South32 Worsley Alumina Boddington Mine and Offset Properties - Numbat Habitat Assessment

Biologic Environmental Survey

Report to South32/ Worsley Alumina

Document Status				
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EXECUTIVE SUMMARY

South32 Worsley Alumina Pty Ltd Joint Venture (Worsley Alumina) currently has a proposal under assessment by the Environmental Protection Authority (EPA) for a mining expansion within the Northern Jarrah Forest region. Additional environmental studies within the mine Primary Assessment Area (herein the PAA, which includes the Marradong, Saddleback, Quindanning areas and the adjacent Newmont Gold Mine (NGM)) and associated offset properties (collectively referred to as the Study Area) are required to support future approvals under Part IV of the *Environmental Protection Act 1986* (EP Act) and the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act). The Study Area is located approximately 95 kilometres (km) south-east of Perth and covers an area of approximately 29,356.11 hectares (ha) across the PAA and 5,068.26 ha across the relevant offset properties.

In 2021, a numbat (*Myrmecobius fasciatus*), currently listed as Endangered under the EPBC Act and *Biodiversity Conservation Act 2016* (BC Act), was recorded adjacent to and within the PAA, near the townsite of Boddington. Worsley Alumina concluded that the proposal was not likely to have a significant impact on the species; however, under review of the Environmental Review Document (ERD), the Department of Climate Change, Energy, the Environment and Water, DCEEW (formerly DAWE) provided comment that potential habitat for *Myrmecobius fasciatus* (numbat) is present within the proposed action area and further information is required before concluding the likely level of impact on the species. As such, South32 require a numbat desktop review and habitat assessment survey across the Study Area.

The numbat habitat assessment survey was completed over four days between the 24th and 27th October 2022. The primary objective of the survey was to assess the suitability of the Study Area to support numbat, calculate habitat quality scores for the EPBC Environmental Offset Policy, and review the suitability of rehabilitation/ ecological restoration for provision of habitat for numbat. Specific methods included a detailed review of relevant contextual information, targeted searches for evidence of numbat presence, and species-specific fauna habitat assessments.

Nineteen fauna habitats, including cleared area, were identified and mapped across the PAA from both the previous basic vertebrate fauna surveys and habitat assessments undertaken during the current survey. These habitats were grouped into the following broad categories; Jarrah/Marri communities, wandoo communities, mallee communities, Riparian/Wetland, Heath communities, and Other (including rehabilitation, agricultural lands, plantation, dam, and cleared land). The habitats of greatest area across the PAA are the “Other” habitats (16,376.21 ha, 55.78%) and Jarrah/Marri communities (9,158.07 ha, 31.20%).

Overall, 38.91% (11,421.68 ha) of the PAA were considered to have the critical habitat elements required to support numbat, being the availability of foraging resources (termites), breeding resources (primarily fallen hollow logs), and provision of protection and refugia (through canopy cover and open to moderate understorey), and on a localised level are considered of “High Suitability”. These habitats were the Jarrah/Marri Communities, Wandoo Woodland, and Mallee Woodlands. However, when assessed through the EPBC Act Environmental Offsets Policy, the incorporation of site context and stocking rate factors reduce the overall quality of habitat for numbat across the Marradong, Saddleback, and Quindanning areas within the central and southern portion of the PAA (scoring 3 to 5 out of 10).

Evidence of numbat presence was recorded in the northern section of the PAA, near the Newmont Gold Mine (NGM) during the current survey, from diggings and scats (confirmed from laboratory analysis). These records are approximately 12.5 km from a previous numbat recorded from camera trap in 2021 near the Boddington townsite. Due to this record, and because the area lies adjacent to the Dwellingup State Forest, the NGM received a higher overall habitat score of the localised habitat quality (scoring 8 out of 10). The Contingency Bauxite Mining Envelope (CBME) at Collie also scored highly, due to the localised habitat quality and location adjacent to the Harris River State Forest area.

Eleven broad fauna habitats, including cleared areas, were identified and mapped across the offset properties from the previous basic vertebrate fauna survey and habitat assessments undertaken in the current survey. Like the PAA, these were grouped into broad categories, comprising; Jarrah/Marri communities, Wandoo Woodlands, Heath Communities, Riparian/Wetland, and Other (Rehabilitation, Cleared land, and Agricultural cleared lands). Jarrah/Marri communities covered the greatest area (2,731.30 ha, 53.89%) and, collectively with the Wandoo Woodlands, were also the most suitable to support numbat on a local scale due to the presence of critical habitat features (foraging, breeding, and refuge resources). When individually assessed with site context and stocking rate considerations for the EPBC Offset Policy, multiple offset properties scored highly overall due to their connectivity with the broader vegetated landscape and proximity to previous records, including more historic records within the Dwellingup State Forest and Harris River State Forest. Offset properties that scored less well against the criteria were those that comprised agricultural or cleared lands and retained little connectivity to broader habitats present.

Ten offset sites (or partial offset sites) are to be rehabilitated as part of Worsley Alumina’s Biodiversity Offset Plan (BOP). As part of the objectives of this assessment, the suitability of ecological restoration for the provision of numbat habitat was assessed through a review of previous translocations, management plans for the species, and peer-reviewed literature. Key factors that determined the success of previous numbat translocations were determined to be:

- predator animal control,
- maintenance of patch size and linkages to broader habitat to support large home range sizes,
- maintenance of foraging and breeding resources through provision of hollow logs and woody debris and leaf litter to promote termite availability, and
- availability of canopy cover and moderate-sparse understorey.

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1 INTRODUCTION

1.1 Background

South32 is the managing company for the South32 Worsley Alumina Pty Ltd Joint Venture (Worsley Alumina) operation, which currently includes bauxite mining near Boddington, bauxite transport via overland conveyor, an alumina refinery near Collie, and port operations in the Bunbury Port. Worsley Alumina currently has a proposal under assessment by the Environmental Protection Authority (EPA) for a mining expansion within the Boddington region and have undertaken environmental studies to support approvals under Part IV of the *Environmental Protection Act 1986* (EP Act) and the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act). Several offset options for the project expansion have been identified following preliminary analysis to fully account for the Significant Residual Impact (SRI) to significant species from the proposed activities. These offset options were prioritised according to effectiveness, feasibility, scale, and in consideration of risks and additional benefits.

In 2021, a numbat (*Myrmecobius fasciatus*), currently listed as Endangered under the EPBC Act and *Biodiversity Conservation Act 2016* (BC Act), was recorded within the Primary Assessment Area (PAA), near the townsite of Boddington (Figure 1.1). As part of the Environmental Review Document (ERD), Worsley Alumina noted that although the individual was recorded within the proximity of the mining proposal, it was concluded that the proposal was not likely to have a significant impact on the species. Under review of the ERD, the Department of Climate Change, Energy, the Environment and Water, (DCEEW, formerly DAWE) provided additional comments, specifically that provided comment that potential habitat for *Myrmecobius fasciatus* (numbat) is present within the proposed action area and further information is required before concluding the likely level of impact on the species.

As such, South32 require a desktop review and field survey across the PAA (29,356.11 ha) and relevant offset properties (5,068.26 ha) (collectively referred to as the Study Area) to clarifying potential impacts to potential numbat habitat. The offset packages relevant to suitable habitat for numbat are:

- Direct Offset 1 – Provision of Worsley Alumina land (4,175 hectares) for habitat protection and 435 ha of ecological restoration of cleared agricultural land (Figure 1.2, Figure 1.3). These offset properties are located within the PAA as well as spread through the Dwellingup State Forest and Harris River State Forest near Collie.
- Direct Offset 2 – Provision of Worsley Alumina land (220 hectares) for habitat protection, and 417 ha of ecological restoration of cleared agricultural land (Figure 1.2). This offset is located within the Saddleback portion of the PAA.

1.2 Objectives

The overarching objective of this assessment was to document the value of the Study Area for numbat. The specific objectives of this assessment were to:

- undertake a desktop review of the habitat within the PAA, specifically focusing on whether the area contains suitable habitat for numbat, and if so, quantifying the potential impact to these habitats;
- review suitability of rehabilitation/ ecological restoration for provision of habitat for numbat with an emphasis on providing input into the Commonwealth offset calculations;
- review the proposed offsets with an emphasis on the Collie Area (Direct Offsets 1 and 2) to determine whether or not the areas proposed contain suitable habitat for numbat, and if so, quantifying the potential areas; and
- undertake ground truthing of habitat suitability at both the PAA and the proposed offset properties (Direct Offsets 1 and 2) including an assessment of the abundance of foraging resources.

1.3 Survey Locations

This report involves desktop and ground-truthing assessments across multiple regions and properties, collectively referred to as the "Study Area" (Figure 1.2, Figure 1.3). Within the Study Area, the PAA encompasses the Worsley Mine Development Envelope (WMDE) and Bauxite Transport Corridor (BTC) (collectively called the BBM), and Contingency Bauxite Mining Envelope (CBME), located in Collie. To facilitate discussion, the BBM is split into general geographic reference points; the Newmont Gold Mine (NGM) in the section of the PAA north of the Hotham River, and the Marradong, Saddleback, and Quindanning sections of the bauxite mine (Table 1.1), as used in the previous targeted fauna reports (Biostat, 2018, 2020, 2021a, 2021b).

Twenty-three individual properties under the "Direct Offset 1" and one property under the "Direct Offset 2" provision were surveyed during the current assessment (Table 1.2; Figure 1.2, Figure 1.3). These properties were grouped under 14 alphabetical labels according to their location and lot number by Biostat (2020), and for consistency, these labels are retained in this report. Properties not previously surveyed by Biostat (2020) (Offsets H, I, and J) were named in the same fashion during the current assessment based on the provided spatial data.

