2008), with all these identified as likely to be present in both studies. The sampling therefore contributed little to an understanding of the assemblage composition (ie the species that make up the assemblage), but results are examined below to determine if they contribute to an understanding of assemblage organisation (such as variation in abundance and local distribution of species). For example, there are slight differences in vegetation and soils across the landscape, with VSA 1 (Kwongan Heath) on high ground, and with small, low-lying and seasonally damp areas with taller thicket vegetation being distinctive of VSA 2(Dampland Thickets). Fire history also varies greatly across the landscape, with some of the sampling sites in recently burnt areas but others in relatively long-unburnt areas (see Table 7; Figure 9). In addition to comparing the sampling results with these variables, the opportunity exists to compare results between the 2021 and the 2008 surveys as these used substantially similar techniques.

The four sampling transects are described in Table 7 with locations illustrated on Figure 8. Layouts were similar except Transects B01 and B02 had half the number of sampling locations and therefore half the effort and half the area sampled of Transects B03 and B04. Transects B01 and B03 both passed through dampland vegetation (VSA 2), but the majority of traps on these transects, and all the traps on Transects B02 and B04, were in Kwongan (VSA 1). Transect B01 was most recently burnt (c. 8

months previously), B02 was burnt about two years previously, Transect B03 was burnt four years previously except for the around for the last few pitfalls where fire had passed through two years previously, and Transect B04 had been last burnt 10 years previously. The transects thus provided a chrono-sequence with respect to time since fire. The transects have also varied in fire history (Table 7). Transect B04 has experienced only two fires in the last 30 years, whereas the other transects have experienced three or four fires over the same period.

3.3.2 Pitfall and funnel trapping

The pitfall and funnel sampling recorded 13 reptile, three mammal and one bird species, with a total of 342 captures (16 in funnels) (Table 13). The number of species recorded was similar irrespective of effort and time since fire, but the number of captures varied greatly. Transect B01 (the most recently burnt) had the lowest number of captures, but if adjusted for effort its capture rate was only slightly lower than that of Transect B04, the longest unburnt. In comparison, Transect B02, burnt only two years previously, had the highest capture rate of all transects and for almost all species. A few species had particularly notable patterns:

- *Ctenophorus adalaidensis*. Caught infrequently on Transect B01 but at similar and high levels of abundance on remaining transects. Suppressed shortly after fire but not subsequently?
- *Ctenophorus maculatus*. Caught infrequently on Transects B01 and B04, but at similar and high rates on Transects B02 and B03. Most abundant in areas of intermediate fire age? Effect of VSA 2 uncertain.
- *Lucasium alboguttatum*. Abundant only on Transect B02 (two years after fire).
- *Mus musculus*. Data suggest more abundant shortly after fire.
- *Pseudomys albocinereus*. Abundant only on Transect B02 (two years after fire).

While based upon a single sampling session, these results indicate a high degree of variability in the assemblage of small, terrestrial vertebrates with respect to recent fire history. Transect B02 has experienced multiple fires and a recent fire, but was rich in species and numbers, while Transect B04, with the lowest fire frequency and the longest period since fire, had only 40% of the capture rate of Transect B02, and only a slightly higher capture rate than the recently-burnt Transect B01. Interestingly, the Honey Possum was not recorded on any of the transects and is known to recover poorly after fire (Wooller and Wooller undated).

Distribution along transects was not uniform and gives a better understanding of the differences in numbers of captures between transects (Figure 12). The pattern of distribution is not easy to explain, particularly in Transect B04 where the vegetation and soils were very uniform but captures were not. However, on Transect B03 captures were clearly clumped in two areas, both on the interface between VSA 1 and VSA 2. The high numbers of captures were reflected by high numbers of species (Figure 13). This observation is complicated by fire age, as the western end of Transect B03 was on the edge of an area burnt in 2005 and burnt in 2012 an area burnt in 2017.

The sampling in the Project area (December 2021) took place in the same general landscapes of Kwongan on sand as the sampling in the Tronox Dongara project area immediately to the east in 2007. Total numbers of captures in December 2021 and November 2007 are compared in

Table 14. Even without adjusting for differences in sampling effort, it is clear that much larger numbers of two dragon lizards, *Ctenophorus maculatus* and *Ctenophorus adelaidensis* were caught at Beharra than at Tronox, resulting in much larger numbers of captures overall at Beharra. The skinks *Ctenotus fallens* and *Lerista christinae*, and the dragon *Pogona minor*, were caught more often at Tronox. There were slightly more species at Tronox, but this may have been due to the additional sampling effort and/or the greater number of sampling locations (90 compared with 60). The high numbers of the two dragons in particular are probably related to recent fire history in the Beharra project area. Also linked to fire, Davis and Doherty (2015) found that *C. fallens* was adversely affected by fire, and that frequent, extensive fires 'simplified' the reptile assemblage. This may be what is happening in the Project area with a very strong bias towards a few species.

Table 13. Numbers of captures of each species along each transect. Pitfall and funnel trap captures pooled.

Capture rates in Transects B03 and B04 are standardised to the rate per 50 trapnights for comparative purposes.

Species	Transect B01	Transect B02	Transect B03		Transect B04	
			Pitfall trap-nights	Funnel trap-nights	Pitfall trap-nights	Funnel trap-nights
	50	50	100	50	100	50
<i>Cryptoblepharus buchananii</i>	1	0	0		1	0.5
<i>Ctenophorus adelaidensis</i>	6	21	35	17.5	32	16
<i>Ctenophorus maculatus</i>	7	36	63	31.5	12	6
<i>Ctenotus fallens</i>	1	3	8	4	5	2.5
<i>Delma grayii</i>	0	1	3	1.5	0	0
<i>Diplodactylus ornatus</i>	0	0	1	0.5	0	0
<i>Lerista elegans</i>	0	0	1	0.5	0	0
<i>Lerista planiventralis</i>	1	2	1	0.5	2	1
<i>Lerista praepedita</i>	0	0	0	0	2	1
Little Button-quail	1	1	0	0	0	0
<i>Lucasium alboguttatum</i>	2	10	4	2	3	1.5
<i>Morethia lineocellata</i>	0	0	0	0	1	0.5
<i>Mus musculus</i>	7	5	7	3.5	5	2.5
<i>Pogona minor</i>	2	1	4	2	0	0
<i>Pseudomys albocinereus</i>	0	11	3	1.5	5	2.5
<i>Sminthopsis granulipes</i>	0	1	0	0	0	0
<i>Strophurus spinigerus</i>	4	2	2	1	6	3
TOTAL CAPTURES	32	94	132	66	74	37
N species	10	12	12	12	11	11

Table 14. Comparison of numbers of captures in the Project area (December 2021) and the adjacent Tronox Dongara project area (November 2007).

Sampling effort varied: Beharra Project: 300 pitfall nights and 75 funnel-nights. Tronox: 450 pitfall nights and 225 funnel nights.

Species	Beharra 2021	Tronox 2007
<i>Heleioprus eyrei</i>	-	3
<i>Limnodynastes dorsalis</i>	-	3
<i>Cryptoblepharus buchananii</i>	2	2
<i>Ctenophorus adalaidensis</i>	94	17
<i>Ctenophorus maculatus</i>	118	10
<i>Ctenopus fallens</i>	17	70
<i>Ctenopus pantherinus</i>	-	3
<i>Ctenopus impar</i>	-	1
<i>Cyclodomorphus celatus</i>	-	1
<i>Delma grayii</i>	4	-
<i>Diplodactylus ornatus</i>	1	-
<i>Gehyra variagata</i>	-	2
<i>Lerista christinae</i>	-	10
<i>Lerista elegans</i>	1	7
<i>Lerista planiventralis</i>	6	-
<i>Lerista praepedita</i>	2	-
<i>Lucasium alboguttatum</i>	19	-
<i>Menetia greyii</i>	-	1
<i>Morethia lineoocellata</i>	1	-
<i>Mus musculus</i>	24	1
<i>Neelaps calonotos</i>	-	1
<i>Pogona minor</i>	7	29
<i>Strophurus spinigerus</i>	24	13
<i>Pseudomys albocinereus</i>	19	6
<i>Sminthopsis dolichura</i>	-	4
<i>Sminthopsis granulipes</i>	1	6
Little Button-quail	2	-
<i>Tarsipes rostratus</i>	-	1
TOTAL CAPTURES	342	191
N species	17	21

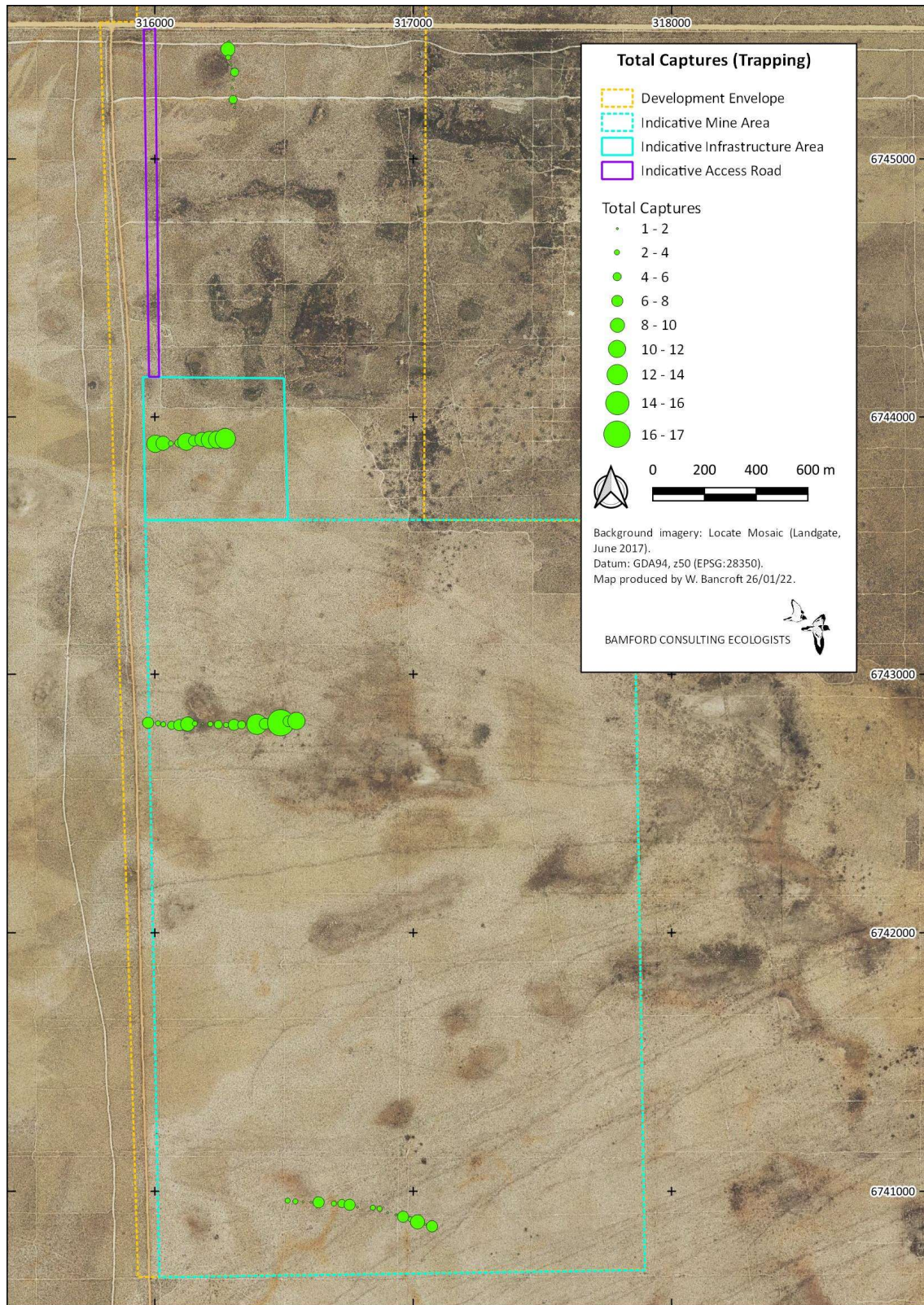


Figure 12. Distribution of numbers of captures per sampling location on the four transects in the Project area, Dec. 2021. Transects numbered B01 to B04 from the north.

