Fauna Assessment of Arrowsmith North

Extensive Kwongan in the VRX Arrowsmith North Survey Area (M. Bamford)

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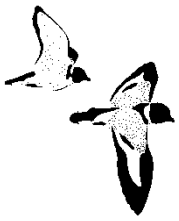

4th April 2022 Revised 20/12/22

Executive Summary

VRX Silica Ltd is proposing to develop the Arrowsmith North Project (Project) a silica sand mine approximately 270 km North of Perth, Western Australia. VRX has commissioned Bamford Consulting Ecologists (BCE) to conduct detailed (level 2) and targeted fauna investigations to inform the impact assessment process. This assessment provides information on the fauna values of the Survey Area, particularly for conservation significant species.

BCE uses a 'values and impacts' assessment process with the following components:

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

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

The Survey Area was visited on 18th November 2018 for an initial site walkover, with a targeted survey being conducted between 23rd and 25th October 2019, and with further targeted survey work and detailed (level 2) investigations undertaken from 1st to 9th December 2021. The primary aims of the survey conducted in October 2019 was to assess how Carnaby's Black-Cockatoo utilises the landscape in the area, to undertake an aural survey for the Western Ground Parrot, to develop descriptions of Vegetation and Substrate Associations (VSAs), and to make opportunistic fauna observations. The December 2021 survey involved inspecting the alignment for a proposed access corridor, which had not been visited previously, and included some additional targeted survey work and some general trapping, thus extending the investigations to a detailed survey (formerly Level 2). The December 2021 work coincided with a comprehensive detailed survey on an adjacent property for another client, and some targeted black-cockatoo work on a third property nearby. The general area had previously been visited and surveyed intensively (2007-2012) for another resource development company (Tiwest Joint Venture; now Tronox), with multiple previous reports from that and several other studies available. A review of fauna data for the general area was undertaken, accessing a range of databases but also utilising several detailed fauna surveys previously undertaken by BCE adjacent to the lease.

Description of Survey Area

The Project consists of a mine area located wholly within mining lease (M 70/1389) and an access (transport) corridor to the south of this lease. The Project lies entirely within a broader Survey Area. The vegetation of the Survey Area primarily consists of Kwongan (heath or shrubland) on sand. There is a linear, seasonal dampland in the west of the mining lease and running south parallel to and partly overlapping with the access route. This supports denser vegetation than the higher ground of the lease and part of the access route. Towards the south of the access route there is a drainage line that runs into the Arrowsmith River, and a large wetland (Arrowsmith Lake) lies just outside the access route. The Project lies within a large region of mostly undisturbed native vegetation along the coastal plain, with conservation reserves bordering the south-west, north and south boundaries. The Project lies within the Lesueur Sandplain subregion of the Geraldton bioregion.

The Survey Area supports three Vegetation and Substrate Associations. Kwongan Heath on sand (VSA 1) is most widespread in the mining lease; the lease also has small areas of Riparian Thicket (VSA 2) that lie low in the landscape, and small areas of Banksia Open Woodland (VSA 3) that are scattered through and merge with VSA 1. The access corridor supports VSAs 1 and 2, with a distinctive area of *Eucalyptus erythrocorys* Low Woodland on limestone derived soils (VSA 4), just outside the southern end of the access corridor. Arrowsmith Lake also lies outside the southern end of the access corridor.

Key fauna values

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

Fauna assemblage. A rich assemblage but incomplete with some locally extinct mammal species, and possibly an extinct reptile and bird species. Extinctions most likely due to impacts from introduced predators and possibly altered fire regimes. Assemblage is typical of the Lesueur Sandplains subregion. It is notable for high reptile species richness and a high proportion of non-resident birds, many of which are seasonal visitors to exploit seasonal nectar resources.

Species of conservation significance. Few species of high conservation significance are present or expected, but the Carnaby's Black-Cockatoo is important and forages in the area. There are also roosting records for the species nearby, but no confirmed nearby breeding. Despite this, there is potential breeding habitat within a few kilometres of the Survey Area (large eucalypts along wetlands to the east and large eucalypts along the Arrowsmith River to the south). Vegetation within the Survey Area represents foraging habitat of at least moderate value for the species. The locally significant Rufous Fieldwren and Shy Heathwren have been recorded within the Survey Area or nearby and the Rainbow Bee-eater, formerly listed as Migratory under federal and state legislation and still of local significance, is almost certainly a breeding visitor. There are unconfirmed records of the Critically Endangered Western Ground Parrot in the region, and of the Vulnerable Malleefowl. The Woma (python), listed as Priority 1, may also be present but, like the Western Ground Parrot, may be locally extinct. Surveys for these three species failed to confirm their presence; the Malleefowl is almost certainly not present (based on searching and lack of records), but the Western Ground Parrot and Woma are extremely cryptic species that may be overlooked. Several conservation significant invertebrates have been recorded or may be present. Landscape features suggest there may be an

assemblage of Short Range Endemic Invertebrates (SREs) present, particularly in low-lying areas (VSA 2) and where limestone underlies the landscape (VSA 4).

Patterns of biodiversity. Within the Survey Area all VSAs are intact and likely to support a high level of species richness. VSA 1 (Kwongan heath) is by far the most extensive and is likely to have a rich assemblage of reptiles and small mammals. These assemblages have been affected by the fire regime of the region and by introduced predators. VSA 2 is likely to have some species not found or uncommon elsewhere due to the dense, moderately tall vegetation and slightly moister condition. VSAs 2 and 4 have potential for SRE and other significant invertebrates due to these VSAs being small in extent, distinctive and having seasonal mesic conditions. VSA 4 also has potential for significant invertebrates, possibly including subterranean fauna, due to the presence of limestone. Arrowsmith Lake is locally important for waterbirds and other aquatic fauna and while it is outside the project area, it may be linked via hydrology.

Key ecological processes. The main processes which may affect the fauna assemblage are likely to be local hydrology, the fire regime and the presence of feral predators including Red Fox and Feral Cat.

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1 Introduction

VRX Silica Ltd is proposing to develop the Arrowsmith North Project (Project), a silica sand mine approximately 270 km north of Perth in Western Australia (see Figure 1). The Project lies within mining lease M 70/1389 which is located east of Brand Highway between Dongara and Eneabba. The Project includes the development of an access route south to the Brand Highway. Bamford Consulting Ecologists (BCE) was commissioned to provide information on the fauna values within a broader Survey Area (Figure 2) (particularly for significant species), to give an overview of the ecological function of the site within the local and regional contexts, and to provide discussion on the interaction of development on the site with these fauna values and functions. Investigations undertaken included an initial Basic (*sensu* EPA 2020) assessment of fauna values (desktop review and site inspection), followed by targeted and detailed (formerly Level 2; EPA 2020) surveys, undertaken in conjunction with other studies carried out in the Survey Area. These investigations focussed on the vertebrate fauna assemblage, but the Basic assessment did consider desktop information on invertebrates and opportunistic observations on invertebrates did take place. Separate invertebrate studies were undertaken by Bennelongia (2022). This report presents the results of the investigations carried out by BCE.

Figure 1. Location plan for Arrowsmith North.

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 impact assessment process with the following components:

- The identification of fauna values:
    - Assemblage characteristics: uniqueness, completeness and richness;
    - Species of conservation significance;
    - Recognition of ecotypes or vegetation/substrate associations (VSAs) that provide habitat for fauna, particularly those that are rare, unusual and/or support significant fauna;
    - Patterns of biodiversity across the landscape; 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.

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 (CS2), and those that can be considered of local or other significance, but which have no formal listing (CS3). Appendix 2 describes threatening processes, while Appendix 3 outlines the legal definitions and classes of conservation significance, and Appendix 4 presents the threatening processes recognised under legislation. This report focusses on the fauna values and the review of impacting processes is being developed separately.

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 any field investigations necessary to supplement information obtained from the literature and database review, and to ensure familiarity with the Survey Area;
3. Review the list of fauna expected to occur on the Survey Area 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, and
7. Identify potential impacts upon fauna and propose recommendations to avoid, reduce or mitigate impacts.

As noted above, this report presents the results of the literature review and field investigations into fauna values; assessments of impacts and provision of recommendations are presented elsewhere.

1.3 Description of Survey Area and background environmental information

1.3.1 Survey area

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

The Survey Area is located in the Shire of Irwin and lies within a broad area of native vegetation with some agricultural clearing just to the west (Figure 2). Apart from minor tracks and exploration lines, the vegetation is undisturbed. Yardanogo Nature Reserve lies to the north, and Beekeepers' Nature Reserve to the south, while there are nearby mineral and silica sands leases to the north (Perpetual Nominees Beharra Springs Silica project) and north-east (Tronox Dongara Mineral Sands Project).

The Survey Area supports intact native vegetation with Kwongan heath over much of the landscape, and thickets and woodlands along drainage lines and dampland areas. There are no permanent water courses within the Survey Area, however an intermittent drainage system is located in the western part of the Survey Area and adjacent to the access corridor, and a larger (but also seasonal) drainage system, including some broad wetlands, lies about 500m to the east (outside the Survey Area). Vegetation and Substrate Associations are described in detail in Section 3.1. Aerial imagery shows fire has affected the northern half of the project area as recently as 2012, while the most recent burn in the southern part was in 2007 (Figure 3).

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

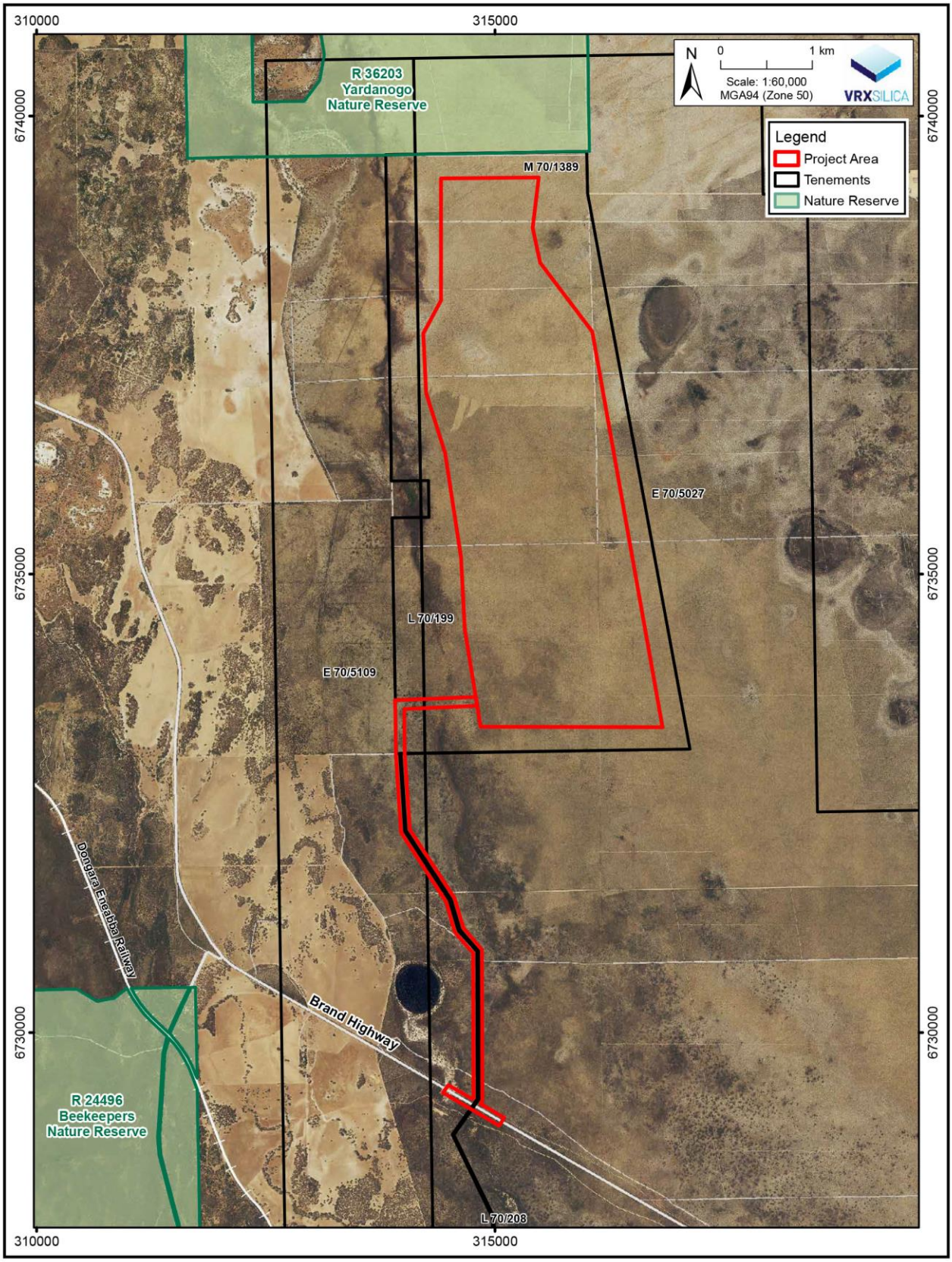
The Interim Biogeographic Regionalisation of Australia (IBRA) has identified 26 bioregions in Western Australia which are further divided into subregions (DAWE 2020a). Bioregions are classified on the basis of climate, geology, landforms, vegetation and fauna (Thackway and Cresswell 1995). IBRA Bioregions are affected by a range of different threatening processes and have varying levels of sensitivity to impact (EPA 2004). The Survey Area lies within the Lesueur Sandplain (GES02) subregion of the Geraldton Sandplains bioregion, comprising coastal Aeolian and limestones of the central Perth basin overlain with shrub-heaths and rich in endemic plants (Figure 4). 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. The dominant land uses in this bioregion are agriculture, conservation reserves and crown reserves.

1.3.3 Climate information

The Survey Area lies within the South-West botanical province of Western Australia's Southern climatic region. The Survey 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 5.

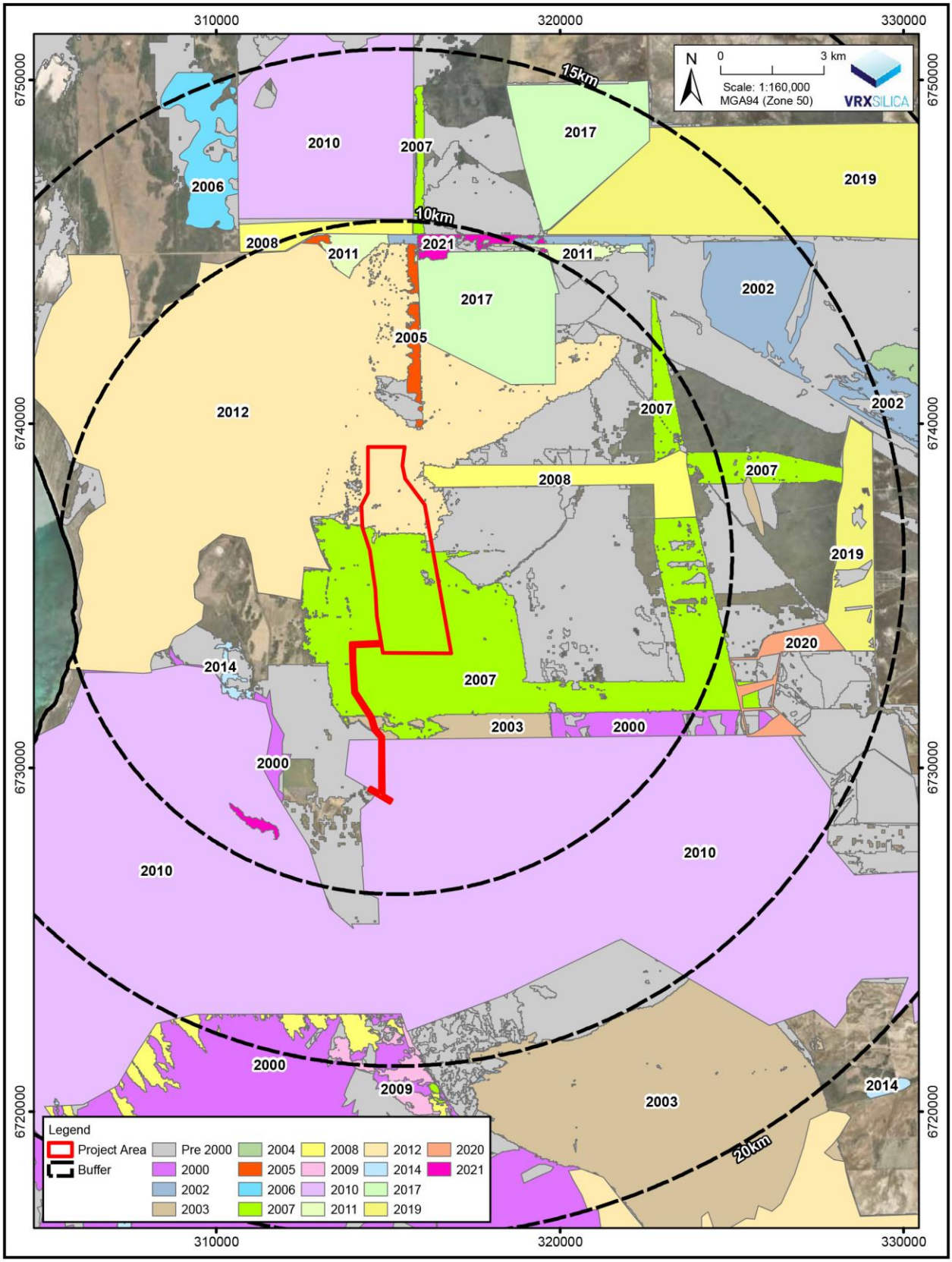
1.4 Project Description

The Project involves extraction of high-quality silica sand which lies close to the surface. Mined areas are proposed to be progressively rehabilitated using Vegetation Direct Transfer (VDT) and infill planting. VDT occurs before the extraction of the resource. VDT includes mulching, removal and relocation of topsoil (including plant stems and root stock *in situ*) in blocks of about 3 m square and 0.5 m deep. This is intended to be placed directly on areas following sand extraction. The VDT process is provided in a video by VRX: https://vrxsilica.com.au/miningandrehabilitationmethodology/. The potential effectiveness of this as a rehabilitation technique is discussed by Bamford (2020), including potential value as foraging habitat for Carnaby's Black-Cockatoo (a key significant species in the region).



Source: Aerial Photography: Landgate (Nov 2016), Tenements: DMIRS
Author: Bamford Consulting Ecologists, Drawn: CAD Resources (08 9246 3242), Date: Mar 2022, CAD Ref: a2602_f55_01, Rev: A

Figure 2. VRX Silica Arrowsmith North Project Area.



Source: Aerial Photography: Landgate (Nov 2016), Tenements: DMIRS
Author: Bamford Consulting Ecologists, Drawn: CAD Resources (08 9246 3242), Date: Mar 2022, CAD Ref: a2602_f55_02, Rev: A

Figure 3. Recent fire history in the vicinity of the Project Area.

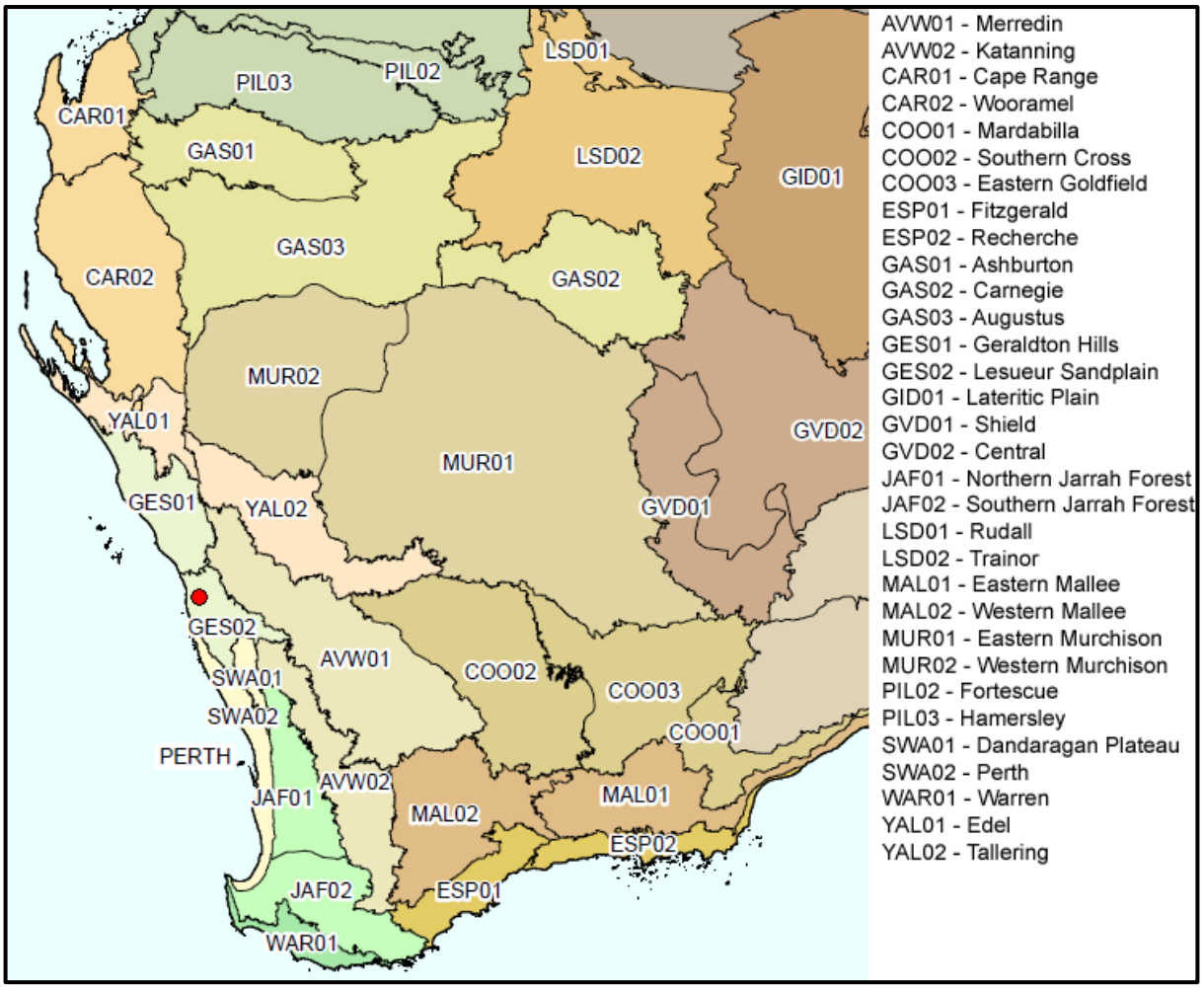


Figure 4. Bioregions across Western Australia; project area is located in the Lesueur Sandplain subregion and indicated by a red dot.

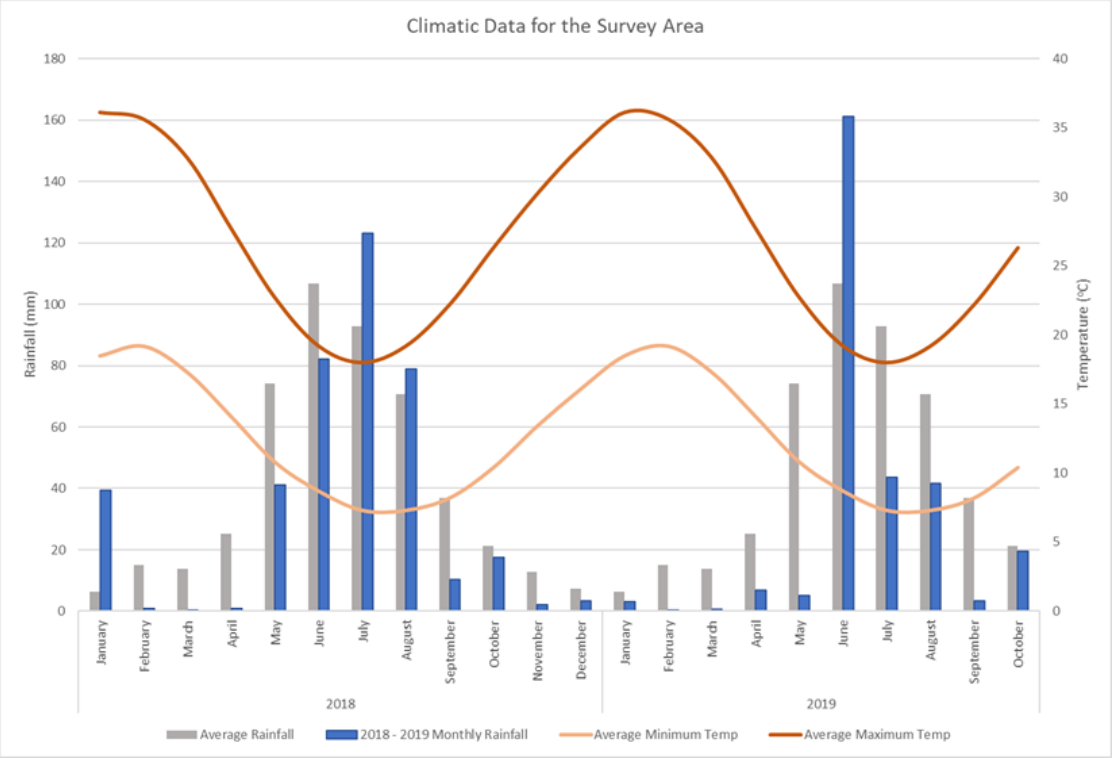


Figure 5. Climatic data from Green Grove, near Carnamah.