Table 1.1: Survey locations across the PAA

Site	Location	Area Code	Area (ha)
Newmont Gold Mine	"BBM" Boddington	NGM	5,068.26
Boddington Bauxite Mine – Marradong		MAR	
Boddington Bauxite Mine – Saddleback		SAD	
Boddington Bauxite Mine – Quindanning		QUIN	
Contingency Bauxite Mining Envelope (CBME)	Collie	CBME	

Table 1.2: Survey locations across the offset properties and their associated areas

Site	Area Code		Area (ha)	Location
Direct Offset 1 (Habitat Protection and Restoration)				
BBM SE 1	A, termed in Biostat (2020)		77.37	BBM (Boddington)
BBM SE 2	B, termed in Biostat (2020)		13.12	BBM (Boddington)
7 Ex-Bulgara and Power-Kennedy	C, termed in Biostat (2020)		152.65	BBM (Boddington)
Ex-Talbot Nth	D1	Ex-Talbot offset properties are collectively termed "D" in Biostat (2020)	53.91	Between BBM (Boddington) and Collie along conveyor
Ex-Talbot Sth	D2		175.37	
North Refinery	E, termed in Biostat (2020)		90.49	Collie area (near CBME)
25 Lot 102	F1	Lot 102 and 103 properties are collectively termed "F" in Biostat (2020). Part of Lot 10	2226.81	Collie
28 Lot 102	F2		30.92	
27 Lot 102	F3		2.66	
26 Lot 102	F4		12.33	
21 Lot 103	F5		295.33	
16 Lot 103	F6		56.24	
23 Lot 103	F7		0.24	
17 Lot 103	F8		6.38	
20 Lot 103	G1	SE Block offset properties are collectively termed "G" in Biostat (2020)	154.76	Collie
SE block - name TBD	G2		255.55	
Ex-Nicholls	H	Not surveyed by Biostat (2020); termed from the provided spatial data	107.41	BBM (Boddington)
BBM NE 2	I		19.98	BBM (Boddington)
Lot 103	J		14.06	Collie
Lot 103	K		26.90	Collie
BBM NE 1	L		35.55	BBM (Boddington)
Lot 100	M		801.29	Collie
Direct Offset 2 (Habitat Protection and Restoration of the Saddleback Offset)				
Saddleback (Lot 2026)	N	Not surveyed by Biostat (2020); termed from the provided spatial data	458.95	BBM (Boddington)

400000
420000
440000
460000
6380000
6360000
6340000
6320000

Perth
Bunbury
Albany

Newmont Gold Mine
Bannister
Marradong Rd
Albany Hwy
Pinjarra Williams Rd
Ranford
Boddington
Marradong
Saddleback
N
Quindanning
Yalup Brook
Waterous
Wagerup
Yarloop
Cookernup
South Western Hwy
Harvey
Wokalup
Worsley Refinery
D1
Collie Williams Rd
Coalfields Rd
A
Worsley
Allanson
Collie
Boolading

Legend

- Primary Assessment Area (PAA)
- Indicative Disturbance Footprint
- State Road

Direct Offset 1
Offset Type
- Protection
- Restoration

Direct Offset 2
Offset Type
- Protection
- Restoration

IBRA Region
- Jarrah Forest

IBRA Subregion
- Northern Jarrah Forest
- Southern Jarrah Forest

0 3 6 9 12 Km

Coordinate System: GDA2020 MGA Zone 50
Projection: Transverse Mercator
Datum: GDA2020 Created 14/12/2022

N

biologic Environmental Survey

Scale: 1:257,000

Perth
Bunbury
Muja

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Boddington Mine and Offset Properties Targeted Numbat Habitat Assessment

Figure 1.1: Study Area and regional location

440000 450000 460000 470000

6380000 6370000 6360000 6350000

Newmont Gold Mine

Boddington

Ranford

Marradong

Saddleback

Hwy

Pinjarra Williams Rd

Pinjarra Williams Rd

L

I

A

B

H

C

N

D1

D2

Legend

- Primary Assessment Area (PAA)
- Indicative Disturbance Footprint
- State Road

Direct Offset 1

Offset Type

- Protection
- Restoration

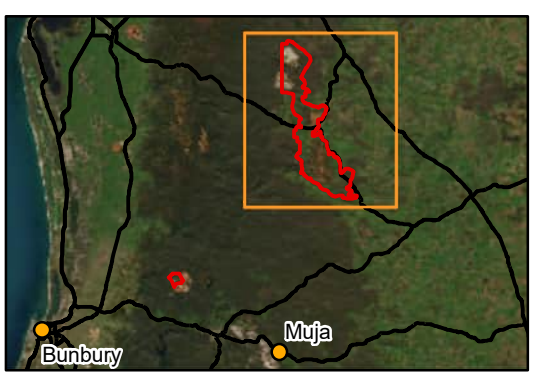
Direct Offset 2

Offset Type

- Protection
- Restoration

0 3 6 9 Km

Coordinate System: GDA2020 MGA Zone 50
Projection: Transverse Mercator
Datum: GDA2020 Created 14/12/2022



N

biologic Environmental Survey

Scale: 1:150,000

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Boddington Mine and Offset Properties Targeted Numbat Habitat Assessment

Figure 1.2: Primary Assessment Area (PAA) Study Area and proximate offset properties

400000 405000 410000 415000

6330000 6325000 6320000 6315000

E

F1

F2 F3 F4

M

F5 F6 F7 J F8

K G1 G2

Worsley Refinery

Worsley

Coalfields Rd

Legend

- Primary Assessment Area (PAA)
- Indicative Disturbance Footprint
- State Road

Direct Offset 1

Offset Type

- Protection
- Restoration

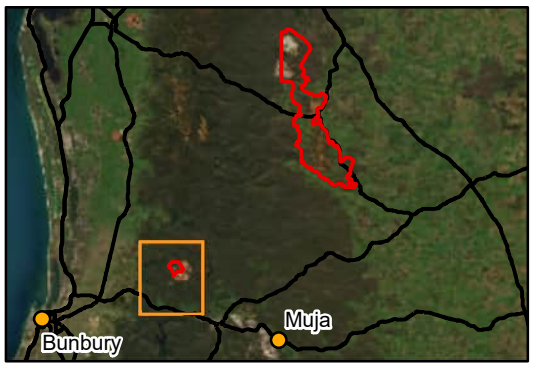
0 1 2 3 Km

Coordinate System: GDA2020 MGA Zone 50
Projection: Transverse Mercator
Datum: GDA2020 Created 14/12/2022

N

biologic Environmental Survey

Scale: 1:60,000



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Boddington Mine and Offset Properties Targeted Numbat Habitat Assessment

Figure 1.3: Worsley Refinery Study Area and south-west offset properties

1.4 Background to Protection of Fauna

Within Western Australia, native fauna are protected under the BC Act and at a national level under the EPBC Act. Any action that has the potential to impact on native fauna needs to be approved by relevant state and/or federal departments as dictated by the state EP Act.

Some species of fauna that are determined to be at risk of extinction or decline are afforded extra protection under these Acts. For the purposes of this report, these species are deemed to be of significant species. A summary of applicable legislation and status codes is provided in Table 1.3. A number of migratory bird species are also prioritised for conservation under international agreements and therefore protected under the EPBC Act and BC Act as Migratory.

For some species, there is insufficient information to determine their status. These species are also considered by the EPA and the Department of Biodiversity, Conservation and Attractions (DBCA) as being significant species. These species are listed on a Priority List that is regularly reviewed and maintained by the DBCA (Table 1.3).

Table 1.3: Definitions and terms for species and communities of significance

Agreement, Act or List	Status Codes
Federal	
EPBC Act The DCCEEW (Department of Climate Change, Energy, the Environment and Water) lists Threatened fauna, which are determined by the Threatened Species Scientific Committee (TSSC) per criteria set out in the Act. The Act lists fauna that are considered to be of significance under one of eight categories (listed under 'Status Codes').	• Extinct (EX) • Extinct in the Wild (EW) • Critically Endangered (CR) • Endangered (EN) • Vulnerable (VU) • Conservation Dependent (CD) • Migratory (MI)
Threatened Ecological Communities (TECs) are those that are at risk of extinction.	• Critically Endangered (CR) • Endangered (EN) • Vulnerable (VU)
State	
BC Act At a state level, native fauna are protected under the BC Act. Species in need of conservation are given a ranking ranging from Critically Endangered to Vulnerable. TECs are given a ranking ranging from Vulnerable to Presumed Totally Destroyed.	Species • Extinct (EX) • Extinct in the Wild (EW) • Critically Endangered (CR) • Endangered (EN) • Vulnerable (VU) • Migratory (MI) • Conservation Dependent Fauna (CD) • Other specially protected species (OS)
	TECs • Presumed Totally Destroyed (PD) • Critically Endangered (CR) • Endangered (EN) • Vulnerable (VU)

Agreement, Act or List	Status Codes
DBCA Priority List DBCA produces a list of Priority species and ecological communities that have not been assigned statutory protection under the BC Act. This system gives a ranking from Priority 1 to Priority 4.	• Priority 1 (Poorly known species) (P1) • Priority 2 (Poorly known species) (P2) • Priority 3 (Poorly known species) (P3) • Priority 4 (Rare, Near Threatened, and other species in need of monitoring) (P4)

1.5 Numbat *Myrmecobius fasciatus*

The numbat is currently listed as Endangered under the EPBC Act and BC Act, following an upgrade in conservation status in 2015 following recommendations in Woinarski *et al.* (2014).

Many of the characteristic features of the numbat are a result of its adaptation to a specialised diet of termites (*Isoptera* species, with no strong preference any species), although ants (*Formicoidea*) are also occasionally taken (Calaby, 1960; DPaW, 2017). Numbats intercept termites in feeding galleries, rather than in the termite mounds/ nests, which are exposed by digging in the upper 50 millimetres (mm) of the soil, as well as turning over small pieces of dead wood, and scratching bark and decayed wood from old logs, stumps, and fallen trees limbs (Calaby, 1960; Christensen *et al.*, 1984).

Young numbats are born in January or early February (DPaW, 2017; Friend, 2008). The female will utilise a number of nests in logs, trees or other burrows in her home range to home her litter (Christensen *et al.*, 1984; DPaW, 2017; Maisey & Bradbury, 1982). All young leave the maternal home range and disperse by November or early December. Dispersal appears to take place as straight-line movements, while the animal is moving through the bush. A dispersing juvenile numbat at Dryandra was followed over several days, during which time it moved four kilometres from its natal area straight to the edge of farmland (DPaW, 2017). It then moved along the forest-farmland boundary for two kilometres before reaching the area in which it established its home range. Radio-tracking of dispersing numbats has shown that they rarely cross farmland, but often end up in suitable habitat at the edge of cleared land. This evidence indicates that the farmland-forest interface is a barrier for dispersing numbats.

The male pattern of adjacent home ranges overlaps the female pattern. Although use of habitat by each sex changes during the year (females contract their area of movement in summer, males in winter), overall, there is approximately one pair of established adults per 50 ha in high-quality habitat (Christensen *et al.*, 1984; DPaW, 2017). Home ranges are exclusive between individuals of the same sex.

Historic records of the species are scattered across a wide arc stretching from western New South Wales and south-eastern South Australia, north to the southern border of the Northern Territory, and across to the south-west of Western Australia (DPaW, 2017). In the 1970's, a rapid reduction of habitat in the Western Australian wheatbelt saw a significant decline in numbat sightings, with some subpopulations becoming extinct (e.g. Boyagin Nature Reserve near Brookton, in remnant bushland in the Pingaring area (including Dragon Rocks Nature Reserve) and at Tutanning Nature Reserve near Pingelly (Connell & Friend, 1985; Friend, 2008). In the Northern Jarrah Forest, numbat populations

were almost extinct by the mid-1980's, and there have been no sightings of numbats on the coastal plain since 1985.

The only remaining original numbat sub-populations are at Dryandra Woodland (150 km south-east of Perth, 40 km east of the Study Area) and the Upper Warren area (including Tone-Perup Nature Reserve, Greater Kingston National Park, and adjoining State Forest) (280 km south-south-east of Perth, 105 km south of the Study Area) (DPaW, 2017) (Figure 1.4). Since 1985 there have been translocations of the numbat to 12 different sites within its former range, including three sites outside of Western Australia in South Australia and New South Wales (Bester & Rusten, 2009; DPaW, 2017; Hayward *et al.*, 2015; Moseby *et al.*, 2011). Of the 12 reintroduction sites, six have maintained self-sustaining subpopulations, expanding the current distribution of the species into previously occupied areas in the jarrah forest and wheatbelt in WA.