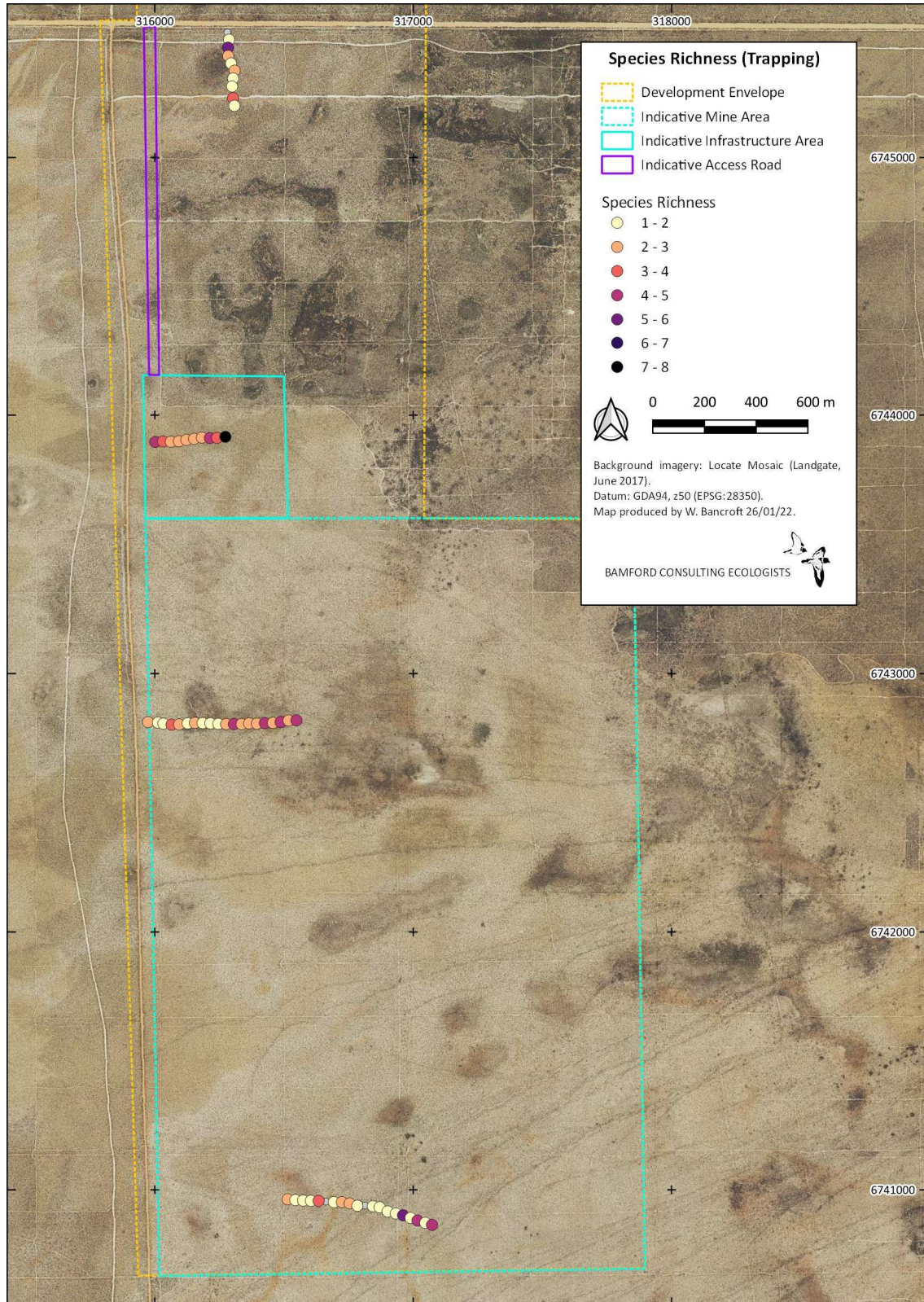


Figure 13. Distribution of numbers of species trapped sampling location on the four transects in the Project area, Dec 2021. Transects numbered B01 to B04 from the north.

3.3.3 Bird Censusing

The bird censusing along the transects recorded 21 bird species, far fewer than the 34 bird species recorded overall (Table 15). The number of species and of records was highest along Transect B01 and B03, both associated with a mixture of VSA 1 and VSA 2, and were particularly low in Transect B04 which was in very uniform and long-unburnt Kwongan (VSA 1). The high numbers of records was due to aggregations of birds at just a few locations (Figure 14). Along Transect B01, this was on high and burnt ground which appeared to be attracting species such as the Black-faced Woodswallow, Pied Honeyeater, Tree Martin and White-winged Triller. Along Transect B03, birds were aggregated in a transitional area between VSA 1 and VSA 2, with some species attracted to dense thickets (three fairy-wren species), but others to a group of tall banksias (Brown Honeyeater). The distribution of species reflected the distribution of abundance (Figure 15). Birds appeared to be responding to local structural and floristic features of the landscape, and it is probably pertinent that structurally rich areas, such as where the two VSAs are adjacent, are often high in numbers and rich in species.

Table 15. Numbers of records of each bird species along each transect.

Species	Transect B01	Transect B02	Transect B03	Transect B04
N census events	50	50	100	100
Australian Pipit	2	0	0	0
Black-faced Woodswallow	3	0	0	1
Blue-breasted Fairy-wren	0	0	8	0
Brown Honeyeater	1	0	10	1
Crimson Chat	1	0	0	0
Hooded Robin	2	0	0	0
Horsfield's Bronze-Cuckoo	0	0	2	0
Little Button-quail	0	1	0	5
Nankeen Kestrel	0	1	1	0
Pied Honeyeater	2	0	0	0
Purple-backed Fairy-wren	0	0	18	0
Rufous Fieldwren	0	1	0	0
Rufous Songlark	1	0	0	0
Silvereye	0	0	8	0
Singing Honeyeater	2	3	1	0
Splendid Fairy-wren	2	0	3	0
Tawny-crowned Honeyeater	4	3	3	14
Tree Martin	3	0	0	0
White-browed Scrubwren	0	0	4	0
White-winged Fairy-wren	0	2	1	0
White-winged Triller	10	3	0	0
N records	33	14	59	21
N species	12	7	11	4

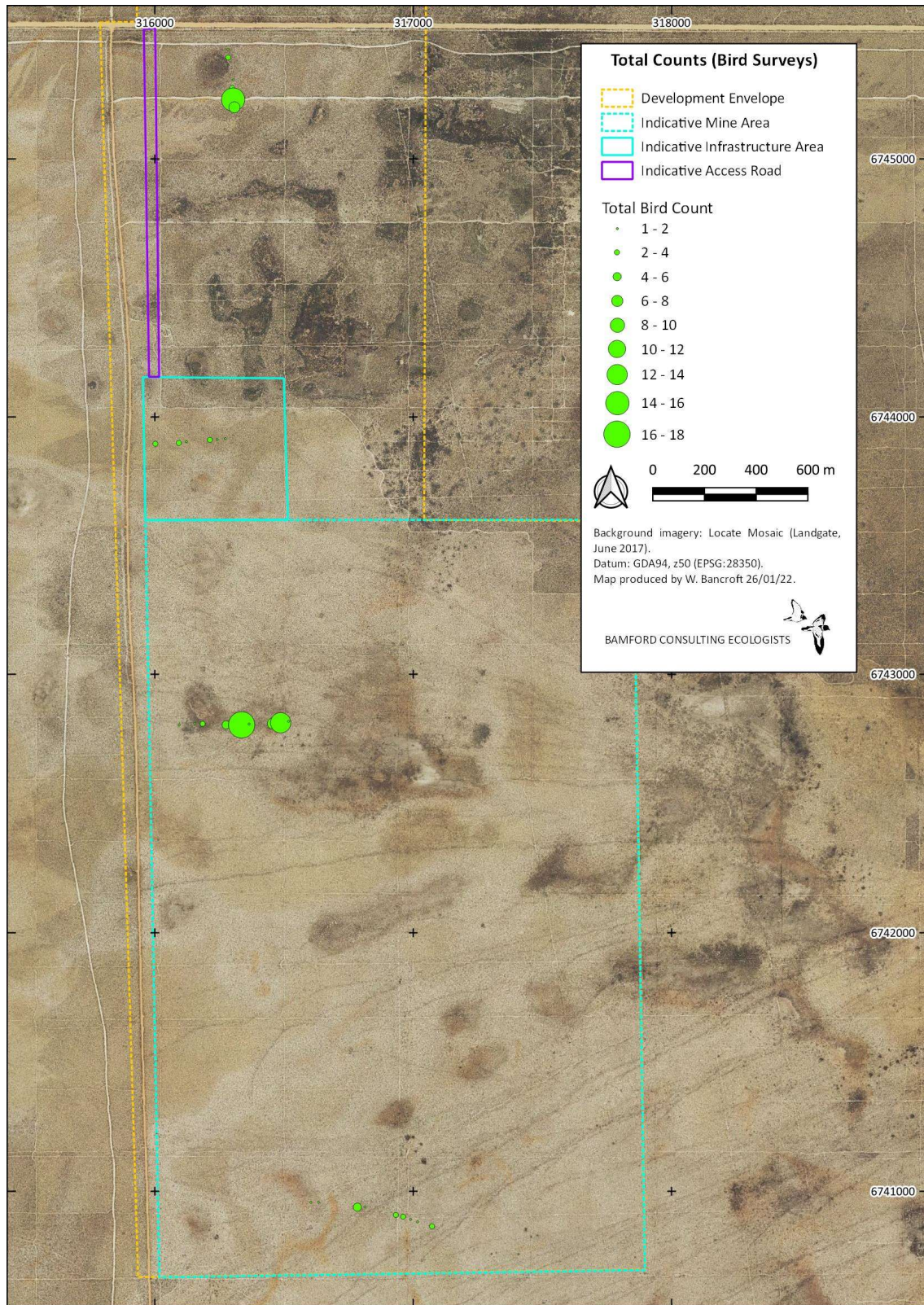


Figure 14. Distribution of bird records at sampling location on the four transects in the Project area, December 2021. Transects are numbered B01 to B04 from the north.

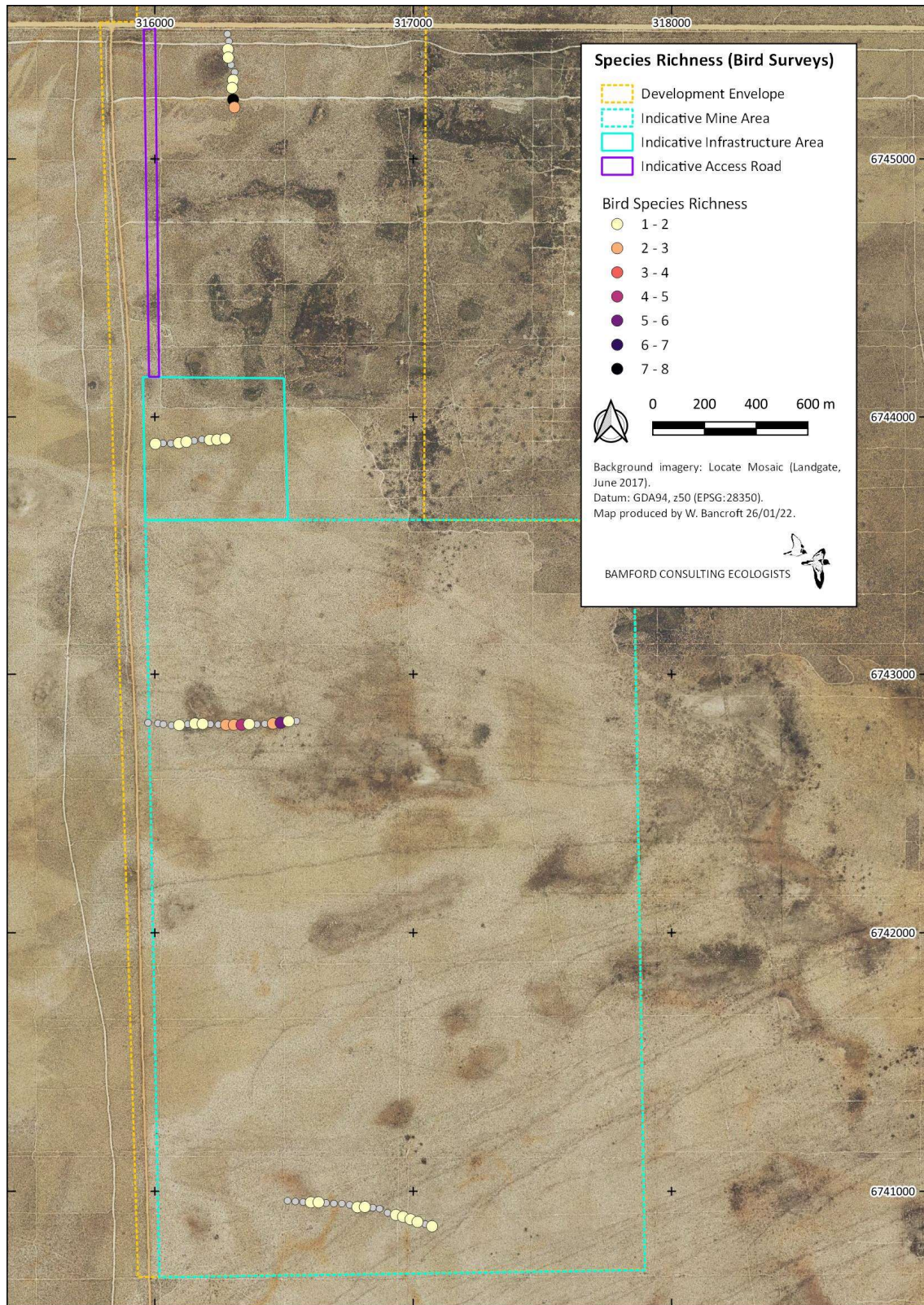


Figure 15. Distribution of numbers of bird species at census points on the four transects in the Project area, December 2021. Transects are numbers B01 to B04 from the north.