2 Methods

2.1 Overview

2.1.1 *Level of investigations*

This approach to fauna impact 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 partly by geographic position, with a statement that detailed surveys are expected across all of the state except the south-west, 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). These aspects should be considered in the context of the information acquired by the desktop study. 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 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.

A 'basic' level survey (desktop review, fauna habitat identification and a site inspection) and targeted investigations are considered appropriate for the Project. This is based upon the level of existing knowledge (which is extensive; see section 2.2.2 below), the extent, distribution and significance of habitats (widespread) and the significance of species likely to be present (generally a limited assemblage of significant species). There is a slight possibility of the Western Ground Parrot being present, suggesting survey to target this species (surveys conducted and outlined below). Conducting a detailed survey is suggested only by the potential value of abundance and habitat information for regional management in reserves, and in other proposed developments, all of which will have a rehabilitation component. In this case, basic and targeted surveys were undertaken, with some components of a detailed survey, supplemented by a more comprehensive detailed survey undertaken to the north at the same time. 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 three groupings that relate to the stages and the objectives of impact assessment:

- **Desktop assessment.** The purpose of the desktop review is to produce a species list that can be considered to represent the vertebrate fauna assemblage of the project area based on unpublished and published data using a precautionary approach.
- **Field investigations.** The purpose of the field investigations carried out for a Basic assessment is to gather information on the vegetation and soil associations ('habitats') that support the fauna assemblage and place the list generated by the desktop review into the context of the environment of the Survey Area. The brief field investigations that form part of a Basic assessment also allow for some fauna observations to be made and assist the consultant to develop an understanding of the ecological processes that may be operating in the Survey Area.

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.	Existing data reduces need for baseline survey. Similarity/uniformity of environments need to be high to extrapolate from regional knowledge	Extensive regional knowledge from previous detailed, targeted and basic investigations in similar landscapes (see Figure 6).
Type and comprehensiveness of recent local surveys.	*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*	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.	*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*	Broad landscape is intact and well-connected
Extent, distribution and significance of environments	*In general, rare, unusual, restricted and/or environments linked to significant species need more investigation that broad and widely-represented environments due to their likely higher significance for fauna*	Project area supports shrublands (kwongan) typical of the broader region and well-represented in adjacent reserves.
Significance of species likely to be present	*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*	Limited range of significant species present. Desktop review suggests about 13 significant species are now locally extinct. Species that may require investigation (but all may also be locally extinct) 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.	*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*	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.
Scale and nature of impact. Geographic position.	*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 impact area is small in a regional context, due to the large reserve system nearby. Rehabilitation will be carried out including VDT and infill planting. The Project lies in Bioregion group 2, for which the EPA (2016c) suggests detailed surveys

Factor: site and project characteristic	Rationale for decision on level of investigations	Application to current Project
	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	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.
Potential value of presence, abundance and distributional data.	*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).*	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. This is likely to be the case as a novel rehabilitation technique is proposed. The area within and surrounding the project has been subject to multiple fires and there may also be value in investigating impacts of these fires. 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 management.

Table 2. Level of assessment suggested for Arrowsmith North.

- 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/High

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) 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. For this project, the project area and survey area are the same and encompass mining lease M 70/1389 and the access route to the south.

2.2 Desktop Assessment

2.2.1 Sources of information

Information on the fauna assemblage of the desktop survey area(Figure 6) was drawn from a wide range of sources. These included state and federal government databases and results of regional studies. Databases accessed were the Atlas of Living Australia (ALA), the WA Department of Biodiversity, Conservation and Attractions (DBCA) NatureMap (incorporating the Western Australian Museum's FaunaBase and the DBCA Threatened and Priority Fauna Database), BirdLife Australia's Birdata (Atlas) Database (BA), the EPBC Protected Matters Search Tool and the Bamford Consulting Ecologists (BCE) Database (Table 3). A 20 km buffer was considered sufficient due to the extensive work BCE had conducted at this location previously; this buffer is illustrated on Figure 12.

. Information from the above sources was supplemented with species expected in the area based on general patterns of distribution. Sources of information used for these general patterns were:

- Frogs: Tyler *et al.* (2000) and Anstis (2013);
- Reptiles: Storr *et al.* (1983, 1990, 1999 and 2002) and Wilson and Swan (2013);
- Birds: Blakers *et al.* (1984); Johnstone and Storr (1998, 2004), Barrett *et al.* (2003) and Menkhorst *et al.* (2017); and
- Mammals: Menkhorst & Knight (2004); Armstrong, 2011, Churchill (2008); and Van Dyck and Strahan (2008).

Table 3. Database **s**ources of information used in the desktop assessment.

Database	Type of records held on database	Area searched
Atlas of Living Australia (ALA 2019)	Records provided by collecting institutions, individual collectors and community groups	From centroid of project- 29.4883°S, 115.0926°E – plus 20 km buffer.
NatureMap (DBCA 2019a)	Records in the WAM and DPaW databases. Includes historical data and records on Threatened and Priority species in WA.	From centroid of project- 29.4883°S, 115.0926°E – plus 20 km buffer.
BirdLife Australia Birdata (Atlas Database)	Records of bird observations in Australia, 1998-2018.	Approximately 20 km buffer from the project.
EPBC Protected Matters	Records on matters of national environmental significance protected under the EPBC Act.	From centroid of project - 29.4883°S, 115.0926°E – plus 20 km buffer.

2.2.2 Previous fauna surveys

BCE has conducted multiple fauna surveys at Arrowsmith and nearby areas which have included several level 1 assessments (Basic *sensu* EPA 2020), monitoring, targeted fauna assessments and a level 2 (detailed *sensu* EPA 2020) fauna assessment. There have also been studies by other consultants in the region, particularly for the Eneabba mineral sands mine (results collated in BCE desktop reviews). Species records from these studies are contained in the NatureMap database which was consulted as part of the desktop assessment. In addition, BCE 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), Bancroft and Bamford (2020), and Bamford 2020. Some of these studies (Metcalf and Bamford 2008, Bamford 2009, 2012) were undertaken within or immediately adjacent to the Survey Area for Tronox (formerly Tiwest Joint Venture) and included a two-season Level 2 fauna survey. In addition, a detailed (level 2) survey was undertaken at the Beharra Springs Silica Project area immediately to the north of the Survey Area and at the same time as the current investigations (ie December 2021). Other studies occurred within 20 km. All species records used to inform the expected species list for the Survey Area (and the source of the records) are included in Appendix 6. For invertebrates of conservation significance, records from the entire Mid-West region (DBCA 2020a) were accessed from the DBCA threatened and priority fauna list (2019) to produce a broad list that was then interpreted on the basis of the environments within the Survey Area and the distance to the nearest records. Note that a targeted invertebrate survey was undertaken separately (Bennelongia 2021).

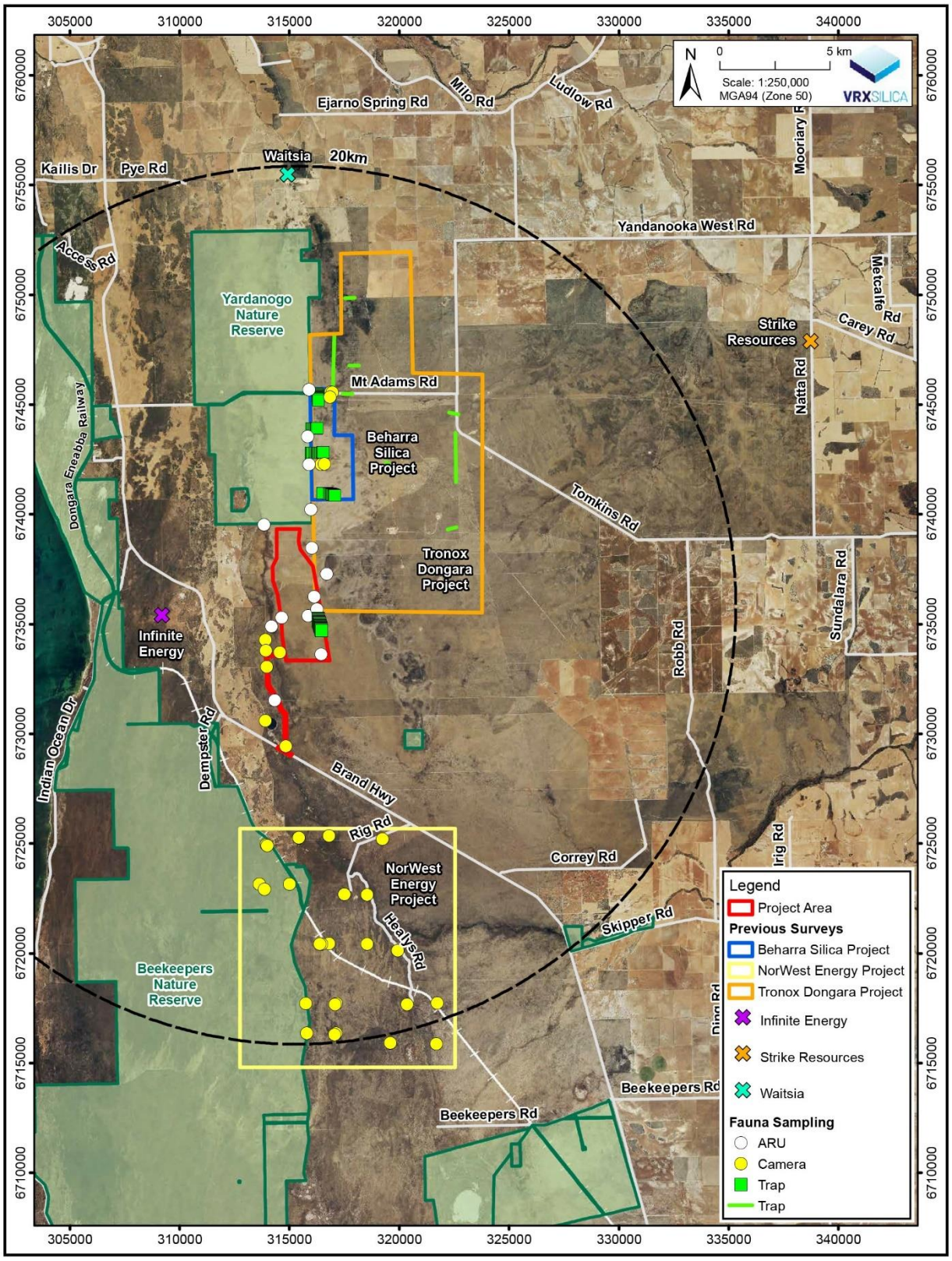
Details of previous studies are summarised below (Table 4). The previous studies used a range of techniques as they were carried out for different purposes but were consistent with guidance at the time. In combination, they are consistent with current (EPA 2020) guidance in the range of techniques used; 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). They were also used at the Beharra Spring site (Bamford and Bancroft 2022). These two detailed (level 2) surveys carried out within about 5km of the Survey Area had two minor deviations from current guidance (EPA 2020). These deviations are discussed below.

Metcalf and Bamford (2008) carried out bat surveys 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 (with understanding landscape function being more important than confirming the presence of a species). Bat surveys were not undertaken by Bamford and Bancroft (2022) on the basis they were not necessary due to previous studies.

In 2007 (Metcalf and Bamford 2008), trapping for small terrestrial vertebrates used pitfall, funnel, Elliott and cage traps; BCE would not use Elliotts and cages in a site such as this now due to the risk to animal welfare. Cages and Elliotts caught nothing not recorded by other means. Traps were run 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. Trapping (pitfall and funnel traps only) was also limited to five nights by Bamford and Bancroft. Despite the EPA's guidance, trapping beyond five nights rarely adds

additional species to the list. Figure 7 presents a simple analysis of the accumulation of species during a trapping program for several sites, including the Tronox Dongara Project area of Metcalf and Bamford (2008). Trapping ran for up to eight nights on some of these 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 suggest any further trap nights would have yielded little. The only species of conservation significance caught by trapping (the Black-striped Snake *Neelaps calonotos*) was recorded on the fourth night; all other species recorded were expected and were not of listed conservation significance. Figure 8 presents the same analysis for trapping at Beharra Springs and VRX Arrowsmith North with similar results. Despite the difference in sampling effort, the number of species and addition of species with additional trapping were similar. The sampling at Arrowsmith North did add one species on the sixth (and last) night. This was the Moaning Frog *Heleioporus eyrei*, previously recorded in the area in several studies and one of the most widespread frogs in the South-West.

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 7, from 15% to 44% of small, terrestrial vertebrates were recorded only by observation/searching. The average proportion of the small, terrestrial vertebrate assemblage recorded only by searching/observation across these projects is 30.3%. The December 2021 trapping at Beharra Springs and VRX Arrowsmith North recorded 16 and 15 species respectively, and a combined total of 19 species. A further four species were found by observation/searching only, representing 17% of the total small vertebrate assemblage recorded. Based on these sorts of observations, the use of five nights trapping by Metcalf and Bamford (2008) and by Bamford and Bancroft (2022) 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 might not detect some that were found in 2007, due to annual variation and Beta diversity (How and Dell 1990, Bamford *et al.* 2010).



Source: Aerial Photography: Landgate (Nov 2016), Tenements: DMIRS
Author: Bamford Consulting Ecologists, Drawn: CAD Resources (08 9246 3242), Date: Apr 2022, CAD Ref: a2602_f55_03, Rev: A

Figure 6. Locations of previous fauna studies undertaken around the project area by BCE. Sampling locations and types are also indicated.

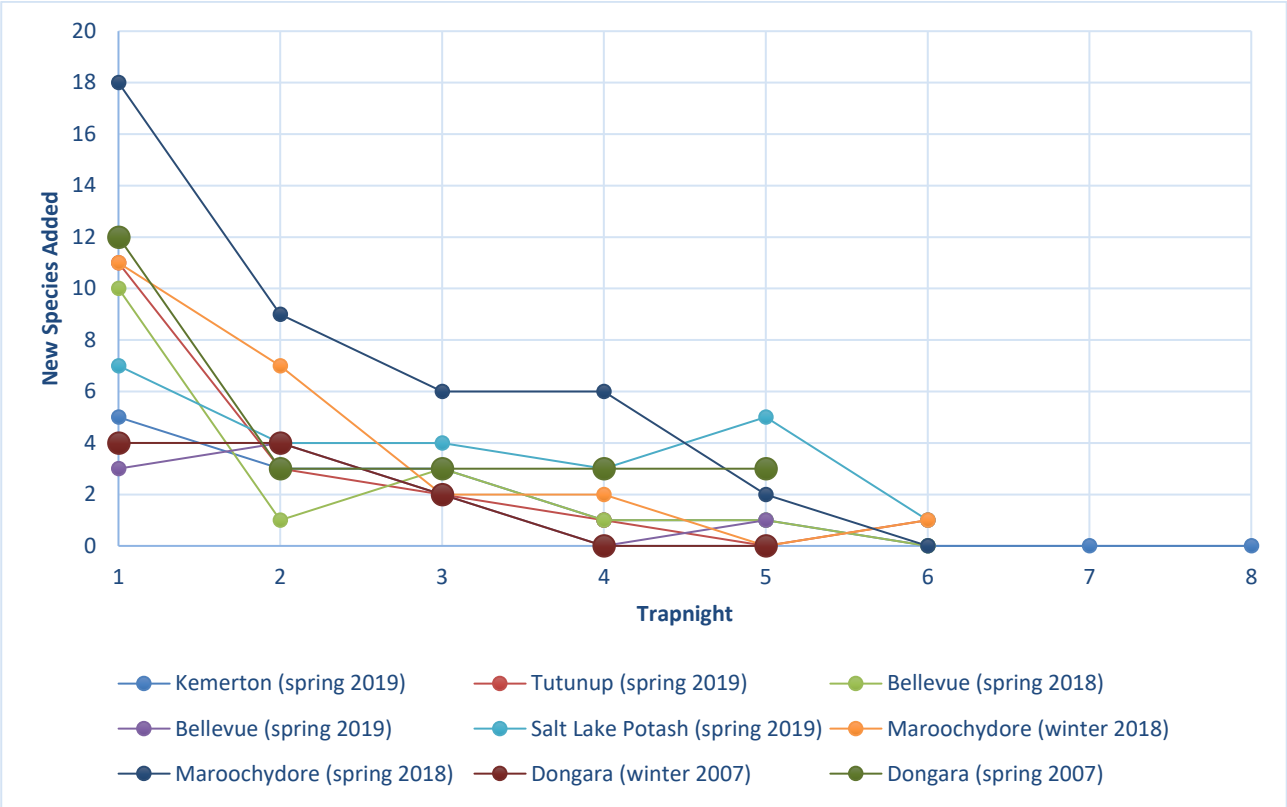


Figure 7. The relationship between the number of trap nights and the addition of species in sampling for small, terrestrial vertebrates at a range of sites. The majority of captures were in pitfalls and sampling effort similar (around 500 pitfall nights). Winter and spring at the Tronox Dongara Project are included.

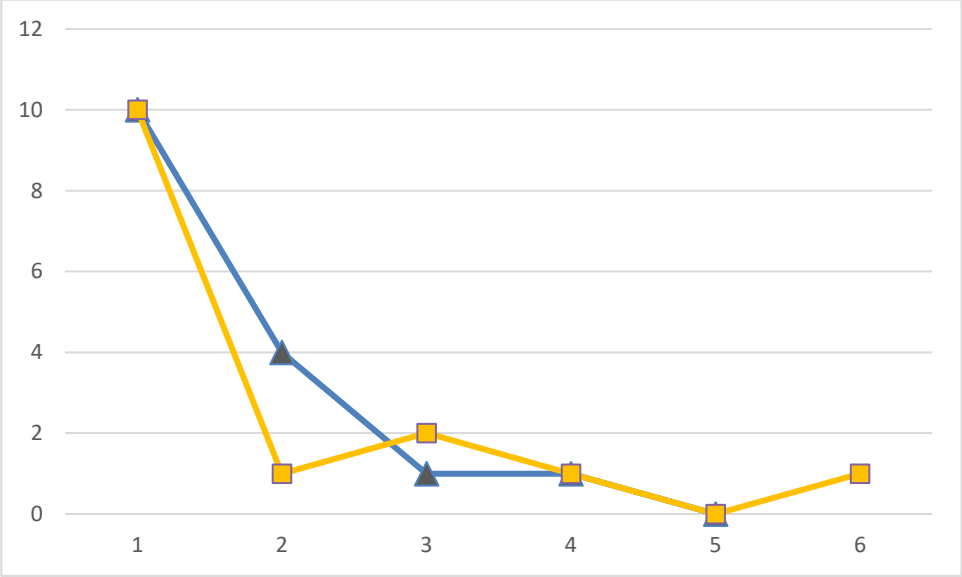


Figure 8. The relationship between the number of trap nights and the addition of species in sampling for small, terrestrial vertebrates at the Beharra Springs Silica project (blue), and VRX Arrowsmith North (orange) in December 2021. Sampling effort was 300 pitfall nights at Beharra springs (60 traps for five nights) and 120 pitfall nights (20 traps for six nights) at VRX Arrowsmith North.

Table 4. Previous BCE surveys within c. 20km of project area (except where noted).

Authors	Description	Alignment with current guidance (EPA 2020)	Limitations
Harris *et al.* 2008	Survey for threatened fauna in the Tronox My Adams project area. Hand-searching and aural surveys targeting the Millipede *Antichiropus* 'Eneabba 1' (previously found in the Mt Adams project area (Metcalf and Bamford 2008), the Phasmid-mimic Cricket *Phasmodes jeeba* (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 (*sensu* 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 uncertainly 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 censussing, 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 0 (see also Figure 7).	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 uncertainly always surrounds surveys for rare species and absence can rarely be confirmed. Possible calls were heard in June 2012 but this was not followed up.
Bamford *et al.* 2015	Desktop review and site inspection of Waitsia project area for AWE; northern edge of Yardanogo Nature Reserve. Included targeted surveys for Western Ground Parrot and observations on roosting Carnaby's Black-Cockatoo.	Basic and targeted survey.	No limitations.

Authors	Description	Alignment with current guidance (EPA 2020)	Limitations
Bamford and Chuk 2015-2017	Use of motion-sensitive cameras (baited) to detect fauna activity along 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.

2.2.3 Nomenclature and taxonomy

As per the recommendations of EPA (2004), the nomenclature and taxonomic order presented in this report are based on the Western Australian Museum's (WAM) Checklist of the Fauna of Western Australia 2016. The authorities used for each vertebrate group were: amphibians (Doughty *et al.* 2016a), reptiles (Doughty *et al*. 2016b), birds (Johnstone and Darnell 2016), and mammals (Travouillon 2016). 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 names of species where available are used throughout the text; Latin species names are presented with corresponding English names in tables in the appendices.

2.2.4 Interpretation of species lists

Species lists generated from the review of sources of information are generous as they include records drawn from a large region and possibly from environments not represented in the project area. Therefore, some species that were returned by one or more of the data searches have been excluded because their ecology, or the environment within the project area, meant 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 databases but excluded from species lists are presented in Appendix 7. These may include errors and out of date taxonomic names.

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. 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;
- **Migrant or regular visitor**: Species that occur within the project area regularly in at least moderate numbers, such as part of 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. Locally extinct species are therefore part of the original expected assemblage.

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, or may have been previously confirmed as present. The status categories are assigned conservatively.

For example, a lizard known from the general area is assumed to be a resident unless there is very good evidence that 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 predicted unless a species has been confirmed to be present.

2.2.5 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

The Survey Area has been visited by BCE on three occasions as part of investigations for VRX (November 2018, October 2019 and December 2021). It was first visited on 18th November 2018 to conduct a site inspection, but adjacent areas had previously been visited multiple times over the period 2002 to 2012 by BCE personnel for studies undertaken for Tronox (formerly Tiwest Joint Venture; see references). The nearby Beharra Springs Silica project area was also visited in August 2020 and December 2021, the latter in conjunction with studies at Arrowsmith North. The purpose of the site inspection was to gain a better understanding of the fauna values of the project area, and to place the expected species list generated from the desktop assessment into the context of the environment of the project area. This involved traversing the project area to examine vegetation and substrate present (and consequent habitat available for fauna), and to record opportunistic observations of fauna.

A further visit was undertaken between 23rd and 25th October 2019 specifically for Carnaby's Black-Cockatoo and the Western Ground Parrot which are Endangered and Critically Endangered respectively under state and commonwealth legislation. A walkover survey was undertaken to search for evidence of Black-Cockatoo foraging and to assess the foraging value of the vegetation, and a search of the surrounding landscape was carried out for features that could support roosting and breeding Carnaby's Black-Cockatoos. A vantage point survey on one evening took place to watch for any evening movements of Carnaby's Black-Cockatoos, which can reveal roosting and nesting sites.

The third survey took place from 1st to 9th December 2021 and occurred in conjunction with a detailed survey in the Beharra Springs silica project area. Key activities during this survey were:

- Inspection of the southern transport corridor to generally familiarise the consultant with this area and verify VSAs;

- Install and operate one systematic sampling transect;
    - Pitfall trapping
    - Funnel traps
    - Bird censusing
- Black-Cockatoo foraging habitat assessment;
- Motion sensitive cameras;
- Autonomous recording units (ARUs) primarily for the Western Ground Parrot;
- Opportunistic invertebrate collection; and
- Opportunistic observations.

Details of sampling and assessment methods are given in the following sections. Figure 9 illustrates tracks and locations of sampling points and all sampling locations are given in Appendix 5. Personnel involved in field investigations are listed in Table 5.