Numbats have historically been present in a large variety of habitat types, including eucalypt forest, eucalypt woodland (including jarrah (*Eucalyptus marginata*), marri (*Corymbia calophylla*), York gum (*Eucalyptus loxophleba*) and mallee (*Eucalyptus* spp.) woodland, mulga woodland in central Australia, and mallee woodland in South Australia) (Friend, 2008), *Acacia* woodland, and *Triodia* grassland (DPaW, 2017). At Dryandra, numbats inhabit brown mallet (*Eucalyptus astringens*) plantations (DEC, 2011). Key habitat characteristics where subpopulations currently exist or historically existed include:

- Presence of termites in sufficient abundance - all evidence relating to the diet of the numbat throughout its range indicates an almost complete dependence on termites (Calaby, 1960).
- Presence of eucalypt species - the majority of sites where numbats occur and were recorded in the past are characterised by the presence of eucalypt species providing logs and hollows and possibly higher termite densities. An exception to this may be the apparent existence of numbat subpopulations in *Triodia* tussock grasslands of the arid zone, but these may have relied on proximity to woodland patches.
- Sufficient cover - adequate cover near ground level is required to provide refuge from predators. Cover may be provided by thickets or a combination of thickets, hollow logs, and other fallen debris.
- Sufficient openness - although a degree of cover is required for refuge from predators, a sufficiently open understorey is required for feeding sites. A combination of an open understorey interspersed with thickets and hollow logs is considered ideal.

Numbats use hollows and burrows for nesting at night, resting during the day, and as refuges when under threat of predation. Nests are made in hollows with only one entrance and an internal diameter of 60-80 mm (Friend, 2008). A nest fills the chamber and consists of readily available plant material such as grass, leaves, or shredded eucalypt bark (Christensen, 1975, 1980; Christensen *et al.*, 1984; Friend & Burrows, 1983). Nest hollows can be located in in trees (up to 5 metres above ground) or in hollow logs on or near the ground (DPaW, 2017). Numbats also construct their own burrows, consisting of a single, gently sloping shaft 1–2 metres long widening out into a roughly spherical, terminal chamber about 25 cm in diameter, which can contain nests (Bester & Rusten, 2009; DPaW, 2017).

350000
500000
650000
800000
6700000
6550000
6400000
6250000

Perth
Boddington
Albany
Roxby Downs
Scotia Sanctuary
Yookamurra Sanctuary
Karroun Hill Nature Reserve
Perth
Mt Dale Conservation Park
Boyagin Nature Reserve
Dryandra Woodland
Tutanning Nature Reserve
Brookton Highway East
Boddington
Dragon Rocks Nature Reserve
Bunbury
Batalling Forest Block
Cocanarup Timber Reserve
Kingston National Park
Tone-Perup Nature Reserve
Palgarup State Forest
Stirling Range National Park

Legend

- Primary Assessment Area (PAA)
- State Road

Extant Populations

- Extension of original extant population
- Original extant population
- Translocated population

0 25 50 75 Km

Coordinate System: GDA2020 MGA Zone 50
Projection: Transverse Mercator
Datum: GDA2020 Created 12/12/2022

N

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Scale: 1:1,900,000

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Boddington Mine and Offset Properties Targeted Numbat Habitat Assessment

Figure 1.4: Extant distribution of the numbat

2 ENVIRONMENT

2.1 Biogeographical Regionalisation of Australia

The Study Area is located within the Jarrah Forest bioregion, as described by the Interim Biogeographic Regionalisation for Australia (IBRA) (Thackway & Cresswell, 1995). This bioregion is described as duricrusted plateau of the Yilgarn Craton and is characterised by jarrah – marri forest on laterite gravels and, in eastern parts, by wandoo – marri woodlands on clayey soils. Eluvial and alluvial deposits support *Agonis* shrublands, and in areas of Mesozoic sediments, jarrah forests occur in a mosaic with a variety of species rich shrublands (Williams & Mitchell, 2001).

The Jarrah Forest bioregion is classified into two subregions, the Northern Jarrah Forest (JAF01), of which the Study Area is located, and Southern Jarrah Forest (JAF02) (Figure 1.1). The Northern Jarrah Forest subregion is characterised by jarrah – marri forest on laterite gravels in the west, with bullich (*Eucalyptus megacarpa*) and blackbutt (*Eucalyptus patens*) in the valleys, grading to wandoo – marri woodlands on clayey soils in the east, with powder bark (*Eucalyptus accedens*) on breakaways (Williams & Mitchell, 2001). There are extensive, but localised, sand sheets with *Banksia* low woodlands, and heath is found on granite rocks and as a common understory of forests and woodlands in the north and east (Williams & Mitchell, 2001). Most of the diversity in the communities occurs on lower slopes or near granite soils where there are rapid changes in site conditions (Williams & Mitchell, 2001).

2.2 Climate

The climate of the region is characterised by cool wet winters, and warm, relatively dry summers. Average annual rainfall for the Northern Jarrah Forest ranges from 1,300 mm on the scarp, to approximately 700 mm in the east and north (Williams & Mitchell, 2001). This is noted across the Study Area where there is a change in climatic conditions from west (Collie) to east (Boddington), with a decline in rainfall experienced in the eastern areas when compared to the escarpment in the west, and with the eastern areas also experiencing warmer spring and summer periods. The weather station most likely to accurately document the long-term average weather, climate, and rainfall for the Study Area is the Bureau of Meteorology's (BoM) Dwellingup station (weather station number 009538), located approximately 25 km east of the PAA and 50 km north of the Worsley North Refinery near Collie (BoM, 2022).

The highest average daily maximum temperature recorded in the Study Area region occurs in January (29.8°C) and February (29.7°C), whilst the lowest average minimum temperature experienced is in July (5.5°C) (length of record 1931-2022; BoM, 2022). The average annual rainfall at the Dwellingup station is 1,227.1 mm (length of record 1877-2020; BoM, 2022), with average monthly rainfall peaking from late autumn to early spring (May–September). The highest average monthly rainfall occurs in June and July (232.7 mm and 234.9 mm respectively), with the lowest occurring in January (16.3 mm) (BoM, 2022).

2.3 Pre-European Vegetation

The pre-European vegetation mapping of Western Australia dataset maps the original native vegetation presumed to have existed prior to European settlement (Beard, 1981). The overall Study Area intersects six vegetation complexes (Table 2.1; Figure 2.1). The most common being East Darling 3 (72.22%) across the PAA, and West Darling 3 (71.96%) across the offset properties. This reflects a change in land systems from east (PAA) to west (offset properties), as the Collie area is primarily located in Lowden Valley and Darling Plateau land systems, whereas the Boddington area are on Marradong Upland and Quindanning systems (Tille, 2006). Most vegetation complexes present across the Study Area are characterised by the presence of jarrah, marri, and wandoo, which are dominant eucalypt species present in the habitat of the remaining original numbat populations (Dryandra Woodland and Tone-Perup Forest).

Table 2.1: Pre-European vegetation across the PAA and offset properties

Vegetation complex	Description	PAA		Offsets	
		Area (ha)	%	Area (ha)	%
Bannister 3	Mainly jarrah and marri *Eucalyptus marginata, Corymbia calophylla*	3,387.81	11.54%	190.91	3.29%
Bannister 4	Jarrah, marri and wandoo *Eucalyptus marginata, Corymbia calophylla, E. wandoo.*	3,512.36	11.97%	379.42	6.54%
Bannister 49	Low shrubs of mixed composition.	506.73	1.73%	144.52	2.49%
East Darling 3	Mainly jarrah and marri *Eucalyptus marginata, Corymbia calophylla*	21,200.00	72.22%	383.87	6.62%
West Darling 3	Mainly jarrah and marri *Eucalyptus marginata, Corymbia calophylla*	746.55	2.54%	4,175.44	71.96%
West Darling 1184	Jarrah, marri and wandoo *Eucalyptus marginata, Corymbia calophylla, E. wandoo.*	0	0	528.38	9.11%
Total		**29,353.44**	**100.00%**	**5,802.55**	**100.00%**

400000 420000 440000 460000

6380000 6360000 6340000 6320000

Marradong
Newmont Gold Mine
Boddington
Waroona
Saddleback
Quindanning
Worsley
Allanson
Worsley Refinery
Bannister
Albany Hwy
Williams Rd
Coalfields Rd

L I A B H C D1 D2 E F1 F2 F3 M F5 J F8 K G1 G2 F4 F6

Pre-European Vegetation

- Bannister 3
- Bannister 4
- Bannister 49
- Bannister 128
- Bannister 1003
- Bannister 1005
- Bridgetown 3
- Bridgetown 1114
- Bridgetown 1185
- East Darling 3
- East Darling 128
- East Darling 1114
- Pinjarra 3
- Pinjarra 968
- Pinjarra 1182
- West Darling 3
- West Darling 4
- West Darling 1114
- West Darling 1184
- West Darling 1185
- Williams 3
- Williams 4
- Williams 992
- Williams 1003

Legend

- Primary Assessment Area (PAA)
- State Road

Direct Offset 1

Offset Type

- Protection
- Restoration

Direct Offset 2

Offset Type

- Protection
- Restoration

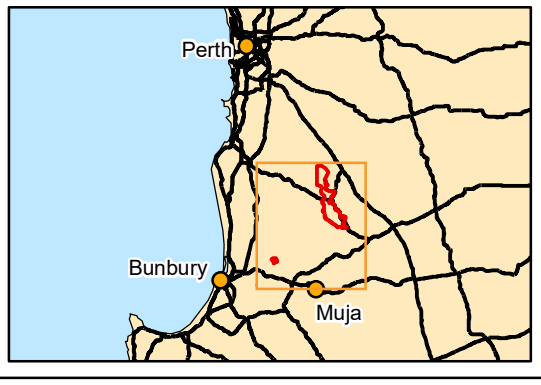
0 5 10 15 Km

Coordinate System: GDA2020 MGA Zone 50
Projection: Transverse Mercator
Datum: GDA2020 Created 14/12/2022

N

biologic Environmental Survey

Scale: 1:260,000



SOUTH32/WORSLEY ALUMINA

Boddington Mine and Offset Properties Targeted Numbat Habitat Assessment

Figure 2.1: Pre-European vegetation associations of the Study Area

2.4 Bioregional Significance and Conservation Areas

Several large state forests and nature reserves are located immediately adjacent to or in the vicinity of the Study Area (Figure 2.2). These include the Dwellingup State Forest, Harris River State Forest, and Wellington Regional Park that bound most of the offset properties and the western and northern boundaries of the PAA. These state forests and parks support many significant fauna species, including chuditch (*Dasyurus geoffroii*), quokka (*Setonix brachyurus*), woylie (*Bettongia penicillata*), and western brush wallaby (*Notamacropus irma*) (DEC, 2013; Dunlop & Morris, 2012; TSSC, 2018). Smaller adjacent reserves include Lane Poole Nature Reserve within the Dwellingup State Forest, Mooradung Nature Reserve and Lavender Nature Reserve to the east of the PAA (separated by agricultural land), and Youralling State Forest approximately 10 km north-east of the NGM. Dryandra Woodland, including Lol Gray State Forest, is approximately 40 km east of the PAA, separated by agricultural land and remnant vegetation corridors. As noted in Section 1.5, the numbat population at Dryandra Woodland is one of only two remaining original populations (DPaW, 2017). Batalling Forest block, a small self-sustaining numbat population is approximately 28 km south of the PAA and 35 km east of the CBME.

Overall, the native vegetation that lies between the PAA and south-west offset properties forms part of an existing large network of protected natural areas, with the patch size of remnant vegetation facilitating the maintenance of ecological processes and the movement of organisms within, and across, the landscape (Figure 2.2). To the east of the PAA, the degree of fragmentation is high, with remnant vegetation existing only in small patches and corridors across agricultural landscapes.