3.4 Ecological processes

The nature of the landscape and the fauna assemblage indicate some of the ecological processes that may be important for ecosystem function (see Appendix 1 for descriptions and other ecological processes). These include the aspects discussed below.

Local hydrology. Alterations to local hydrology may affect vegetation condition and therefore fauna habitat. It is notable that VSA 2 (Dampland Thickets) and its ecotone with VSA 1 (Kwongan Heath) was associated with high numbers of records of both birds and reptiles.

Fire. Native vegetation throughout the project area is subject to fire and while appropriate fire regimes can benefit biodiversity, inappropriate regimes can lead to a loss of biodiversity. There is some evidence that the reptile (and possibly small mammal) assemblage has been altered by frequent fires, and the probably local extinction of the Western Ground Parrot is likely to be a result of infrequent but extensive fires that have destroyed a former mosaic of fire ages.

Feral species and interactions with over-abundant native species. Feral species occur throughout Western Australia and are a major component of the current mammal fauna of the project area. They have contributed to local extinction and may be affecting populations of extant species. Feral species are known to use cleared lines through native vegetation to access such areas (Bamford and Chuk 2017).

Connectivity and landscape permeability. The project area lies in a region with extensive clearing for agriculture but lies within a large patch of undisturbed native vegetation and is adjacent to a large reserve (Yardanogo Nature Reserve). Of itself, the project area therefore does not have a major connectivity function.

4 Summary of fauna values

The desktop study identified 205 vertebrate fauna species as potentially occurring in the project area currently: 10 frogs, 51 reptiles, 119 birds and 25 mammals. An additional 16 species (1 reptile, 3 birds and 12 mammals) are considered locally extinct.

VSAs. Vegetation and soils can be broadly grouped into two VSA types: Kwongan Heath on sand high in the landscape (VSA 1) and Dampland Thickets on heavier and seasonally damp soil low in the landscape (VSA 2).

Fauna assemblage. Fairly complete except for medium-sized and small mammals which have been lost as is common throughout the region. A rich and distinctive assemblage that has a limited distribution in the north of the Geraldton Sandplain bioregion. Well-represented in the immediate region but depauperate to the north, east and to some extent west due to clearing for agriculture.

Species of conservation significance. The 16 vertebrate species of conservation significance includes only six species that are expected to be resident or regular migrants/visitors to the site: Carpet Python (southwest), Black-striped Snake, Peregrine Falcon, Carnaby's Black-Cockatoo, Little Dunnart and Brush Wallaby. Of these, only the Falcon and the Black-Cockatoo are listed under legislation, and the Falcon is expected only as a visitor with the project area likely to be part of the home range of a pair that breeds nearby. Carnaby's Black-Cockatoo is notable as it is likely to be seasonally abundant in the area, there is extensive foraging habitat and there are two confirmed roosts within 10 km of the project area. There is no suitable breeding habitat either within the project area or nearby, but observations made in August 2020 suggest that breeding birds may occasionally visit the area to forage. There is a slight possibility of the Western Ground Parrot and Woma persisting in the area. If present, a population of the Western Ground Parrot would be very important. However, targeted surveys have been undertaken in the Tronox leases just to the west of the project area, and aural surveys were undertaken in the current study, and these did not confirm the presence of the species.

Patterns of biodiversity.

Sampling indicates that VSA 2 (Dampland Thickets) and the transition between this and VSA 1 (Kwongan Heath) may be locally high in species richness and abundance. The kwongan represents more important foraging habitat for Carnaby's Black-Cockatoo than the thickets.

Key ecological processes.

The main ecological processes which may be influencing the fauna assemblage are local hydrology, fire and feral species.

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6 Appendices

Appendix 1. Explanation of fauna values.

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

Assemblage characteristics

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

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

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

Vegetation/Substrate Associations (VSAs)

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

Because VSAs provide the habitat for fauna, they are important in determining assemblage characteristics. For the purposes of impact assessment, VSAs can also provide a surrogate for detailed information on the fauna assemblage. For example, rare, relict or restricted VSAs should automatically be considered a significant fauna value. Impacts may be significant if the VSA is rare, a large proportion of the VSA is affected and/or the VSA supports significant fauna. The disturbance of even small

amounts of habitat in a localised area can have significant impacts to fauna if rare or unusual habitats are disturbed.

Patterns of biodiversity across the landscape

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

Species of conservation significance

Species of conservation significance are of special importance in impact assessment. The conservation status of fauna species in Australia is assessed under Commonwealth and State Acts such as the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) and the *Western Australian Biodiversity Conservation Act 2016* (BC Act). In addition, the Western Australian Department of Biodiversity, Conservation and Attractions (DBCA) recognises priority levels, while local populations of some species may be significant even if the species as a whole has no formal recognition. Therefore, two broad levels of conservation significance can be recognised and are used for the purposes of this report, and are outlined below. A full description of the conservation significance categories, schedules and priority levels mentioned below is provided in Appendix 2.

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

Species listed under the EPBC Act are assigned to categories recommended by the International Union for the Conservation of Nature and Natural Resources (IUCN), or are listed as migratory. Migratory species are recognised under international treaties such as the China Australia Migratory Bird Agreement (CAMBA), the Japan Australia Migratory Bird Agreement (JAMBA), the Republic of South Korea Australia Migratory Bird Agreement (ROKAMBA), and/or the Convention on the Conservation of Migratory Species of Wild Animals (CMS; also referred to as the Bonn Convention). The BC Act uses a series of Schedules to classify status, but also recognizes the IUCN categories and ranks species within the Schedules using the categories of IUCN (2012).

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

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

Invertebrates

Invertebrate species considered to be short range endemics (SREs) have no legislative or published recognition and their significance is based on interpretation of distribution information. Harvey (2002) notes that the majority of species that have been classified as short-range endemics have common life history characteristics such as poor powers of dispersal or confinement to discontinuous habitats. Several groups, therefore, have particularly high instances of short-range endemic species: Gastropoda (snails and slugs), Oligochaeta (earthworms), Onychophora (velvet worms), Araneae (mygalomorph spiders), Pseudoscorpionida (pseudoscorpions), Schizomida (schizomids), Diplopoda

(millipedes), Phreatoicidea (phreatoicidean crustaceans), and Decapoda (freshwater crayfish). The poor understanding of the taxonomy of many of the short-range endemic species hinders their conservation (Harvey 2002).

Introduced species

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

Ecological processes upon which the fauna depend

These are the processes that affect and maintain fauna populations in an area and as such are very complex; for example, populations are maintained through the dynamic of mortality, survival and recruitment being more or less in balance, and these are affected by a myriad of factors. The dynamics of fauna populations in a project may be affected by processes such as fire regime, landscape patterns (such as fragmentation and/or linkage), the presence of feral species and hydrology. Impacts may be significant if processes are altered such that fauna populations are adversely affected, resulting in declines and even localised loss of species. Threatening processes as outlined in Appendix 3 are effectively the ecological processes that can be altered to result in impacts upon fauna.

Appendix 2. Categories used in the assessment of conservation status.

IUCN categories (IUCN 2012) as used for the *Environment Protection and Biodiversity Conservation Act 1999* and the Western Australian *Biodiversity Conservation Act 2016*.

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

Schedules used in the WA *Biodiversity Conservation Act 2016*

Schedule 1 (S1)	Critically Endangered fauna.
Schedule 2 (S2)	Endangered fauna
Schedule 3 (S3)	Vulnerable Migratory species listed under international treaties.
Schedule 4 (S4)	Presumed extinct fauna
Schedule 5 (S5)	Migratory birds under international agreement
Schedule 6 (S6)	Conservation dependant fauna
Schedule 7 (S7)	Other specially protected fauna

WA DBCA Priority species (species not listed under the *WA Biodiversity Conservation Act 2016*, but for which there is some concern).

Priority 1 (P1)	Taxa with few, poorly known populations on threatened lands.
Priority 2 (P2)	Taxa with few, poorly known populations on conservation lands; or taxa with several, poorly known populations not on conservation lands.
Priority 3 (P3)	Taxa with several, poorly known populations, some on conservation lands.
Priority 4. (P4)	Taxa in need of monitoring. Taxa which are considered to have been adequately surveyed, or for which sufficient knowledge is available, and which are considered not currently threatened or in need of special protection, but could be if present circumstances change.
Priority 5 (P5)	Taxa in need of monitoring. Taxa which are not considered threatened but are subject to a specific conservation program, the cessation of which would result in the species becoming threatened within five years (IUCN Conservation Dependent).

Appendix 3. Explanation of threatening processes.

Potential impacts of proposed developments upon fauna values can be related to threatening processes. This is recognised in the literature (e.g. Gleeson and Gleeson 2012) and under the EPBC Act, in which threatening processes are listed. Processes that may impact fauna values are discussed below. Rather than being independent of one another, processes are complex and often interrelated. They are the mechanisms by which fauna can be affected by development. Impacts may be significant if large numbers of species or large proportions of populations are affected.

Note that the terms direct and indirect impacts are used by the DotE (2013), SEWPaC (2013) and EPA (2016), but there is some inconsistency in how these are defined. The federal guidance does not define direct impact but has a very broad definition of indirect, and makes the statement (DotE 2013) *'Consideration should be given to all adverse impacts that could reasonably be predicted to follow from the action, whether these impacts are within the control of the person proposing to take the action or not. Indirect impacts will be relevant where they are sufficiently close to the proposed action to be said to be a consequence of the action, and they can reasonably be imputed to be within the contemplation of the person proposing to take the action.'* Indirect impacts therefore can even include what the DotE (2013) calls facilitated impacts, which are the result of third party actions triggered by the primary action. In contrast, the EPA (2016) defines direct impacts to *'include the removal, fragmentation or modification of habitat, and mortality or displacement of individuals or populations.'* This document then lists as indirect impacts what in many cases are the consequences of the removal, fragmentation or modification of habitat. For example, *'disruption of the dispersal of individuals required to colonise new areas inhibiting maintenance of genetic diversity between populations'* is a consequence of habitat fragmentation. Impacts of light, noise and even roadkill are defined as indirect but they are clearly the result of the action and in control of the person taking the action. Roadkill is as direct a form of mortality as can be observed, but it is considered as an indirect impact in the context of a development presumably because it is not directly linked to land clearing. The EPA (2016) makes a strong distinction between removal of vegetation (direct impact) and the consequences of such clearing and other aspects of a development (indirect impacts). It is not obvious how this distinction between direct and indirect impacts is helpful in the EIA process, as the key aim is to ensure that all impacts that result from a project are addressed in this assessment process. Interestingly, Gleeson and Gleeson (2012), in a major review of impacts of development on wildlife, do not use the terms direct or indirect. In the following outlines of threatening processes that can cause impacts, the emphasis is upon interpreting how a threatening process will cause an impact. For example, loss of habitat (threatening process) can lead to population decline and to population fragmentation, which are two distinct impacts, with population decline considered a direct impact and fragmentation an indirect impact by the EPA (2016).

Loss of habitat affecting population survival

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

Loss of habitat leading to population fragmentation

Loss of habitat can affect population movements by limiting movement of individuals throughout the landscape as a result of fragmentation (Gleeson and Gleeson 2012, Soule *et al.* 2004). Obstructions associated with the development, such as roads, pipes and drainage channels, may also affect movement of small, terrestrial species. Fragmented populations may not be sustainable and may be sensitive to effects such as reduced gene flow.

Degradation of habitat due to weed invasion leading to population decline

Weed invasion, such as through introduction by human boots or vehicle tyres, can occur as a result of development and if this alters habitat quality, can lead to effects similar to habitat loss.

Increased mortality

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

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

Species interactions, including predation and competition

Changes in species interactions often occur with development. Introduced species, including the feral Cat, Red Fox and Rabbit, may have adverse impacts upon native species and development can alter their abundance. In particular, some mammal species are very sensitive to introduced predators and the decline of many mammals in Australia has been linked to predation by the Red Fox, and to a lesser extent, the feral Cat ([Burbidge and McKenzie 1989](#)). Introduced grazing species, such as the Rabbit, Goat, Camel and domestic livestock, can also degrade habitats and deplete vegetation that may be a food source for other species.

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

Hydroecology

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

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

Fire

The role of fire in the Australian environment and its importance to vertebrate fauna has been widely acknowledged (Gill *et al.* 1981; Fox 1982; Letnic *et al.* 2004). It is also one of the factors that has contributed to the decline and local extinction of some mammal and bird species (Burbidge and McKenzie 1989). Fire is a natural feature of the environment but frequent, extensive fires may adversely impact some fauna, particularly mammals and short-range endemic species. Changes in fire regime, whether to more frequent or less frequent fires, may be significant to some fauna. Impacts of severe fire may be devastating to species already occurring at low densities or to species requiring long unburnt habitats to survive. In terms of conservation management, it is not fire *per se* but the fire regime that is important, with evidence that infrequent, extensive and intense fires adversely affect biodiversity, whereas frequent fires that cover small areas and are variable in both season and intensity can enhance biodiversity. Fire management may be considered the responsibility of managers of large tracts of land, including managers of mining tenements.