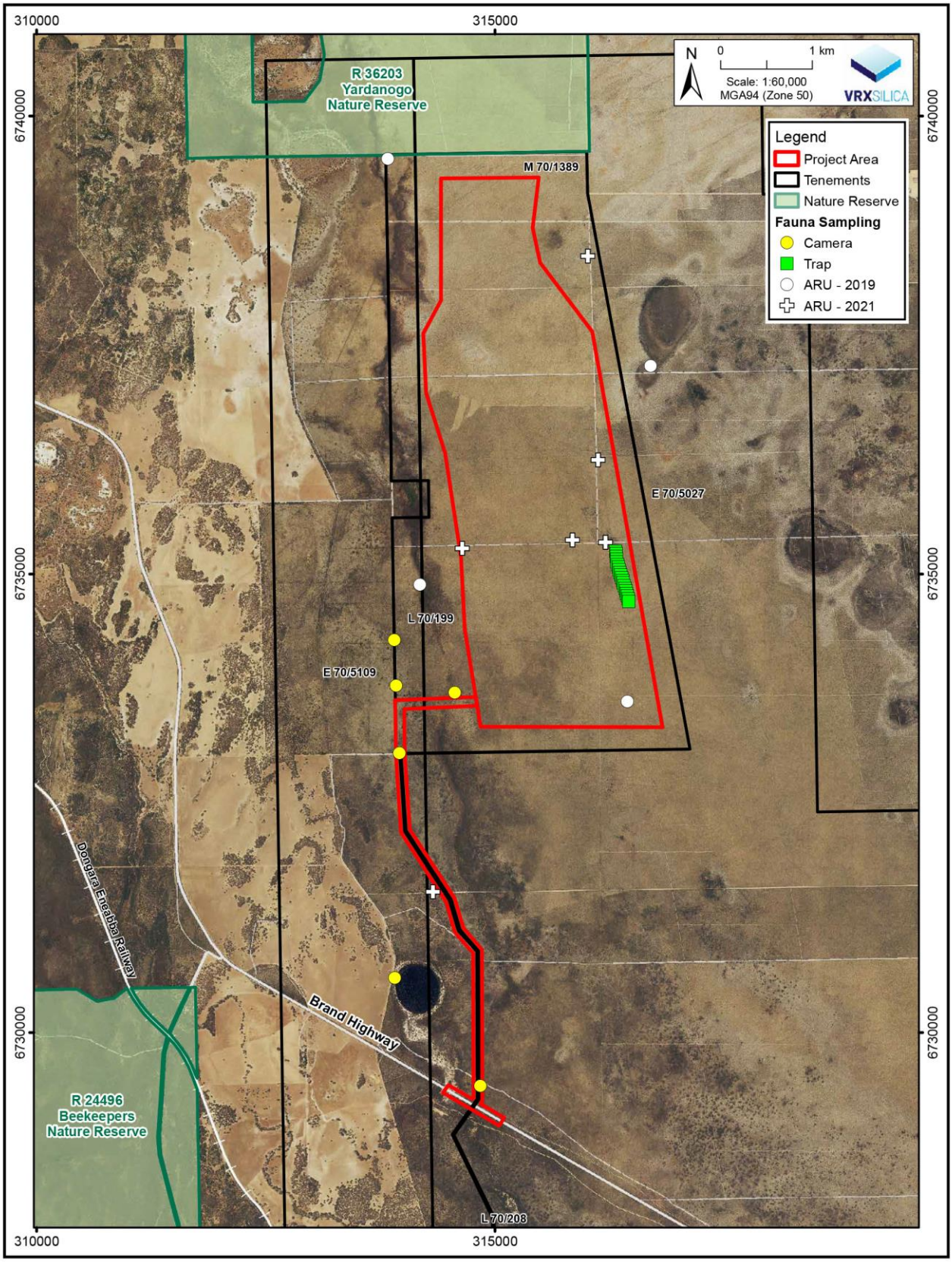
In addition to the BCE investigations, botanists from Mattiske Consulting had undertaken detailed flora and vegetation surveys which included personnel walking transects spaced at 20m intervals across the entire lease area. While searching for rare plants, the personnel are very familiar with features such as Malleefowl mounds and were asked to report any observations they made. Similarly, aboriginal heritage surveys carried out across the project area provided an opportunity to record Malleefowl mounds.

2.3.2 Personnel and permits

Personnel involved in the field investigations and report preparation (including desktop review) are listed in Table 5. The field investigations were carried out under Regulation 27 permit No BA27000568.

Table 5. Personnel involved in the field investigations and report preparation.

Personnel	EIA Experience	Field Investigations			Report Preparation
		18th November 2018	23rd to 25th October 2019	1st to 9th December 2021	
Dr Mike Bamford *BSc, Hons (Biology), PhD (Biology)*	40 years	+	+	+	+
Dr Wes Bancroft *BSc (Zool/Microbiol), Hons (Zoology), PhD (Zoology)*	24 years	+		+	+
Mr Andy McCreery *BSc. (Wildlife and Cons. Biol.)*	10		+	+	+
Dr Jamie Wadey *BSc, Hons (Biology), PhD (Biology)*	2			+	
Ms Eliza-Joyce Mellersh *(BSc. Wildlife and Cons. Biol.)*	4			+	
Ms Rhiannon de Visser *BSc. (Zool.)*	1			+	
Dr Barry Shepherd *(BSc Hons (Biology) PhD (Zoology)*	15		+		+
Mr Peter Smith *(Dip Ag Sc)*	25	+			
Mrs Sarah Smith *(BSc. Biology)*	25	+			



Source: Aerial Photography: Landgate (Nov 2016), Tenements: DMIRS
Author: Bamford Consulting Ecologists, Drawn: CAD Resources (08 9246 3242), Date: Apr 2022, CAD Ref: a2602_f55_04, Rev: B

Figure 9. Sampling locations in the Project Area.

2.3.3 Systematic Fauna Sampling

Systematic fauna sampling was based on one transect of trap and census points; the transect is described in Table 6 and details of locations are given in Appendix 5. Sampling locations are mapped on Figure 9. In addition to this transect of 20 locations, there were four other transects (total of 60 locations) in the Beharra Spring silica project area, located within 5km to the north and sampled at the same time. The transect consisted of 20 sampling points spaced approximately 20 metres apart. Each sampling point had a pitfall trap (pitfall) and there was a funnel trap at about every third location (total of six funnel traps). 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 1.2m in length where there was no funnel trap, but where there was a funnel, one fence was 3m 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 ^{o}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 10:30am 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 six nights as species return had declined to zero by the fifth night, with jut one species added on the sixth night (Figure 8), and there was increasing concern with trapping during extreme weather conditions. The total trapping effort was 120 pitfall nights and 36 funnel-trap nights.

Bird census surveys were carried out during each pitfall check, so there were effectively 20 bird census points along the transect, depending on the number of sampling points on a transect. Birds were identified visually and acoustically within 25m of each sampling point. Censusing was carried out six times at each point (ie once on each day the traps were checked), so there were 120 census events in total.

Table 6. Systematic sampling site description and sampling effort.

Location codes	Transect description	Environment	Sampling effort
Transect V01. Locations V01 to V20	20 pitfalls, 6 funnels and 20 census points. Set 3/12/21 Collected 9/12/21	Kwongan on sandplain with a slight rise supporting patches of Woody Pear Xylomelum occidentalis. Sand is very pale grey. Aerial imagery indicates that the transect area was last burnt in 2007, with the northern third of the project area last burnt in 2012.	120 pitfall trap nights, 36 funnel nights and 6 bird surveys (120 bird census events)

2.3.4 Motion sensitive cameras

Five motion sensitive cameras were set up in the Arrowsmith North project area during the December 2021 survey, with a further five cameras set at the nearby Beharra springs project area to the north. 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 Arrowsmith North project area are illustrated on Figure 9, and details of

all cameras are given in Appendix 5. The cameras were placed in a range of environments, with a focus on the southern access corridor.

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)

ARUs were used in both the September 2019 and December 2021 field surveys. Locations of all units deployed are indicated on Figure 9 and given in Appendix 5. Four audio recording units (ARUs) were deployed in and around the project area on 23rd and 24th September and collected on 18th October 2019. They were set up to sample for calling Western Ground Parrots. One ARU was an AudioMoth (Hill *et al*., 2018 and 2019) running firmware version 1.2.2, while the other three were SOLO biological recorders (Whytock and Christie, 2017) running SOSI-2019-09-20.img.zip. These recording units were chosen for their cost effectiveness and compatible audio response with that of commercial ARUs. Both recorders were placed in low-lying, dense heath (maximum of 1 m high), set to record during peak calling periods of the Ground Parrot; one hour after sunset and one hour before sunrise. Recorders recorded over 70 nights in total. The software for the SOLO was customised by James Christie and Barry Shepherd for the particular timing.

Two Song Meters (SM2s) (Wildlife Acoustics Ltd) and four Audiomoths were set in the Arrowsmith North project area during the December 2021 field survey, with a further four SM2s set in the Beharra Springs project area to the north. The detectors were set to record bird calls to target the Western Ground Parrot as described above. They operated from 4th to 10th December (nights of 4th to 9th December; therefore 36 unit-nights in the Arrowsmith North project area).

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 (Metcalf and Bamford 2008). However, a hand-held bat detector (Echo Meter 2 Pro from Wildlife Acoustics) running on an Android mobile phone was used during evening surveys in September 2019. This was done within the region but not within the project area to augment the species list.

2.3.6 Black-cockatoo habitat analysis

2.3.6.1 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.

2.3.6.2 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).

2.3.6.3 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 5. The size of the project area precluded detailed inspections of all areas of native vegetation, however all vegetation types were traversed and descriptions of vegetation types (from Mattiske 2020) were reviewed. Projected foliage cover for key forage plants such as *Banksia* species were estimates for broad areas in line with the broad categories used for the calculation of vegetation characteristic scores. This approach is necessary to provide a value that can be applied over large areas.

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 Federal Department of Agriculture, Water and the Environment to assess impact significance and potential 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 in Appendix 5. These three components are drawn from the DAWE offset calculator but 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.

Foraging value can thus be assigned a score out of six, based upon site vegetation characteristics, or a score out of 10 if context and species density are also considered. The score out of 10 is generally 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.

2.3.6.4 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 records from the Great Cocky Count (Peck *et al.* 2016; A. Peck pers. comm. 2021; DBCA 2020) and previous records from BCE some of which were subsequent to Great Cocky Count locations.

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 and could not be searched for by Bennelongia due to the narrow period of seasonal activity.

2.4 Survey limitations

The EPA Guidance Statement 56 (EPA 2004) and the EPA (2020) outline a number of limitations that may arise during field investigations for Environmental Impact Assessment. These survey limitations are discussed in the context of the BCE investigation of the survey area in Table 7. No limitations were identified.

The level of sampling, with a single season trapping survey and a multi-season targeted approach, is not considered a limitation as this assemblage is well-understood in the area due to multiple previous field investigations, including detailed, concurrent survey nearby (within 5km). Furthermore, EPA guidance does not consider limitations related to the effectiveness of field sampling for fauna, but appears to make an assumption that the purpose of such sampling is to confirm the fauna assemblage, and that confirming an assemblage is even possible. This is implicit in the EPA (2020) technical guidance that does provide suggestions for sampling techniques, but the level of field investigations suggested cannot confirm the presence of an entire assemblage, or confirm the absence of a species. This requires far more work than is possible (or recommended) for studies contributing to the EIA process because fauna assemblages vary seasonally and annually, and often have high levels of variation even over short distances (Beta diversity). For example, in an intensive trapping study, How and Dell (1990) recorded in any one year only about 70% of the vertebrate species found over three years. In a study spanning over two decades, Bamford *et al.* (2010) found that the vertebrate assemblage varies over time and space, meaning that even complete sampling at a set of sites only defines the assemblage of those sites at the time of sampling. In the latter study, a sampling effort of over 2,000 trapnights (pitfall traps) along two transects about 400m apart recorded 42 species of frogs, reptiles and small mammals, but only 74% of these were recorded from both transects. A further 11 species were not recorded in the pitfalls but were detected by hand-searching and/or additional pitfall trapping over a broader area (12km radius) in the same vegetation and soils (Bamford *et al.* 2013). The limited effectiveness of short periods of fauna sampling is not a limitation for impact assessment *per se*, as long as database information is interpreted effectively and field investigations are targeted appropriately. That is the approach taken by BCE.

Table 7. Survey limitations as outlined by EPA (2020).

EPA Survey Limitations	BCE Comment
Availability of data and information	Abundant information from databases, previous and concurrent studies (see Table 4).
Competency/experience of the survey team, including experience in the bioregion surveyed	The ecologists have had extensive experience in conducting desktop reviews and reconnaissance surveys for environmental impact assessment fauna studies, and have undertaken a number of studies within the immediate region. See Table 4 for further details.
Scope of the survey (e.g. were faunal groups were excluded from the survey)	The survey focused on terrestrial vertebrate fauna and fauna values. Some information on invertebrates was available from databases and some invertebrate collection undertaken. Detailed invertebrate survey carried out by Bennelongia (2022). Note that invertebrates not of conservation significance were excluded from investigations.
Timing, weather and season	Not a limitation, except maxima were very high in the December 2021 survey period. Rainfall in the previous few years had been low and may have suppressed the abundance of some species.
Disturbance that may have affected results	None. There had been no recent fires that could have affected fauna populations; aerial imagery indicated that the northern half of the project area was last burnt in 2012 whilst the southern half was last burnt in 2007. Nearby locations where other studies had bene carried out had not been affected by recent fire at the time of those studies.
The proportion of fauna identified, recorded or collected	All fauna observed were identified.
Adequacy of the survey intensity and proportion of survey achieved (e.g. the extent to which the area was surveyed)	The site was adequately surveyed to the level appropriate for a Basic level assessment. Fauna database searches covered a 25 km radius beyond the centroid of the survey area. The Basic level assessment was completed.
Access problems	There were no access problems encountered.
Problems with data and analysis, including sampling biases	There were no data problems.

2.5 Presentation of results

While some impacts are unavoidable during a development, of concern are long-term, deleterious impacts upon biodiversity. This is reflected in documents such as the Significant Impact Guidelines provided by DotE (2013). Significant impacts may occur if:

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

The impact assessment process therefore involves reviewing the fauna values identified through the desktop assessment and field investigations with respect to the project and impacting processes. The severity of impacts on the fauna assemblage and conservation significant fauna can then be quantified based on predicted population change. This report presents only the fauna values as the review of threatening processes is being developed separately. The results of the desktop and field investigations in terms of key fauna values are presented under the following headings (described in detail in Appendix 1):

- Assemblage characteristics (uniqueness, completeness and richness) - based upon desktop assessment and information from the site inspection;
- Species of conservation significance – based upon desktop assessment and site inspection;
- Recognition of ecotypes or vegetation/substrate associations (VSAs) - based upon desktop assessment and site inspection;
- Patterns of biodiversity across the landscape - based upon desktop assessment and site inspection;
- Ecological processes upon which the fauna depend - based upon desktop assessment and site inspection.

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 Mattiske Consulting (2020). The proposed mine area consists largely of Kwongan heath and associated shrublands typical of the subregion, with small low-lying areas subject to seasonally damp conditions. There is no clearing except for exploration tracks and firebreaks. These environments are also represented along the transport corridor, but the corridor traverses close to a linear riparian feature which lies in some cases 100m to the east. It also passes close to woodland of *Eucalyptus erythrocorys* over shrubs on sand with outcropping limestone (Mattiske vegetation types W4 and W5; as close as 50m to the west), and close to Arrowsmith Lake (c. 500m to the west). The vegetation and soils along the transport corridor therefore tend to be more complex than in the mine area, with more shrubby elements. There are large wetlands lying east (outside) of the project area that include tall woodland of eucalypts (Plate 10). Although outside the Survey Area, they may be relevant to some fauna using the project area. There is also a wetland (Arrowsmith Lake) c. 500m of the transport corridor. This contained water at the time of the September 2019 and December 2021 site visits.

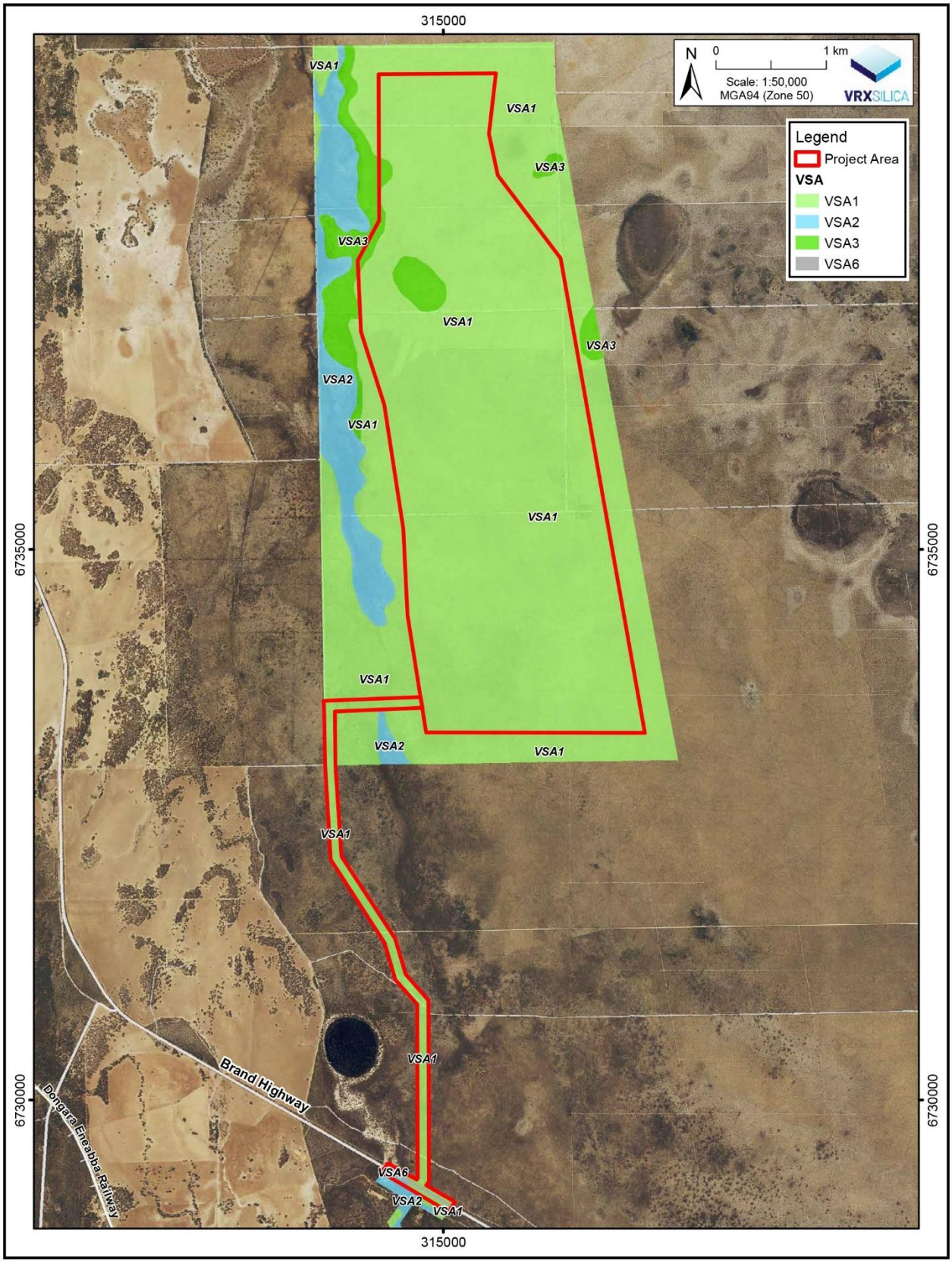
The vegetation types can be broadly classed into a series of Vegetation and Substrate Associations (VSAs) which combine vegetation with some similarity in floristics and structure, and some similarity in landscape position and substrate type. VSAs in the mining lease and the transport corridor (Figure 10) are:

1. Kwongan heath – Low, dense, proteaceous/myrtaceous shrubland on yellow and pale sands. This VSA contains several *Banksia* species that flower at different times of the year. In September 2019, *Banksia hookeriana* and *B. menziesii* were flowering prolifically, whereas in December 2021 *B. attenuata* was in flower. Occurs across majority of the project area and varies slightly with landscape position from high to low on stabilised dunes. It also varies with time since fire (Plates 1, 2 and cover photo). Vegetation types H1, H2, H3, H4, H5 and S3 (Mattiske Consulting 2020). Occupies most of the mining lease and the transport corridor. Plates 1, 2, 3, 6 and 8.
2. Dense Riparian thickets (and seasonal watercourse and swamps)– Dense thickets mostly of *Acacia blakelyi*, in some areas *Allocasuarina campestris,* growing on peaty-sand low in the landscape but extending onto slopes (Plate 3 and 4). Vegetation types S6 and T1 (Mattiske Consulting 2020). These

thickets are limited in the mining lease to a small drainage line in the west and south-west of the lease, but are also present adjacent to the transport corridor; there is a distinctive linear thicket of this VSA lying just to the east of the transport corridor. Plates 4, 5 and 6.

3. Open, low woodland of *Banksia* sp. With scattered *Eucalyptus todtiana* and *Xylomelum angustifolium* over shrubs on sand (Plate 7 and Plate 9). Vegetation type W2 (Mattiske Consulting 2020). Present in small patches in the mining lease but tends to merge with VSA 1. Plate 5.
6. Cleared land (code VSA 6 used to avoid confusion with codes used for VSAs just outside the survey area). This is primarily land cleared for agriculture and lies immediately to the west of the project area, but includes some small, cleared areas where the transport corridor meets the Brand Highway. There are also cleared tracks and firebreaks within the project area. Vegetation type CL (Mattiske Consulting 2020). Plate 12.

VSAs 1 and 3 are very extensive in the region, being widespread in the nearby Yardanogo and Beekeepers Nature Reserves. VSA 2 has a more limited distribution but does occur extensively along the Arrowsmith River drainage system. The relationship of VSAs with the fauna assemblage is discussed below (3.2.1 fauna assemblage and 0 patterns of biodiversity). VSAs with the project area are illustrated in Plate 1 to Plate 8, and Plate 12 . Other vegetation and landform types nearby but not in the project area are illustrated in Plate 9 to 11.



Source: Aerial Photography: Landgate (Nov 2016), Tenements: DMIRS
Author: Bamford Consulting Ecologists, Drawn: CAD Resources (08 9246 3242), Date: Mar 2022, CAD Ref: a2602_f55_05, Rev: A

Figure 10. Distribution of VSAs in the project area: VSA 1 – Kwongan heath; VSA 2 – Dense Acacia thickets along drainage line; VSA 3 – open woodland over heath; VSA 6 - cleared.

Plate 1. **VSA 1.** Kwongan heath burnt about three years previously.

Plate 2. VSA 1. Kwongan heath in September 2019 showing *Banksia hookeriana* in flower.

Plate 3. VSA 1. Kwongan heath in December 2021 showing *Banksia attenuata* in flower.

Plate 4. VSA 2. Dense riparian Acacia thickets lining the creekline running north to south along the western boundary of the project area.

Plate 5. VSA 2. Dense riparian Acacia thickets along access corridor.

Plate 6. VSA 1 (right) and VSA 2 (left). Transition between the two VSAs in south-west corner of the mining lease.

Plate 7. VSA 3. Open, low woodland of *Banksia* sp. with scattered *Eucalyptus todtiana* and *Xylomelum angustifolium* over shrubs on sand.

Plate 8. VSA 1 at northern end of systematic sampling transect V01, December 2021.

Plate 9. Arrrowsmith Lake, December 2021.

Plate 10. Eucalypt woodland (acacia thickets behind) associated with drainage system south-east (outside) of the Arrowsmith North project area. Location indicated on **Figure 11**.

Plate 11. Low woodland of *Eucalyptus erythrocorys* over shrubs on sand with outcropping limestone adjacent to (but outside) access corridor (VSA 4).

Plate 12. River Gums and open ground (VSA 6) west of the intersection of access corridor and Brand Highway.

3.2 Vertebrate Fauna Assemblage

3.2.1 Overview of fauna assemblage of the project area

The desktop study identified 203 vertebrate fauna species as potentially occurring in the project area (see Table 8a and Appendix 6): 3 freshwater fish, 10 frogs, 51 reptiles, 114 birds and 25 mammals. The assemblage includes 14 vertebrate species of conservation significance, discussed in Section 3.2.2. It is expected that at least 13 mammals, and possibly one bird and one reptile, have become locally extinct (not included in the totals above). Extinct species are also discussed in Section 3.2.2 while conservation significant invertebrates are discussed in Section 3.2.5. Species returned from databases but which are considered not to be present are listed in Appendix 8. Excluded species include waterbirds that may overfly the project area and visit nearby wetlands, but which would not use it due to the lack of habitat. Several waterbird species were observed nearby in September 2019 and December 2021, and are included in Appendix 9 which provides an annotated list of species observed in and around Arrowsmith North.

Freshwater fish

No native freshwater fish were returned from databases (several marine species were; see Appendix 8), but Allen *et al.* (2002) report the Arrowsmith River as being the northern limit of the distribution of the Western Minnow and Western Pygmy-perch, and that the Swan River Goby occurs in drainage systems of the south-west. All three species may therefore be seasonally present in the drainage system that passes under Brand Highway at the intersection with the access corridor. No fish were observed in Arrowsmith Lake. The introduced Green Swordtail (listed in Appendix 8) has been recorded by BCE in a permanent wetland about 20 km to the north (Ejarno Spring), but it appears very unlikely that the drainage systems and wetlands in the Arrowsmith North project area, including the Arrowsmith River, are ever directly linked to Ejarno Spring.