400000 420000 440000 460000

6380000 6360000 6340000 6320000

Marradong
Newmont Gold Mine
Boddington
Bannister
Albany Hwy
Dwellingup State Forest
Saddleback
Quindanning
Mooradung Nature Reserve
Nature Reserve
State Forest
Korijekup Conservation Park
Lane Poole Reserve
Worsley Refinery
Harris River State Forest
Muja State Forest
Coalfields Rd
Allanson
Collie
Wellington National Park
Westralia Conservation Park
Collie State Forest
Mumballup State Forest
Wyvern Road Nature Reserve
Wellington State Forest

Legend

- Primary Assessment Area (PAA)
- State Road
- National Park
- Nature Reserve
- Conservation Park
- Section 5(1)(g) Reserve
- Section 5(1)(h) Reserve
- State Forest
- Timber Reserve
- Section 34A Freehold

Direct Offset 1

Offset Type

- Protection
- Restoration

Direct Offset 2

Offset Type

- Protection
- Restoration

0 5 10 15 Km

Coordinate System: GDA2020 MGA Zone 50
Projection: Transverse Mercator
Datum: GDA2020 Created 15/12/2022

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biologic Environmental Survey

Scale: 1:260,000

Perth
Bunbury
Muja

SOUTH32/WORSLEY ALUMINA

Boddington Mine and Offset Properties Targeted Numbat Habitat Assessment

Figure 2.2: Conservation areas of the Study Area

3 METHODS

3.1 Compliance

The survey was carried out in a manner consistent with documents developed by the Western Australian EPA, and the Department of Climate Change, Energy, the Environment and Water (DCCEEW) (formally the DSEWPaC, and the DoE) for the environmental surveying and reporting of vertebrate fauna. The relevant government guidelines are outlined below in Table 3.1.

Table 3.1: Guidelines, technical guidelines and procedures for the field survey

Survey component	Guidance documents
General / EIA	EPA (2016) *Environmental factor guideline: Terrestrial fauna*
	EPA (2006) *Guidance for the assessment of environmental factors: Rehabilitation of terrestrial ecosystems*.
	EPA (2020) *Statement of environmental principles, factors and objectives*
	DoE (2013) *Significant impact guidelines 1.1: Matters of national environmental significance*
Vertebrate fauna survey	EPA (2020) *Technical Guidance: Terrestrial vertebrate fauna surveys for environmental impact assessment*
	DSEWPaC (2011) *Survey guidelines for Australia's threatened mammals*

3.2 Desktop Assessment

3.2.1 Database Searches

Three fauna databases were searched to obtain information on historic and contemporary numbat records from the local region (NatureMap, DBCA Threatened and Priority Fauna Database, and Atlas of Living Australia) (Table 3.2). These database searches were conducted around a central coordinate at both the BBM and CBDE to accommodate the spatial spread of the Study Area.

Table 3.2: Details of database searches conducted

Database	Parameters
Threatened and Priority Fauna DBCA (2022b)	A 40 km buffer of two central coordinates – • 116.4228°, -32.8683° • 115.9868°, -33.2750°
NatureMap DBCA (2022a)	
Atlas of Living Australia Database Search ALA (2022)	

3.2.2 Literature Review

A review of available literature relevant to the objectives of the survey was undertaken, to provide contextual information in assessing the suitability of the habitat present within the PAA and offset for numbat (Table 3.3). The review included the following sources of information:

- key habitat characteristics where subpopulations currently exist or historically existed, including broad vegetation complexes and landscapes;
- review of contemporary numbat sightings and associated habitat in the region;
- review of previous fauna surveys undertaken in the PAA, offset properties, and general region;
- management plans for known numbat habitat and populations;
- comprehensive review of translocation attempts (successes/failures) for numbat to determine impact of habitat suitability on presence; and
- peer-reviewed research discussing the potential for suitable management practices and rehabilitation to support numbat.

Table 3.3: Literature used in the review

Title	Reference
Survey reports	
The vertebrate fauna of the Boddington Gold Mine	Ninox (2003)
Mining extension areas associated with the Worsley Alumina production increase to 5.1Mtpa - Level 1 fauna assessment (1009025-002)	Biostat (2017)
Vertebrate fauna monitoring 2017-2018, Saddleback operations.	Biostat (2018)
PAA Offset fauna habitat assessment desktop study/ecological values field surveys 2020.	Biostat (2020)
Targeted Surveys: Newmont Boddington Gold Mine and Worsley Refinery Lease Area	Biostat (2021a)
Worsley Alumina Mine Expansion (PAA) Desktop Fauna Assessment.	Biostat (2021b)
South32 (Worsley): Summary progress report fauna investigations of proposed offset areas spring 2021.	Bamford Consulting Ecologists (2021)
Management Plans	
Stirling Range and Porongurup National Parks Management Plan 1999-2009	CALM (1999)
Dryandra Woodland Management Plan	DEC (2011)
Perup Management Plan No. 72	DEC (2012)
Wheatbelt Region Parks and Reserves Management Plan 95	DBCA (2021)
Habitat and Translocation literature	
Trial translocation of the numbat (*Myrmecobius fasciatus*) into arid Australia	Bester and Rusten (2009)
Numbat (*Myrmecobius fasciatus*) Recovery Plan.	DPaW (2017)
The numbat *Myrmecobius fasciatus* (Myrmecobiidae): History of decline and potential for recovery	Friend (1990)
Reintroduction and the numbat recovery program	Friend and Thomas (1994)
Conservation of the numbat (Myrmecobius fasciatus)	Friend and Thomas (2003)
Numbat nirvana: conservation ecology of the endangered numbat (*Myrmecobius fasciatus*) (Marsupialia : Myrmecobiidae) reintroduced to Scotia and Yookamurra Sanctuaries, Australia	Hayward *et al.* (2015)
Predation determines the outcome of 10 reintroduction attempts in arid South Australia	Moseby *et al.* (2011)

3.3 Field Survey Methodology

3.3.1 Survey Personnel, Timing and Weather

The survey was undertaken from the 24th to the 27th of October 2022 by Senior Zoologists Claire Brooks and Jari Cornelis, and Zoologists Sian Thorn and Aleesha Turner. Collectively, the field personnel have over two decades of experience completing fauna surveys within Western Australia. At the time of the survey, Sian Thorn was finalising her Doctor of Philosophy (PhD) thesis on numbat ecology, and as such, is considered highly experienced in the detection of numbat signs and habitat. The survey timing coincided with the period of juvenile numbat dispersal (November to early December) (DPaW, 2017), and therefore the time of maximum numbat abundance when detection is most likely.

Rainfall in the two months leading up to the initial previous numbat record in the Study Area in 2021 was in general slightly higher than long-term averages and remained high during some winter months (July 2021 received 412.6 mm of rainfall compared to the long-term average of 234.9 mm) (Figure 3.1). Rainfall was also average or above average in the two months leading up to the field survey (296.0 mm for August to September 2022, compared to the long-term average of 323.0 mm for the same period) (Figure 3.1). Approximately 12.4 mm of rainfall was recorded during the survey period, including 9 mm on the first day of survey (Table 3.4). This partially reduced the ability to record secondary signs (scats, tracks, and diggings) made prior to the rainfall. The temperatures recorded during the 12 months prior to the survey remained generally consistent with the long-term averages (Figure 3.1), although the previous summer period (December to February 2022) recorded consistently below average temperatures. The highest temperature recorded during the survey period was 19.5°C (Table 3.4). Overall, the conditions experienced were considered suitable to assess the suitability of habitat for numbat, as foraging and breeding resources would not have been detrimentally affected by climatic conditions leading up to the field survey.

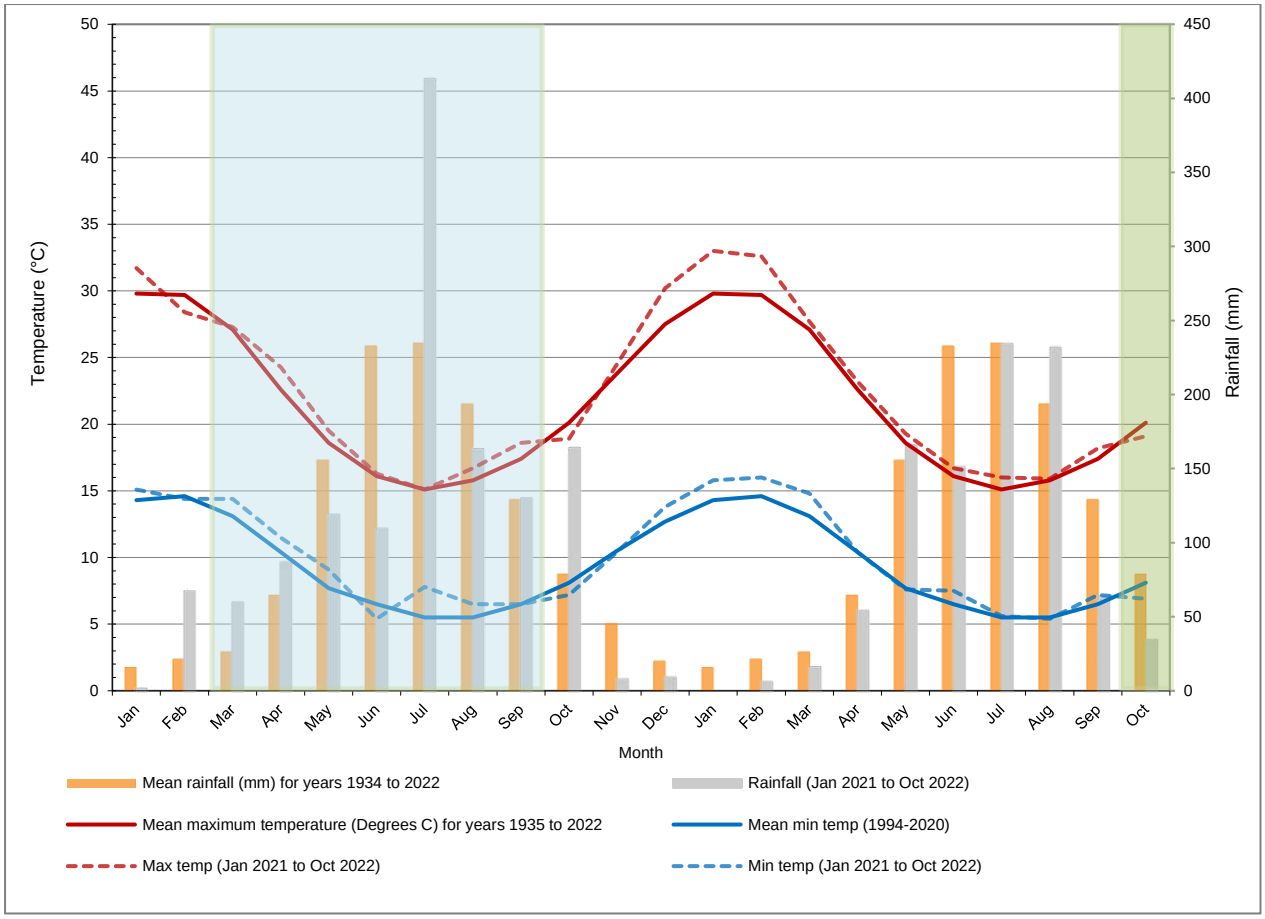


Figure 3.1: Long-term and recent climate data relevant to the Study in the 2 months prior to the 2021 numbat survey (blue shading) and leading up to the current survey period (green shading) (BOM Station 009538; BoM, 2022).