Dust, light, noise and vibration

Impacts of dust, light, noise and vibration upon fauna are difficult to predict. Some studies have demonstrated the impact of artificial night lighting on fauna, with lighting affecting fauna behaviour more than noise ([Rich and Longcore 2006](#)). Effects can include impacts on predator-prey interactions, changes to mating and nesting behaviour, and increased competition and predation within and between invertebrates, frogs, birds and mammals.

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

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

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

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

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

Threatening processes (EPBC Act)

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

- Competition and land degradation by rabbits.
- Competition and land degradation by unmanaged goats.
- Dieback caused by the root-rot fungus (*Phytophthora cinnamomi*).
- Incidental catch (bycatch) of Sea Turtle during coastal otter-trawling operations within Australian waters north of 28 degrees South.
- Incidental catch (or bycatch) of seabirds during oceanic longline fishing operations.
- Infection of amphibians with chytrid fungus resulting in chytridiomycosis.
- Injury and fatality to vertebrate marine life caused by ingestion of, or entanglement in, harmful marine debris.
- Invasion of northern Australia by Gamba Grass and other introduced grasses.
- Land clearance.
- Loss and degradation of native plant and animal habitat by invasion of escaped garden plants, including aquatic plants.
- Loss of biodiversity and ecosystem integrity following invasion by the Yellow Crazy Ant (*Anoplolepis gracilipes*) on Christmas Island, Indian Ocean.
- Loss of climatic habitat caused by anthropogenic emissions of greenhouse gases.
- Novel biota and their impact on biodiversity.
- Predation by European red fox.
- Predation by exotic rats on Australian offshore islands of less than 1000 km² (100,000 ha).
- Predation by feral cats.
- Predation, Habitat Degradation, Competition and Disease Transmission by Feral Pigs.
- Psittacine Circoviral (beak and feather) Disease affecting endangered psittacine species.
- The biological effects, including lethal toxic ingestion, caused by Cane Toads (*Bufo marinus*).
- The reduction in the biodiversity of Australian native fauna and flora due to the red imported fire ant, *Solenopsis invicta* (fire ant).

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

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

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

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

Appendix 5. Sampling location descriptions and coordinates.

Beharra Project area. NB. Funnel traps on each even-numbers location

Name	Zone	Easting	Northing	Date set	Type
SM2-17697	50J	315890	6745679	6/12/2021	Audio recording unit
SM2-17709	50J	315974	6740220	6/12/2021	Audio recording unit
SM2-17731	50J	315906	6742566	6/12/2021	Audio recording unit
SM2-17755	50J	315849	6743845	6/12/2021	Audio recording unit
Cam-BCE05	50J	316338	6745540	2/12/2021	Motion-sensitive camera point
Cam-BCE11	50J	316272	6745558	2/12/2021	Motion-sensitive camera point
Cam-BCE13	50J	316234	6745340	2/12/2021	Motion-sensitive camera point
Cam-BCE16	50J	316137	6742766	2/12/2021	Motion-sensitive camera point
Cam-C2	50J	316290	6742793	2/12/2021	Motion-sensitive camera point
B01	50J	315974	6742812	1/12/2021	Pitfall and bird census point
B02	50J	316012	6742810	1/12/2021	Pitfall and bird census point
B03	50J	316033	6742806	1/12/2021	Pitfall and bird census point
B04	50J	316065	6742802	1/12/2021	Pitfall, funnel and bird census point
B05	50J	316094	6742803	1/12/2021	Pitfall and bird census point
B06	50J	316127	6742807	1/12/2021	Pitfall and bird census point
B07	50J	316155	6742809	1/12/2021	Pitfall and bird census point
B08	50J	316185	6742808	1/12/2021	Pitfall, funnel and bird census point
B09	50J	316215	6742807	1/12/2021	Pitfall and bird census point
B10	50J	316246	6742805	1/12/2021	Pitfall and bird census point
B11	50J	316276	6742804	1/12/2021	Pitfall and bird census point
B12	50J	316306	6742804	1/12/2021	Pitfall, funnel and bird census point
B13	50J	316336	6742804	1/12/2021	Pitfall and bird census point
B14	50J	316365	6742807	1/12/2021	Pitfall and bird census point
B15	50J	316395	6742806	1/12/2021	Pitfall and bird census point
B16	50J	316426	6742808	2/12/2021	Pitfall, funnel and bird census point
B17	50J	316457	6742809	2/12/2021	Pitfall and bird census point
B18	50J	316487	6742812	2/12/2021	Pitfall and bird census point
B19	50J	316518	6742818	2/12/2021	Pitfall and bird census point
B20	50J	316548	6742819	2/12/2021	Pitfall, funnel and bird census point
B21	50J	316514	6740963	2/12/2021	Pitfall and bird census point
B22	50J	316544	6740960	2/12/2021	Pitfall and bird census point
B23	50J	316574	6740958	2/12/2021	Pitfall and bird census point
B24	50J	316604	6740957	2/12/2021	Pitfall, funnel and bird census point
B25	50J	316634	6740957	2/12/2021	Pitfall and bird census point
B26	50J	316663	6740954	2/12/2021	Pitfall and bird census point
B27	50J	316693	6740952	2/12/2021	Pitfall and bird census point

B28	50J	316724	6740952	2/12/2021	Pitfall, funnel and bird census point
B29	50J	316754	6740947	2/12/2021	Pitfall and bird census point
B30	50J	316784	6740938	2/12/2021	Pitfall and bird census point
B31	50J	316813	6740939	2/12/2021	Pitfall and bird census point
B32	50J	316844	6740936	2/12/2021	Pitfall, funnel and bird census point
B33	50J	316870	6740932	2/12/2021	Pitfall and bird census point
B34	50J	316901	6740916	2/12/2021	Pitfall and bird census point
B35	50J	316933	6740908	2/12/2021	Pitfall and bird census point
B36	50J	316961	6740901	2/12/2021	Pitfall and bird census point
B37	50J	316990	6740891	2/12/2021	Pitfall and bird census point
B38	50J	317017	6740881	2/12/2021	Pitfall, funnel and bird census point
B39	50J	317047	6740872	2/12/2021	Pitfall and bird census point
B40	50J	317073	6740864	2/12/2021	Pitfall, funnel and bird census point
B41	50J	316002	6743896	2/12/2021	Pitfall and bird census point
B42	50J	316032	6743898	2/12/2021	Pitfall and bird census point
B43	50J	316062	6743897	2/12/2021	Pitfall and bird census point
B44	50J	316093	6743899	2/12/2021	Pitfall, funnel and bird census point
B45	50J	316122	6743904	2/12/2021	Pitfall and bird census point
B46	50J	316152	6743908	2/12/2021	Pitfall and bird census point
B47	50J	316182	6743913	2/12/2021	Pitfall and bird census point
B48	50J	316213	6743911	2/12/2021	Pitfall, funnel and bird census point
B49	50J	316241	6743912	2/12/2021	Pitfall and bird census point
B50	50J	316273	6743916	2/12/2021	Pitfall and bird census point
B51	50J	316281	6745484	2/12/2021	Pitfall and bird census point
B52	50J	316287	6745456	2/12/2021	Pitfall, funnel and bird census point
B53	50J	316283	6745425	2/12/2021	Pitfall and bird census point
B54	50J	316284	6745393	2/12/2021	Pitfall and bird census point
B55	50J	316295	6745364	2/12/2021	Pitfall and bird census point
B56	50J	316309	6745336	2/12/2021	Pitfall, funnel and bird census point
B57	50J	316303	6745306	2/12/2021	Pitfall and bird census point
B58	50J	316299	6745275	2/12/2021	Pitfall and bird census point
B59	50J	316303	6745230	2/12/2021	Pitfall and bird census point
B60	50J	316308	6745200	2/12/2021	Pitfall, funnel and bird census point

Sampling in adjacent area; VRX Silica Arrowsmith North project area. NB. Funnel traps on every third location.

AM-BCE05	50J	314647	6735284	4/12/2021	Audio recording unit
AM-BCE06	50J	315842	6735373	4/12/2021	Audio recording unit
AM-BCE07	50J	316122	6736247	4/12/2021	Audio recording unit
AM-BCE08	50J	316012	6738469	4/12/2021	Audio recording unit
SM2-17715	50J	316204	6735350	6/12/2021	Audio recording unit
SM2-17769	50J	314326	6731532	5/12/2021	Audio recording unit
Cam-BCE01	50J	313903	6734282	4/12/2021	Motion-sensitive camera point
Cam-BCE02	50J	314433	6731528	5/12/2021	Motion-sensitive camera point
Cam-BCE03	50J	313924	6733783	4/12/2021	Motion-sensitive camera point
Cam-BCE04	50J	313911	6730592	5/12/2021	Motion-sensitive camera point
Cam-BCE06	50J	314566	6733705	4/12/2021	Motion-sensitive camera point
Cam-BCE17	50J	314118	6733618	4/12/2021	Motion-sensitive camera point
Cam-BCE20	50J	313962	6733048	4/12/2021	Motion-sensitive camera point
Cam-BCE23	50J	314132	6733698	4/12/2021	Motion-sensitive camera point
Cam-BCE32	50J	314845	6729421	5/12/2021	Motion-sensitive camera point
V01	50J	316315	6735254	3/12/2021	Pitfall and bird census point
V02	50J	316320	6735225	3/12/2021	Pitfall and bird census point
V03	50J	316322	6735194	3/12/2021	Pitfall and bird census point
V04	50J	316324	6735166	3/12/2021	Pitfall and bird census point
V05	50J	316326	6735134	3/12/2021	Pitfall and bird census point
V06	50J	316335	6735105	3/12/2021	Pitfall and bird census point
V07	50J	316346	6735078	3/12/2021	Pitfall and bird census point
V08	50J	316354	6735048	3/12/2021	Pitfall and bird census point
V09	50J	316363	6735019	3/12/2021	Pitfall and bird census point
V10	50J	316374	6734990	3/12/2021	Pitfall and bird census point
V11	50J	316381	6734961	3/12/2021	Pitfall and bird census point
V12	50J	316391	6734933	3/12/2021	Pitfall and bird census point
V13	50J	316396	6734904	3/12/2021	Pitfall and bird census point
V14	50J	316407	6734877	3/12/2021	Pitfall and bird census point
V15	50J	316418	6734847	3/12/2021	Pitfall and bird census point
V16	50J	316426	6734818	3/12/2021	Pitfall and bird census point
V17	50J	316435	6734788	3/12/2021	Pitfall and bird census point
V18	50J	316445	6734762	3/12/2021	Pitfall and bird census point
V19	50J	316451	6734732	3/12/2021	Pitfall and bird census point
V20	50J	316459	6734702	3/12/2021	Pitfall and bird census point

Appendix 6. Scoring system for the assessment of foraging value of vegetation for black-cockatoos. Revised 5th June 2020

Bamford Consulting Ecologists

Introduction

Application of the Offset Assessment Guide (offsets guide) developed by the federal environment department for assessing black-cockatoo foraging habitat requires the calculation of a score out of 10. The following system has been developed by Bamford Consulting Ecologists (BCE) to provide an objective scoring system that is practical and can be used by trained field zoologists with experience in the environments frequented by the species.

The foraging value score provides a numerical value that reflects the significance of vegetation as foraging habitat for Black-Cockatoos, and this numerical value is designed to provide the information needed by the Federal Department of Agriculture, Water and the Environment (DAWE) to assess impact significance and offset requirements. The foraging value of the vegetation depends upon the type, density and condition of trees and shrubs in an area and can be influenced by the context such as the availability of foraging habitat nearby. The BCE scoring system for value of foraging habitat has three components as detailed above. These three components are drawn from the DAWE offsets guide but the scoring approach was developed by BCE and includes a fourth (moderation) component.

Calculating the total score (out of 10) requires the following steps:

- A Site condition. Determining a score out of six for the vegetation composition, condition and structure; plus
- B Site context. Determining a score out of three for the context of the site; plus
- C Species stocking rate. Determining a score out of one for species density.
- D Determining the total score out of 10, which may require moderation for context and species density with respect to the site condition (vegetation) score. Moderation also includes consideration of pine plantations as a special case for foraging value.

Calculation of scores and the moderation process are described in detail below.