Frogs

The 10 frog species consist mostly of burrowing frogs which rely on seasonal flooding for breeding, and all of these have been recorded in previous BCE surveys within about 15km of the project area. Three of these previously recorded species were detected in the current survey of Arrowsmith North: the Moaning Frog was recorded during pitfall sampling and the Turtle Frog was recorded on ARUs in December 2021, and the Banjo Frog was calling at Arrowsmith Lake just outside the access corridor in September 2020. A fifth species, the Crawling Toadlet, was recorded along Mt Adams road to the north in August 2020. Such burrowing species are likely to breed in seasonal wetlands but disperse widely through upland vegetation for the rest of the year, except for the Turtle Frog that breeds terrestrially and has no need of free water. The drainage line and damplands within the project area, Arrowsmith Lake, and the wetland system to the east, are thus likely to be important for frogs. Three of the frog species (Motorbike Frog, Slender Tree-Frog and Squelching Froglet) do not burrow and are often confined to permanent or near-permanent wetlands. They have been recorded by BCE at Ejarno Spring (c. 20 km north of the project area) and are expected as residents only along the Arrowsmith River and its tributaries and associated wetlands. They may be present at Arrowsmith Lake.

Reptiles

The majority of the 51 reptile species expected are considered resident in the project area except for the Long-necked Tortoise (expected only as an Irregular visitor in the vicinity of the drainage line and Arrowsmith Lake near Brand Highway) and the Woma (probably locally extinct). The Woma is discussed below as it is of conservation significance and there is a very slight possibility that it is still present. Another reptile of conservation significance returned from databases, the Western Spiny-tailed Skink, is considered not to be present due to lack of suitable habitat (large trees). The Lesueur Sandplains Subregion and more broadly the

mid-west coast of Western Australia is recognised for high reptile richness and a large number of species that are at their distributional limits (Maryan 2005). Species close to their distributional limits includes the gecko *Diplodactylus ornatus*, which was caught in the VRX Arrowsmith North and nearby Beharra Springs project areas in the December 2021 sampling. Previous BCE surveys in the general area have recorded 40 reptile species, with 15 confirmed in Arrowsmith North in the current surveys. Due to the sandy substrate, scarcity of rocky areas (limestone lies just outside the access corridor) and geographic location of the project area, the expected assemblage would be a mix of sand specialists, fossorial and coastal species along with widespread, generalist species.

Birds

The bird assemblage of 114 species includes 39 classed as residents, 40 as regular visitors or migrants, 27 considered to be irregular visitors and seven vagrants. Three introduced species are expected. One species, the Western Ground Parrot, is probably locally extinct but there are occasional reports that it persists in the area; this species is discussed further below. Some other bird species, such as the Western Whipbird *Psophodes nigrogularis* and Bush Stone-curlew *Burhinius grallarius,* may be locally extinct, but there are no confirmed historical records of these species ever being present in the area, so they have not been included. A total of 106 bird species has been confirmed in the general region by BCE, and Metcalf and Bamford (2008) recorded 68 bird species in the Tronox Dongara project area in a two-season survey in 2007. The current series of surveys in Arrowsmith North recorded only 35 species, but this doesn't include the 11 waterbird species recorded around Arrowsmith Lake.

There is likely to be a high seasonal abundance of nectivorous birds present in the project area when vegetation is in flower. The project area is also subject to incursions of arid zone bird species in some years. For example, in a 30 year study between Cataby and Badgingarra, the Black Honeyeater was absent most years, but approximately one year in 10 it was among the most abundant of nectarivores (M. Bamford unpubl. data). Similarly, the White-fronted Honeyeater, Pied Honeyeater, Red-backed Kingfisher, Masked Woodswallow, Ground Cuckoo-shrike and Budgerigar have each been recorded on fewer than five occasions in the 30 year study north of Cataby. It is possible that a sub-species of Red-tailed Black-Cockatoo, the Inland Forest Red-tailed Black-Cockatoo (*Calyptorhynchus banksia escondidus*), may visit the project area occasionally. It must be stressed that this sub-species is not of conservation significance. The significant Carnaby's Black-Cockatoo is present and is discussed further below. The project area is also expected to be rich in resident birds utilising the dense Kwongan heaths (VSA 1) and thickets (VSA 2), in particular those that prefer to keep low in the vegetation strata such as White-browed Scrubwren, White-breasted Robin and three Fairy-wren species. The riparian thickets (VSA 2) may support some birds through drier periods. Several waterbird species were observed on Arrowsmith Lake in September 2019; notes on these species are include in Appendix 8 but these species are not included in the fauna assemblage of the project area as they all rely on at least moderately large water bodies outside the project area.

Mammals

The mammal assemblage is depauperate, with 28 species known generally from the area, but 13 of these being locally extinct due to predation by introduced predators, habitat destruction and changing fire regimes. Extinct species are discussed in section 3.2.2. An additional nine introduced species may be present. The extant native mammal assemblage includes 12 residents, one irregular visitor (Rakali) and two regular visitors (both bats). Three Dunnart species may occur in the area, including the Grey-bellied Dunnart which is at the northern edge of its range, and the White-tailed Dunnart (confirmed by Metcalf and Bamford 2008) which also has a limited range along the west-coast extending from Kalbarri to Mooliabeenee (near Gingin). The

'Little Dunnart' (confirmed by Metcalf and Bamford 2008) is a currently unrecognised taxon similar to *Sminthopsis dolichura* (but with a shorter tail being same length as head and body rather than noticeably longer) and known from 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. The project area may be an important foraging habitat for bats, although it lacks major roosting sites such as caves (but caves are located in Beekeepers NR). The nine Introduced species expected to occur in the project area include feral predators (Fox and Cat). A total of 13 native and nine introduced species have been confirmed in the general region by BCE; with 11 native and five introduced species confirmed in the project area in recent surveys.

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

- Uniqueness: The assemblage is broadly typical of the Lesueur Sandplain subregion and is therefore widespread within that subregion, but includes species that may be confined to the subregion. It is of note because it has good connectivity to nearby conservation reserves and is rich in reptiles, many of which are limited to sandplains. It has a high proportion of seasonally abundant nectivorous birds.
- Completeness: The assemblage of species from the project area is substantially intact, with the exception of locally extinct critical weight range mammals, and the probable loss of one reptile and one birds.
- Richness: The Lesueur Sandplain subregion is recognised as being rich in reptile (Maryan (2005). Other vertebrate fauna groups are not especially rich, but the bird assemblage is notable for high levels of seasonal variation due to the movements of nectar-dependent birds. The mammal assemblage has suffered a high level of species loss.

As a fauna value, the most important features of the project area's assemblage are that it is rich in reptiles and seasonally rich in nectar-dependent birds. It is also important because the assemblage is substantially intact and occurs as part of a large area of intact native vegetation, but with extensive clearing particularly to the east.

Table 8. Composition of vertebrate fauna assemblage of the project area.

Taxon	Number of species			Number of species in each status category				
	Expected project area	Recorded BCE previous	Recorded AN	Resident	Regular visitor or migrant	Irregular visitor	Vagrant	Locally extinct
Fish	3	0	0	-	-	3	-	
Frogs	10	10	3	10	-	-	-	-
Reptiles	51	40	15	49	-	1	0	1?
Birds	114	106	35	39	40	27	7	1?
Mammals (native)	15	13	11	12	2	1	-	13
Mammals (introduced)	9	9	5	5	-	3	1	-
Total	**202**	**178**	**69**	**115**	**42**	**35**	**8**	**13 to 15**

NB. Number of species: expected in project area - excludes locally extinct mammals.
Number of species: recorded BCE previous – recorded in previous BCE surveys within c. 15km.
Number of species: Recorded AN – recorded in Arrowsmith North is 2019, 2020 and/or 2021 surveys.

3.2.2 Species of conservation significance

The expected vertebrate assemblage includes 18 vertebrate species of conservation significance (Table 9 and Table 10; but note three of these species may be locally extinct) comprising five CS1, four CS2 and nine CS3 species. In addition, there are several conservation significant invertebrate species returned from databases (see Section 3.3). As outlined in Appendix 3, species classed as CS1 are those listed under WA State and/or Commonwealth legislation, while those classed as CS2 are listed as Priority by the DBCA. The CS3 class is subjective and is assigned by BCE (no regulatory listing), but includes species that have declined extensively across the region, and some 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 local extinction than populations at the centre of the range (Curnutt *et al*. 1996). Thirteen additional species of conservation significance are considered to be locally extinct; these are also discussed below.

Table 9. Composition of extant conservation significant vertebrate fauna. Locally extinct species are not included.

Taxon	Conservation Significant (CS) fauna			
	CS1	CS2	CS3	Total
Fish	0	0	2	2
Frogs	0	0	0	0
Reptiles	0	2	1	3
Birds	5	0	5	10
Mammals	0	2	1	3
Total	5	4	9	18

(CS1 – listed under legislation; CS2 – listed as priority by DBCA; CS3 – locally significant).

Table 10. Conservation significant vertebrate fauna species expected to occur in the project area. Species known to be locally extinct are not included; the list includes three species that are possibly locally extinct.

Species		CS level	Cons listing	Confirmed	Expected Status
FISH					
Western Minnow	*Galaxias occidentalis*	CS3			Irregular visitor
Western Pygmy-perch	*Nonnoperca vittata*	CS3			Irregular visitor
REPTILES					
Woma	*Aspidites ramsayi*	CS2	P1		Locally extinct?
Carpet Python	*Morelia spilota imbricata*	CS3			Resident
Black-striped Snake	*Neelaps calonotos*	CS2	P3	X	Resident
BIRDS					
Malleefowl	*Leipoa ocellata*	CS1	V S3		Irregular visitor
Fork-Tailed Swift	*Apus pacificus*	CS1	M S5		Irregular visitor
Peregrine Falcon	*Falco peregrinus*	CS1	S7		Irregular visitor
Rainbow Bee-eater	*Merops ornatus*	CS3		X	Regular visitor
Carnaby's Black-Cockatoo	*Calyptorhynchus latirostris*	CS1	E S2	X	Regular visitor
Western Ground Parrot	*Pezoporous flaviventris*	CS1	Cr S1		Locally extinct?
Rufous Fieldwren	*Calamanthus campestris*	CS3		X	Resident
Shy Heathwren	*Calamanthus cautus*	CS3		X	Irregular visitor
White-browed Babbler	*Pomatostomus superciliosus*	CS3			Vagrant
Crested Bellbird	*Oreoica gutturalis*	CS3			Resident
MAMMALS					
Brushtail Possum	*Trichosurus vulpecula*	CS3		?	Locally extinct?
Brush Wallaby	*Notamacropus irma*	CS2	P4	X	Resident
Rakali	*Hydromys chrysogaster*	CS2	P4		Irregular visitor
Number of species expected:	**17**			**6**	

See Appendix 1 and 3 for descriptions of conservation significance levels. Species recorded are indicated and the predicted status of each species in the project area is also given.

EPBC Act listed species: V = Vulnerable, E = Endangered, C = Critically Endangered, M = Migratory.

WC Act listed species: S1 – S7 = Schedule 1 - 7; DPaW Priority Species: P1 - P5 = Priority 1 - 5.

Conservation significance level 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. Males maintain breeding mounds and do almost all work on the mound. They have several mounds in their home range of up to 4.6 km^2 and change mounds at intervals of several years as litter reserves become depleted, but are generally sedentary within their home range (Marchant and Higgins (1993).
Expected occurrence:	Irregular Visitor. Occasionally recorded in the general area. The Storr-Johnstone Bird Databank (R. Johnstone, pers comm.) has records of disused mounds of the Malleefowl 10km south of Eneabba (c.50km south of the project area) and at a location along the Arrowsmith River about 10km south of the project area (see Figure 11). The latter was of two mounds found in 2008, with one described as 'fairly new'. The two disused mounds were in acacia shrubland and such vegetation associated with the Arrowsmith River is the most likely environment in the broader region to provide habitat for the Malleefowl. Such shrubland is not present in the project area but has some similarity with VSA 2. There is a recent (2022) unconfirmed report of an active mound in the same general area (R. Johnstone pers comm.). This suggests there may be a breeding population to the south. However, there is no indication that there is a resident, breeding population in the project area, with no evidence of the species found during the site visits to the project area or nearby despite the tracks and mounds being distinctive and conspicuous. Similarly, across multiple surveys in the broader region carried out by BCE (Figure 6) the species has not been encountered. The project area was subject to an intensive search for rare flora, with personnel at a 20m spacing across the entire area, and no mounds were encountered (the botanists were familiar with mounds of the species and this sort of transect search approach is consistent with current guidance on searching for Malleefowl (NHT 2004, McGrath *et al.* 2010)). Heritage surveys undertaken with aboriginal people at 5om spacing also did not detect Malleefowl mounds. Much of the vegetation may be too low as the Malleefowl usually occurs in woodlands and tall shrublands. Acacia shrubland (VSA 2; see Figure 10) does occur in the west of the project area, but the lack of records suggests no Malleefowl are present and impacted areas do not support this sort of environment. If present, the birds would occur at a low density of <1 bird/km^2 based on information provided by Marchant and Higgins (1993).

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. Flocks may pass over the project area briefly at intervals of a year or more. A flock of about 10 birds was observed high (several hundred metres) over Dongara on 7th December 2021, during the field trip, and was possibly part of a much larger group of birds moving across the landscape. The birds were present for about five minutes and then moved on, which is typical of observations of this species.

Peregrine Falcon

Conservation status:	Schedule 7. Only listed under the BC Act.
Distribution and habitat:	More or less cosmopolitan throughout Australia (Menkhorst *et al.* 2017). This species occurs in a variety of habitats 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, and shallow rivers 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 150 100 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 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 2 km from the eastern boundary (Fig). 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 area. The aural record was in close proximity to the project area - 6 km east of the south-eastern boundary. Both 1992 and 2012 records were in areas of Kwongan shrubland. ARUs set in and just to the north of the project area in October 2019 and 2021 did not detect the species.

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 September 2019; also regularly recorded during other work in the broader region including 14 birds observed just south of Mt Adams Road in August 2020, and a flock of about 70 birds observed about 5km to the west in December 2021. The project area provides foraging habitat of proteaceous and myrtaceous shrubland in VSA 1 and VSA 3, however roosting and breeding are unlikely due to the lack of suitable trees. There is potential nesting habitat approximately 2 km east of the project area in River Gums along a drainage line (Plate 10), and roosting locations are known to the north, west and south-west. This species is discussed in detail in Section 3.2.3.

Conservation significance level 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. It is this South-West population that is listed as Priority 1. The northern (western deserts) population 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. Still widespread in the Great Sandy and Little Sandy Deserts. 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:	Possibly 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 *et al.* (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. It was 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 VSAs 1 and 3.

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. It
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 of VSAs 2 and 3 than the low heath of VSA 1.

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:	Irregular visitor. The species may occur occasionally along the Arrowsmith River and other rivers in the region, so individuals may at times move through the drainage systems from the Arrowsmith River to Arrowsmith Lake, but they are too seasonal and intermittent to support the species regularly.

Conservation significance level 3

Western Minnow

Conservation status:	Considered of local significance (CS3) because the Arrowsmith River is the northern limit of the species' range. Has probably suffered some range contraction due to wetland loss and degradation, and declining rainfall.
Distribution and habitat:	Endemic to permanent wetlands of the South-West from the Arrowsmith River to 100km east of Albany. Occurs in fresh and brackish water.
Ecology:	A fast-moving predator that moves upstream to breed in winter, so will spread into usually dry sections of watercourses on a seasonal basis.
Expected occurrence:	Irregular visitor. Likely to occur seasonally in the upper reaches of the Arrowsmith River and small numbers may occasionally disperse into the drainage system crossed by the access route.

Western Pygmy-perch

Conservation status:	Considered of local significance (CS3) because the Arrowsmith River is the northern limit of the species' range. Has probably suffered some range contraction due to wetland loss and degradation, and declining rainfall.
Distribution and habitat:	Endemic to permanent wetlands of the South-West from the Arrowsmith River to near Hopetoun (east of Albany). Occurs in fresh and slightly brackish water. Considered by Allen *et al.* (2002) to be the most widespread and abundant native freshwater fish in the South-West.
Ecology:	A predator but able to take only small items due to small mouth. Will disperse during high water levels.
Expected occurrence:	Irregular visitor. Likely to occur seasonally in the upper reaches of the Arrowsmith River and small numbers may occasionally disperse into the drainage system crossed by the access route.

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 python 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. Often in 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.). It probably occurs in all VSAs in the project area.

Rainbow Bee-eater

Conservation status:	This species was recently removed from the Migratory list of the EPBC Act and Schedule 5 of the WA 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 (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. The Rufous Fieldwren and Shy Heathwren were observed in September 2019, the latter just outside and to the south of the project area. The Rufous Fieldwren was also observed in December 2021, and the Crested Bellbird was recorded in the Beharra Project area just to the north, also in December 2021. All these records were in Kwongan heath (VSA 1).
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, such as VSA 2 and dense areas of VSA 3, while the White-browed Babbler usually occurs in tall and moderately open shrubland with scattered thickets. The babbler is a conspicuous species and has not been recorded despite multiple visits to the general area, hence it is considered likely only as a vagrant. 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, Shy Heathwren and Crested Bellbird are expected as residents and have been recorded in the project area or nearby. The Babbler is expected only as a vagrant 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. The Rufous Fieldwren readily colonises early stage rehabilitation (M. Bamford pers obs) so may be temporarily abundant in young rehabilitation.

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 to the east. 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:	May be locally extinct, but the species does persist in some areas of the South-West despite extensive clearing, and scats possibly of this species were found in November 2018, amongst large trees east of the project area. Much of the project area, however, is probably not suitable due to the general absence of large trees.

Locally extinct species

Thirteen mammal species that formally occurred in the area, some probably well into the 20th Century, are now considered locally extinct (Appendix 6). These species are mostly of high conservation significance and in some cases are now represented only by island sub-species, with the mainland subspecies that would have been present in the project area being extinct. Their local extinction is likely due to a combination of factors including habitat degradation, changed fire regime and feral predators. Some of these locally extinct species do still occur in the South-West (Chuditch, Tammar, Quenda and Woylie) but there is no evidence they persist in the general region. All would almost certainly have been detected in the multiple previous surveys in the region, particularly surveys with high use of cameras (see Figure 6).

3.2.3 Black-Cockatoos

One black-cockatoo species of conservation significance has been confirmed in the general area, Carnaby's Black-Cockatoo. The other two significant black-cockatoos in the South-West, Baudin's and the Forest Red-tailed, do not occur on the northern Swan Coastal Plain. Red-tailed Black-Cockatoos in the general region of the project are a different and widespread (inland) sub-species (*Calyptorhynchus banksia escondidus*). Carnaby's Black-Cockatoo may forage on proteaceous and myrtaceous vegetation in the project area and roost in large trees near water courses. Foraging and roosting by Carnaby's Black-Cockatoos has been confirmed adjacent to the project area and are discussed below. Breeding is also discussed below. Locations of foraging signs and other records of Carnaby's Black-Cockatoo collected in September 2019 and December 2021 are plotted in Figure 11. Breeding nearby is also a possibility but is unconfirmed.

Overall, Carnaby's Black-Cockatoo is likely to be present in the region for much of the year with the project area representing foraging habitat used by non-breeding birds. There is no roosting or breeding habitat in the project area and no regular surface (drinking) water.

Foraging habitat

Banksias, hakeas, eucalypt trees, acacias and Woody Pears (*Xylomelum*) provide foraging habitat for Carnaby's Black-Cockatoos, and acacias and banksias in particular are widespread throughout the project area. Furthermore, a large number of scattered and chewed Banksia inflorescences consistent with Carnaby's foraging were found across the project area in September 2019. Two flocks (one of 50 individuals) were also spotted flying over the project area mid-afternoon during the September 2019 survey. Large flocks have occasionally been recorded in the general area, foraging in Kwongan heath and banksia low woodland, including about 500 birds just north of Yardanogo Nature Reserve (April 2015; Bamford *et al.* 2015) and flocks of over 300 individuals in the vicinity of the Arrowsmith River just west of Brand Highway (Bamford and Chuk 2015-2017).

The vegetation can be assigned a foraging value score for Carnaby's Back-Cockatoo as outlined in Section 2.3.2 and Appendix 5, with scores for each VSA assigned in

Table 11. The vegetation characteristics scores (out of 6) were assigned as follows:

- VSA 1 (Kwongan Heath). Vegetation characteristics score of 4 out of 6. Kwongan/ Shrubland in which species of foraging value, such as shrubby banksias, have 20-40% projected foliage cover (from Appendix 6).
- VSA 2 (Riparian Thicket). Vegetation characteristics score of 2 out of 6. Shrubland in which species of foraging value, such as shrubby banksias, have <10% projected foliage cover (from Appendix 6). However, some patches of Riparian Thicket supported a wide range of other foraging species such as *Hakea, Acacia* and Myrtaceae such as *Calothamnus*, and therefore the score was adjusted slightly by assigning a context score of 1 out of 3 (see below)
- VSA 3 (Open Woodland): Vegetation characteristics score of 4 out of 6. This score is based on the vegetation being a blend of 'Woodland with tree banksias 5-20% projected foliage cover' (score of 3 out of 6 in Appendix 6) and 'Kwongan/ Shrubland in which species of foraging value, such as shrubby banksias, have 20-40% projected foliage cover'.
- VSA 6 (cleared land). Vegetation characteristics score of 1 out of 6. While Carnaby's Black-Cockatoo will forage on weeds in cleared land, it is not considered to be an important food source (Appendix 6).

The context score was the same (2) for VSAs 1 and 3, but this is based upon the total survey area and could be lowered to a context score of 1 if impact areas and rehabilitation effectiveness are taken into account. VSA 2 had a context score of 1 as while it received a vegetation characteristics score of only 2, it is limited in area and has some secondary foraging species. VSA 4 had no context score due to its low score for vegetation characteristics (as outlined in Appendix 6). As noted in Appendix 6, Site Context is a function of site size, availability of nearby habitat and the availability of nearby breeding areas. The project area lies in a landscape with extensive similar vegetation in two nature reserves, which lowers the context value, but the total impact area is uncertain so the assessment is based on the total survey area. If breeding were confirmed nearby then a higher context score could be applied. The species density score of 1 is used for VSAs 1, 2 and 3, as Carnaby's Black-Cockatoos were seen regularly in the area. VSA 4 receives no species density score as per Appendix 6.

Overall, the Kwongan heath (VSA 1) and the low, open woodland (VSA 3) have a high foraging value for the species (7 out of 10). This is on the basis of having high proportions of key food plants, notably banksias. The Kwongan Heath (VSA 1), however, is much more extensive. The Riparian Thicket (VSA 2) is also extensive and has a moderate foraging value with few banksias but high densities of acacias and some hakeas. *Eucalyptus erythrocorys* Woodland (VSA 4) is also of moderate value but small in extent, while VSAs 5 and 6 are low in value and small in extent. Observations at roosting sites suggest that the species is present in the region throughout the year, albeit probably in varying numbers, and therefore foraging habitat is likely to be used across much of the year.

The project area has no permanent surface water for drinking. The nearest more or less permanent sources of water are Arrowsmith Lake and stock watering points on farmland to the west of the project area.

Breeding habitat

The project area is unlikely to support breeding by Carnaby's Black-Cockatoos. There are no large trees (trees of sufficient size to provide nesting hollows) in the mining lease, while just one large tree with two potential (but unused) hollows was found in the access corridor (Plate 13). These potential hollows were examined from the ground so cannot be confirmed as actually being hollows of sufficient depth. They had no evidence of use (ie no chew marks or other marks) and even if they were found to be too shallow for current use, they are still potential hollows. A search of the wider landscape for suitable roosting and breeding trees was conducted in September 2019; this identified several locations with trees (River Gums *Eucalyptus*

camaldulensis) of possibly suitable stature along the Arrowsmith River and around wetlands to the south and south-east of the project area (Figure 11; see Plate 10 for example). A few trees in these areas may contain hollows of suitable size for nesting by black-cockatoos. Ron Johnstone (pers comm.) noted that he has checked some large trees along the Arrowsmith River for nesting black-cockatoos but found no evidence. The nearest known breeding by Carnaby's Black-Cockatoo is at Coomallo Creek, about 100km south of the Arrowsmith area (DBCA 2019b; Saunders and Dawson 2017).

Table 11. Foraging value score for Carnaby's Black-Cockatoo for each VSA, based upon vegetation characteristics (maximum of 6), context (maximum of 3) and species density (maximum of 1), as described in Appendix 5. The maximum score is 10.

Survey area (lease and transport corridor)

VSA	Area (ha)	Foraging value score			
		Vegetation characteristics	Context	Species density	Total (out of 10)
1 (Kwongan heath)	1,254	4	2	1	**7**
2 (Riparian thickets)	377	2	1	1	**4**
3 (open woodland)	95	4	2	1	**7**

Roosting habitat

Three Carnaby's Black-Cockatoo roost sites have been confirmed and one is suspected within proximity of but outside the project area (Figure 11). Bamford and Chuk (2015-2017) recorded a flock of 300+ individuals roosting at 317663mE 6723633mS on 15/06/2016, 10 km south of the project area (along the Arrowsmith River). In April 2015, Bamford (pers. obs) recorded a roost of 500+ individuals approximately 13 km north, near the north-eastern boundary of Yardanogo Nature Reserve located at 316325mE 6752399mS. Two groups of Carnaby's Black-Cockatoos of ten or so individuals were seen flying very directionally and at speed across the Brand Highway (one group flying west, the other east) approximately 5 km south-east of the Study Area on the evening of the 23rd September 2019 just after dusk. This timing and flight pattern suggest they were travelling to roost sites; possibly the roost site identified by Bamford and Chuk (2015-2017). Additionally, approximately 45 minutes before sunrise on the mornings of 24th and 25th September 2019, Carnaby's Black-Cockatoos could be heard calling from the accommodation (Western Flora Caravan Park) where the surveyors were staying; this lies just over 18 km south-east of the project area. Static calls at this time of the day strongly suggest the presence of a roost. On 6th December 2021, a roost of at least 60 birds was found just west of Brand Highway and about 4km east of the project area. These birds flew in from the south in the evening, crossed Brand Highway and may have visited a stock watering point to drink, then flew west back to the roost site. Roosting activity at these sites occurs across the year (April, June, September and December), suggesting that some birds are present almost year-round.