Table 3.4: Climatic conditions recorded for the vicinity of the Study Area during the field assessment (BOM Station 009538)

Date	Temperature		Rainfall (mm)
	Min. temp (°C)	Max. temp (°C)	
24/10/2022	12.1	18.7	9.0
25/10/2022	9.7	18.6	3.2
26/10/2022	5.9	19.2	0.2
27/10/2022	5.2	19.5	0.0
Average/ Total	**8.2**	**19.0**	**12.4 mm**

3.3.2 Habitat Assessments and Mapping

The mapping and nomenclature of broad fauna habitats described in the previous fauna surveys (Biostat, 2020, 2021b) were used for the current assessment. Additional fauna habitat assessments were undertaken throughout the Study Area during the current field survey to assess the suitability to support numbats. Habitat assessments were undertaken at 91 locations (Figure 3.2; Figure 3.3; Appendix A). Mapping and nomenclature remained consistent with the previous fauna surveys; however, area calculations of suitable fauna habitat were re-assessed to suit the survey objectives, as additional offset properties were assessed during the current survey that were not previously surveyed by Biostat (2020).

The assessments focused on specific critical habitat characteristics relevant for numbat, including (but not limited to):

- foraging resources;
- breeding resources;
- protection and refuge resources (Table 3.5).

The presence and quality of the above resources was combined to determine an overall suitability score for each habitat type to support numbats, with scoring corresponding with a High, Medium, Low, and Nil rating (Table 3.5). This habitat score is considered specific to the local microhabitat conditions of the fauna habitat types. Overall suitability for numbat on a larger spatial scale was assessed after consideration of factors such as dispersal capability, connectivity to other habitat, and patch size, and is presented through assessment with the EPBC Environmental Offset Policy as a habitat quality score (see Section 3.4).

Table 3.5: Targeted habitat assessment criteria used to determine suitability of habitat for numbat

Habitat Aspect	Requirements	Assessment criteria	Scoring
Foraging resources (i.e. termites).	All evidence relating to the diet of the numbat throughout its range indicates an almost complete dependence on termites (Calaby, 1960). Feeding sites are also associated with a sufficiently open understorey (DPaW, 2017).	• Termite Abundance Assessment (Friend, 2004) • Presence of termite mounds, fallen, decomposing wood, debris, and leaf litter • Visual observation of termite damage (tunnels) on fallen wood or exposed galleries • Presence of other digging mammals (echidna, quenda)	Overall score of either: • High • Medium • Low • Nil Scoring is based on a combined assessment of the quantity and quality of the three habitat aspects
Breeding resources (i.e. hollow logs and burrows).	Nests are made in hollows with only one entrance and an internal diameter of 60–80 mm (DPaW, 2017). Hollows in trees, up to 5 metres above ground are used as well as hollow logs on or near the ground (DPaW, 2017).	• Number of fallen logs • Dimensions of entrance • Evidence of use • Presence of low (<5m) tree hollows • Presence of earth burrows	
Refugia from predators and daytime rest areas.	The majority of sites where numbats occur(ed) are characterized by the presence of eucalypt species providing logs and hollows for cover from predators (DPaW, 2017). Cover may also consist of thickets or a combination of thickets and hollow	• Proportion of cover from both canopy and understorey • Type and degree of disturbance • Evidence of predator presence	

Habitat Aspect	Requirements	Assessment criteria	Scoring
	logs, within which numbats are known to rest during the day (DPaW, 2017).	• Small "bolt holes" in and beneath fallen logs offer protection from predators but are unlikely to form breeding chambers.	

3.3.3 Targeted Searches

Numbats naturally occur at low densities and are not easily trapped. As such, they are primarily surveyed by sighting surveys from vehicles along transects, track counts, or sign surveys (diggings and scats) (Connell & Friend, 1985; Seidlitz *et al.*, 2021b; Thorn *et al.*, 2022). Targeted searches were undertaken across the Study Area, with the aim to detect the species from primary (i.e. direct observation) and/or secondary evidence (i.e. scats, tracks, diggings) of numbat presence using expert advice (Sian Thorn) and available literature (Table 3.6). Any potential scats found were sent to Georgeanna Storey from ScatsAbout, for morphological identification.

Field personnel walked and drove sections the Study Area where access was not restricted by mining activities, private property, or inaccessible tracks (Figure 3.2; Figure 3.3). At all times while surveying, all records pertaining to rare species, significant species, or other fauna of interest were documented. These records included those from primary or secondary evidence.

Table 3.6: Targeted search criteria for the presence of numbat

Type of evidence	Characteristics
Primary evidence	
Observational sightings (Seidlitz *et al.*, 2021b)	• observation of individuals via walked and driving transects
Secondary evidence	
Diggings (Project Numbat, undated)	• 40mm deep • 50–100mm wide • circular • lack of unidirectional soil scatter • entry into termite gallery • clumps of diggings together
Foraging evidence (Maisey & Bradbury, 1982)	• chewing and scratching at the end of logs • turning over, chewing, and scratching at decomposing wood • destruction/opening of termite mounds is not likely to be numbat foraging.
Scats (Calaby, 1960)	• 7–10 mm diameter, 10–20mm length (3mm diameter for juveniles) • dark brown/black when fresh, fading to grey • generally smooth surface but may be rough if sand or ant contents are high • friable if sand content is high • consist of termite and ant fragments mixed with a dark grey to black "ground mass" and varying amounts of sand grains. Scats can be mostly ground mass with only a small quantity of insect remains, or potentially no insect remains at all. Some scats consisted almost entirely of coarse sand with many fragments of ants and soldier termites. • found on old, weathered logs, low flat-topped mounds of termites, and bare soil near hollow logs
Nest chambers (Calaby, 1960; Christensen *et al.*, 1984; Friend & Burrows, 1983; Maisey & Bradbury, 1982)	• Nests are made in hollows with only one entrance and an internal diameter of 60–80 mm. A nest fills the chamber and consists of readily available plant material such as grass, leaves or shredded eucalypt bark (Christensen, 1975, 1980; Christensen *et al.*, 1984; Friend & Burrows, 1983).

Type of evidence	Characteristics
	• Nest hollows can be located in in trees (up to 5 metres above ground) or in hollow logs on or near the ground. • Numbats also construct their own burrows, consisting of a single, gently sloping shaft 1–2 metres long widening out into a roughly spherical, terminal chamber about 25 cm in diameter, which can contain nests.

3.4 Assessment of habitat quality according to the EPBC Act Environmental Offsets Policy

The EPBC Act Environmental Offsets Policy (DSEWPaC, 2012a) outlines the Australian Government's approach to the use of environmental offsets under the EPBC Act. Conservation gain is the benefit that a direct offset delivers to the protected matter, which maintains or increases its viability or reduces any threats of damage, destruction, or extinction. During assessment for an offset proposal, several factors need to be considered at the impact site, including the presence and conservation status of protected matters likely to be impacted by the proposed action, and specific attributes of the protected matter being impacted at a site, for example the type of threatened species or ecological community habitat, the quality of habitat, population attributes such as recruitment or mortality, landscape attributes such as habitat connectivity, or heritage values (DSEWPaC, 2012a). The offset site must include consideration of factors such as the extent to which the proposed offset actions correlate to, and adequately compensate for, the impacts on the attributes for the protected matter (DSEWPaC, 2012a).

For the current assessment, the impact site is the disturbance envelope within the PAA, with the properties contained within Direct Offset 1 and 2 defined as the offset site. The Worsley Alumina offsets were identified and subsequently assessed for their environmental offset value (e.g. landscape connectivity, contiguity with existing habitat, tenure, viability, future level of threat), via desktop study and on-ground reconnaissance (Worsley Alumina, 2022b).

The current survey requires a calculation of a habitat quality score for numbat due to the species presence and/or potential to occur within the Study Area. The quality score for the area of habitat or area of community is a measure of how well a particular site supports a particular threatened species or ecological community and contributes to its ongoing viability (DSEWPaC, 2012b). There are three components that contribute to the calculation of habitat quality: site condition, site context, and species stocking rates (Table 3.7). These components contribute to the final habitat quality score, a value between 0–10. Equal weighting has been assigned to each attribute, and the overall score is the average score rounded (up) to the nearest whole number.

Table 3.7 Habitat quality definitions and factors of consideration (from the EPBC Environmental Offset Assessment Guide (DSEWPaC, 2012b))

Habitat Quality Attribute	Definition	Site Characteristic Factors
Site Condition	The condition of a site in relation to the ecological requirements of a threatened species or ecological community. This includes considerations such as vegetation condition and structure, the diversity of habitat species present, and the number of relevant habitat features.	• What is the structure and condition of the vegetation on the site? • What is the diversity of relevant habitat species present (including both endemic and non-endemic)? • What relevant habitat features are on the site?
Site Context	The relative importance of a site in terms of its position in the landscape, taking into account the connectivity needs of a threatened species or ecological community. This includes considerations such as movement patterns of the species, the proximity of the site in relation to other areas of suitable habitat, and the role of the site in relation to the overall population or extent of a species or community.	• What is the connectivity with other suitable/known habitat or remnants? • What is the importance of the site in relation to the overall species population or the occurrence of the community? • What threats occur on or near site?
Species Stocking Rate	The usage and/or density of a species at a particular site. The principle acknowledges that a particular site may have a high value for a particular threatened species, despite appearing to have poor condition and/or context. It includes considerations such as survey data for a site in regard to a particular species population or, in the case of a threatened ecological community this may be a number of different populations. It also includes consideration of the role of the site population in regard to the overall species population viability or community extent.	• What is the presence of the species on the site? (i.e. confirmed/ modelled). • What is the density of species known to utilise the site? • What is the role of the site population in regard to the overall species population?