A. Site condition. Vegetation composition, condition and structure scoring

Site Score	Description of Vegetation Values		
	Carnaby's Black-Cockatoo	Baudin's Black-Cockatoo	Forest Red-tailed Black-Cockatoo
0	<p>No foraging value. No Proteaceae, eucalypts or other potential sources of food. Examples:</p> <ul style="list-style-type: none"> • Water bodies (e.g. salt lakes, dams, rivers); • Bare ground; • Developed sites devoid of vegetation (e.g. infrastructure, roads, gravel pits) or with vegetation of no food value, such as some suburban landscapes. • Mown grass 	<p>No foraging value. No eucalypts or other potential sources of food. Examples:</p> <ul style="list-style-type: none"> • Water bodies (e.g. dams, rivers); • Bare ground; • Developed sites devoid of vegetation (e.g. infrastructure, roads, gravel pits). 	<p>No foraging value. No eucalypts or other potential sources of food. Examples:</p> <ul style="list-style-type: none"> • Water bodies (e.g. dams, rivers); • Bare ground; • Developed sites devoid of vegetation (e.g. infrastructure, roads, gravel pits).
1	<p>Negligible to low foraging value. Examples:</p> <ul style="list-style-type: none"> • Scattered specimens of known food plants but projected foliage cover of these is < 2%. This could include urban areas with scattered foraging trees; • Paddocks that are lightly vegetated with melons or other known food-source weeds (e.g. <i>Erodium</i> spp.) that represent a short-term and/or seasonal food source; • Blue Gum plantations (foraging by Carnaby's Black-Cockatoos has been reported but appears to be unusual). 	<p>Negligible to low foraging value. Scattered specimens of known food plants but projected foliage cover of these < 1%. This could include urban areas with scattered foraging trees.</p>	<p>Negligible to low foraging value. Scattered specimens of known food plants but projected foliage cover of these < 1%. Could include urban areas with scattered foraging trees.</p>

Site Score	Description of Vegetation Values		
	Carnaby's Black-Cockatoo	Baudin's Black-Cockatoo	Forest Red-tailed Black-Cockatoo
2	<p>Low foraging value. Examples:</p> <ul style="list-style-type: none"> • Shrubland in which species of foraging value, such as shrubby banksias, have < 10% projected foliage cover; • Woodland with tree banksias 2-5% projected foliage cover; • Open eucalypt woodland/mallee of small-fruited species; • Paddocks that are densely vegetated with melons or other known food-source weeds (e.g. <i>Erodium</i> spp.) that represent a short-term and/or seasonal food source. 	<p>Low foraging value. Examples:</p> <ul style="list-style-type: none"> • Woodland with scattered specimens of known food plants (e.g. Marri and Jarrah) 1-5% projected foliage cover; • Urban areas with scattered foraging trees. 	<p>Low foraging value. Examples:</p> <ul style="list-style-type: none"> • Woodland with scattered specimens of known food plants (e.g. Marri, Jarrah or Sheoak) 1-5% projected foliage cover; • Urban areas with scattered food plants such as Cape Lilac, <i>Eucalyptus caesia</i> and <i>E. erythrocorys</i>.
3	<p>Low to Moderate foraging value. Examples:</p> <ul style="list-style-type: none"> • Shrubland in which species of foraging value, such as shrubby banksias, have 10-20% projected foliage cover; • Woodland with tree banksias 5-20% projected foliage cover; • Eucalypt Woodland/Mallee of small-fruited species; • Eucalypt Woodland with Marri < 10% projected foliage cover. 	<p>Low to Moderate foraging value. Examples:</p> <ul style="list-style-type: none"> • Eucalypt Woodland with known food plants (especially Marri) 5-20% projected foliage cover; • Parkland-cleared Eucalypt Woodland/Forest with known food plants 10-40% projected foliage cover (poor long-term viability without management); • Younger areas of (managed) revegetation with known food plants 10-40% projected foliage cover (establishing food sources with good long-term viability). 	<p>Low to Moderate foraging value. Examples:</p> <ul style="list-style-type: none"> • Eucalypt Woodland with known food plants (especially Marri and Jarrah) 5-20% projected foliage cover; • Parkland-cleared Eucalypt Woodland/Forest with known food plants 10-40% projected foliage cover (poor long-term viability without management); • Younger areas of (managed) revegetation with known food plants 10-40% projected foliage cover (establishing food sources with good long-term viability).

Site Score	Description of Vegetation Values		
	Carnaby's Black-Cockatoo	Baudin's Black-Cockatoo	Forest Red-tailed Black-Cockatoo
4	<p>Moderate foraging value. Examples:</p> <ul style="list-style-type: none"> Woodland/low forest with tree banksias (of key species <i>B. attenuata</i> and <i>B. menziesii</i>) 20-40% projected foliage cover; Kwongan/ Shrubland in which species of foraging value, such as shrubby banksias, have 20-40% projected foliage cover; Eucalypt Woodland/Forest with Marri 20-40% projected foliage cover. 	<p>Moderate foraging value. Examples:</p> <ul style="list-style-type: none"> Marri-Jarrah Woodland/Forest with 20-40% projected foliage cover; Marri-Jarrah Forest with 40-60% projected foliage cover but vegetation condition reduced due to weed invasion and/or some tree deaths. Eucalypt Woodland/Forest with diverse, healthy understorey and known food trees (especially Marri) 10-20% projected foliage cover. Orchards with highly desirable food sources (e.g. apples, pears, some stone fruits). 	<p>Moderate foraging value. Examples:</p> <ul style="list-style-type: none"> Marri-Jarrah Woodland/Forest with 20-40% projected foliage cover; Marri-Jarrah Forest with 40-60% projected foliage cover but vegetation condition reduced due to weed invasion and/or some tree deaths; Sheoak Forest with 40-60% projected foliage cover.
5	<p>Moderate to High foraging value. Examples:</p> <ul style="list-style-type: none"> Banksia Low Forest (of key species <i>B. attenuata</i> and <i>B. menziesii</i>) with 40-60% projected foliage cover; Banksia Low Forest (of key species <i>B. attenuata</i> and <i>B. menziesii</i>) with > 60% projected foliage cover but vegetation condition reduced due to weed invasion and/or some tree deaths; Pine plantations with trees more than 10 years old (but see pine note below in moderation section). 	<p>Moderate to High foraging value. Examples:</p> <ul style="list-style-type: none"> Marri-Jarrah Forest with 40-60% projected foliage cover; Marri-Jarrah Forest with > 60% projected foliage cover but vegetation condition reduced due to weed invasion and/or some tree deaths. 	<p>Moderate to High foraging value. Examples:</p> <ul style="list-style-type: none"> Marri-Jarrah Forest with 40-60% projected foliage cover; Marri-Jarrah Forest with > 60% projected foliage cover but vegetation condition reduced due to weed invasion and/or some tree deaths. Sheoak Forest with > 60% projected foliage cover.

Site Score	Description of Vegetation Values		
	Carnaby's Black-Cockatoo	Baudin's Black-Cockatoo	Forest Red-tailed Black-Cockatoo
6	<p>High foraging value. Example:</p> <ul style="list-style-type: none"> Banksia Low Forest (of key species <i>B. attenuata</i> and <i>B. menziesii</i>) with > 60% projected foliage cover and vegetation condition good with low weed invasion and/or low tree deaths (indicating it is robust and unlikely to decline in the medium term). 	<p>High foraging value. Example:</p> <ul style="list-style-type: none"> Marri-Jarrah Forest with > 60% projected foliage cover and vegetation condition good with low weed invasion and/or low tree deaths (indicating it is robust and unlikely to decline in the medium term). 	<p>High foraging value. Example:</p> <ul style="list-style-type: none"> Marri-Jarrah Forest with > 60% projected foliage cover and vegetation condition good with low weed invasion and/or low tree deaths (indicating it is robust and unlikely to decline in the medium term).

Vegetation structural class terminology follows Keighery (1994).

B. Site context.

Site Context is a function of site size, availability of nearby habitat and the availability of nearby breeding areas. Site context includes consideration of connectivity, although Black-Cockatoos are very mobile and will fly across paddocks to access foraging sites. Based on BCE observations, Carnaby's are unlikely to regularly go over open ground for a distance of more than a few kilometres and prefer to follow tree-lines.

The maximum score for site context is 3, and because it is effectively a function of presence/absence of nearby breeding and the distribution of foraging habitat across the landscape, the following table, developed by Bamford Consulting in conjunction with DEE, provides a *guide* to the assignment of site context scores. Note that 'local area' is defined as within a 15 km radius of the centre point of the study site. This is greater than the maximum distance of 12km known to be flown by Carnaby's Black-Cockatoo when feeding chicks in the nest.

Site Context Score	Percentage of the existing native vegetation within the 'local' area that the study site represents.	
	'Local' breeding known/likely	'Local' breeding unlikely
3	> 5%	> 10%
2	1 - 5%	5 - 10%
1	0.1 - 1%	1 - 5%
0	< 0.1%	< 1%

The table above provides weighting for where nearby breeding is known (or suspected) and for the proportion of foraging habitat within 15 km represented by the site being assessed. Some adjustments may be needed based on the judgement of the assessor and in relation to the likely function of the site. For example, a small area of foraging habitat (eg 0.5% of such habitat within 15km) could be upgraded to a context of 2 if it formed part of a critical movement corridor. In contrast, the same sized area of habitat, of the same local proportion, could be downgraded if it were so isolated that birds could never access it.

C. Species density (stocking rate).

Species stocking rate is described as "the usage and/or density of a species at a particular site" in the offsets guide. The description also implies that a site supports a discrete population, which is unlikely in the case of very mobile black-cockatoos. Assignment of the species density score (0 or 1) is based upon the black-cockatoo species being either abundant or not abundant. A score of 1 is used where the species is seen or reported regularly and/or there is abundant foraging evidence. Regularly is when the species is seen at intervals of every few days or weeks for at least several months of the year. A score of 0 is used when the species is recorded or reported very infrequently and there is little or no foraging evidence. Where information on actual presence of birds is lacking, a species density score can be assigned by interpreting the landscape and the site context. For example, a site with a moderate condition score that is part of a network of such habitat where a black-cockatoo species is known would get a species density score of 1 even without clear presence

data, while a species density score of 0 can be assigned to a site where the level of usage can confidently be predicted to be low.

D. Moderation of scores for the calculation of a value out of 10.

The calculation out of 10 requires the vegetation characteristics (out of 6) to be combined with the scores given for context and species density. It is considered that the context and density scores are not independent of vegetation characteristics; otherwise habitat of absolutely no value for black-cockatoo foraging (such as concrete or a wetland) could get a foraging score out of 10 as high as 4 if it occurred in an area where the species breed (context score of 3) and are abundant (species density score of 1). Similarly, vegetation of negligible or low characteristics which could not support black-cockatoos could be assigned a score as high as 6 out of 10. In that case, the score of 6 would be more a reflection of nearby vegetation of high characteristics than of the foraging value of the negligible to low scoring vegetation. The Black-Cockatoos would only be present because of vegetation of high characteristics, so applying the context and species density scores to vegetation of low characteristics would not give a true reflection of their foraging value.

For this reason, the context and species density scores need to be moderated for the vegetation characteristic score to prevent vegetation of little or no foraging value receiving an excessive score out of 10. A simple approach is to assign a context and species density score of zero to sites with a Condition score of low (2), negligible (1) or none (0), on the basis that birds will not use such areas unless they are adjacent to at least low-moderate quality foraging habitat (≥ 3). The approach to calculating a score out of 10 can be summarised as follows:

vegetation composition, condition and structure score (out of 6)	context score	Species density score
3-6 (low/moderate to high value)	Assessed as per B above	Assessed as per C above
0-2 (no to low value)	0	0

Note that this moderation approach may require interpretation depending on the context. For example, vegetation with a condition score of 2 could be given a context score of 1 under special circumstances. Such as when very close to a major breeding area or if strategically located along a movement corridor.

Pine plantations

Pine plantations are an important foraging resource for Carnaby's Black-Cockatoo (only) but are not directly comparable with native vegetation. In comparing native vegetation with pine plantations for the purpose of calculating offsets, the following should be noted:

- Pine plantations are a commercial crop established with the intention of being harvested and thus have short-term availability (30-50 years), whereas native vegetation is available indefinitely if protected. Due to the temporary nature of pines as a food source, site condition and context differs between pines and native vegetation.
- Although pines provide a high abundance of food in the form of seeds, they are a limited food resource compared with native vegetation which provides seeds, insect larvae, flowers and nectar. The value of insect larvae in the diet of Carnaby's Black-Cockatoo has not been quantified, but in the vicinity of Perth, the birds forage very heavily on insect larvae in young cones of *Banksia attenuata* in winter, ignoring the seeds in these cones and seeds in older cones on the same trees (Scott and Black 1981; M. Bamford pers. obs.). This suggests that insect larvae are of high nutritional importance immediately prior to the breeding season.
- Pine plantations have very little biodiversity value other than their importance as a food source for Carnaby's Black-Cockatoos. They inhibit growth of other flora. While this is not a factor for direct consideration with respect to Carnaby's Black-Cockatoo, it is a factor in regional conservation planning of which offsets for the cockatoos are a part.