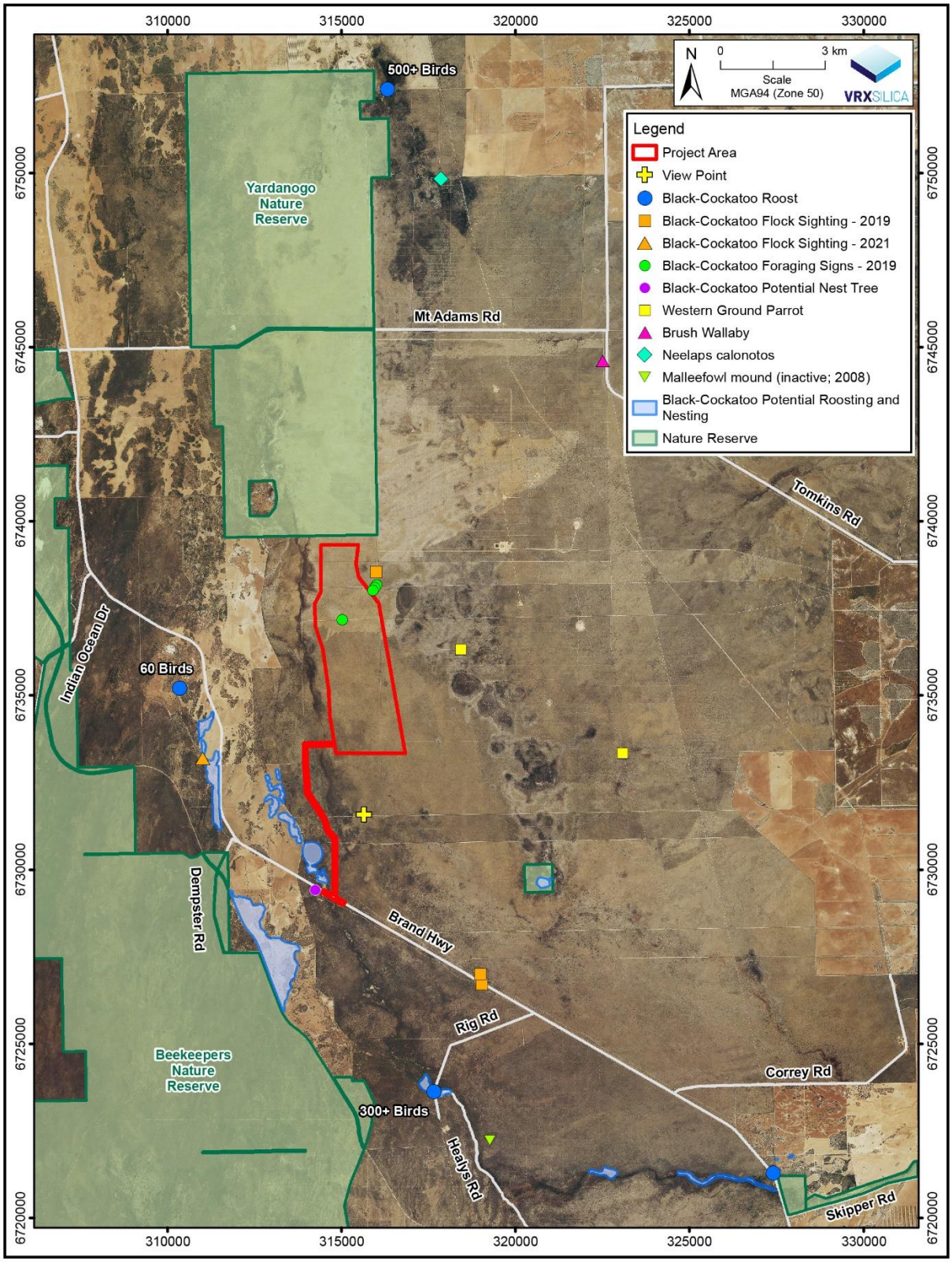
Data retrieved from the Great Cocky Count coordinator, Adam Peck (pers. comm) confirmed the absence of any other known Carnaby's Black Cockatoo roosts within 12 km of the project area. While there are no large trees within the project area that are likely to be used for roosting, there are large trees nearby, particularly along drainage lines that may be suitable. The presence of roosts 4km west, 10 km south and 13 km north means that the project area may regularly be visited by foraging Carnaby's Black-Cockatoos.

While watching and listening at dusk on the evening of 24th September 2019 from a vantage-point located 1.7 km south of the site (see Figure 11) no Carnaby's Black-Cockatoo were seen or heard. This suggests low activity of the species in the area during the breeding season, but observations made in August 2020 in the

Beharra Project area to the north (a small flock of mostly male Carnaby's Black-Cockatoos) suggests that some breeding may be occurring in the region. A search of the wider landscape for suitable roosting and breeding trees was conducted in September 2019 identified several areas where large trees that might be suitable for roosting are present (Figure 11).

Black-cockatoos are likely to move regularly to and from roosting sites, departing in the morning and returning in the evening. Flight paths around roosting sites and across the landscape will be determined by the availability of water resources and foraging habitat. The project area lies within a broad swathe of continuous foraging habitat (see Figure 11) similar in quality to that within the project area (ie mostly kwongan heath), so the birds are likely to move across the landscape in search of seasonal and annual changes in foraging resources. Patterns of movement will thus vary seasonally and even annually. Movement pathways can therefore not be predicted except very close to roost sites.

Plate 13. Large River Gum with a potential nest hollow for Carnaby's Black-Cockatoo at 314245mE, 6729408mN. Outside the access corridor near Brand Highway. There was no evidence that the hollow had been used.



Source: Aerial Photography: Landgate (Nov 2016), Tenements: DMIRS
Author: Bamford Consulting Ecologists, Drawn: CAD Resources (08 9246 3242), Date: Dec 2022, CAD Ref: a2602_f55_06, Rev: C

Figure 11. Locations of records of Carnaby's Black-Cockatoos during September 2019 and December 2021. Locations of records of the Black-striped Snake and Brush Wallaby (in 2007), and of recent Malleefowl activity (2008) are also shown, while areas of potential roosting and nesting for black-cockatoos are indicated.

3.2.4 Introduced species

Fourteen introduced vertebrate species could occur in the project area and ten have been recorded in previous surveys within or close to the project area: Laughing Kookaburra, Laughing Dove, Dog, Goat, Cat, Pig, House Mouse, Black Rat, Rabbit and Red Fox. There were Goat scats at the southern end of the access Corridor, and a Fox recorded on a camera set in this location (December 2021). The species of greatest interest are the Red Fox and Cat, due to the threat they pose to mammals and ground-nesting birds which can lead to local extinctions. A recent study investigated the presence and frequency of feral animals along exploration tracks approximately 8 kms south of the project area (Bamford & Chuk, 2017). Motion sensitive cameras were used for monitoring and Fox, Goat, Rabbit and Cat were recorded regularly, while the House Mouse and Black Rat were infrequent, and Dog was noted through footprints. Also of interest were the findings that some feral mammals (Cat, Goat and Red Fox) appear to favour disturbed habitats and were seen more frequently on cleared tracks compared with undisturbed vegetation. It would be expected that the project area would have a similar assemblage of feral animals, and the usage of tracks by these species has implications for the current project and its interactions with native fauna.

3.3 Invertebrate Fauna

The Arrowsmith North project area sits within DBCA's Midwest management region (DBCA 2020). DBCA (2019a) listed 22 threatened or priority invertebrate fauna in this region, as outlined in Table 12. At least 10 of these species are not expected to occur within the project area and the reasons for exclusion are presented in Table 12 (e.g. wholly or locally extinct, absence of suitable habitat in the survey area, distance from known populations). To help ascertain the status of the remaining 12 species, all location records from ALA (2020) and WAM (2020) were compiled, collated and mapped in relation to the project area. In addition, BCE has some records of significant invertebrates in the region which are not in these databases.

Separate to this review, Bennelongia (2022) carried out targeted surveys for conservation significant and potential short range endemic (SRE) invertebrate species in the project area in 2021. Key findings of their survey are included in this review. Locations of records are presented in Figure 12 and species are discussed below.

The land snail *Bothriembryon perobesus* (Priority 1). Recorded in the project area by Bennelongia (2022).

The slater *Buddelundia callosa* (not listed but a possible SRE and therefore CS3). Recorded by BCE in June 2021 at the Strike Energy project area c. 20km to the east (Figure 4). The next nearest records are from Geraldton to Northampton and S. Judd (pers. comm.) commented that there were no further records between these sites or further south, despite extensive collection of the group. This makes the presence of the species in the vicinity of project area, and potentially within the project area, of conservation interest.

Thorny Bush Katydid *Hemisaga vepreculae* (Priority 2). Recorded 30km to the south of the project area, possibly from coastal shrubland. Not detected by Bennelongia (2022).

Woollybush Bee *Hylaeus globuliferus (*Priority 3). Recorded from shrubland about 30km south-south-east of the project area. Not detected by Bennelongia (2022), but that survey took place out of the species late spring/summer period of activity. The BCE field investigations took place at the right time of year and

flowering bushes were regularly scanned for the distinctive black and yellow *Hylaeus* bees. No members of the genus were seen.

Kwongan Shield-backed Trapdoor Spider *Idiosoma kwongan* (Priority 1). Recorded by Bennelongia (2022) in the project area, and also found (in 2021) in the Beharra project area to the north and with further probable specimens (awaiting identification) from the Strike Energy project area c. 20km to the east. The other *Idiosoma* species present in the Mid-West region are also listed as priority by the DBCA, but there are no records of these within 50km. They may therefore be absent but sampling of this group is incomplete.

Springtime Corroboree Stick Katydid *Phasmodes jeeba* (Priority 3). There is a cluster of records of this species about 25km south-east of the project area, likely in Kwongan heath similar to that present within the project area. However, this species was not found by Bennelongia (2022).

Millipede *Antichiropus* Eneabba 1 (possible Short Range Endemic (SRE); CS3). This millipede has a restricted distribution and may therefore be a SRE (*sensu* Harvey 2002). Near the project area, it was recorded close to drainage lines by Metcalf and Bamford (2008), so is probably associated with mesic conditions such as the dampland areas (VSA 2). It was not found by Bennelongia (2022).

It should be noted that the ecology and distribution of short-range endemic invertebrates is often poorly understood or documented, and the project area occurs in a region that is relatively remote and likely to be poorly-surveyed for these groups. Thus there may be undetected SRE species present, with the most suitable environments being the limestone rises of VSA 4 (outside areas of direct impact), and the seasonally damp environments and distinctive soils of damplands (VSA 2 along the western edge of the mine area and parts of the access corridor). Extensive surveys would be required to document these species, which may well be undescribed, and therefore on a precautionary basis these VSAs should be recognised as important for conservation significant invertebrates and impact risk assessed accordingly. For example VSA 2 could be affected by hydrological change.

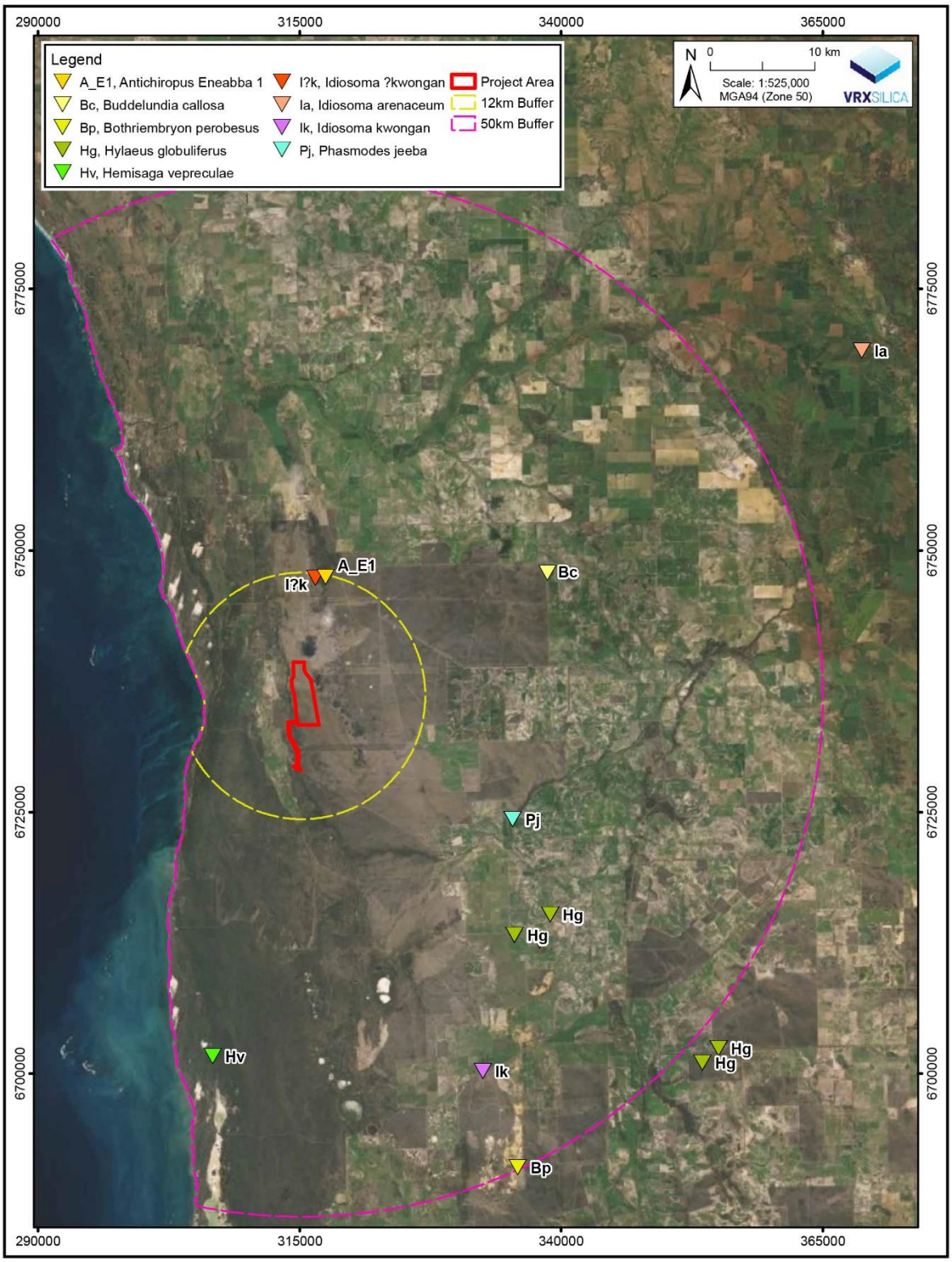
There is no information from databases on subterranean fauna, but in a study undertaken by Rockwater Pty Ltd (2011) for Tronox in the area to the north-east, only six stygofauna species were recorded and none was considered to have a restricted distribution. The study also concluded that the superficial lithology of the area occurs across surrounding regions of the Swan Coastal Plain, and that the underlying rocks lacked suitable voids to support troglofauna. This may not be true of VSA 4 (adjacent to the access corridor) which lies outside the areas investigated for Tronox, as the underlying limestone is potentially suitable for subterranean fauna. This limestone is widespread in the region and thus any subterranean fauna may be widespread, but the assumption should be made that significant subterranean fauna are present in the limestone underlying VSA 4, and the risk of impact assessed based upon the likelihood of changes to this environment resulting from any aspect of the project.

Table 12. Conservation significant invertebrate fauna species expected to occur in the Midwest region (as per DBCA 2019, 2020), including conservation status and likely residency status in the project area.

See Appendix 3 for descriptions of conservation significance levels. The predicted status of each species in the project area is given (as per Section 3.1.4).
EPBC Act listed species: V = Vulnerable, E = Endangered, Cr = Critically Endangered, M = Migratory.
WC Act listed species: S1 - S4 = Schedule 1 - 4, DEC Priority Species: P1 - P5 = Priority 1 - 5.
Species immediately considered as unlikely to occur in the project area are listed in grey font.
Other exclusions (plain black text) followed spatial analysis of current records.
Expected species are highlighted.
* indicates species not listed by DBCA (2019a) but are known from the region (BCE database) and likely to be a SRE.

Species		Conservation Status	Expected Status in Project Area
Aganippe castellum	Tree-Stem Trapdoor Spider	CS2 (P4)	Absent. Project area more than 200 km outside of species known range.
Austrosaga spinifer	Spiny Katydid (Swan Coastal Plain)	CS2 (P2)	Absent. No records within 50 km of the project area.
Bothriembryon perobesus	A bothriembryontid land snail (Moore River)	CS2 (P1)	Resident; recorded by Bennelongia (2022).
Bothriembryon whitleyi	Whitley's Bothriembryontid Land Snail (Geraldton)	Extinct	Absent. Extinct.
Buddelundia callosa	Slater	CS3	Likely to be present and resident, as collected in Strike Energy project area, 20km east, in June 2021, by BCE. A possible SRE (S. Judd pers. comm.). No previous records within 50km and the record represents a range extensive from the Geraldton/Northampton area.
Branchinella denticulata	A fairy shrimp (Carnavon to Kalgoorlie)	CS2 (P3)	Absent. No suitable wetland habitat.
Branchinella simplex	A fairy shrimp (inland WA)	CS2 (P1)	Absent. No suitable wetland habitat.
Branchinella wellardi	A fairy shrimp (Carnarvon and Murchison)	CS2 (P3)	Absent. No suitable wetland habitat.
Daphnia jollyi	A water flea (inland south west)	CS2 (P1)	Absent. No suitable wetland habitat.
Hemisaga vepreculae	Thorny Bush Katydid (Moora)	CS2 (P2)	Uncertain. Records within 50 km of survey area.
Hylaeus globuliferus	Woollybush Bee	CS2 (P3)	Uncertain. Records within 50 km of survey area.
Idiosoma arenaceum	Geraldton Sandplain Shield-Backed Trapdoor Spider	CS2 (P3)	Absent. No records within 50 km of the project area.
Idiosoma dandaragan	Dandaragan Plateau Shield-Backed Trapdoor Spider	CS2 (P2)	Absent. No records within 50 km of the project area.
Idiosoma gutharuka	Gutha Pintharuka Shield-Backed Trapdoor Spider	CS2 (P1)	Absent. No records within 50 km of the project area.
Idiosoma incomptum	Carnarvon Shield-Backed Trapdoor Spider	CS2 (P3)	Absent. Project area more than 200 km outside of species known range.

Species		Conservation Status	Expected Status in Project Area
Idiosoma kwongan	Kwongan Heath Shield-Backed Trapdoor Spider	CS2 (P1)	Resident. Recorded by Bennelongia (2022) and other recent records from within 20km.
Idiosoma nigrum	Shield-Backed Trapdoor Spider	CS1 (V, S3)	Absent. Project area more than 200 km outside of species known range.
Neopasiphae simplicior	A short-tongued bee	CS1 (E, S3)	Absent. No records within 50 km of the project area.
Phasmodes jeeba	Springtime Corroboree Stick Katydid (Eneabba)	CS2 (P3)	Uncertain. Records within 50 km of survey area.
Psacadonotus seriatus	A fan-winged katydid (Champion Bay)	CS2 (P1)	Absent. No records within 50 km of the project area.
Synemon gratiosa	Graceful Sunmoth	CS2 (P4)	Absent. No records within 50 km of the project area.
Teyl sp. (BY Main 1953/2683, 1984/13)	Minnivale Trapdoor Spider	CS1 (S1)	Absent. Survey area more than 100 km outside of species known range.
Throscodectes xederoides	Mogumber Bush Cricket, Northern Throsco	CS2 (P3)	Absent. Survey area more than 100 km outside of species known range.
**Antichiropus* Eneabba 1	A millipede	CS3	Resident. Records in the Tronox Mt Adams Road project area from winter 2008; from low in the landscape (e.g. VSA 2). At (50J) 317520mE, 6747470mN.



Source: Aerial Photography: Landgate (Nov 2016), Tenements: DMIRS
Author: Bamford Consulting Ecologists, Drawn: CAD Resources (08 9246 3242), Date: Mar 2022, CAD Ref: a2602_f55_07, Rev: A

Figure 12. Records of DBCA-listed (threatened or priority) and potential SRE invertebrate species within 50 km of the survey area.

3.4 Patterns of biodiversity

3.4.1 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. Most were also recorded in the Beharra project area surveyed at the same time as VRX Arrowsmith North (Bamford 2022). Just three reptile and four bird species recorded in the Arrowsmith North project area had not been detected by Metcalf and Bamford (2008), while there was one frog, one reptile, one bird and one mammal species recorded in Arrowsmith North that were not recorded during simultaneous surveys of the Beharra project area (Table 13 and Appendix 7). The species not at the Beharra site had been recorded at the Tronox site. With all species considered to be expected in all three study areas, 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 differences in fire regime between the Tronox, Beharra and Arrowsmith North sampling sites (as shown on Figure 6), and the similarity of sampling methods allows for comparisons in measures of abundance to be made.

Sampling results are presented in the following two sections. Comprehensive analysis of patterns of biodiversity requires substantially more data than can be gained from several short field trips, particularly in an environment that varies annually. However, in combination with landscape interpretation, some general conclusions can be made from the field investigations at the Arrowsmith North, Beharra Silica and Tronox Dongara project areas. General conclusions that can be drawn regarding patterns of biodiversity are:

- The Kwongan heath and open woodland (VSAs 1 and 3) occupy almost all of the proposed mine area and part of the access route. These VSAs are expected to be particularly rich in reptile and small terrestrial mammal species, and support plants that are important seasonal nectar sources for the many nectar-dependent birds that are either residents or regular visitors. For example, patches of VSA 3 were the only locations where the White-cheeked Honeyeater was regularly recorded. The Kwongan heaths (VSA 1) are the only environment where the Western Ground Parrot may occur if it is still present.
- The ecotone between Kwongan heath (VSA1) and Riparian thickets (VSA 2) appear important for some birds and reptiles, with high levels of abundance, and high levels of species richness particularly for birds. This sort of ecotone occurs in the west of M70/1389 and just to the east of the access route.
- The Riparian Thicket (VSA 2) is likely to support some birds that favour very dense vegetation, with the only records of several species (eg. Grey Shrike-thrush, Rufous Whistler). The thickets also contribute to the seasonal variation in flowering that is important to support nectarivores

and could harbour short range endemic invertebrates due to the moister conditions than prevail across the bulk of the landscape.

- There was no evidence of seasonal surface water being present in the project area except where the Brand Highway crosses a watercourse (dry in December 2021). Pools may persist at this crossing. While outside the project area, Arrowsmith Lake is a very distinctive wetland that is presumably seasonal but was extensive in December 2021. It supports waterbirds and is likely to be used by most of the frog species for breeding.
- *Eucalyptus erythrocorys* Low Woodlands with outcropping limestone (VSA 4) lie just outside the access route; these may support SRE invertebrates specific to this substrate, and may also have subterranean fauna. The outcroppings of limestone are fragmented so distributions of terrestrial SREs may also be fragmented, but the subterranean invertebrates may occur throughout the extent of underlying limestone (extensive in a belt through this region).
- Fire history appears to have a strong influence on the fauna assemblage, and in particular the reptiles and small mammals. It appeared that Kwongan subject to multiple fires over a 20 year period had high abundances of a few species but low abundances of several other species.

3.4.2 Pitfall and funnel trapping

Trapping results for frogs, reptiles and small mammals are compared for the three survey areas in Table 13. Allowing for differences in sampling effort, there were marked differences in the abundance of a few species considering that all sampling took place in broadly similar vegetation (Kwongan VSA 1, with some sampling in thickets VSA 2). Key differences were:

- The dragon *Ctenophorus adelaidensis*. Most abundant on the Beharra site and uncommon on the Tronox site.
- The dragon *Ctenophorus maculatus*. Very abundant on the Beharra site and uncommon on the remaining sites.
- The skink *Ctenotus fallens*. Abundant on the Tronox site but uncommon on the Beharra and Arrowsmith North sites.
- The skink *Morethia lineoocellata*. Common only at Arrowsmith North and not recorded at the Tronox site despite the high level of sampling effort at the latter.
- The Noodji *Pseudomys albocinereus*. Common at Arrowsmith North but not at remaining sites.