440000 450000 460000 470000

6380000 6370000 6360000 6350000

Newmont Gold Mine

VBOD-19 VBOD-25 VBOD-17 VBOD-21 VBOD-23 VBOD-05 VBOD-01 VBOD-15 VBOD-13 VBOD-27 VBOD-11 VBOD-07 VBOD-09

L VBOD-06 VBOD-04 I VBOD-08

VBOD-18 A VBOD-16 VBOD-12 B VBOD-14

Ranford

Boddington

Pinjarra Williams Rd

L VBOD-02 VBOD-10 I

Marradong

VBOD-42 A B VBOD-20

VBOD-29 H H VBOD-24

VBOD-31 C

VBOD-44 VBOD-22 VBOD-46 H VBOD-68 VBOD-66 VBOD-48 VBOD-32 VBOD-26 VBOD-28 C VBOD-50 VBOD-56 VBOD-58 VBOD-38 VBOD-64 VBOD-30 Saddleback N VBOD-40 VBOD-52

D1 D2 VBOD-60 VBOD-62

VBOD-34 VBOD-36 N VBOD-54 Pinjarra Williams Rd

VBOD-70 D1 D2 VBOD-72 VBOD-74

Legend

- Primary Assessment Area (PAA)
- State Road

Direct Offset 1

Offset Type

- Protection
- Restoration

Direct Offset 2

Offset Type

- Protection
- Restoration

Sampling Method

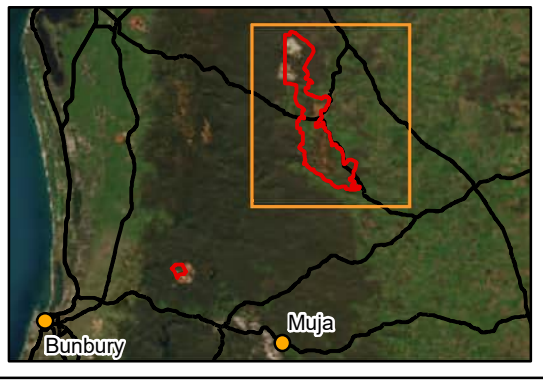
- Habitat Assessment
- Traverse

0 3 6 9 Km

Coordinate System: GDA2020 MGA Zone 50
Projection: Transverse Mercator
Datum: GDA2020 Created 14/12/2022

N

Scale: 1:150,000



SOUTH32/WORSLEY ALUMINA

Boddington Mine and Offset Properties Targeted Numbat Habitat Assessment

Figure 3.2: Fauna sample sites and traverses in the Primary Assessment Area (PAA) Study Area and proximate offset properties

400000 405000 410000 415000

6325000 6320000 6315000

VBOD-41
E
VBOD-37
VBOD-33
VBOD-80
VBOD-82
VBOD-78
VBOD-88
VBOD-76
VBOD-84
VBOD-90
VBOD-86
F1
VBOD-92
VBOD-39
VBOD-35
Worsley Refinery
VBOD-75
VBOD-94
F2
F3
F4
VBOD-67
VBOD-65
VBOD-47
VBOD-45
VBOD-73
M
VBOD-63
VBOD-49
VBOD-71
F5
VBOD-61
VBOD-69
VBOD-53
F6
F7
VBOD-59
VBOD-55
J
Worsley
F8
Coalfields Rd
K
VBOD-102
G1
VBOD-104
G2
VBOD-100
VNOD-98
VNOD-96

Legend

- Primary Assessment Area (PAA)
- State Road

Direct Offset 1

Offset Type

- Protection
- Restoration

Sampling Method

- Habitat Assessment
- Traverse

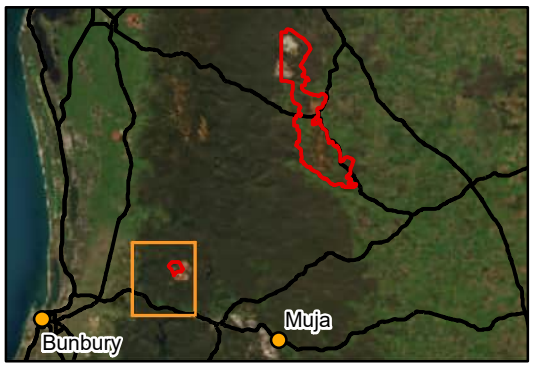
0 1 2 3 Km

Coordinate System: GDA2020 MGA Zone 50
Projection: Transverse Mercator
Datum: GDA2020 Created 15/12/2022

N

biologic Environmental Survey

Scale: 1:60,000



SOUTH32/WORSLEY ALUMINA

Boddington Mine and Offset Properties Targeted Numbat Habitat Assessment

Figure 3.3: Fauna sample sites and traverses in the Worsley Refinery Study Area and south-west offset properties

4 RESULTS AND DISCUSSION

4.1 Primary Assessment Area Habitat Assessment

4.1.1 Desktop Assessment

Previous records

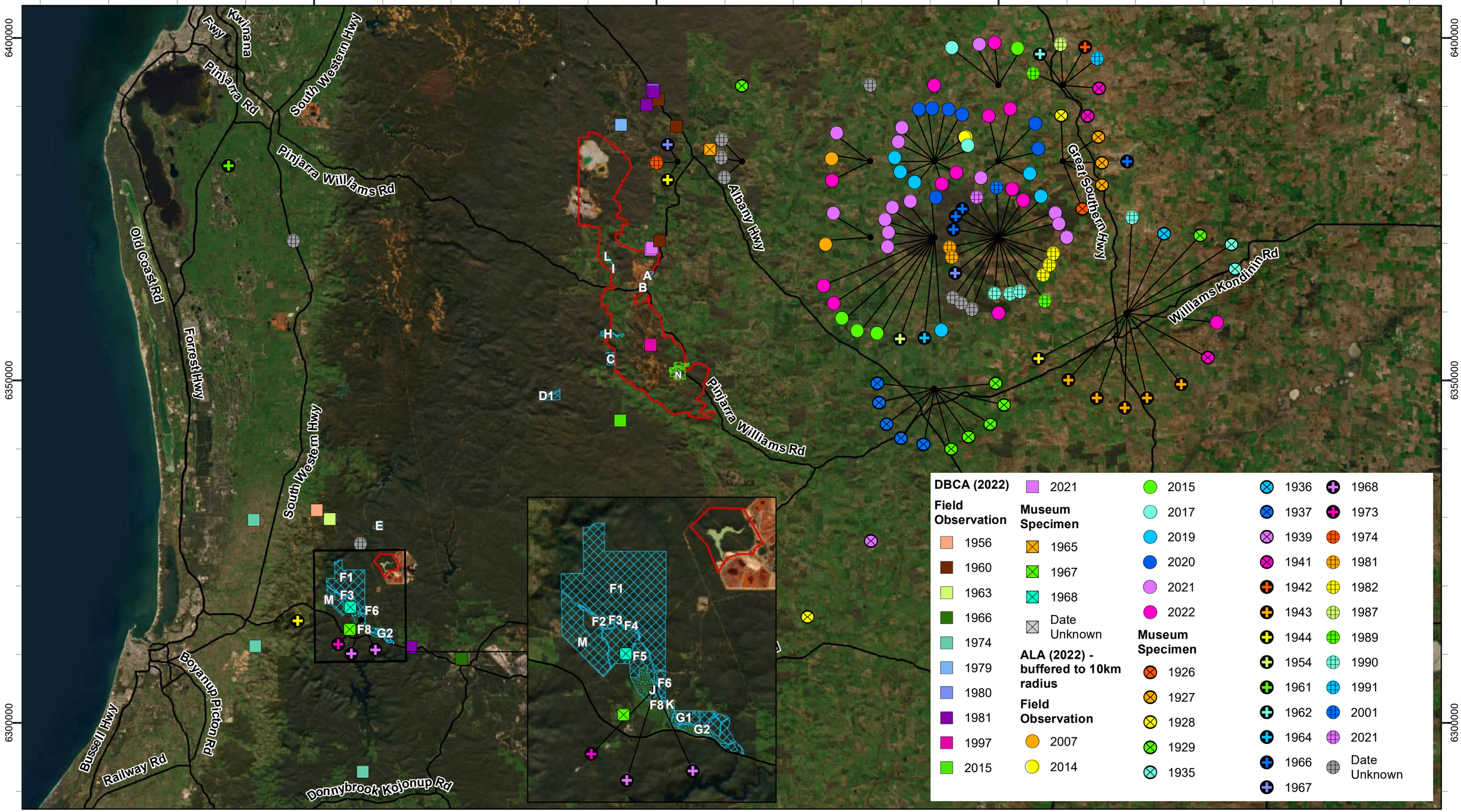
There are 24 records of numbat within 40 km of the Study Area from the DBCA database search undertaken, 19 of which are historical records (i.e. greater than 50 years old) (DBCA, 2022b) (Figure 4.1; Appendix C). Searches of the Atlas of Living Australia (ALA, 2022) show an additional 121 numbat records (including 72 historic or preserved specimens) within the same search radius, of which 107 records are from known populations at the Dryandra Woodland or Batalling Forest Block (Figure 4.1; Appendix C). These populations are the nearest known extant populations of numbat to the Study Area. Of the eight records within 10 km of the PAA, most are historic, recorded from 1960 – 1981 in the Youralling State Forest, north-east of the NGM. One previous opportunistic record exists from 1997 within the Marradong area of the PAA from a mine access road; however this record did not coincide with any known fauna survey results, and upon consultation with Ninox Wildlife Consulting who undertook the fauna surveys of the period, Biostat (2021b) concluded that the sighting was likely a misidentification of a chuditch or quenda. In 2015, an opportunistic sighting was made in the Bell Conservation Park on the corner of Bell Brook Road and Boundary Road, 5.5 km south-west of the PAA and 9.4 km south-east of the ex-Talbot offset property (Offset D), verified by photographic evidence (DBCA, 2022b).

The individual recorded from within the PAA boundary, and adjacent to the Boddington townsite, was verified by camera trap footage and visual observations from March to September 2021, with the length of time indicating that that the individual resides in the area. This period falls outside the primary dispersal period of November or early December (DPaW, 2017). The individual was initially sighted opportunistically, with the record confirmed by camera trap footage (Loney, 2021). Observations of the individual were made both in a remnant dominated by wandoo woodland adjacent to agricultural land, and within Jarrah/Marri/*Allocasuarina* Woodland within the PAA boundary. The individual was sighted on multiple occasions, including crossing major roads between the remnant vegetation and Boddington townsite (P. Bullock, Worsley Alumina, *pers. comms,* October 2021). This area was re-visited during the current survey to compare the habitat quality and characteristics to other areas of the PAA (Plate 4.1). At a local scale, the site had the critical habitat characteristics required to support numbat, including hollow logs (where the 2021 camera trap photos were taken), foraging resources with supporting open patches of cover, and sufficient canopy and understorey cover for protection. However, the extent of the habitat patch was small, with narrow connecting corridors to larger habitat patches, and is unlikely to support the individual in its entirety if these adjacent supporting areas are removed.

This record was previously considered most likely “a single individual that has moved from Dryandra Woodland”, and that the dispersal distance, although higher than that previously recorded (~22 km dispersal during the 1992 population peak, compared to a 35–40 km), is achievable for the species (T. Friend, pers comms in Biostat, 2021b). However, in consideration of the distance and the highly fragmented landscape between Dryandra Woodland and the Study Area, other possibilities include:

- The individual represents a dispersed individual from the Batalling Forest Block, approximately 30 km south of the PAA boundary, which has continuous linkage with the Study Area through the Muja State Forest, Harris River State Forest, and Dwellingup State Forest. The Batalling population is self-sustaining, with approximately 50–100 individuals estimated to be present (DPaW, 2017). During the reintroduction to Batalling, over half of the numbats released were never located again, and it is likely that many animals dispersed well beyond the search area (DPaW, 2017).
- Small, undetected populations may exist in the Dwellingup State Forest or Youralling State Forest. There have been no detailed surveys across these expansive areas of woodland, with both contemporary (Dwellingup State Forest, 2015) and historic (Youralling State Forest, 1960-1981) (DBCA, 2022b) records of numbat present.

Plate 4.1: Habitat present at the site record of the individual recorded in 2021.