Taking the above points into consideration, it is possible to assign pine plantations a foraging value as follows:

- Site condition. The actual foraging value of pines is high. Stock *et al.* (2013) report that it takes nearly twice as many seeds of *Pinus pinaster* to meet the daily energy requirements for Carnaby's Black-Cockatoo compared with Marri, and three times as many *P. pinaster* seeds compared with Slender Banksia. However, pines are planted at a high density so the food supply per hectare can be high. Taking account of the lack of variety of food from pines, this suggests a site condition score of 4 or 5 out of 6 (5 is used in Section A above). As a source of food, pines are thus comparable to the best banksia woodland. This site condition score then needs to be adjusted to take account of the short-term nature of the food supply (for pine plantations to be harvested. Where pines are 'ornamental, such as in some urban contexts, they can be treated as with other trees in urban landscapes). The foraging value of a site after pines are harvested will effectively be 0, or possibly 1 if there is some retention. It is proposed that this should approximately halve the site condition score; young pine plantations could be redacted slightly less than old plantations on the basis that a young plantation provides a slightly longer term food supply. If a maximum site condition score of 5 is given, then a young plantation (>10 but <30 years old) could be assigned a score of 3, and an old plantation (>30 years old) could be assigned a score of 2. Plantations <10 years old and thus not producing large quantities of cones could also get a score of 2, but recognising they may increase in value.
- Site context. Although a temporary food source, pines can be very important for Carnaby's Black-Cockatoo in some contexts; they could be said to carry populations in areas where there is little native vegetation. The system for assigning a context score as outlined above (Section

B) also applies to pines. Thus, a context score of 3 can be given where pines are a significant proportion of foraging habitat (>5% if breeding occurs; >10% if no breeding), but where pines are a small part of the foraging landscape they will receive a context score of less than this.

- Species density. As outlined above (Section C), pines will receive a species density score of 1 where Carnaby's Black-Cockatoo are regular visitors. This is irrespective of an old plantation having a moderated condition score of 2.

Based on the above, pine plantations that represent a substantial part of the foraging landscape, such as in the region immediately north of Perth, would receive a total score (out of 10) of 6; young plantations in this area would receive a score of 7. In contrast, isolated and small plantations in rural landscapes could receive a score of just 2 if they are only a small proportion of foraging habitat and Carnaby's Black-Cockatoo are not regularly present.

Scott, J. K. and Black, R. (1981). Selective Predation by White-Tailed Black Cockatoos on Fruit of *Banksia attenuata* Containing the Seed-Eating Weevil *Alphitopis nivea*. *Australian Wildlife Research* **8(2)**, 421-430.

Stock, W.D., Finn, H., Parker, J. and Dods, K. (2013). Pine as Fast Food. Foraging Ecology of an Endangered Cockatoo in a Forestry Landscape. *PlosOne* 8: issue 4.

Appendix 7. Expected vertebrate fauna in the project area (including species now considered locally extinct).

These lists are derived from the results of database and literature searches (Section 2.1.1), from previous field surveys conducted in the local area and from the current investigations. Species for which no source is cited are included on the basis of the literature and interpretation of the environment. Sources of information are:

- ALA = Atlas of Living Australia, searched January 2019 and June 2021.
- N = Naturemap Database, searched January 2019 and June 2021.
- EPBC = EPBC Protected Matters, searched January 2019 and June 2021.
- BA = Birdlife Australia's Birdata database, searched January 2019 and June 2021.
- BCE = BCE surveys undertaken in the general area (BCE database records 1981 to 2018, including Harris *et al.* (2008), Metcalf and Bamford (2008), Bamford (2009), Bamford (2012), Everard and Bamford (2014), Bamford *et al.* (2015), Bamford and Chuk 2015-2017). This is a radius of approximately 15km. Note that BCE records from the Beharra Springs Silica sands project area in 2020 and 2021 are indicated in **bold**. These species (in bold) have thus been recorded on the project area. An asterisk indicates species recorded only in the project area (and not in previous regional studies).

Conservation significance (CS) codes are:

- CS1, CS2, CS3 = (summary) levels of conservation significance. See Appendix 2 for full explanation.
- EPBC Act listings: Cr = Critically Endangered, E = Endangered, V = Vulnerable, Mig = Migratory (see Appendix 3).
- Biodiversity Conservation Act listings: for all CS1 species S1 to 7 = Schedules 1 to 7 respectively, (see Appendix 3).
- DBCA Priority species: P1 to P4 = Priority 1 to 4 (see Appendix 3).

Expected status categories:

See Section 2.2.3 for explanation of expected occurrence categories.

FROGS	CS	ALA	N	EPBC	BCE	Expected status in project area
HYLIDAE						
Slender Tree Frog <i>Litoria adelaidensis</i>		X			X	Irregular visitor
Motorbike Frog <i>Litoria moorei</i>		X			X	Irregular visitor
LIMNODYNASTIDAE						
Western Spotted Frog <i>Heleioporus albopunctatus</i>					X	Resident
Moaning Frog <i>Heleioporus eyrei</i>		X	X		X	Resident
Sand Frog <i>Heleioporus psammophilus</i>					X	Resident
Banjo Frog <i>Limnodynastes dorsalis</i>					X	Resident
Humming Frog <i>Neobatrachus pelobatoides</i>		X	X		X	Resident
MYOBATRACHIDAE						
Bleating Froglet <i>Crinia pseudinsignifera</i>					X	Irregular visitor

FROGS		CS	ALA	N	EPBC	BCE	Expected status in project area
Turtle Frog	<i>Myobatrachus gouldii</i>		X	X		X	Resident
Gunther's Toadlet	<i>Pseudophryne guentheri</i>		X	X		X	Resident
Number of Species Expected:	10	0					

REPTILES		CS	ALA	N	EPBC	BCE	Expected status in project area
CHELIDAE							
South-west Long-necked Tortoise	<i>Chelodina oblonga</i>						Vagrant
AGAMIDAE							
Western Heath Dragon	<i>Ctenophorus adelaidensis</i>		X	X		X	Resident
Spotted Military Dragon	<i>Ctenophorus maculatus</i>		X	X		X	Resident
Thorny Devil	<i>Moloch horridus</i>		X			X	Resident
Dwarf Bearded Dragon	<i>Pogona minor</i>		X	X		X	Resident
DIPLODACTYLIDAE							
South-Western Clawless Gecko	<i>Crenadactylus ocellatus</i>						Resident
Western Stone Gecko	<i>Diplodactylus granariensis</i>					X?	Resident
	<i>Diplodactylus ornatus</i>			X		X*	Resident
Spotted Sandplain Gecko	<i>Diplodactylus polyopthalmus</i>		X			X	Resident
White-spotted Ground Gecko	<i>Lucasium alboguttatus</i>					X	Resident
South-western Spiny-tailed Gecko	<i>Strophurus spinigerus</i>		X	X		X	Resident
GEKKONIDAE							
Tree Dtella	<i>Gehyra variegata</i>		X	X		X	Resident
PYGOPODIDAE							
Sedgeland's Worm-Lizard	<i>Aprasia repens</i>					X	Resident
Javelin Legless Lizard	<i>Aclys concinna</i>					X	Resident
Fraser's Delma	<i>Delma fraseri</i>					X	Resident
Side-barred Delma	<i>Delma grayii</i>		X			X	Resident

REPTILES	CS	ALA	N	EPBC	BCE	Expected status in project area
Burton's Snake-Lizard <i>Lialis burtonis</i>		X	X		X	Resident
Keeled Legless Lizard <i>Pletholax gracilis</i>						Resident
Common Scaly-Foot <i>Pygopus lepidopus</i>		X	X		X	Resident
SCINCIDAE						
Buchanan's Snake-eyed Skink <i>Cryptoblepharus buchananii</i>		X	X		X	Resident
West-coast Ctenotus <i>Ctenotus fallens</i>			X		X	Resident
Odd-striped Ctenotus <i>Ctenotus impar</i>					X	Resident
Leopard Ctenotus <i>Ctenotus pantherinus</i>		X	X		X	Resident
<i>Ctenotus schomburgkii</i>						Resident
Western Slender Blue-tongue <i>Cyclodomorphus celatus</i>		X	X		X	Resident
<i>Lerista christinae</i>					X	Resident
Elegant Slider <i>Lerista elegans</i>		X	X		X	Resident
Dotted-Line Robust Slider <i>Lerista lineopunctulata</i>		X	X			Resident
<i>Lerista planiventralis</i>			X		X*	Resident
Blunt-Tailed West-Coast Slider <i>Lerista praepedita</i>		X	X		X	Resident
Southern Sand-skink <i>Liopholis multiscutata</i>			X			Resident
Common Dwarf Skink <i>Menetia greyii</i>		X	X		X	Resident
West Coast Morethia Skink <i>Morethia lineocellata</i>					X*	Resident
Shrubland Morethia Skink <i>Morethia obscura</i>					X	Resident
Western Blue-tongue <i>Tiliqua occipitalis</i>		X	X		X	Resident
Bobtail <i>Tiliqua rugosa</i>		X	X		X	Resident
VARANIDAE						
Gould's Goanna <i>Varanus gouldii</i>		X	X		X	Resident
Black-Headed Monitor <i>Varanus tristis</i>					X	Resident
TYPHLOPIDAE						
Southern Blind Snake <i>Anilius australis</i>		X				Resident

REPTILES	CS	ALA	N	EPBC	BCE	Expected status in project area
Beaked Blind Snake <i>Anilius waitii</i>						Resident
PYTHONIDAE						
Woma <i>Aspidites ramsayi</i>	P1					Locally extinct?
Carpet Python <i>Morelia spilota imbricata</i>	CS3					Resident
ELAPIDAE						
Narrow-banded Shovel-nosed Snake <i>Brachyuropsis fasciolata</i>						Resident
Southern Shovel-nosed Snake <i>Barchyuropsis semifasciata</i>						Resident
Yellow-Faced Whip Snake <i>Demansia psammophis</i>					X	Resident
Bardick <i>Echiopsis curta</i>		X	X		X	Resident
Black-naped Snake <i>Neelaps bimaculata</i>						Resident
Black-striped Snake <i>Neelaps calonotos</i>	P2		X		X	Resident
Gould's Hooded Snake <i>Parasuta gouldii</i>					X	Resident
King Brown (Mulga) Snake <i>Pseudechis australis</i>					X	Resident
Western Brown Snake <i>Pseudonaja mengdeni</i>		X	X		X	Resident
Jan's Banded Snake <i>Simoselaps bertholdi</i>					X	Resident
Number of Species Expected: 50	3					

BIRDS	CS	ALA	N	EPBC	BA	BCE	Expected status in project area
CASUARIIDAE							
Emu <i>Dromaius novaehollandiae</i>		X	X		X	X	Resident
MEGAPODIDAE							
Malleefowl <i>Leipoa ocellata</i>	V S3		X	X			Irregular visitor
PHASIANIDAE							
Stubble Quail <i>Coturnix pectoralis</i>							Regular visitor

BIRDS	CS	ALA	N	EPBC	BA	BCE	Expected status in project area
TURNICIDAE							
Painted Button-quail <i>Turnix varius</i>						X*	Resident
Little Button-quail <i>Turnix velox</i>						X*	Regular visitor
COLUMBIDAE							
Rock Pigeon <i>Columba livia</i>	Int.	X		X			Vagrant
Crested Pigeon <i>Ocyphaps lophotes</i>		X	X		X	X	Resident
Common Bronzewing <i>Phaps chalcoptera</i>		X	X		X	X	Resident
Brush Bronzewing <i>Phaps elegans</i>			X		X	X	Resident
Laughing Dove <i>Streptopelia senegalensis</i>	Int.	X		X	X	X	Regular visitor
CUCULIDAE							
Fan-tailed Cuckoo <i>Cacomantis flabelliformis</i>		X	X		X	X	Regular migrant
Pallid Cuckoo <i>Cacomantis pallidus</i>		X	X		X		Regular migrant
Horsfield's Bronze-Cuckoo <i>Chrysococcyx basalis</i>		X	X		X	X	Regular migrant
Shining Bronze-Cuckoo <i>Chrysococcyx lucidus</i>		X			X		Regular migrant
Black-eared Cuckoo <i>Chalcites osculans</i>				X	X		Vagrant
APODIDAE							
Fork-tailed Swift <i>Apus pacificus</i>	M S5	X	X	X	X	X	Irregular migrant
RALLIDAE							
Buff-banded Rail <i>Gallirallus philippensis</i>							Irregular visitor
Black-tailed Native-hen <i>Tribonyx ventralis</i>		X	X		X		Irregular visitor
BURHINIDAE							
Bush Stone-curlew <i>Burhinus grallarius</i>							Locally extinct
CHARADRIIDAE							
Black-fronted Dotterel <i>Euseyornis melanops</i>					X		Irregular visitor
Banded Lapwing <i>Vanellus tricolor</i>		X	X		X	X	Irregular visitor
OTIDIDAE							
Australian Bustard <i>Ardeotis australis</i>		X	X				Irregular visitor