It is difficult to interpret these differences based upon limited sampling, and they may reflect Beta-diversity, which is the variation in abundance that occurs across seemingly uniform landscapes. However, there may also be a fire effect, with the Beharra sampling locations more frequently (and recently) burnt than either the Arrowsmith North or Tronox sampling locations. The abundance of the two dragons at Beharra may be a result of frequent fires, as the analysis of within site sampling at Beharra suggested the dragons were favoured by recent fires (Bamford and Bancroft 2022). In contrast, the skinks *C. fallens* and *M. lineoocellata*, and the Noodji, may have been adversely impacted by frequent fires. The Honey Possum, often extremely abundant in low woodlands at Cooljarloo and adversely affected by frequent fires (M. Bamford 1986) was caught infrequently at the Arrowsmith North and Tronox project areas, and was not recorded across the Beharra silica project area.

Table 13. Comparison of numbers of captures in the Arrowsmith North project area, the Beharra Silica project area (both December 2021), and the adjacent Tronox Dongara project area (November 2007).

Sampling effort varied: Arrowsmith North: 120 pitfall nights and 36 funnel-nights. Beharra Springs: 300 pitfall nights and 75 funnel-nights. Tronox: 450 pitfall nights and 225 funnel nights. Capture rates for selected species standardised to 100 trapnights provided in parenthesis.

Species	Arrowsmith North	Beharra 2021	Tronox 2007
Heleioprus eyrei	1	-	3
Limnodynastes dorsalis	-	-	3
Cryptoblepharus buchananii	-	2	2
Ctenophorus adelaidensis	15 (12.7)	94 (31.3)	17 (3.8)
Ctenophorus maculatus	6 (5.0)	118 (39.3)	10 (2.2)
Ctenotus fallens	8 (6.7)	17 (5.7)	70 (15.6)
Ctenotus pantherinus	-	-	3
Ctenotus impar	-	-	1
Cyclodomorphus celatus	-	-	1
Delma grayii	-	4	-
Diplodactylus ornatus	3	1	-
Gehyra variagata	-	-	2
Lerista christinae	-	-	10
Lerista elegans	-	1	7
Lerista planiventralis	-	6	-
Lerista praepedita	4	2	-
Lucasium alboguttatum	1	19	-
Menetia greyii	2	-	1
Morethia lineoocellata	11 (9.2)	1 (0.3)	(0)
Mus musculus	7	24	1
Neelaps calonotos	-	-	1
Pogona minor	5 (4.2)	7 (2.3)	29 (6.4)
Strophurus spinigerus	7 (5.8)	24 (8)	13 (2.9)
Pseudomys albocinereus	29 (24.2)	19 (6.3)	6 (1.3)
Sminthopsis dolichura	-	-	4
Sminthopsis granulipes	3	1	6
Little Button-quail	-	2	-
Tarsipes rostratus	4	-	1
TOTAL CAPTURES	106	342	191
N species	15	17	21

3.4.3 Bird Censusing

The bird censusing along the transects recorded just six species, which was poor compared with equivalent censusing carried out in the same period at the Beharra Silica project area; census results are compared in Table 14. The low species richness is typical of Kwongan (VSA 1), with much higher numbers of species in riparian thickets (VSA 2). This is also reflected in the opportunistic bird records, with 49 species recorded in the Arrowsmith North project area and immediate surrounds (Appendix 9), although this includes 10 waterbird species around Arrowsmith Lake which lies just outside the project area. Despite the low number of species along the Arrowsmith North transect, there was a high number of individuals due to an aggregation of White-cheeked Honeyeaters in a small patch of Banksia Woodland (VSA 2). A feature of the distribution of birds noted in the analysis of the Beharra Silica data (Bamford and Bancroft 2022), was that richness and abundance were high in structurally complex environments, such as where Kwongan (VSA 1) and Riparian thickets (VSA 2) graded into each other.

Table 14. Numbers of records of each bird species along each transect.

Species	Beharra silica project area				Arrowsmith North
	Transect B01	Transect B02	Transect B03	Transect B04	
N census events	50	50	100	100	**120**
Australian Pipit	2	-	-	-	**-**
Black-faced Woodswallow	3	-	-	1	**-**
Blue-breasted Fairy-wren	-	-	8	-	**-**
Brown Honeyeater	1	-	10	1	**-**
Crimson Chat	1	-	-	-	**-**
Hooded Robin	2	-	-	-	**-**
Horsfield's Bronze-Cuckoo	-	-	2	-	**-**
Little Button-quail	-	1	-	5	**1**
Nankeen Kestrel	-	1	1	-	**-**
Pied Honeyeater	2	-	-	-	**-**
Purple-backed Fairy-wren	-	-	18	-	**-**
Rufous Fieldwren	-	1	-	-	**1**
Rufous Songlark	1	-	-	-	**-**
Silvereye	-	-	8	-	**-**
Singing Honeyeater	2	3	1	-	**-**
Southern Emu-wren	-	-	-	-	**7**
Splendid Fairy-wren	2	-	3	-	**-**
Tawny-crowned Honeyeater	4	3	3	14	**9**
Tree Martin	3	-	-	-	**-**
White-browed Scrubwren	-	-	4	-	**-**
White-cheeked Honeyeater	-	-	-	-	**25**
White-winged Fairy-wren	-	2	1	-	**7**

White-winged Triller	10	3	-	-	**-**
N records	33	14	59	21	**50**
N species	12	7	11	4	**6**

3.4.4 Ecological processes

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

Local hydrology. The project area includes Riparian Thickets (VSA 2) in the west of the proposed mining area and along the access route, and groundwater approaches the surface in this landscape in winter. The vegetation is therefore almost certainly groundwater dependent. There is also a substantial wetland (Arrowsmith Lake) just west of the southern end of the access route. Surface and sub-surface hydrology are likely to be very important for some components of the fauna assemblage in these areas, while some components of the Kwongan heath (VSA 1) and Open Woodland (VSA 3) may be groundwater dependent. If groundwater-filled voids are present in limestone underlying VSA 4, then stygofauna may potentially be present and reliant on groundwater. It is notable that VSA 2 (Riparian Thickets) and its ecotone with VSA 1 (Kwongan heath) was associated with high numbers of records of both birds and reptiles.

Fire. Fire is natural in the landscape and the vegetation has adapted to and relies upon fire to regenerate. However, changes to the frequency, size and intensity of fire can have a negative impact on the landscape and therefore the fauna. Fires have almost certainly been too extensive and frequent in the area for many decades, and this is likely to have adversely affected the fauna. There is some evidence of this from analysis of trapping data from the Tronox, Beharra Silica and Arrowsmith North project areas, with an increase in some species but a decline in others. The Western Ground Parrot, appears to need access to long-unburnt vegetation and too-frequent and too-extensive fires may have rendered it extinct in the region. The project area has been affected by relatively recent fires. The northern third of the site was last burnt in 2012 whilst the southern half was last burnt in 2007. Evidence of this can be seen through aerial imagery (Figure 3). Despite this, most fauna species are remarkably resilient in the face of fires and altered fire regimes (Bamford 1986, 1992, 1995; Bamford and Roberts 2003).

Feral species and interactions with over-abundant native species. Feral species are a major component of the mammal fauna, and several are known to have a negative impact on native fauna; for example most of the locally extinct native mammals are affected by Foxes and Cats, and the feral Cat has been implicated in the decline of the Western Ground Parrot on the south coast. Over-abundant native species are probably not a significant problem in the largely intact native landscape.

Connectivity and landscape permeability. Broadly, the project area is part of a 25 km wide corridor along the coast connecting nature reserves and crown land. The corridor extends over 150 km south, however only 13 km north until agriculture becomes the dominant land use. Directly surrounding the site consists of similar bushland except for a partly cleared agricultural property to the west. The project area is thus currently more or less intact and continuous except for this property in the west,

although the Riparian Thickets (VSA 2) are linear in nature and thus represent a natural corridor for the movement of some fauna. Otherwise, VSA 1 in particular is very broadly-distributed across the landscape, and therefore species such as Carnaby's Black-cockatoo is very unlikely to be following defined movement corridors, but will rather disperse to source food supplies.

3.4.5 Summary of fauna values

The desktop study identified 203 vertebrate fauna species as potentially occurring in the project area: 3 freshwater fish, 10 frogs, 51 reptiles, 114 birds and 25 mammals. Thirteen mammal species are likely to be locally extinct, and one reptile, one bird and one mammal may also be locally extinct. A small suite of conservation significant invertebrates is present.

Fauna values within the project area are summarised below.

Fauna assemblage. Moderately rich but incomplete with some species locally extinct, mostly critical weight range mammals. Notable for a rich reptile assemblage, in particular fossorial and sand inhabiting species. There is a high proportion of non-resident birds, including many which are nectivorous and exploit seasonal abundance of nectar and pollen from the species-rich flora. The presence of Riparian Thickets in the west and along the access route increases the species richness. Some aquatic and wetland species may inhabit the drainage line and Arrowsmith Lake in the south. Overall, the vertebrate fauna assemblage is likely to be well represented and typical of the Lesueur Sandplains subregion. The invertebrate fauna assemblage is likely to include some species with restricted distributions (SREs) associated with particular landscape features.

Species of conservation significance. Eighteen vertebrate and at least seven invertebrate species of conservation significance may be present, although of these one reptile, one bird and one mammal may be locally extinct. Half the significant species are only locally significant (CS3), or of higher significance but considered unlikely to be present regularly. Carnaby's Black-Cockatoo is important as it is likely to be a regular foraging visitor to the project area and known roost sites are located nearby. Breeding in the region is not known but there may be suitable breeding habitat to the east and along Arrowsmith River to the south. The most extensive VSA across the project area, Kwongan heath (VSA 1), is of high foraging value for Carnaby's Black-Cockatoo and is widespread in the mining lease. The Western Ground Parrot may be locally extinct but because of its very high conservation significance (with the only known wild population estimated as c. 150 birds; A. Burbidge pers. comm.) and previous records within close proximity of the project area, the slight possibility of the species being extant in the general area is important; if present, it is likely to be restricted to Kwongan Heath (VSA 1). While significant invertebrates are probably incompletely documented, landscape interpretation suggest that Riparian thickets (VSA 2) and *Eucalyptus erythrocorys* Low Woodland (VSA 4; just outside the access route) may support SRE species. There is likely to be a subterranean fauna assemblage in the limestone underlying VSA 4.

Vegetation and Substrate Associations (VSAs). The most extensive VSA is Kwongan Heath (VSA 1) that occurs across most on the mine area and some of the access route. Small patches of Banksia Woodland (VSA 2) occur within and blend with VSA 1, but the presence of small trees affect the bird assemblage in particular. Riparian Thickets (VSA 2) occur low in the landscape where groundwater approaches the

surface in winter. These thickets are variable in floristic composition and structure and occur in the west of and immediately outside the proposed mining area, and along parts of the access route. VSA 2 is linear and groundwater movement may feed into Arrowsmith Lake and a drainage line in the south. VSA 4 (*E. erythrocorys* Low Woodland) is associated with limestone substrate on low rises just west of the southern end of the access route.

Patterns of biodiversity. Important patterns of biodiversity include:

- The Kwongan heath and open woodland (VSAs 1 and 3) are expected to be particularly rich in reptile and small terrestrial mammal species, and seasonally important for nectarivores (many birds, Honey Possum).
- The ecotone between Kwongan Heath (VSA1) and Riparian Thickets (VSA 2) supports a high richness and abundance of reptiles and birds.
- The Riparian Thicket (VSA 2) is likely to support some birds that favour very dense vegetation and that do not occur or occur infrequently in the Kwongan. The thickets also contribute to the seasonal variation in flowering, and could harbour short range endemic invertebrates due to the seasonally moist soils.
- While wetlands appear not to be present in the project area, Arrowsmith Lake is a substantial wetland that lies just outside the access route and is probably linked through hydrology to the project area. It supports wetland-dependent fauna.
- *Eucalyptus erythrocorys* Low Woodlands with outcropping limestone (VSA 4) lie just outside the access route; these may support SRE invertebrates specific to this substrate, and may also have subterranean fauna.
- Fire history appears to have a strong influence on the fauna assemblage, and in particular the reptiles and small mammals. It appeared that Kwongan subject to multiple fires over a 20 year period had high abundances of a few species but low abundances of several other species.

Key ecological processes. The main processes which may affect the fauna assemblage are likely to be local hydrology, the fire regime and the presence of feral predators. Local hydrology may be of particular importance in the Riparian Thickets (VSA 2) and possibly in VSA 4. The fauna assemblage appears to have been affected by the recent fire regime, especially frequent and extensive fires. Feral predators have contributed to the local extinction, or probable local extinction, of several species.

4 References

ALA. (2020). Atlas of Living Australia. http://www.ala.org.au

Allen, G.R., Midgeley, S.H. and Allen, M (2002). Field Guide to the Freshwater Fishes of Australia. Western Australian Museum. Perth, Western Australia.

Anstis, M. (2013). Tadpoles and Frogs of Australia. New Holland Publishers, Sydney.

Armstrong, K.N. (2011). The current status of bats in Western Australia. In: Law, B., Eby, P., Lunney, D. and Lumsden, L. (Eds) (2011). *The Biology and Conservation of Australasian Bats*. Royal Zoological Society of NSW, Mosman, NSW, Australia.

Atlas of Living Australia occurrence download at https://biocache.ala.org.au/occurrences/search?q=*%3A*&lat=-29.488266&lon=115.092606&radius=20.1 accessed on Wed Oct 16 11:49:08 AEDT 2019.

Bamford, M.J. (1986). The Dynamics of Small Vertebrates in Relation to Fire in Banksia Woodland near Perth, Western Australia. Unpubl. Ph.D. Thesis, Murdoch University, Perth.

Bamford, M.J. (1992). The impact of fire and increasing time after fire upon *Heleioporus eyrei*, *Limnodynastes dorsalis* and *Myobatrachus gouldii* (Anura: Leptodactylidae) in Banksia woodland near Perth, Western Australia. Aust. Wildl. Res. 19: 169-78.

Bamford, M.J. (1995). Responses of reptiles to fire and increasing time after fire in Banksia woodland. CALMScience suppl. 4: 175-186.

Bamford, M.J. and Roberts, J.D. (2003). The impact of fire upon frogs and reptiles in south-west Western Australia.pp. 349-362 in: Fire in ecosystems of south-west Western Austrlaia. Eds. I. Abbott and N. Burrows. Backhuys Publishers, Leiden.

Bamford, M. (2009). Fauna Investigations of Iluka's Proposed Eneabba Future Mining Operations. Unpublished report for Iluka.

Bamford, M.J. (2012). Tronox Joint Venture. Survey for the Western Ground Parrot Pezoporus flaviventris within the Dongara Project Area and Beekeepers' Nature Reserve. Unpubl. report to Tronox Joint Venture by Bamford Consulting Ecologists, Perth.

Bamford, M.J. and Bamford, A.R. (1999). A study of the Brush or Black-gloved Wallaby *Macropus irma* (Jourdan 1837) in Whiteman Park. Whiteman Park Technical Report Series No. 1. Western Australian Planning Commission, Perth.

Bamford, M., Bancroft, W. and Sibbell, N. (2010). Twenty years and two transects; spatial and temporal variation in local patterns of biodiversity – frogs, reptiles and small mammals. Presentation at 2010 conference of the Ecological Society of Australia, Canberra.

Bamford, M. and Chuk, K. (2015-2017). Arrowsmith Rehabilitation - Feral Fauna Monitoring. Unpubl, report by Bamford Consulting Ecologists to Stratagen.

Bamford, M. and Chuk, K. (2019). Ventnor's Arrowsmith Central Fauna Assessment. Unpublished report for Ventnor.

Bamford, M., Everard, C. and Chuk, K. (2015). Waitsia Wells, Dongara Fauna Assessment. Unpublished report for AWE.

Bamford, M. (2020). VRX Silica. Arrrowsmith Silica Sands Project Rehabilitation Strategy. Discussion on the potential foraging value of the rehabilitated landscape for Carnaby's Black-Cockatoo. Unpubl. report to VRX Silica by Bamford consulting Ecologists, Kingsley.

Bamford, M. and Bancroft, W. (2022). Beharra Springs Silica Project. Fauna Values Assessment. Unpubl. report to Perpetual Resources Ltd by Bamford Consulting Ecologists, Kingsley.

Bancroft, W. and Bamford, M. (2020). Beach Energy's Zemira 3D Siesmic Survey. Fauna Values Assessment. Unpubl. report to Strategen JBS & G by Bamford Consulting Ecologists, Kingsley.

Barrett, G., Silcocks, A., Barry, S., Cunningham, R. and Poulter, R. (2003). The new atlas of Australian birds. Melbourne: Birds Australia.

Beard, JS (1980). A new phytogeographic map of Western Australia, Western Australian Herbarium Research Notes 3: 37–58.

Bennelongia (2022). Arrowsmith north Project SRE Invertebrate Assessment. Unpubl. report to VRX Silica by Bennelongia Environmental Consultants.

Birdlife Australia (2019). Birdata Database and Map Tool. http://birdata.birdlife.org.au/ (accessed January 2019).

Blakers, M., Davies, S.J.J.F. and Reilly, P.N. (1984). The Atlas of Australian Birds. Royal Australasian Ornithologists Union. Melbourne University Press.

Bureau of Meteorology (2020). *Climate Data Online.* Commonwealth of Australia. Accessed on 7 January 2021 via: http://www.bom.gov.au/climate/data/

Bush, B., Maryan, B., Browne-Cooper, R. and Robinson, D. (2007). Reptiles and Frogs In the Bush: South western Australia. University of Western Australia Press, Perth.

Churchill, S. (2008). Australian Bats. Reed New Holland Press, Sydney.

Curnutt, J.L., Pimm, S.L. and Maurer, B.A. (1996). Population variability of sparrows in space and time. Oikos 76: 131-144.

DBCA. (2019a). Threatened and Priority Fauna List. Department of Biodiversity, Conservation and Attractions, Kensington, Western Australia.

DBCA. (2019b). 'Black Cockatoo Breeding Sites - Buffered (DBCA-063)'. Department of Biodiversity, Conservation and Attractions (on www.Data.wa.gov.au). https://catalogue.data.wa.gov.au/dataset/black-cockatoo-breeding-sites-buffered.

DBCA. (2020). DBCA Region Boundaries (DBCA-022). Department of Biodiversity, Conservation and Attractions. https://catalogue.data.wa.gov.au/dataset/dpaw-region-boundaries

Department of Biodiversity, Conservation and Attractions (WA) (2019). NatureMap Database. http://naturemap.dec.wa.gov.au/default.aspx (accessed January 2019).

Department of the Environment and Energy (2019). EPBC Protected Matters Search Tool. https://www.environment.gov.au/epbc/protected-matters-search-tool (accessed January 2019).

Doughty, P., Ellis, R.J. & Bray, R. (2016a). Checklist of the Amphibians of Western Australia. Department of Terrestrial Zoology, Western Australian Museum, Welshpool, Western Australia.

Doughty, P., Ellis, R.J. & Bray, R. (2016b). Checklist of the Reptiles of Western Australia. Department of Terrestrial Zoology, Western Australian Museum, Welshpool, Western Australia.

Environmental Protection Authority (EPA). (2002). Terrestrial Biological surveys as an Element of Biodiversity Protection. Position Statement No. 3. Environmental Protection Authority, Perth, Western Australia.

Environmental Protection Authority (EPA). (2004). Guidance for the assessment of environmental factors: Terrestrial fauna surveys for environmental impact assessment in Western Australia. No. 56. Environmental Protection Authority, Perth, Western Australia.

Environmental Protection Authority (EPA). (2016). Environmental Factor Guideline Terrestrial Fauna. EPA Western Australia.

Everard, C. and Bamford, M. (2014). ILUKA Resources Limited IPL North Project Area Fauna Assessment. Unpublished report for Iluka.

Harris, I., Metcalf, B. and Bamford, M. (2008). Mt Adams Rd Project Threatened Fauna Investigations September 2008. Unpublished report for TiWest Joint Venture.

Hill, A.P., Prince, P., Covarrubias, E.P., Doncaster, C.P., Snaddon, J.L. and Rogers, A. (2018). AudioMoth: Evaluation of a smart open acoustic device for monitoring biodiversity and the environment. *Methods in Ecology and Evolution*. 9, 1199-1211.

Hill, A.P., Prince, P., Snaddon, J.L., Doncaster, C.P. and Rogers, A. (2019). AudioMoth: a low-cost acoustic device for monitoring biodiversity and the environment. *HardwareX*, 6.

How, R.A. and Dell, J. (1990). Vertebrate fauna of Bold Park, Perth. West. Aust. Nat. 18: 122-131.

Johnstone, R. E and Darnell, J.C. (2016). Checklist of the Birds of Western Australia. Department of Terrestrial Zoology, Western Australian Museum, Welshpool, Western Australia.

Johnstone, R.E. and Storr, G.M. (1998). Handbook of Western Australian Birds Vol 1 – Non-passerines (Emu to Dollarbird). Western Australian Museum, Perth.

Johnstone, R.E. and Storr, G.M. (2004). Handbook of Western Australian Birds. Vol 2: Passerines (Blue-winged Pitta to Goldfinch). Western Australian Museum, Perth.

McGrath, M., Weston, M., Olsen, P., Antos, M. and Herrod, A. (2010). Survey guidelines for Australia's threatened birds. Commonwealth of Australia.

Marchant, N. and Higgins, P.J. (1993). Handbook of Australian, New Zealand and Antarctic Birds Vol. 2. Raptors to Lapwings. Oxford University Press, Melbourne.

Maryan, B. (2005). A herpetofauna hotspot, the central west coast of Western Australia. The Western Australian Naturalist Journal 25: 1–24.

Mattiske Consulting (2020). Flora and vegetation assessment. Arrowsmith project area. Unpubl. report to Ventnor Resources Ltd by Mattiske Consulting Pty Ltd.

Menkhorst, P. and Knight, F. (2004). A Field Guide to the Mammals of Australia. Oxford University Press, Melbourne.

Menkhorst, P., Rogers, D., Clarke, R., Davies, J., Marsack, P. and Franklin, K. (2017). The Australian Bird Guide. CSIRO Publishing, Clayton South.

Metcalf, B. and Bamford, M. (2008). Fauna Assessment of the Mt Adams Road Project. Unpublished report for TiWest Joint Venture.

NHT (2004). National manual for the Malleefowl Monitoring System. Natural Heritage Trust.

Peck, A., Barret, G. and Williams, M. (2017). The 2017 Great Cocky Count: A community-based survey for Carnaby's Black-Cockatoo (*Calyptorhynchus latirostris*) and Forest Red-tailed Black-Cockatoo (*Calyptorhynchus banksii naso*). BirdLife Australia, Floreat, Western Australia.

Rentz, D. C. F. (1993). *Tettigoniidae of Australia Volume 2: Austrosaginae, Zaprochilinae and Phasmodinae*. CSIRO Publishing, Australia.

Rentz, D. (1996). Grasshopper country: the abundant orthopteroid insects of Australia. UNSW Press, Sydney.

Rix, M. G., Huey, J. A., Cooper, S. J. B., Austin, A. D. and Harvey, M. S. (2018). Conservation systematics of the shield-backed trapdoor spiders of the nigrum-group (Mygalomorphae, Idiopidae, Idiosoma): integrative taxonomy reveals a diverse and threatened fauna from south-western Australia. ZooKeys 756: 1-121.

Rockwater 2011, *Dongara Mineral Sands Project Subterranean Fauna Sampling Programme*, unpublished report prepared for Tiwest, June 2011.

Saunders, D.A, and Dawson, R. (2017). Cumulative learnings and conservation implications of a long-term study of the endangered Carnaby's Cockatoo *Calyptorhynchus latirostris*. Australian Zoologist. Available at: https://doi.org/10.7882/AZ.2017.010

Storr, G.M., Smith, L.A. and Johnstone, R.E. (1983). Lizards of Western Australia. II. Dragons and Monitors. W.A. Museum, Perth.

Storr, G.M., Smith, L.A. and Johnstone, R.E. (1990). Lizards of Western Australia. III. Geckoes and Pygopodids. W.A. Museum, Perth.

Storr, G.M., Smith, L.A. and Johnstone, R.E. (1999). Lizards of Western Australia. I. Skinks. Revised Edition. W.A. Museum, Perth.

Storr, G.M., Smith, L.A. and Johnstone, R.E. (2002). Snakes of Western Australia. W.A. Museum, Perth.

Thackway, R. and Cresswell, I.D. (Eds) (1995). An Interim Biogeographic Regionalisation for Australia: a framework for establishing the national system of reserves, Version 4.0. Australian Nature Conservation Agency, Canberra.

Travouillon, K. (2016). Checklist of the Mammals of Western Australia. Department of Terrestrial Zoology, Western Australian Museum, Welshpool, Western Australia.

Tyler, M.J., Smith, L.A. and Johnstone, R.E. (2000). Frogs of Western Australia. W.A. Museum, Perth.

Van Dyck, S. and Strahan, R. (Eds.) (2008). Mammals of Australia. 3rd Edition. Australian Museum, Sydney.

WAM. (2020). Terrestrial Zoology Datasets. Department of Terrestrial Zoology, Western Australian Museum. http://data.museum.wa.gov.au/dataset/terrestrial-zoology.