Legend

- Primary Assessment Area (PAA)
- State Road

Direct Offset 1	Direct Offset 2
Offset Type	**Offset Type**
Protection	Protection
Restoration	Restoration

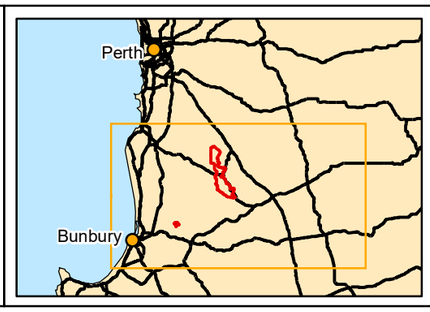
N

biologic Environmental Survey

Scale: 1:518,000

0 10 20 Km

Coordinate System: GDA2020 MGA Zone 50
Projection: Transverse Mercator
Datum: GDA2020 Created 14/12/2022



SOUTH32/WORSLEY ALUMINA

Boddington Mine and Offset Properties Targeted Numbat Habitat Assessment

Figure 4.1: Previous numbat records from the vicinity of the Study Area

4.1.2 Ground-truthing Assessment

Significant results

Up to five patches of fresh diggings attributed to numbat were recorded in the NGM during the current survey within a patch of rehabilitated habitat (VBOD-03) (Plate 4.2; Figure 4.2). The diggings were of the correct diameter, depth, shape, lacking a unidirectional soil scatter, contained entry points into termite galleries, and were recorded in small groups (of approximately ten diggings) across multiple exposed soil piles. Due to these characteristics, the diggings were considered unlikely to have been made by quenda, goanna, or echidna. A scat was collected showing the correct characteristics for numbat, in particular the high percentage of termite exoskeletons and ground mass present, the size and shape of scat, and the location next to the recorded diggings from the same site. Upon analysis by Scats About, the scat was deemed most likely to be numbat, as the "content and amount of sample confirms numbat over echidna". Depending on weather conditions, it is assumed that numbat diggings can last for several days, and scats potentially for several weeks (Seidlitz *et al.*, 2021b). Due to the rain experienced in the days prior to the field survey (Table 3.4), the diggings were assessed as freshly made (i.e. within a week) as the edges were not collapsed or washed down by water. As such, it is reasonable to assume, that at least one numbat was foraging within and in the vicinity of the PAA.

It is not known yet if the individual is the same as that previously recorded in the area. However, as numbat can be identified by their stripe pattern (Thorn *et al.*, 2022), if recent camera trap images are captured, it can be determined if it is either the same individual as previously recorded from the Boddington townsite or another individual. Once a juvenile numbat has established its home range after dispersal (approximately one pair of established adults per 50 hectare), that animal remains in or close to that area for the rest of its life (DPaW, 2017). Comments from Dr. Tony Friend in Biostat (2021b) state that "a lone male is likely to stay in the area until September/ October but will then leave in search of females if there are none nearby. A female is more likely to stay at least for another year but may move later if there are no males nearby. Conversely, if a) both sexes are present and b) habitat, especially termite abundance, is adequate, they are likely to stay."

If an individual dispersed from Dryandra to Boddington, it would have had to avoid all cleared areas, remaining within contiguous habitat corridors to avoid raptor predation. Given the extent of clearing between Dryandra and Boddington with no true ecological connectivity between the areas, the probability that the individual was able to disperse across not only a single paddock, but extensive agricultural land, is low. Cleared zones do not provide suitable habitat for numbat in any of the key characteristics required, and the species is known to avoid fence lines and agricultural areas (DPaW, 2017). Therefore, in consideration of the numbat records from the current survey and from 2021, and the distance and highly fragmented agricultural land between Dryandra Woodland and the Study Area there is the potential that:

- The individual (of unknown origin) is potentially a permanent resident within or in the vicinity of the PAA, dispersing to (and recorded in) the NGM in search of a larger and more suitable habitat patch away from disturbance and threat sources, or in search of a mate (which may be present in the NGM). Therefore, there is the potential for the area north of Hotham River within the PAA to provide suitable habitat for the species to occur as residents.

- The current survey record represents a new individual from either known (e.g. Dryandra Woodland, Batalling Forest) or undetected (e.g. Dwellingup State Forest, Youralling State Forest) populations. Numbats are difficult to detect and occur in low densities (Seidlitz *et al.*, 2021a); therefore, the possibility of previously undetected individuals in the adjacent State Forests cannot be dismissed. As mentioned above, if both sexes are present and habitat is adequate, individuals are likely to stay in an area.
- The current survey record represents a dispersed or dispersing juvenile numbat juvenile representing offspring from 2021 records of the species. All young leave the maternal home range and disperse by November or early December (DPaW, 2017).

The extensive previous survey effort across the PAA (e.g. Biostat, 2017, 2018; Biostat, 2020, 2021a, 2021b, 2021c; Ninox, 2003) did not identify numbat presence through camera traps or targeted searches. The potential conclusions provided in this report incorporate the results and new record of the current survey; however, these are still made based on the limited targeted searching and assessments undertaken within the survey period.

Plate 4.2: Numbat diggings recorded at site VBOD-03

The habitat of the numbat record from the current survey consisted of dense *Banksia squarrosa* and *B. sessilis*, over laterite, sandy soils. The rehabilitation of site VBOD-03 was suitable to support foraging and protection resources for numbat where exposed sandy patches were present. However, due to the lack of mature eucalypts present, the site did not contain fallen trees and branches to support breeding and nocturnal refuges for the species. Traverses of the jarrah and marri woodland directly north of the site (VBOD-05) revealed suitable log hollows and bolt holes (small entrances in and beneath logs for predator avoidance) to support breeding, nocturnal refuges, and protection from threats. Overall, it is likely that recently rehabilitated areas, comprised of dense understorey and middle storey shrub species, can form part of an individual's home range, but without hollow logs, any numbats present will also require adjacent habitat containing mature eucalypts such as jarrah, marri, and wandoo. The habitat of the NGM is continuous with the native woodland extending outside the PAA to both the west (Dwellingup State Forest) and east. As shown on Figure 4.1, there are historic records approximately 10 km north of the NGM, recorded from 1960–1981, in the Youralling State Forest, indicating previous suitability of the area to support the species.

Plate 4.3: Rehabilitated habitat (VBOD-03) where numbat diggings and scat were found

Plate 4.4: Eucalypt (jarrah) woodland at site VBOD-05, adjacent to site VBOD-03, containing logs and with hollows and bolt holes

Critical Habitat Review

Numbats, through natural and translocated populations, currently occur across several IBRA subregions of Western Australia, including the Northern and Southern Jarrah Forests (JAF01 and JAF02), Avon Wheatbelt (AVW01), Western Mallee (MAL02), Esperance Plains (ESP01), Yalgoo (YAL02), and Coolgardie (COO02). Despite their threatened status and isolated occurrence, numbats are habitat generalists, and have historically occupied a wide variety of habitat types, including eucalypt forest, eucalypt woodland, *Acacia* woodland and *Triodia* grassland (DPaW, 2017). However, since European settlement, the habitat of most populations is characterized by the presence of eucalypt species that provide foraging, breeding, and refugia resources (Friend & Thomas, 2003) (Table 3.5).

Biostat (2021b) categorised the habitats present across the PAA into 19 types, which were grouped into six broad groups; Jarrah/Marri communities, Wandoo communities, Mallee woodlands, Riparian/Wetland, Heath communities, and Other (Rehabilitation, Plantations, Dam, and Cleared) (Table 4.1; Figure 4.2). Apart from cleared areas, Jarrah/Marri communities comprise the greatest area across the PAA (9,158.07 ha, 31.20%). On a localised scale, five habitat types across the PAA have the general features to

support numbat for foraging, breeding, and predator protection, and are considered of High Suitability; Marri/jarrah on lower slopes, Jarrah/Marri/*Allocasuarina* woodlands on slopes and ridges, Jarrah/Marri woodlands on slopes, wandoo woodlands, and low *Eucalyptus* woodland over low shrubs (Table 4.1). Overall, these habitats comprise 38.91% ha of the PAA.

Termite presence was recorded within these habitats through the presence of individual termite mounds, termite galleries within hollow logs (both under the surface and at the exposed ends), and under decomposing wood and bark (Plate 4.5). Termite activity differs seasonally; with activity in small sticks and branches laying on the forest floor, and in galleries under the surface on large logs during winter and changing to the underside of larger logs or pieces of wood partially buried during summer due to higher temperatures (Maisey & Bradbury, 1982). As such, the presence of termites across different micro-habitats provides greater reassurance of high-quality foraging resources across seasons for numbat. In relation to breeding resources, there was a high number of appropriate hollow logs or logs with burrows/ bolt holes found concealed under logs across the Jarrah/Marri communities and Wandoo Woodlands (Plate 4.6). Numbat burrow entrances are often found under logs (Maisey & Bradbury, 1982; Seidlitz, 2021) that help conceal and protect burrow entrances from digging predators such as red fox (*Vulpes vulpes*) and monitor lizards (*Varanus* spp.). There is a trend of higher log availability in jarrah-based habitats compared to wandoo forest, and therefore an increased numbat habitat use of jarrah forest (Seidlitz, 2021); however, Wandoo Woodland was still assessed as High Suitability. For example, wandoo woodlands are the dominant habitat occupied by the species at Dryandra Woodland (DEC, 2011).

In general, rehabilitated lands within mine sites follow similar successional trajectories following planting; from bare ground to heath-like habitat through to shrubland, low closed forest, and finally tall forest. As noted above, the Rehabilitation habitat (outside agricultural areas) generally lacked mature eucalypts and therefore fallen logs and branches that support breeding and nocturnal refuges for the species. These areas were therefore rated as providing “Medium Suitability” for the species. The rehabilitated area where numbat diggings and scats were recorded during the current survey was encompassed by original Jarrah/Marri/*Allocasuarina* woodland that contained suitable breeding resources. Rehabilitation areas are therefore more likely to become suitable for numbat as age since planting increases.

Plantation habitats within agricultural systems can provide additional foraging resource and some limited connectivity, if adjacent to relatively undisturbed habitats; however, on a localised scale they are considered of Low Suitability for numbat.

Plate 4.5: Examples of potential foraging resources for numbat within High Suitability habitats in the PAA

Plate 4.6: Examples of potential breeding and refuge resources within High Suitability habitats of the PAA

The remaining habitats have been assessed as Low-Medium to Low or Nil suitability. The riparian environments, including communities of blackbutt, flooded gum, or *Melaleuca* on lower slopes (964.06 ha, 3.28%) are unlikely to support high quantities of termite colonies due to flooding or water presence, or support tree species likely to produce refuge hollows (e.g. *Melaleuca*, *E. rudis*). Stands of trees within the agricultural areas, although are stands of native tree species, generally lack a native vegetation understorey or are in poor condition. Cleared zones do not provide suitable habitat for numbat in any of the key characteristics required, and the species is known to avoid fence lines and agricultural areas (DPaW, 2017).

The critical habitat assessment is based on microhabitat features assessed during the field survey using criteria in Table 3.5 that are required to support numbat. Due to the fragmented nature of the habitat present across the PAA, in particular across the Marradong, Saddleback, and Quindanning areas, each individual patch of habitat was not assessed for its suitability to support numbat outside of the critical habitat elements required. As noted in Biostat (2021b), the true ecological value of habitats for any species is determined by many factors including on-going management activities and, importantly, connectivity in the landscape. Overall suitability for numbat on a larger spatial scale within the Study Area was assessed after consideration of factors such as dispersal capability, connectivity to other habitat, and patch size, and is presented in section 4.1.3 below.