BIRDS	CS	ALA	N	EPBC	BA	BCE	Expected status in project area
ACCIPITRIDAE							
Brown Goshawk <i>Accipiter fasciatus</i>		X	X		X	X	Regular visitor
Collared Sparrowhawk <i>Accipiter cirrocephalus</i>		X	X		X	X	Resident
Wedge-tailed Eagle <i>Aquila audax</i>		X	X		X	X	Regular visitor
Swamp Harrier <i>Circus approximans</i>							Irregular visitor
Spotted Harrier <i>Circus assimilis</i>		X					Regular visitor
Black-shouldered Kite <i>Elanus axillaris</i>		X	X		X		Regular visitor
Whistling Kite <i>Haliastur sphenurus</i>		X			X	X	Regular visitor
Little Eagle <i>Hieraaetus morphnoides</i>		X	X		X	X	Regular visitor
Square-tailed Kite <i>Lophoictinia isura</i>						X	Irregular visitor
Black Kite <i>Milvus migrans</i>							Vagrant
FALCONIDAE							
Brown Falcon <i>Falco berigora</i>			X		X	X	Resident
Nankeen Kestrel <i>Falco cenchroides</i>		X	X		X	X	Regular visitor
Australian Hobby <i>Falco longipennis</i>			X		X	X	Regular visitor
Peregrine Falcon <i>Falco peregrinus</i>	S7	X	X		X		Irregular visitor
STRIGIDAE							
Southern Boobook <i>Ninox novaeseelandiae</i>		X			X		Resident
TYTONIDAE							
Barn Owl <i>Tyto alba</i>							Regular visitor
PODARGIDAE							
Tawny Frogmouth <i>Podargus strigoides</i>		X	X	X		X	Resident
CAPRIMULGIDAE							
Spotted Nightjar <i>Eurostopodus argus</i>						X	Regular visitor
AEGOTHELIDAE							
Australian Owlet-nightjar <i>Aegotheles cristatus</i>				X			Irregular visitor

BIRDS	CS	ALA	N	EPBC	BA	BCE	Expected status in project area
MEROPIDAE							
Rainbow Bee-eater <i>Merops ornatus</i>	CS3	X	X	X	X	X	Regular migrant
ALCEDINIDAE							
Laughing Kookaburra <i>Dacelo novaeguineae</i>	Int.	X	X		X		Vagrant
Red-backed Kingfisher <i>Todiramphus pyrrhopygius</i>							Irregular visitor
Sacred Kingfisher <i>Todiramphus sanctus</i>		X	X		X		Regular migrant
CACATUIDAE							
Western Corella <i>Cacatua pastinator</i>						X	Regular visitor
Little Corella <i>Cacatua sanguinea</i>		X	X		X		Irregular visitor
Carnaby's Black-Cockatoo <i>Calyptorhynchus latirostris</i>	E S2	X	X	X	X	X	Regular migrant
Inland Red-tailed Black-Cockatoo <i>Calyptorhynchus banksii escondidus</i>			X			X	Irregular visitor
Galah <i>Eolophus roseicapillus</i>		X	X		X	X	Regular visitor
Cockatiel <i>Nymphicus hollandicus</i>		X					Vagrant
PSITTACIDAE							
Australian Ringneck <i>Barnardius zonarius</i>		X	X		X	X	Resident
Budgerigar <i>Melopsittacus undulatus</i>		X	X		X		Vagrant
Western Ground Parrot <i>Pezoporus flaviventris</i>	Cr S1						Locally extinct?
Elegant Parrot <i>Neophema elegans</i>		X	X		X	X	Regular visitor
Scarlet-chested Parrot <i>Neophema splendida</i>						X	Vagrant
MALURIDAE							
Purple-backed (Variegated) Fairy-wren <i>Malurus assimilis</i>		X				X	Resident
Blue-Breasted Fairy-wren <i>Malurus pulcherrimus</i>		X	X		X	X*	Resident
Splendid Fairy-wren <i>Malurus splendens</i>		X	X		X	X	Resident
White-winged Fairy-wren <i>Malurus leucopterus</i>		X	X		X	X	Resident
Southern Emu-wren <i>Stipiturus malachurus</i>						X*	Resident

BIRDS	CS	ALA	N	EPBC	BA	BCE	Expected status in project area
MELIPHAGIDAE							
Spiny-cheeked Honeyeater		X	X		X	X	Irregular visitor
Western Spinebill		X	X		X		Irregular visitor
Western Wattlebird		X	X		X	X	Regular visitor
Red Wattlebird		X	X		X	X	Regular visitor
Pied Honeyeater						X*	Irregular visitor
White-fronted Chat		X	X		X	X	Irregular visitor
Crimson Chat		X	X		X	X	Irregular visitor
Tawny-crowned Honeyeater		X	X		X	X	Regular visitor
Singing Honeyeater		X			X	X	Resident
Brown Honeyeater		X	X		X	X	Resident
Yellow-throated Miner		X	X		X	X	Regular visitor
Brown-headed Honeyeater		X	X		X		Regular visitor
White-cheeked Honeyeater		X	X		X	X	Resident
New Holland Honeyeater		X	X		X		Irregular visitor
White-fronted Honeyeater		X	X		X	X*	Irregular visitor
Black Honeyeater		X					Irregular visitor
PARDALOTIDAE							
Striated Pardalote		X	X		X	X	Regular visitor
Spotted Pardalote		X	X		X	X	Vagrant
ACANTHIZIDAE							
Inland Thornbill		X	X		X	X	Resident
Yellow-rumped Thornbill		X	X		X		Resident
Western Thornbill		X					Resident
Rufous Fieldwren	CS3		X			X	Resident

BIRDS		CS	ALA	N	EPBC	BA	BCE	Expected status in project area
Shy Heathwren	<i>Calamanthus cautus</i>	CS3				X		Regular visitor
Western Gerygone	<i>Gerygone fusca</i>		X	X		X	X	Regular visitor
White-browed Scrubwren	<i>Sericornis frontalis</i>		X	X		X	X	Resident
Weebill	<i>Smicronis brevirostris</i>		X	X		X	X	Resident
POMATOSTOMIDAE								
White-browed Babbler	<i>Pomatostomus superciliosus</i>	CS3	X	X		X		Vagrant
CAMPEPHAGIDAE								
Black-faced Cuckoo-shrike	<i>Coracina novaehollandiae</i>		X	X		X	X	Regular visitor
White-winged Triller	<i>Lalage sueurii</i>		X			X	X	Regular visitor
PACHYCEPHALIDAE								
Grey Shrike-thrush	<i>Colluricincla harmonica</i>		X	X		X	X	Resident
Rufous Whistler	<i>Pachycephala rufiventris</i>		X	X		X	X	Resident
Western Whistler	<i>Pachycephala occidentalis</i>		X			X	X	Irregular visitor
OREOICIDAE								
Crested Bellbird	<i>Oreoica gutturalis</i>		X	X		X	X	Resident
PSOPHODIDAE								
Western Whipbird	<i>Psophodes nigrogularis</i>							Locally extinct
ARTAMIDAE								
Black-faced Woodswallow	<i>Artamus cinereus</i>		X	X		X	X	Regular visitor
Dusky Woodswallow	<i>Artamus cyanopterus</i>		X	X		X		Irregular visitor
Masked Woodswallow	<i>Artamus personatus</i>		X					Vagrant
Pied Butcherbird	<i>Cracticus nigrogularis</i>		X	X		X	X	Resident
Australian Magpie	<i>Cracticus tibicen</i>		X	X		X		Resident
Grey Butcherbird	<i>Cracticus torquatus</i>		X	X		X	X*	Resident
Grey Currawong	<i>Strepera versicolor</i>		X	X		X		Irregular visitor
RHIPIDURIDAE								
Grey Fantail	<i>Rhipidura albiscapa</i>		X	X		X		Regular visitor

BIRDS	CS	ALA	N	EPBC	BA	BCE	Expected status in project area
Willie Wagtail <i>Rhipidura leucophrys</i>		X	X		X	X	Resident
CORVIDAE							
Little Crow <i>Corvus bennetti</i>		X	X		X	X	Regular visitor
Australian Raven <i>Corvus coronoides</i>		X	X		X	X	Resident
MONARCHIDAE							
Magpie-Lark <i>Grallina cyanoleuca</i>		X	X		X	X	Resident
Restless Flycatcher <i>Myiagra inquieta</i>			X				Vagrant
PETROICIDAE							
Southern Scrub-robin <i>Drymodes brunneopygia</i>		X	X		X		Vagrant
White-breasted Robin <i>Eopsaltria georgiana</i>		X	X		X		Resident
Hooded Robin <i>Melanodryas cucullata</i>		X			X	X*	Resident
Red-capped Robin <i>Petroica goodenovii</i>		X	X		X	X	Resident
NECTARINIIDAE							
Mistletoebird <i>Dicaeum hirundinaceum</i>		X	X		X	X	Regular visitor
ESTRILDIDAE							
Zebra Finch <i>Taeniopygia guttata</i>		X				X	Irregular visitor
MOTACILLIDAE							
Australian Pipit <i>Anthus novaeseelandiae</i>		X			X	X	Resident
MEGALURIDAE							
Brown Songlark <i>Cincloramphus cruralis</i>		X			X	X	Irregular visitor
Rufous Songlark <i>Cincloramphus mathewsi</i>		X			X	X	Regular visitor
HIRUNDINIDAE							
White-backed Swallow <i>Cheramoeca leucosterna</i>		X	X		X	X	Regular visitor
Welcome Swallow <i>Hirundo neoxena</i>		X	X		X	X	Regular visitor
Fairy Martin <i>Petrochelidon ariel</i>		X	X		X		Regular visitor
Tree Martin <i>Petrochelidon nigricans</i>		X	X		X	X	Regular visitor

BIRDS	CS	ALA	N	EPBC	BA	BCE	Expected status in project area
ZOSTEROPIDAE							
Silvereye <i>Zosterops lateralis</i>		X	X		X	X	Regular visitor
Total Number of Species Expected:	123	9				44	

MAMMALS	CS	ALA	N	EPBC	BCE	Expected status in project area
TACHYGLOSSIDAE						
Echidna <i>Tachyglossus aculeatus</i>					X	Resident
DASYURIDAE						
Chuditch <i>Dasyurus geoffroii</i>	V S3			X		Locally extinct
Dibbler <i>Parantechinus apicalis</i>	E S2			X		Locally extinct
Little Dunnart <i>Sminthopsis aff. dolichura</i>					X	Resident
Grey-bellied Dunnart <i>Sminthopsis fuliginosa</i>						Resident
White-tailed Dunnart <i>Sminthopsis granulipes</i>					X	Resident
THYLACOMYIDAE						
Greater Bilby <i>Macrotis lagotis</i>	V S3					Locally extinct
PERAMELIDAE						
Boodie <i>Bettongia lesueur</i>	V S2					Locally extinct
Quenda <i>Isodon fusciventer</i>	P4					Locally extinct
Western Barred Bandicoot <i>Perameles bougainville</i>	E S3					Locally extinct
TARSIPEDIDAE						
Honey Possum <i>Tarsipes rostratus</i>					X	Resident
PHALANGERIDAE						
Australian Brushtail Possum <i>Trichosurus vulpecula</i>	CS3				X?	Vagrant
POTOROIDAE						
Woylie <i>Bettongia penicillata</i>	E S1					Locally extinct

MAMMALS		CS	ALA	N	EPBC	BCE	Expected status in project area
MACROPODIDAE							
Tammar Wallaby	<i>Macropus eugenii</i>	P4					Locally extinct
Western Grey Kangaroo	<i>Macropus fuliginosus</i>		X	X		X	Resident
Banded Hare-Wallaby	<i>Lagostrophus fasciatus</i>	V S3					Locally extinct
Brush Wallaby	<i>Notamacropus irma</i>	P4		X		X	Resident
MEGADERMATIDAE							
Ghost Bat	<i>Macroderma gigas</i>	V S3					Locally extinct
MOLOSSIDAE							
White-striped Freetail-Bat	<i>Austronomus australis</i>					X	Regular visitor
VESPERTILIONIDAE							
Gould's Wattled Bat	<i>Chalinolobus gouldii</i>					X	Regular visitor
Chocolate Wattled Bat	<i>Chalinolobus morio</i>		X	X		X	Resident
Lesser Long-eared Bat	<i>Nyctophilus geoffroyi</i>					X	Resident
Southern Forest Bat	<i>Vespadelus regulus</i>						Regular visitor
MURIDAE							
Rakali	<i>Hydromys chrysogaster</i>	P4		X			Vagrant
Noodji	<i>Pseudomys albocinereus</i>					X	Resident
Shark Bay Mouse, Djoongarri	<i>Pseudomys fieldi</i>	V S3					Locally extinct
Moodit	<i>Rattus fuscipes</i>			X			Resident
Pale Field Rat	<i>Rattus tunneyi</i>						Locally extinct
Number of native species expected (not including locally extinct):		15	3				
INTRODUCED MAMMALS							
Dog, Dingo	<i>Canis lupus</i>	Int.	X		X		Irregular visitor
Goat	<i>Capra hircus</i>	Int.	X	X	X	X	Regular visitor
Horse	<i>Equus caballus</i>	Int.					Vagrant
Cat	<i>Felis catus</i>	Int.	X	X	X	X	Resident
House Mouse	<i>Mus musculus</i>	Int.	X	X	X	X	Resident
Rabbit	<i>Oryctolagus cuniculus</i>	Int.		X	X	X	Resident

MAMMALS	CS	ALA	N	EPBC	BCE	Expected status in project area
Black Rat <i>Rattus rattus</i>	Int.		X			Irregular visitor
Pig <i>Sus scrofa</i>	Int.			X	X	Irregular visitor
Red Fox <i>Vulpes vulpes</i>	Int.	X	X	X	X	Resident
Number of introduced mammals:	9					

Appendix 8. Species returned in database searches but unlikely to occur in the project area

Database searches often return species found nearby but that are unlikely to be present in the project area due to lack of suitable habitat (e.g. marine species) or ecological barriers preventing them from reaching the area (e.g. island species). There are also some errors, out-of-date Latin names, zoo specimens and subtleties of distribution that are not recognised in databases. The species listed below are considered highly unlikely to be found in the project area (although some bird species could occur as very rare vagrants, such as marine species flying overhead). Notes are made on why species have been excluded.