Whytock, R.C. and Christie, J. (2017). Solo: an open source, customizable and inexpensive audio recorder for bioacoustics research. *Methods in Ecology and Evolution*, 8, 308-312.

Wilson, S. and Swan, G. (2013). A Complete Guide to Reptiles of Australia. Fourth edition. New Holland Publishers (Australia), Sydney.

5 Appendices

5.1 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 rather 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 by other factors, for example, by the sorts of species present.

Vegetation and Substrate Associations

Vegetation and Substrate Associations (VSAs) combine broad vegetation types, the soils or other substrate with which they are associated, and the landform. In the context of fauna assessment, VSAs are the environments that provide habitats for fauna. The term habitat is widely used in this context, but by definition an animal's habitat is the environment that it utilises (Calver *et al.* 2009; Bamford and Calver 2014), 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, which VSAs will recognise. VSAs also do not necessarily correspond with soil types, but may reflect some of these elements.

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

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

Patterns of biodiversity across the landscape

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

Species of conservation significance

Species of conservation significance are of special importance in impact assessment. The conservation status of fauna species in Australia is assessed under Commonwealth and State Acts such as the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) and the Western Australian *Biodiversity Conservation Act 2016* (Biodiversity Conservation 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, three broad levels of conservation significance can be recognised and are used for the purposes of this report and are outlined below. A full description of the conservation significance levels, schedules and priority levels mentioned below is provided in Appendix 3.

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

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

Conservation Significance (CS) level 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 Biodiversity Conservation Act but for which the DBCA believes there is cause for concern. Some Priority species are also assigned to the Conservation Dependent category of the IUCN.

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

This level of significance has no legislative or published recognition and is based on interpretation of distribution information and expert judgment, but is used here as it may have links to preserving biodiversity at the genetic level (EPA 2002). If a population is isolated but a subset of a widespread

(common) species, then it may not be recognised as threatened, but may have unique genetic characteristics. Conservation significance is applied to allow for the preservation of genetic richness at a population level, and not just at a species level. Species on the edge of their range, or that are sensitive to impacts such as habitat fragmentation, may also be classed as CS3, as may colonies of waterbirds. The Western Australian Department of Environmental Protection, now DBCA, used this sort of interpretation to identify significant bird species in the Perth metropolitan area as part of the Perth Bushplan (DEP 2000).

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

Introduced species

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

Ecological processes upon which the fauna depend

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

Appendix 1 references

Bamford, M.J. and Calver, M.C. (2014). A precise definition of habitat is needed for effective conservation and communication. Australian Zoologist. 2014: 245-247.

Calver, M., Lymbery, A., McComb, J. and Bamford, M. (2009). Environmental Biology. Cambridge University Press, Melbourne.

Department of Environmental Protection (DEP) (2000). Bush Forever Volume 2. Government of Western Australia, Perth.

Environmental Protection Authority (EPA) (2002). Terrestrial Biological surveys as an Element of Biodiversity Protection. Position Statement No. 3. Environmental Protection Authority, Perth, Western Australia.

Harvey, M. (2002). Short-range Endemism amongst the Australian fauna: examples from non-marine environments. *Invertebrate Systematics*, 16: 555-570.

Mace, G. and Stuart, S. (1994). Draft IUCN Red List Categories, Version 2.2. Species; Newsletter of the Species Survival Commission. IUCN - The World Conservation Union. No. 21-22: 13-24.

5.2 Appendix 2. Explanation of threatening processes.

Potential impacts of proposed developments upon fauna values can be related to threatening processes. This is recognised in the literature (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.

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, Bamford and Roberts 2003). It is also one of the factors that has contributed to the decline and local extinction of some mammal and bird species (Burbidge and McKenzie 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 2 references

Bamford, M.J., Roberts, J.D. (2003). The impact of fire on frogs and reptiles in south-west Western Australia in *Fire in ecosystems of south-west Western Australia: impacts and management*, Backhuys Publishers, The Netherlands.

Burbidge, A.A. and McKenzie, N.L. (1989). Patterns in the modern decline of Western Australia's vertebrate fauna: causes and conservation implications. Biol. Cons. 50: 143-198.

Clevenger, A. P. and Waltho, N. (2000). Factors influencing the effectiveness of wildlife underpasses in Banff National Park, Alberta, Canada. Conservation Biology 14: 1-11.

Dufty, A. C. (1989). Some population characteristics of *Perameles gunnii* in Victoria. Wildlife Research 18: 355-365.

Fox, B.J. (1982). Fire and mammalian secondary succession in an Australian coastal heath. Ecology 63: 1332-1341.

Gill, A.M., Groves, R.H. and Noble, I.R. (eds) (1981). Fire and the Australian Biota. Australian Academy of Science, Canberra.

Harrington, R. (2002). The effects of artificial watering points on the distribution and abundance of avifauna in an arid and semi-arid mallee environment. PhD thesis. Department of Zoology, University of Melbourne, Melbourne, Victoria.

Jackson, S. D. and Griffin, C. R. (2000). A Strategy for Mitigating Highway Impacts on Wildlife. In: Messmer, T. A. and West, B. (Eds), Wildlife and Highways: Seeking Solutions to an Ecological and Socio – economic Dilemma, pp. 143-159. The Wildlife Society.

Jones, M. E. (2000). Road upgrade, road mortality and remedial measures: impacts on a population of Eastern Quolls and Tasmanian Devils. Wildlife Research 27: 289-296.

Kofoed, P. (1998). A wizard with wavelengths. Ecos96. CSIRO.

Letnic, M., Dickman, C.R., Tischler, M.K., Tamayo, B. and Beh, C.L. (2004).The responses of small mammals and lizards to post-fire succession and rainfall in arid Australia. Journal of arid environments59 (1): 85-114.

Read, J.L., Parkhurst, B. and Delean, S. (2015). Can Australian bushbirds be used as Canaries? Detection of pervasive environmental impacts at an arid Australian mine-site. Emu 115 (2): 117-125.

Rich, C. and Longcore, T. (2006). Ecological Consequences of Artificial Night Lighting. Island Press.

Scheick, B. K. and Jones, M. D. (1999). Locating wildlife underpasses prior to expansion on Highway 64 in North Carolina. In: Evink, G. L., Garrett, P. and Ziegler, D. (Eds), Proceedings of the Third International Conference on Wildlife Ecology and Transportation, pp. 247-252. Florida Department of Transportation, Tallahassee, Florida, USA.

Soule, M. E., Mackey, B. G., Recher, H. F., Williams, J. E., Woinarski, J. C. Z., Driscoll, D., Dennison, W. C. and Jones, M. E. (2004). The role of connectivity in Australian conservation. *Pacific Conservation Biology* 10: 266-279.

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

IUCN categories (based on review by Mace and Stuart 1994) as used for the *Environment Protection and Biodiversity Conservation Act 1999* and the Western Australian *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 dependent fauna
Schedule 7 (S7)	Other specially protected fauna

WA Department of Biodiversity, Conservation and Attractions Priority species (species not listed under the *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 reference

Mace, G. and Stuart, S. (1994). Draft IUCN Red List Categories, Version 2.2. Species; Newsletter of the Species Survival Commission. IUCN - The World Conservation Union. No. 21-22: 13-24.

5.4 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 interaction of ecological processes with 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 and Energy (DoEE 2018c):

- Competition and land degradation by rabbits.
- Competition and land degradation by unmanaged goats.
- Dieback caused by the root-rot fungus (*Phytophthora cinnamomi*).
- Incidental catch (bycatch) of Sea Turtle during coastal otter-trawling operations within Australian waters north of 28 degrees South.
- Incidental catch (or bycatch) of seabirds during oceanic longline fishing operations.
- Infection of amphibians with chytrid fungus resulting in chytridiomycosis.
- Injury and fatality to vertebrate marine life caused by ingestion of, or entanglement in, harmful marine debris.
- Invasion of northern Australia by Gamba Grass and other introduced grasses.
- Land clearance.
- Loss and degradation of native plant and animal habitat by invasion of escaped garden plants, including aquatic plants.
- Loss of biodiversity and ecosystem integrity following invasion by the Yellow Crazy Ant (*Anoplolepis gracilipes*) on Christmas Island, Indian Ocean.
- Loss of climatic habitat caused by anthropogenic emissions of greenhouse gases.
- Novel biota and their impact on biodiversity.
- Predation by European red fox.
- Predation by exotic rats on Australian offshore islands of less than 1000 km^2 (100,000 ha).

- Predation by feral cats.
- Predation, Habitat Degradation, Competition and Disease Transmission by Feral Pigs.
- Psittacine Circoviral (beak and feather) Disease affecting endangered psittacine species.
- The biological effects, including lethal toxic ingestion, caused by Cane Toads (*Bufo marinus*).
- The reduction in the biodiversity of Australian native fauna and flora due to the red imported fire ant, *Solenopsis invicta* (fire ant).

General processes that threaten biodiversity across Australia (The National Land and Water Resources Audit, 2008):

- 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 saltwater intrusion;
- Changed hydrology— such as altered flow regimes affecting riparian vegetation; and
- Pollution.

In addition to the above processes, DSEWPaC (2013) (now DoEE) has produced Significant Impact Guidelines that provide criteria for the assessment of the significance of impacts. These criteria provide a framework for the assessment of significant impacts. The criteria are:

- 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 4 references

Department of Sustainability, Environment, Water, Population and Communities (DSEWPaC) (2013). Matters of National Environmental Significance. Significant Impact Guidelines 1.1. Commonwealth of Australia.

Soule, M. E., Mackey, B. G., Recher, H. F., Williams, J. E., Woinarski, J. C. Z., Driscoll, D., Dennison, W. C. and Jones, M. E. (2004). The role of connectivity in Australian conservation. Pacific Conservation Biology10: 266-279.

Appendix 5. Sampling location descriptions and coordinates in the Arrowsmith North project area.

Zone 50J, datum GDA94.

2019

Name	Eastings	Northings	Date set	Date collected	ARU type
ARU 1	316698	6737272	24/09/19	18/10/19	SOLO
ARU 2	313834	6739532	24/09/19	18/10/19	SOLO
ARU 3	316444	6733612	24/09/19	18/10/19	AudioMoth
ARU 4	314181	6734885	24/09/19	18/10/19	SOLO

2021

Name	Easting	Northing	Date set	Type
AM-BCE05	314647	6735284	4/12/2021	Audio recording unit
AM-BCE06	315842	6735373	4/12/2021	Audio recording unit
AM-BCE07	316122	6736247	4/12/2021	Audio recording unit
AM-BCE08	316012	6738469	4/12/2021	Audio recording unit
SM2-17715	316204	6735350	6/12/2021	Audio recording unit
SM2-17769	314326	6731532	5/12/2021	Audio recording unit
Cam-BCE01	313903	6734282	4/12/2021	Motion-sensitive camera point
Cam-BCE03	313924	6733783	4/12/2021	Motion-sensitive camera point
Cam-BCE04	313911	6730592	5/12/2021	Motion-sensitive camera point
Cam-BCE06	314566	6733705	4/12/2021	Motion-sensitive camera point
Cam-BCE20	313962	6733048	4/12/2021	Motion-sensitive camera point
Cam-BCE32	314845	6729421	5/12/2021	Motion-sensitive camera point
V01	316315	6735254	3/12/2021	Pitfall and bird census point
V02	316320	6735225	3/12/2021	Pitfall, funnel and bird census point
V03	316322	6735194	3/12/2021	Pitfall and bird census point
V04	316324	6735166	3/12/2021	Pitfall and bird census point
V05	316326	6735134	3/12/2021	Pitfall and bird census point
V06	316335	6735105	3/12/2021	Pitfall, funnel and bird census point
V07	316346	6735078	3/12/2021	Pitfall and bird census point
V08	316354	6735048	3/12/2021	Pitfall and bird census point
V09	316363	6735019	3/12/2021	Pitfall and bird census point
V10	316374	6734990	3/12/2021	Pitfall, funnel and bird census point
V11	316381	6734961	3/12/2021	Pitfall and bird census point
V12	316391	6734933	3/12/2021	Pitfall and bird census point
V13	316396	6734904	3/12/2021	Pitfall and bird census point
V14	316407	6734877	3/12/2021	Pitfall, funnel and bird census point
V15	316418	6734847	3/12/2021	Pitfall and bird census point
V16	316426	6734818	3/12/2021	Pitfall and bird census point
V17	316435	6734788	3/12/2021	Pitfall and bird census point

V18	316445	6734762	3/12/2021	Pitfall, funnel and bird census point
V19	316451	6734732	3/12/2021	Pitfall and bird census point
V20	316459	6734702	3/12/2021	Pitfall and bird census point
Tree01	314245	6729408	5/12/2021	Possible nest tree for black-cockatoo; diameter at breast height of 1100mm. Two large hollows of suitable size.

5.5 Appendix 6. Scoring system for the assessment of foraging value of vegetation for Black-Cockatoos. Revised 5th November 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) with assistance from Quessentia Consulting 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.

Note that the scoring system can only be applied within the range of the species or at least where the species could reasonably be expected to occur based upon existing information.

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.

The BCE scoring system places the greatest weight on site condition (scale of 0 to 6) because this has the highest influence on the foraging values of a site, which in turn is the fundamental driver in meeting ecological requirements for continued survival.

Site context has a lower weight (scale of 0 to 3) in recognition of the mobility of the species, which means they can access good foraging habitat even in fragmented landscapes, but allowing for recognition of the extent of available habitat in a region and context in relation to activity (such as breeding and roosting). The application of scoring site context is further discussed below.

Species stocking rate is given a low weight (0 to 1) as it is a means only of recognising that a species may or may not be abundant at a site, but that abundance is dependent upon site condition and context and is thus not an independent variable. The abundance of a species is also sensitive to sampling effort, and to seasonal and annual variation, and is therefore an unreliable indicator of actual importance of a site to a species.

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	No foraging value. No Proteaceae, eucalypts or other potential sources of food. Examples: • 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	No foraging value. No eucalypts or other potential sources of food. Examples: • Water bodies (e.g. dams, rivers); • Bare ground; • Developed sites devoid of vegetation (e.g. infrastructure, roads, gravel pits).	No foraging value. No eucalypts or other potential sources of food. Examples: • Water bodies (e.g. dams, rivers); • Bare ground; • Developed sites devoid of vegetation (e.g. infrastructure, roads, gravel pits).
1	Negligible to low foraging value. Examples: • 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. *Erodium* 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).	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.	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.

Site Score	Description of Vegetation Values		
	Carnaby's Black-Cockatoo	**Baudin's Black-Cockatoo**	**Forest Red-tailed Black-Cockatoo**
2	Low foraging value. Examples: • 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. *Erodium* spp.) that represent a short-term and/or seasonal food source.	Low foraging value. Examples: • Woodland with scattered specimens of known food plants (e.g. Marri and Jarrah) 1-5% projected foliage cover; • Urban areas with scattered foraging trees.	Low foraging value. Examples: • 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, *Eucalyptus caesia* and *E. erythrocorys*.
3	Low to Moderate foraging value. Examples: • 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.	Low to Moderate foraging value. Examples: • 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).	Low to Moderate foraging value. Examples: • 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	Moderate foraging value. Examples: • Woodland/low forest with tree banksias (of key species *B. attenuata* and *B. menziesii*) 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.	Moderate foraging value. Examples: • 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).	Moderate foraging value. Examples: • 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	Moderate to High foraging value. Examples: • Banksia Low Forest (of key species *B. attenuata* and *B. menziesii*) with 40-60% projected foliage cover; • Banksia Low Forest (of key species *B. attenuata* and *B. menziesii*) 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).	Moderate to High foraging value. Examples: • 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.	Moderate to High foraging value. Examples: • 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	High foraging value. Example: • Banksia Low Forest (of key species *B. attenuata* and *B. menziesii*) 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).	High foraging value. Example: • 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).	High foraging value. Example: • 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, Black-Cockatoos 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 assignation 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 15km 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. Assignation 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 ($\geq$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-Cockatoos are not regularly present.

Keighery (1994).

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.

5.6 Appendix 7. Fauna expected to occur in the project area

These lists are derived from the results of database and literature searches and from previous field surveys conducted in the local area. 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;
- N = Naturemap Database, searched January 2019;
- EPBC = EPBC Protected Matters, searched January 2019;
- BA = Birdlife Australia's Birdata database, searched January 2019;
- BCE = BCE surveys undertaken previously 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), Bamford and Bancroft (2022)). These records fall within a radius of about 15km. Note that BCE records from the Arrowsmith North project area (surveys in November 2018, August 2020 and/or December 2021) are indicated in **bold**. These species (in bold) have thus been recorded on the project area). Species recorded within 5km of the Arrowsmith North area but not in the area during the September 2020 or December 2021 surveys are indicated with +. This does not include waterbirds which are listed separately.
- Site visits = species observed during the two site visits to the project area (September 2019). Species seen in the actual project area in bold; other seen nearby (within c. 5km) not in bold.

Conservation significance (CS) codes are:

- CS1, CS2, CS3 = (summary) levels of conservation significance. See Appendix 3 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).

FRESHWATER FISH		**CS**	**ALA**	**N**	**EPBC**	**BCE**	**Expected status in project area**
GALAXIIDAE							
Western Minnow	*Galaxias occidentalis*						Regular visitor
NANNOPERCIDAE							
Western Pygmy-perch	*Edelia (Nannoperca) vittata*						Regular visitor
GOBIIDAE							
Swan River Goby	*Pseudogobius olorum*						Regular visitor
Number of species expected	**3**						

FROGS		CS	ALA	N	EPBC	BCE	Expected status in project area
HYLIDAE							
Slender Tree Frog	*Litoria adelaidensis*		X			X	Resident
Motorbike Frog	*Litoria moorei*		X			X	Resident
LIMNODYNASTIDAE							
Western Spotted Frog	*Heleioporus albopunctatus*					X	Resident
Moaning Frog	*Heleioporus eyrei*		X	X		**X**	Resident
Sand Frog	*Heleioporus psammophilus*					X	Resident
Banjo Frog	*Limnodynastes dorsalis*					**X**	Resident
Humming Frog	*Neobatrachus pelobatoides*		X	X		X	Resident
MYOBATRACHIDAE							
Bleating Froglet	*Crinia pseudinsignifera*					X	Resident
Turtle Frog	*Myobatrachus gouldii*		X	X		**X**	Resident
Gunther's Toadlet	*Pseudophryne guentheri*		X	X		X	Resident
Number of Species Expected: 10		**0**				**10**	

REPTILES		CS	ALA	N	EPBC	BCE	Expected status in project area
CHELIDAE							
South-west Long-necked Tortoise	*Chelodina oblonga*						Irregular Visitor
AGAMIDAE							
Western Heath Dragon	*Ctenophorus adelaidensis*		X	X		**X**	Resident
Spotted Military Dragon	*Ctenophorus maculatus*		X	X		**X**	Resident
Thorny Devil	*Moloch horridus*		X			**X**	Resident
Dwarf Bearded Dragon	*Pogona minor*		X	X		**X**	Resident
DIPLODACTYLIDAE							
South-Western Clawless Gecko	*Crenadactylus ocellatus*					X	Resident
Western Stone Gecko	*Diplodactylus granariensis*					X?	Resident
	Diplodactylus ornatus					**X**	Resident
Spotted Sandplain Gecko	*Diplodactylus polyophthalmus*		X			X	Resident

REPTILES		CS	ALA	N	EPBC	BCE	Expected status in project area
White-spotted Ground Gecko	*Lucasium alboguttatus*					**X**	Resident
South-western Spiny-tailed Gecko	*Strophurus spinigerus*		X	X		**X**	Resident
GEKKONIDAE							
Tree Dtella	*Gehyra variegata*		X	X		X	Resident
PYGOPODIDAE							
Sedgelands Worm-Lizard	*Aprasia repens*					X	Resident
Javelin Legless Lizard	*Aclys concinna*					X	Resident
Fraser's Delma	*Delma fraseri*					X	Resident
Side-barred Delma	*Delma grayii*		X			**X**	Resident
Burton's Snake-Lizard	*Lialis burtonis*		X	X		X	Resident
Keeled Legless Lizard	*Pletholax gracilis*						Resident
Common Scaly-Foot	*Pygopus lepidopodus*		X	X		X	Resident
SCINCIDAE							
Buchanan's Snake-eyed Skink	*Cryptoblepharus buchananii*		X	X		**X**	Resident
West-coast Ctenotus	*Ctenotus fallens*			X		**X**	Resident
Odd-striped Ctenotus	*Ctenotus impar*					X	Resident
Leopard Ctenotus	*Ctenotus pantherinus*		X	X		X	Resident
Western Slender Blue-tongue	*Cyclodomorphus celatus*		X	X		X	Resident
	Lerista christinae					X	Resident
Elegant Slider	*Lerista elegans*		X	X		X	Resident
Dotted-Line Robust Slider	*Lerista lineopunctulata*		X	X			Resident
	Lerista planiventralis			X		**X**	Resident
Blunt-Tailed West-Coast Slider	*Lerista praepedita*		X	X		**X**	Resident
Southern Sand-Skink	*Liopholis multiscutata*			X		X	Resident
Common Dwarf Skink	*Menetia greyii*		X	X		**X**	Resident
West Coast Morethia Skink	*Morethia lineoocellata*					**X**	Resident
Shrubland Morethia Skink	*Morethia obscura*					X	Resident
Western Blue-tongue	*Tiliqua occipitalis*		X	X		X	Resident

REPTILES		CS	ALA	N	EPBC	BCE	Expected status in project area
Bobtail	*Tiliqua rugosa*		X	X		**X**	Resident
VARANIDAE							
Gould's Goanna	*Varanus gouldii*		X	X		X	Resident
Black-headed Monitor	*Varanus tristis*					X	Resident
TYPHLOPIDAE							
Southern Blind Snake	*Anilios australis*		X				Resident
Beaked Blind Snake	*Anilios waitii*						Resident
PYTHONIDAE							
Woma	*Aspidites ramsayi*	P1					Locally extinct?
Carpet Python	*Morelia spilota imbricata*	CS3					Resident
ELAPIDAE							
Narrow-banded Shovel-nosed Snake	*Brachyurophis fasciolata*						Resident
Southern Shovel-nosed Snake	*Barchyurophis semifasciata*						Resident
Yellow-faced Whip Snake	*Demansia psammophis*					X	Resident
Bardick	*Echiopsis curta*		X	X		X	Resident
Black-naped Snake	*Neelaps bimaculata*						Resident
Black-striped Snake	*Neelaps calonotos*	P2		X		X	Resident
Gould's Hooded Snake	*Parasuta gouldii*					X	Resident
King Brown (Mulga) Snake	*Pseudechis australis*					X	Resident
Gwarder or Western Brown Snake	*Pseudonaja mengdeni*		X	X		X	Resident
Jan's Banded Snake	*Simoselaps bertholdi*					X	Resident
Number of Species Expected:	**51**	**3**				**40**	

BIRDS		CS	ALA	N	EPBC	BA	BCE	Expected status in project area
CASUARIIDAE								
Emu	*Dromaius novaehollandiae*		X	X		X	**X**	Resident
MEGAPODIDAE								
Malleefowl	*Leipoa ocellata*	V S3		X	X			Irregular visitor

BIRDS		CS	ALA	N	EPBC	BA	BCE	Expected status in project area
PHASIANIDAE								
Stubble Quail	*Coturnix pectoralis*						X	Resident
TURNICIDAE								
Painted Button-quail	*Turnix varius*						X	Resident
Little Button-quail	*Turnix velox*						**X**	Regular visitor
COLUMBIDAE								
Rock Pigeon	*Columba livia*	Int.	X		X		X	Vagrant
Crested Pigeon	*Ocyphaps lophotes*		X	X		X	**X**	Resident
Common Bronzewing	*Phaps chalcoptera*		X	X		X	**X**	Resident
Brush Bronzewing	*Phaps elegans*			X		X	X	Resident
Laughing Dove	*Streptopelia senegalensis*	Int.	X		X	X	X	Irregular visitor
CUCULIDAE								
Fan-tailed Cuckoo	*Cacomantis flabelliformis*		X	X		X	**X**	Regular migrant
Pallid Cuckoo	*Cacomantis pallidus*		X	X		X	X	Regular migrant
Horsfield's Bronze-Cuckoo	*Chrysococcyx basalis*		X	X		X	**X**	Regular migrant
Shining Bronze-Cuckoo	*Chrysococcyx lucidus*		X			X	X	Regular migrant
Black-eared Cuckoo	*Chalcites osculans*				X	X		Vagrant
APODIDAE								
Fork-tailed Swift	*Apus pacificus*	M S5	X	X	X	X	+	Irregular migrant
CHARADRIIDAE								
Banded Lapwing	*Vanellus tricolor*		X	X		X	X	Irregular visitor
OTIDIDAE								
Australian Bustard	*Ardeotis australis*		X	X				Irregular visitor
ACCIPITRIDAE								
Brown Goshawk	*Accipiter fasciatus*		X	X		X	**X**	Regular visitor
Collared Sparrowhawk	*Accipiter cirrocephalus*		X	X		X	**X**	Resident
Wedge-tailed Eagle	*Aquila audax*		X	X		X	X	Regular visitor
Swamp Harrier	*Circus approximans*							Irregular visitor
Spotted Harrier	*Circus assimilis*		X				X	Regular visitor
Black-shouldered Kite	*Elanus axillaris*		X	X		X	X	Regular visitor