Species		Comments
ARACHNIDA		
Shield-backed Trapdoor Spider	<i>Idiosoma nigrum</i>	Out of range and old taxonomy
FISH		
Twospot Goby	<i>Eviota bimaculata</i>	Out of range and no suitable habitat
Black-throated Threefin	<i>Helcogramma decurrens</i>	Out of range and no suitable habitat
Many-spotted Blenny	<i>Laiphognathus multimaculatus</i>	Out of range and no suitable habitat
Yellow-striped Leatherjacket	<i>Meuschenia flavolineata</i>	Out of range and no suitable habitat
Wavy Grubfish	<i>Parapercis haackei</i>	Out of range and no suitable habitat
Miller's Damsel fish	<i>Pomacentrus milleri</i>	Out of range and no suitable habitat
Yellowfin Dottyback	<i>Pseudochromis wilsoni</i>	Out of range and no suitable habitat
Western Red Scorpionfish	<i>Scorpaena sumptuosa</i>	Out of range and no suitable habitat
Viviparous Brotula	<i>Zephyrichthys barryi</i>	Out of range and no suitable habitat
Green Swordtail	<i>Xiphophorus helleri</i>	Out of range and no suitable habitat
REPTILES		
Central Notted Dragon	<i>Ctenophorus nuchalis</i>	No suitable habitat
Goldfields Pebble-mimic Dragon	<i>Tympanocryptis pseudopsephos</i>	Out of range
Bar-Shouldered Ctenotus	<i>Ctenotus inornatus</i>	Out of range
Western Spiny-tailed Skink	<i>Egernia stokesii badia</i>	No suitable habitat
BIRDS		
Brown Quail	<i>Coturnix ypsilophora</i>	Out of range
Black Swan	<i>Cygnus atratus</i>	No suitable habitat
Australian Shelduck	<i>Tadorna tadornoides</i>	No suitable habitat
Australasian Shoveler	<i>Anas rhynchos</i>	No suitable habitat
Pacific Black Duck	<i>Anas superciliosus</i>	No suitable habitat
Grey Teal	<i>Anas gracilis</i>	No suitable habitat
Australian Wood Duck	<i>Chenonetta jubata</i>	No suitable habitat
Musk Duck	<i>Biziura lobata</i>	No suitable habitat
Hoary-headed Grebe	<i>Poliiocephalus poliocephalus</i>	No suitable habitat
Australasian Grebe	<i>Tachybaptus novaehollandiae</i>	No suitable habitat
Straw-necked Ibis	<i>Threskiornis spinicollis</i>	No suitable habitat

Species		Comments
Red-capped Plover	<i>Charadrius ruficapillus</i>	No suitable habitat
Bar-tailed Godwit	<i>Limosa lapponica</i>	No suitable habitat
Red-necked Stint	<i>Calidris ruficollis</i>	No suitable habitat
Common Sandpiper	<i>Actitis hypoleucos</i>	No suitable habitat
Sharp-tailed Sandpiper	<i>Calidris acuminata</i>	No suitable habitat
Red Knot	<i>Calidris canutus</i>	No suitable habitat
Curlew Sandpiper	<i>Calidris ferruginea</i>	No suitable habitat
Pectoral Sandpiper	<i>Calidris melanotos</i>	No suitable habitat
Eastern Curlew	<i>Numenius madagascariensis</i>	No suitable habitat
Common Greenshank	<i>Tringa nebularia</i>	No suitable habitat
Eurasian Coot	<i>Fulica atra</i>	No suitable habitat
White-necked Heron	<i>Ardea pacifica</i>	No suitable habitat
White-faced Heron	<i>Ardea novaehollandiae</i>	No suitable habitat
Eastern Great Egret	<i>Ardea modesta</i>	No suitable habitat
Eastern Reef Egret	<i>Egretta sacra</i>	No suitable habitat
Cattle Egret	<i>Ardea ibis</i>	No suitable habitat
Little Pied Cormorant	<i>Microcarbo melanoleucos</i>	No suitable habitat
Black Cormorant	<i>Phalacrocorax carbo</i>	No suitable habitat
Little Black Cormorant	<i>Phalacrocorax sulcirostris</i>	No suitable habitat
Pied Cormorant	<i>Phalacrocorax varius</i>	No suitable habitat
Australasian Darter	<i>Anhinga novaehollandiae</i>	No suitable habitat
Eastern Osprey	<i>Pandion cristatus</i>	No suitable habitat
Osprey	<i>Pandion haliaetus</i>	Old taxonomy
Black-breasted Buzzard	<i>Hamirostra melanosternon</i>	Out of range
White-bellied Sea-Eagle	<i>Haliaeetus leucogaster</i>	No suitable habitat
Grey Wagtail	<i>Motacilla cinerea</i>	Out of range
Chestnut-rumped Thornbill	<i>Acanthiza uropygialis</i>	Out of range
Jacky Winter	<i>Microeca fascinans</i>	Out of range
Eurasian Tree Sparrow	<i>Passer montanus</i>	Out of range
Australian Reed-Warbler	<i>Acrocephalus australis</i>	No suitable habitat
Total Number of Species:	55	

Appendix 9. Fauna observations made during site inspection 19-20 August 2020.

Trap-door spider *Idiosoma* sp. Typical *idiosoma* burrow with ornate lid with a lot of vertical material. In dark loamy-clay of dampland. No constriction.

1. Crawling Toadlet. Tadpoles in flooded area.
2. Heath Dragon. Several active.
3. Spotted Dragon. Several active.
4. Thorny Devil. One on Mt Adams Road.
5. Emu. Tracks, including of a chick.
6. Banded Lapwing. Two flew overhead on 20/08.
7. Common Bronzewing. One flushed from Dampland Thicket.
8. Crested Pigeon. One along Mt Adams Rd.
9. Brown Falcon. Pair south of Mt Adams Rd.
10. Galah. About 10 along Mt Adams Rd.
11. Carnaby's Black-Cockatoo. Recent foraging on seeds (not grubs) of *B. attenuata*; widespread. *Banksia hookeriana* and *B. leptophylla* flower chewed. Eight feeding on flowers of *B. hookeriana*; only one male among them. Two pairs nearby. Just south of Mt Adams Rd (20/08).
12. Horsfield's Bronze-Cuckoo. One calling.
13. Blue-breasted Fairy-wren. Seen and heard in kwongan.
14. White-winged Fairy-wren. Heard in kwongan.
15. White-browed Scrubwren. Seen and heard in Dampland Thickets.
16. Rufous Fieldwren. Heard in kwongan.
17. Red Wattlebird. One seen in *B. prionotes*.
18. Western Wattlebird. Few in *B. prionotes*.
19. White-cheeked Honeyeater. Small numbers throughout.
20. Tawny-crowned Honeyeater. Small numbers throughout.
21. Brown Honeyeater. Small numbers throughout.
22. White-fronted Honeyeater. Several seen and more heard; generally around Dampland Thickets.
23. Singing Honeyeater. Small numbers throughout.
24. Western (Golden) Whistler. One calling from Dampland Thicket.
25. Rufous Whistler. One calling from scattered *M. menziesii*.
26. Crested Bellbird. Several heard in kwongan.
27. Black-faced Cuckoo-shrike. Two seen.
28. Black-faced Woodswallow. Few singles and pairs in kwongan.
29. Grey Butcherbird. One collecting nesting material.
30. Australian Raven. Two birds seen on 20/08.
31. Mistletoebird. One heard.
32. Echidna. Fresh tracks and diggings.
33. Western Grey Kangaroo. Small group in Kwongan.
34. Red Fox. Tracks and an earth.
35. Rabbit. Scats and diggings.

Appendix 10. Fauna observations made during field investigations, 1-10 December 2021.

1. *Diplodactylus ornatus*. One found under bark at base of *Banksia* near Line 4 (2/12). Several pitfalled. Difficult to distinguish from *D. granariensis* and earlier records of *D. granariensis* in Tronox lease may be an error.
2. *Lucasium alboguttatum*. Several caught in pitfalls.
3. *Strophurus spinigerus*. Several caught in pitfalls. Also found regularly in dead shrubs burnt about two years previously.
4. *Pygopus lepidopodus*. One seen along Line 1 (2/12).
5. *Delma greyii*. Caught in funnels at several sites.
6. *Ctenophorus adelaidensis*. Abundant in Kwongan and caught regularly.
7. *Ctenophorus maculatus*. Abundant in Kwongan tending more to heavier soils of damplands and valleys, and in more recently-burnt areas. Caught regularly.
8. *Pogona minor*. Pitfalled regularly.
9. *Cryptoblepharus buchanani*. Several caught in pitfalls.
10. *Ctenopus fallens*. Several caught in pitfalls and funnels.
11. *Lerista elegans*. One caught along line 2.
12. *Lerista planiventralis*. Pitfalled at several sites.
13. *Lerista praepedita*. Two pitfalled line 2.
14. *Morethia lineoocellata*. One pitfalled Line 2.
15. *Tiliqua rugosa*. One along Mt Adams Road in Yandanogo NR and one along Beharra Springs Road.
16. Emu. Scats scattered throughout. Fresh tracks seen regularly.
17. Crested Pigeon. Few seen along Mt Adams Road.
18. Brown Falcon. One near line 4 (2/12) and pair over same area on 3/12.
19. Nankeen Kestrel. Pair near intersection of Mt Adams Road and Beharra lease (2/12).
20. Painted Button-quail. Recorded on motion-sensitive cameras.
21. Little Button-quail. Several flushed each day including from recently burnt areas. Chicks seen nearby.
22. Fork-tailed Swift. About 10 over Port Denison evening of 8/12.
23. Rufous Fieldwren. Heard occasionally in Kwongan.
24. Southern Emu-wren. Groups heard (rarely seen) occasionally.
25. Blue-breasted Fairy-wren. Party along line 1; seen very reliably.
26. Purple-backed Fairy-wren. Groups seen and heard regularly including t same location as BbFw alongline 1.
27. White-winged Fairy-wren. Groups seen and heard regularly.
28. White-browed Scrubwren. Occasional parties throughout.
29. Rufous Fieldwren. Heard occasionally in kwongan.
30. Singing Honeyeater. Individual birds seen occasionally.
31. Tawny-crowned Honeyeater. Seen and heard regularly. Occasional groups of up to 16 birds.
32. Brown Honeyeater. Seen and heard regularly.
33. Pied Honeyeater. Several uncoloured birds along Line 4 (6/12) and few seen along line 1.
34. White-cheeked Honeyeater. Few heard along line 1 on one occasion.
35. Crimson Chat. Single bird seen along Line 4 (6/12).
36. Willie Wagtail. Pair along Mt Adams Road.
37. Black-faced Woodswallow. Groups of two or three birds seen occasionally.
38. White-winged Triller. Small group regularly across kwongan. All uncoloured birds.
39. Tree Martin. Small groups seen occasionally.

40. Silvereye. Small group seen along Line 2 (6/12).
41. Echidna. Some foraging holes seen. One animal observed near Dongara (7/12).
42. *Sminthopsis granulipes*. Several pitfalled on line 3 (burnt about 2 year previously).
43. Western Grey Kangaroo. Few groups of three animals seen but generally in low numbers in native vegetation.
44. Noodji. Few caught on lines 1, 2 and 3.
45. *Mus musculus*. Caught in small numbers at all sites; most abundant at line 4.
46. Fox. Tracks throughout.
47. Rabbit. Tracks along roads and around line 4.

Appendix 11. Results from motion-sensitive cameras set in December 2021.

Date set	Date collected	Camera code	N photos	N events	Species
4/12/2021	6/12/2021	BCE 01	18	-	NIL
		BCE 03	NIL	-	
3/12/2021	10/12/2021	BCE 05	154	3	Painted Button-quail with single chick
5/12/2021	9/12/2021	BCE 06	1087	3	House Mouse
2/12/2021	10/12/2021	BCE 11	6478	1	Western Grey Kangaroo
				1	House Mouse
				1	West Coast Ctenotus
2/12/2021	6/12/2021	BCE 13	8516	2	Western Grey Kangaroo
4/12/2021	8/12/2021	BCE 17	14274	1	House Mouse
				1	West Coast Ctenotus
4/12/2021	9/12/2021	BCE 20	54	6	House Mouse
4/12/2021	9/12/2021	BCE 23	126	2	House Mouse
				1	Cat
6/12/2021	10/12/2021	BCE C2	226	-	NIL