BIRDS		CS	ALA	N	EPBC	BA	BCE	Expected status in project area
Whistling Kite	*Haliastur sphenurus*		X			X	**X**	Regular visitor
Little Eagle	*Hieraaetus morphnoides*		X	X		X	X	Regular visitor
Square-tailed Kite	*Lophoictinia isura*						**X**	Irregular visitor
Black Kite	*Milvus migrans*						X	Vagrant
FALCONIDAE								
Brown Falcon	*Falco berigora*			X		X	**X**	Resident
Nankeen Kestrel	*Falco cenchroides*		X	X		X	**X**	Regular visitor
Australian Hobby	*Falco longipennis*			X		X	X	Regular visitor
Peregrine Falcon	*Falco peregrinus*	S7	X	X		X	X	Irregular visitor
STRIGIDAE								
Southern Boobook	*Ninox novaeseelandiae*		X			X		Resident
TYTONIDAE								
Barn Owl	*Tyto alba (javanica)*						X	Regular visitor
PODARGIDAE								
Tawny Frogmouth	*Podargus strigoides*		X	X	X		X	Resident
CAPRIMULGIDAE								
Spotted Nightjar	*Eurostopodus argus*						X	Regular visitor
AEGOTHELIDAE								
Australian Owlet-nightjar	*Aegotheles cristatus*				X			Irregular visitor
MEROPIDAE								
Rainbow Bee-eater	*Merops ornatus*	CS3	X	X	X	X	X	Regular migrant
ALCEDINIDAE								
Laughing Kookaburra	*Dacelo novaeguineae*	Int.	X	X		X	X	Irregular visitor
Red-backed Kingfisher	*Todiramphus pyrrhopygius*						X	Irregular visitor
Sacred Kingfisher	*Todiramphus sanctus*		X	X		X	+	Regular migrant
CACATUIDAE								
Western Corella	*Cacatua pastinator*							Regular visitor
Little Corella	*Cacatua sanguinea*		X	X		X		Irregular visitor
Carnaby's Black-Cockatoo	*Calyptorhynchus latirostris*	E S2	X	X	X	X	**X**	Regular migrant
Red-tailed Black-Cockatoo (inland subspecies)	*Calyptorhynchus banksii escondidus*			X			+	Irregular visitor

BIRDS		CS	ALA	N	EPBC	BA	BCE	Expected status in project area
Galah	*Eolophus roseicapillus*		X	X		X	**X**	Regular visitor
Cockatiel	*Nymphicus hollandicus*		X				X	Vagrant
PSITTACIDAE								
Australian Ringneck	*Barnardius zonarius*		X	X		X	**X**	Resident
Budgerigar	*Melopsittacus undulatus*		X	X		X	X	Vagrant
Western Ground Parrot	*Pezoporus flaviventris*	Cr S1						Locally extinct?
Elegant Parrot	*Neophema elegans*		X	X		X	X	Regular visitor
Scarlet-chested Parrot	*Neophema splendida*						X	Vagrant
MALURIDAE								
Purple-backed (Variegated) Fairy-wren	*Malurus assimilis*		X				**X**	Resident
Blue-Breasted Fairy-wren	*Malurus pulcherrimus*		X	X		X	X	Resident
Splendid Fairy-wren	*Malurus splendens*		X	X		X	**X**	Resident
White-winged Fairy-wren	*Malurus leucopterus*		X	X		X	**X**	Resident
Southern Emu-wren	*Stipiturus malachurus*						**X**	Resident
MELIPHAGIDAE								
Spiny-cheeked Honeyeater	*Acanthagenys rufogularis*		X	X		X	X	Regular visitor
Western Spinebill	*Acanthorhynchus superciliosus*		X	X		X		Resident
Western Wattlebird	*Anthochaera lunulata*		X	X		X	X	Regular visitor
Red Wattlebird	*Anthochaera carunculata*		X	X		X	**X**	Regular visitor
Pied Honeyeater	*Certhionyx variegatus*						X	Irregular visitor
White-fronted Chat	*Epthianura albifrons*		X	X		X	X	Irregular visitor
Crimson Chat	*Epthianura tricolor*		X	X		X	+	Irregular visitor
Tawny-crowned Honeyeater	*Gliciphila melanops*		X	X		X	**X**	Regular visitor
Singing Honeyeater	*Lichenostomus virescens*		X			X	**X**	Resident
Brown Honeyeater	*Lichmera indistincta*		X	X		X	**X**	Resident
Yellow-throated Miner	*Manorina flavigula*		X	X		X	X	Regular visitor
Brown-headed Honeyeater	*Melithreptus brevirostris*		X	X		X	X	Regular visitor
White-cheeked Honeyeater	*Phylidonyris niger*		X	X		X	**X**	Resident
New Holland Honeyeater	*Phylidonyris novaehollandiae*		X	X		X	X	Irregular visitor
White-fronted Honeyeater	*Purnella albifrons*		X	X		X	X	Irregular visitor

BIRDS		CS	ALA	N	EPBC	BA	BCE	Expected status in project area
Black Honeyeater	*Sugomel niger*		X				X	Irregular visitor
PARDALOTIDAE								
Striated Pardalote	*Pardalotus striatus*		X	X		X	X	Regular visitor
Spotted Pardalote	*Pardalotus punctatus*		X	X		X	X	Irregular visitor
ACANTHIZIDAE								
Inland Thornbill	*Acanthiza apicalis*		X	X		X	X	Resident
Yellow-rumped Thornbill	*Acanthiza chrysorrhoa*		X	X		X	**X**	Resident
Western Thornbill	*Acanthiza inornata*		X				X	Resident
Rufous Fieldwren	*Calamanthus campestris*	CS3		X			**X**	Resident
Shy Heathwren	*Calamanthus cautus*	CS3				X	**+**	Irregular visitor
Western Gerygone	*Gerygone fusca*		X	X		X	**+**	Regular visitor
White-browed Scrubwren	*Sericornis frontalis*		X	X		X	**X**	Resident
Weebill	*Smicrornis brevirostris*		X	X		X	**+**	Resident
POMATOSTOMIDAE								
White-browed Babbler	*Pomatostomus superciliosus*	CS3	X	X		X	X	Vagrant
CAMPEPHAGIDAE								
Black-faced Cuckoo-shrike	*Coracina novaehollandiae*		X	X		X	**X**	Regular visitor
White-winged Triller	*Lalage sueurii*		X			X	X	Regular visitor
PACHYCEPHALIDAE								
Grey Shrike-thrush	*Colluricincla harmonica*		X	X		X	**X**	Resident
Rufous Whistler	*Pachycephala rufiventris*		X	X		X	**X**	Resident
Western Whistler	*Pachycephala occidentalis*		X			X	X	Irregular visitor
OREOICIDAE								
Crested Bellbird	*Oreoica gutturalis*	CS3	X	X		X	X	Resident
ARTAMIDAE								
Black-faced Woodswallow	*Artamus cinereus*		X	X		X	**X**	Regular visitor
Dusky Woodswallow	*Artamus cyanopterus*		X	X		X	X	Irregular visitor
Masked Woodswallow	*Artamus personatus*		X				X	Vagrant
Pied Butcherbird	*Cracticus nigrogularis*		X	X		X	X	Resident
Australian Magpie	*Cracticus tibicen*		X	X		X	X	Resident
Grey Butcherbird	*Cracticus torquatus*		X	X		X	X	Resident

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

BIRDS		CS	ALA	N	EPBC	BA	BCE	Expected status in project area
Total Number of Species Expected:	**117**	**9**					**107**	

MAMMALS		CS	ALA	N	EPBC	BCE	Expected status in project area
TACHYGLOSSIDAE							
Short-Beaked Echidna	*Tachyglossus aculeatus*					**X**	Resident
DASYURIDAE							
Chuditch	*Dasyurus geoffroii*	V S3			X		Locally extinct
Dibbler	*Parantechinus apicalis*	E S2			X		Locally extinct
Little Dunnart	*Sminthopsis aff. dolichura*					**X**	Resident
Grey-bellied Dunnart	*Sminthopsis fuliginosa*						Resident
White-tailed Dunnart	*Sminthopsis granulipes*					**X**	Resident
THYLACOMYIDAE							
Greater Bilby	*Macrotis lagotis*	V S3					Locally extinct
PERAMELIDAE							
Boodie	*Bettongia lesueur*	V S2					Locally extinct
Quenda	*Isoodon fusciventer*	P4					Locally extinct
Western Barred Bandicoot	*Perameles bougainville*	E S3					Locally extinct
TARSIPEDIDAE							
Honey Possum	*Tarsipes rostratus*					**X**	Resident
PHALANGERIDAE							
Australian Brushtail Possum	*Trichosurus vulpecula*	CS3				?	Locally extinct?
POTOROIDAE							
Woylie	*Bettongia penicillata*	E S1					Locally extinct
MACROPODIDAE							
Tammar Wallaby	*Macropus eugenii*	P4					Locally extinct
Western Grey Kangaroo	*Macropus fuliginosus*		X	X		**X**	Resident
Banded Hare-Wallaby	*Lagostrophus fasciatus*	V S3					Locally extinct
Brush Wallaby	*Notamacropus irma*	P4		X		X	Resident
MEGADERMATIDAE							
Ghost Bat	*Macroderma gigas*	V S3					Locally extinct
MOLOSSIDAE							

MAMMALS		CS	ALA	N	EPBC	BCE	Expected status in project area
White-striped Freetail-Bat	*Austronomus australis*					**X**	Regular visitor
VESPERTILIONIDAE							
Gould's Wattled Bat	*Chalinolobus gouldii*					**X**	Resident
Chocolate Wattled Bat	*Chalinolobus morio*		X	X		**X**	Regular visitor
Lesser Long-eared Bat	*Nyctophilus geoffroyi*					**X**	Resident
Southern Forest Bat	*Vespadelus regulus*					**X**	Resident
MURIDAE							
Rakali	*Hydromys chrysogaster*	P4		X			Irregular visitor
Noodji	*Pseudomys albocinereus*					**X**	Resident
Shark Bay Mouse, Djoongarri	*Pseudomys fieldi*	V S3					Locally extinct
Moodit	*Rattus fuscipes*			X		X	Resident
Pale Field Rat	*Rattus tunneyi*						Locally extinct
Number of native species expected (not including locally extinct): 16		**3**				**13**	
INTRODUCED MAMMALS							
Dog, Dingo	*Canis lupus familiaris*	Int.	X		X	X	Irregular visitor
Goat	*Capra hircus*	Int.	X	X	X	**X**	Resident
Horse	*Equus caballus*	Int.				X	Vagrant
Cat	*Felis catus*	Int.	X	X	X	X	Resident
House Mouse	*Mus musculus*	Int.	X	X	X	**X**	Resident
Rabbit	*Oryctolagus cuniculus*	Int.		X	X	**X**	Resident
Black Rat	*Rattus rattus*	Int.		X			Irregular visitor
Pig	*Sus scrofa*	Int.			X	**X**	Irregular visitor
Red Fox	*Vulpes vulpes*	Int.	X	X	X	**X**	Resident
Number of introduced mammals: 9						**9**	

5.7 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 a few waterbird species observed on Arrowsmith Lake; more details on these observations in Appendix 9. There is no waterbird habitat within the project area.

Species		Comments
ARACHNIDA		
Shield-backed Trapdoor Spider	*Idiosoma nigrum*	Taxonomy has been revised; species no longer considered to occur in region
FISH		
Twospot Goby	*Eviota bimaculata*	Marine fish
Black-throated Threefin	*Helcogramma decurrens*	Marine fish
Many-spotted Blenny	*Laiphognathus multimaculatus*	Marine fish
Yellow-striped Leatherjacket	*Meuschenia flavolineata*	Marine fish
Wavy Grubfish	*Parapercis haackei*	Marine fish
Miller's Damselfish	*Pomacentrus milleri*	Marine fish
Yellowfin Dottyback	*Pseudochromis wilsoni*	Marine fish
Western Red Scorpionfish	*Scorpaena sumptuosa*	Marine fish
Viviparous Brotula	*Zephyrichthys barryi*	Marine fish
Green Swordtail	*Xiphophorus helleri*	Recorded Ejarno Spring by BCE
REPTILES		
Central Netted Dragon	*Ctenophorus nuchalis*	Out of range
	Lerista planiventralis decora	Out of range
Goldfields Pebble-mimic Dragon	*Tympanocryptis pseudopsephos*	Out of range
Bar-Shouldered Ctenotus	*Ctenotus inornatus*	Out of range
Western Spiny-tailed Skink	*Egernia stokesii badia*	Out of range
BIRDS		
Brown Quail	*Coturnix ypsilophora*	Out of range
Black Swan	*Cygnus atratus*	Waterbird
Australian Shelduck	*Tadorna tadornoides*	Waterbird; recorded Arrowsmith Lake
Australasian Shoveler	*Anas rhynchotis*	Waterbird; recorded Arrowsmith Lake
Grey Teal	*Anas gracilis*	Waterbird; recorded Arrowsmith Lake
Australian Wood Duck	*Chenonetta jubata*	Waterbird
Musk Duck	*Biziura lobata*	Waterbird; recorded Arrowsmith Lake
Hoary-headed Grebe	*Poliocephalus poliocephalus*	Waterbird
Australasian Grebe	*Tachybaptus novaehollandiae*	Waterbird

Species		Comments
Straw-necked Ibis	*Threskiornis spinicollis*	Waterbird; recorded Arrowsmith Lake
Black-tailed Native-hen	*Gallinula ventralis*	Waterbird; recorded Arrowsmith Lake
Red-capped Plover	*Charadrius ruficapillus*	Waterbird
Black-fronted Dotterel	*Charadrius melanops*	Waterbird
Bar-tailed Godwit	*Limosa lapponica*	Waterbird
Red-necked Stint	*Calidris ruficollis*	Waterbird
Common Sandpiper	*Actitis hypoleucos*	Waterbird
Sharp-tailed Sandpiper	*Calidris acuminata*	Waterbird
Red Knot	*Calidris canutus*	Waterbird
Curlew Sandpiper	*Calidris ferruginea*	Waterbird
Pectoral Sandpiper	*Calidris melanotos*	Waterbird
Eastern Curlew	*Numenius madagascariensis*	Waterbird
Common Greenshank	*Tringa nebularia*	Waterbird
Eurasian Coot	*Fulica atra*	Waterbird; recorded Arrowsmith Lake
White-necked Heron	*Ardea pacifica*	One on lake at Western Flora Caravan Park, September 2019
White-faced Heron	*Ardea novaehollandiae*	Waterbird; recorded Arrowsmith Lake
Eastern Great Egret	*Ardea modesta*	Waterbird
Eastern Reef Egret	*Egretta sacra*	Waterbird
Cattle Egret	*Ardea ibis*	Waterbird
Little Pied Cormorant	*Microcarbo melanoleucos*	Waterbird
Black Cormorant	*Phalacrocorax carbo*	Waterbird
Little Black Cormorant	*Phalacrocorax sulcirostris*	Waterbird
Pied Cormorant	*Phalacrocorax varius*	Waterbird
Australasian Darter	*Anhinga novaehollandiae*	Waterbird
Eastern Osprey	*Pandion cristatus*	Marine bird of prey
Osprey	*Pandion haliaetus*	Alternative name to *P. cristatus*
Black-breasted Buzzard	*Hamirostra melanosternon*	Out of range; very rare vagrant?
White-bellied Sea-Eagle	*Haliaeetus leucogaster*	Marine bird of prey
Grey Wagtail	*Motacilla cinerea*	Out of range
Chestnut-rumped Thornbill	*Acanthiza uropygialis*	Out of range
Jacky Winter	*Microeca fascinans*	Out of range
Eurasian Tree Sparrow	*Passer montanus*	Out of range
Australian Reed-Warbler	*Acrocephalus australis*	Waterbird
Total Number of Species:	**55**	

Add Idiosoma kwongan

Conservation Significant INVERTEBRATES		CS	ALA	N	EPBC	BCE	Site visit	Expected status in project area
DIPLOPODA								
Millipede	*Antichiropus Eneabba 1*	CS3				X		Resident
INSECTA								
Bush Cricket	*Hemisaga vepreculae*	P2						Resident
Springtime Corroboree Stick Katydid	*Phasmodes jeeba*	P3		X				Out of range
Native bee	*Hylaeus globuliferus*	P3						Resident
Total Number of Species Expected:	**4**	**4**					**0**	

Appendix 9. Fauna observations in Arrowsmith North; combined for November 2018, September 2020 and December 2021.

VRX Silica Arrowsmith North.

1. Moaning Frog *Heleioporus eyrei*. One pitfalled December 2021.
2. Banjo Frog *Limnodynastes dorsalis*. Heard at Arrowsmith Lake, September 2020.
3. Turtle Frog *Myobatrachus gouldii.* Recorded on ARU December 2021.
4. Gecko *Diplodactylus ornatus*. Several pitfalled December 2021.
5. Gecko *Lucasium alboguttatum*. Several pitfalled December 2021.
6. Spiny-tailed Gecko Strophurus spinigerus. Several pitfalled December 2021. Also commonly seen on bushes.
7. Grey's Legless-Lizard *Delma greyii*. One caught in funnel December 2021.
8. Heath Dragon *Ctenophorus adelaidensis*. Observed regularly in all site visits; abundant in pitfalls December 2021.
9. Spotted Dragon *Ctenophorus maculatus*. Observed regularly in all site visits; abundant in pitfalls December 2021.
10. Bearded Dragon *Pogona minor*. Observed September 2020 and several pitfalled December 2021.
11. Fence Skink *Cryptoblepharus buchananii*. One caught in pitfall December 2021.
12. West Coast Ctenotus *Ctenotus fallens*. Caught in pitfalls and funnels December 2021. Seen regularly.
13. Skink *Lerista planiventralis*. Several caught in pitfalls December 2021.
14. Blunt-tailed West Coast Slider *Lerista praepedita*. Several pitfalled December 2021.
15. Dwarf Skink *Menetia greyii*. One pitfalled December 2021.
16. West Coast Morethia Skink *Morethia lineoocellata*. Several pitfalled December 2021.
17. Bobtail *Tiliqua rugosa*. Seen in November 2018, September 2020 and December 2021.

1. Emu. Scats scattered throughout on all surveys and fresh tracks seen regularly in December 2021.
2. White-faced Heron. Three on Arrowsmith Lake (September 2020).
3. White-necked Heron. One on farm dam long highway just south of Arrowsmith River September 2020.
4. Straw-necked Ibis. Small flock over Arrowsmith Lake September 2020.
5. Grey Teal. 'A few' on Arrowsmith Lake in September 2020, and five birds on Arrowsmith Lake December 2021.
6. Pacific Black Duck. One on Arrowsmith Lake December 2021.
7. Australasian Shoveler. Pair on Arrowsmith Lake September 2020.
8. Australian Shelduck. Several on Arrowsmith Lake September 2020.
9. Musk Duck. Three on Arrowsmith Lake September 2020 and one heard on like December 2021.
10. Black-tailed Native-hen. Two on Arrowsmith Lake December 2021.
11. Eurasian Coot. 'A few' on Arrowsmith Lake in September 2020 and two present December 2021.
12. Crested Pigeon. Few birds present September 2020 and several seen along western edge of proposed mine area December 2021.
13. Common Bronzewing. Several seen along access route December 2021.

14. Carnaby's Black-Cockatoo. Flock of 50 flying low over the central-east of mine area over Kwongan shrubland at approx. 3pm, 23rd September 2020. Foraging signs in Kwongan. About 70-80 birds roosting c. 5km west in December 2021.
15. Galah. Few flew over mine area September 2020; few on farmland near access route December 2021.
16. Australian Ringneck. Several pairs around Arrowsmith Lake December 2021.
17. Square-tailed Kite. One over mine area September 2020.
18. Whistling Kite. One over mine area September 2020.
19. Brown Falcon. Pair over proposed mine area September 2020 and December 2021.
20. Nankeen Kestrel. Pair over proposed mine area December 2021.
21. Brown Goshawk. Pair over mine area September 2020.
22. Collared Sparrowhawk. One in VSA2 in west of mine area September 2020.
23. Little Button-quail. Birds flushed occasionally December 2021.
24. Painted Button-quail. Male with chicks on camera about 5km to north December 2021.
25. Sacred Kingfisher. One at Arrowsmith Lake September 2020 and December 2021.
26. Horsfield's Bronze-Cuckoo. One heard September 2020 just to the south.
27. Fan-tailed Cuckoo. One heard September 2020 just to the south.
28. Fork-tailed Swift. About 10 over Port Denison evening of 8/12/21.
29. Rufous Fieldwren. Heard occasionally in Kwongan September 2020 and December 2021.
30. Shy Heathwren. Two seen in woodland just south access corridor September 2020.
31. Southern Emu-wren. Groups heard (rarely seen) occasionally December 2021.
32. Purple-backed Fairy-wren. Groups seen and heard regularly December 2021.
33. Blue-breasted Fairy-wren. Recorded in Beharra Springs project area just to north December 2021.
34. Splendid Fairy-wren. Groups in taller thickets in west of mine area, along access route, and around Arrowsmith Lake; September 2020 and December 2021.
35. White-winged Fairy-wren. Groups seen and heard regularly in Kwongan December 2021.
36. White-browed Scrubwren. Seen east of mine area (November 2018) and in Beharra Springs project area (December 2020).
37. Yellow-rumped Thornbill. Party observed November 2018 and party at Arrowsmith Lake December 2021.
38. Weebill. In eucalypts at Arrowsmith Lake (September 2020 and December 2021) and in eucalypts to the east (November 2018).
39. Western Gerygone. Few heard in eucalypts around Arrowsmith Lake (September 2020).
40. Red Wattlebird. Few seen throughout mine area December 2020. Not present in December 2021.
41. Singing Honeyeater. Individual birds seen occasionally.
42. Tawny-crowned Honeyeater. Seen and heard regularly all site visits.
43. White-cheeked Honeyeater. Several along pitfall transect near V07 (December 2021) and appeared more widespread in September 2020.
44. Brown Honeyeater. Seen and heard regularly, particularly in thickets in west of mine area and along access route (September 2020 and December 2021).
45. Red-capped Robin. Pair on edge of thicket to east November 2018.
46. Hooded Robin. Pair in Beharra Springs project area December 2021.
47. Grey Shrike-thrush. Calling from thickets along drainage line near access route (September 2020 and December 2021).
48. Rufous Whistler. Heard occasionally in thickets September 2020.

49. Willie Wagtail. Seen in mine area September 2020 but only a pair at Arrowsmith Lake in December 2021.
50. Grey Fantail. At least one at Arrowsmith Lake December 2021.
51. Black-faced Cuckoo-shrike. Pair east of mine area November 2018 and few along Brand Highway near access corridor September 2020.
52. White-winged Triller. Several in Beharra Springs project area just to north December 2021.
53. Black-faced Woodswallow. Few seen over kwongan December 2021.
54. Magpie-lark. Pair at Arrowsmith Lake September 2020 and December 2021.
55. Tree Martin. Few around Arrowsmith Lake December 2021.
56. Welcome Swallow. Few around Arrowsmith Lake September 2020.
57. Australian Raven. Few along access corridor September 2020.
58. Grey Currawong. One seen about 10km south of access corridor along Brand Highway.
59. Silvereye. Few around Arrowsmith Lake December 2021.

1. Echidna. Some foraging holes seen. One animal observed near Dongara (7/12).
2. White-tailed Dunnart *Sminthopsis granulipes*. Several pitfalled.
3. Honey Possum. Two pitfalled on 7/12and another to on 8/12.
4. Brush-tailed Possum. Scats possibly of this species in area of tall eucalypts east of mine area November 2018.
5. Western Grey Kangaroo. Few groups of three animals seen throughout but generally in low numbers in native vegetation. All site visits.
6. Noodji. Caught in large numbers on pitfall line; unexpected as vegetation quite long unburnt, but fire response may be slower in drier climate than Cooljarloo/Mooliabeenee.
7. House Mouse *Mus musculus*. Caught in small numbers.
8. Fox. Tracks throughout and one on camera at Arrowsmith Lake.
9. Rabbit. Tracks along roads.
10. Feral Goat. Scats around wetlands to east (November 2018), three seen in north-west on mine area (September 2020) and scats on access corridor near Brand Highway (December 2021).
11. Feral Pig. Distinctive scats in thickets September 2020.

Appendix 10. Results from motion-sensitive cameras set in December 2021.

Date set	Date collected	Camera code	Total N photos	N events/species	Species
4/12/2021	6/12/2021	BCE 01	18	Nil	
4/12/2021	9/12/2021	BCE 20	54	6	House Mouse
4/12/2021	9/12/2021	BCE 03	NIL	Nil	
5/12/2021	9/12/2021	BCE 06	1087	3	House Mouse
5/12/2021	9/12/2021	BCE 04	100	1	Red Fox
				1	Magpie-lark
5/12/2021	9/12/2021	BCE 32	Nil	Nil	