Table 4.1: Fauna habitats (from (Biostat, 2021b)) and numbat habitat suitability assessment across the PAA

Fauna Habitats			Habitat Code	Area (ha)		Biologic Suitability Assessment			Overall Suitability for Numbat
				Hectares	%	Foraging Resources	Breeding Resources	Protection/ Refugia	
Jarrah/Marri communities	Marri/jarrah on lower slopes		DL	437.10	1.49	High	High	High	**High**
	Jarrah/Marri/*Allocasuarina* woodlands on slopes and ridges		JC	5,208.57	17.74%	High	High	High	**High**
	Jarrah/Marri woodlands on slopes		JM	3,511.93	11.96%	High	High	High	**High**
Wandoo communities	Wandoo woodlands		WO	2,686.57	9.15%	High	Medium	Medium	**High**
Mallee woodlands	Low *Eucalyptus* woodland over low shrubs		ML	14.14	0.05%	Medium	Medium	Medium	**High**
Riparian/Wetland	Blackbutt woodlands on lower slopes		BB	126.12	0.43%	Low	Low	Low	**Low-Medium**
	Mosaic of marri/jarrah on lower slopes and flooded gum riparian communities		FD	5.35	0.02%	Medium	Low	Low	**Low-Medium**
	Flooded gum woodlands riparian community.		FG	697.99	2.38%	Low		Low	**Low-Medium**
	Jarrah/Marri valley floors/swamps		JS	0.47	<0.01%	Medium	Medium	Low	**Low-Medium**
	Melaleuca shrublands on seasonally wet valley floors		MS	132.94	0.45%	Low		Low	**Low-Medium**
	Flooded gum/*Melaleuca* shrublands on seasonally wet valley floors		MW	1.66	0.01%	Low		Low	**Low-Medium**
Heath communities	Heaths including perched heaths		PH	157.06,	0.54%			Low	**Low**
Others	Rehabilitation	Rehabilitation not in agricultural areas	RE	3,163.57	10.78%	Medium		Low	**Medium**
		Rehabilitation in agricultural areas	RE-Ag	26.94	0.09%	Low		Low	**Low**
	Plantations	Plantations not in agricultural areas	PL	229.00	0.78%	Low		Low	**Low**
		Plantations in agricultural areas	PL-Ag	185.40	0.63%	Low		Low	**Low**
	Dam		DM	63.39	0.22%				**Low**
	Cleared Lands	Cleared Lands not in agricultural areas	CL	6,148.64	20.95%				**Nil**
		Cleared Lands in agricultural areas	CL-Ag	6,559.27	22.34%				**Nil**
Total				**29,356.11**	**100.00**				

440000
450000
6390000
6380000
6370000

Fauna Habitat

Heath Community
- PH

Jarrah/ Marri Community
- DL
- JC
- JM
- JS

Malee Woodland
- ML

Other
- CL
- CL - Ag
- PL
- PL - Ag
- RE
- RE - Ag

Riparian/ Wetland
- BB
- FD
- FG
- MS
- MW

Wandoo Community
- WO

Newmont Gold Mine
Bannister Marradong Rd
Ranford
Boddington
Marradong

Legend

- Primary Assessment Area (PAA)
- State Road

Direct Offset 1

Offset Type
- Protection
- Restoration

Record Type
- Digging
- Scat

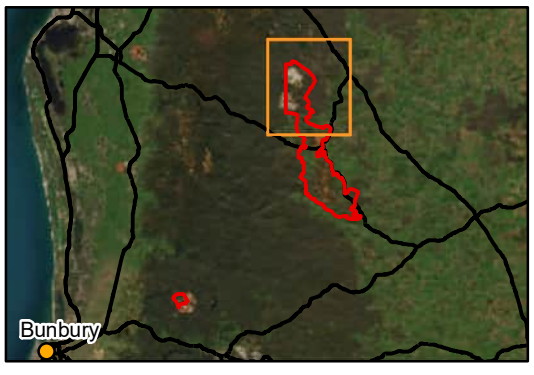
0 2 4 Km

Coordinate System: GDA2020 MGA Zone 50
Projection: Transverse Mercator
Datum: GDA2020 Created 15/12/2022

N

biologic Environmental Survey

Scale: 1:78,600



SOUTH32/WORSLEY ALUMINA

Boddington Mine and Offset Properties Targeted Numbat Habitat Assessment

Figure 4.2a: Broad fauna habitat (PAA)

440000

450000

6370000

6360000

Fauna Habitat

Heath Community

PH

Jarrah/ Marri Community

DL

JC

JM

Malee Woodland

ML

Other

CL

CL - Ag

DM

PL

PL - Ag

RE

RE - Ag

Riparian/ Wetland

BB

FD

FG

MS

Wandoo Community

WO

Boddington

Marradong

Saddleback

Pinjarra Williams Rd

A

B

C

H

L

I

N

Legend

Primary Assessment Area (PAA)

State Road

Direct Offset 1

Offset Type

Protection

Restoration

Direct Offset 2

Offset Type

Protection

Restoration

0 2 4 Km

Coordinate System: GDA2020 MGA Zone 50
Projection: Transverse Mercator
Datum: GDA2020 Created 15/12/2022

N

biologic Environmental Survey

Scale: 1:78,500

Bunbury

SOUTH32/WORSLEY ALUMINA

Boddington Mine and Offset Properties Targeted Numbat Habitat Assessment

Figure 4.2b: Broad fauna habitat (PAA)

440000
450000
6360000
6350000
6340000

Fauna Habitat

Heath Community
- PH

Jarrah/ Marri Community
- DL
- JC
- JM

Malee Woodland
- ML

Other
- CL
- CL - Ag
- DM
- PL
- PL - Ag
- RE
- RE - Ag

Riparian/ Wetland
- BB
- FG
- MS

Wandoo Community
- WO

Pinjarra Williams Rd

A
B
C
H
N
Saddleback
D1
D2

Legend

- Primary Assessment Area (PAA)
- State Road

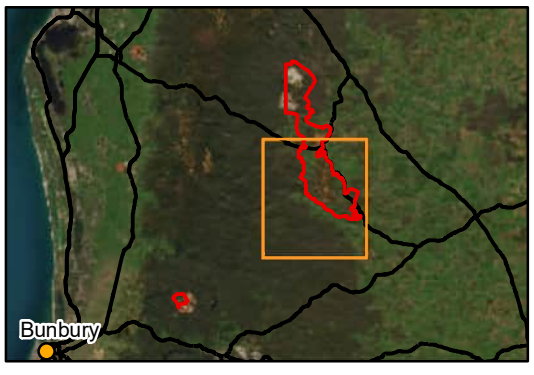
Direct Offset 1	Direct Offset 2
Offset Type	Offset Type
Protection	Protection
Restoration	Restoration

0 2 4 6 Km

Coordinate System: GDA2020 MGA Zone 50
Projection: Transverse Mercator
Datum: GDA2020 Created 15/12/2022

N

Scale: 1:97,900



SOUTH32/WORSLEY ALUMINA

Boddington Mine and Offset Properties Targeted Numbat Habitat Assessment

Figure 4.2c: Broad fauna habitat (PAA)

440000
450000
6390000
6380000
6370000
Albany Hwy
Bannister Marradong Rd
Newmont Gold Mine
Ranford
Boddington
Marradong
L

Legend

- Primary Assessment Area (PAA)
- State Road

Direct Offset 1

Offset Type

- Protection
- Restoration

Numbat Habitat Suitability

- High Suitability
- Medium Suitability
- Low Suitability
- Nil Suitability

Record Type

- Digging
- Scat

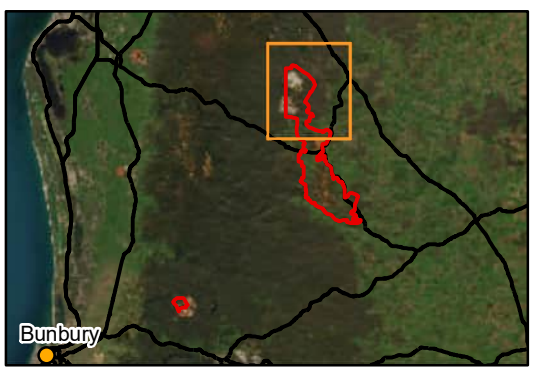
0 2 4 Km

Coordinate System: GDA2020 MGA Zone 50
Projection: Transverse Mercator
Datum: GDA2020 Created 14/12/2022

N

biologic Environmental Survey

Scale: 1:78,600



SOUTH32/WORSLEY ALUMINA

Boddington Mine and Offset Properties Targeted Numbat Habitat Assessment

Figure 4.3a: Numbat suitability (PAA)

440000
450000
6370000
6360000
Boddington
Marradong
Saddleback
Pinjarra Williams Rd
A
B
H
I
C
N
Bunbury

Legend

- Primary Assessment Area (PAA)
- State Road

Direct Offset 1

Offset Type

- Protection
- Restoration

Direct Offset 2

Offset Type

- Protection
- Restoration

Numbat Habitat Suitability

- High Suitability
- Medium Suitability
- Low Suitability
- Nil Suitability

0 2 4 Km

Coordinate System: GDA2020 MGA Zone 50
Projection: Transverse Mercator
Datum: GDA2020 Created 14/12/2022

N

biologic Environmental Survey

Scale: 1:78,500

SOUTH32/WORSLEY ALUMINA

Boddington Mine and Offset Properties Targeted Numbat Habitat Assessment

Figure 4.3b: Numbat suitability (PAA)

440000
450000
6360000
6350000
6340000
Pinjarra Williams Rd
A
B
C
H
N
Saddleback
D1
D2
D1
D2
N
Pinjarra Williams Rd

Legend

- Primary Assessment Area (PAA)
- State Road

Direct Offset 1

Offset Type

- Protection
- Restoration

Direct Offset 2

Offset Type

- Protection
- Restoration

Numbat Habitat Suitability

- High Suitability
- Medium Suitability
- Low Suitability
- Nil Suitability

0 2 4 6 Km

Coordinate System: GDA2020 MGA Zone 50
Projection: Transverse Mercator
Datum: GDA2020 Created 14/12/2022

N

biologic Environmental Survey

Scale: 1:97,900

Bunbury

SOUTH32/WORSLEY ALUMINA

Boddington Mine and Offset Properties Targeted Numbat Habitat Assessment

Figure 4.3c: Numbat suitability (PAA)

4.1.3 EPBC Habitat Offset Calculations

The quality score for the area of habitat or area of community is a measure of how well a particular site supports a particular threatened species or ecological community, and contributes to its ongoing viability (DSEWPaC, 2012b). There are three components that contribute to the calculation of habitat quality; site condition, site context, and species stocking rates (Table 3.7). With equal weighting assigned to each attribute, overall, the habitat quality scores for the PAA in relation to numbat ranged between 3 and 8 out of 10 (Table 4.2).

Site Condition

The site condition scores for the BBM areas of the PAA ranged from 3 to 8 out of 10, as reflected by the habitat suitability shown on Figure 4.3 and discussed in section 4.1.2, with the NGM site (8 out of 10) assessed as the highest quality condition habitat (Figure 4.2;Table 4.2). This reflects the smaller disturbance footprint from the gold mining operations that have meant more Highly Suitable habitat (particularly Jarrah/Marri communities) has been retained across the northern section of the PAA, compared to cleared or agricultural land. This has meant critical habitat elements for numbat (hollow logs, canopy and understorey coverage, and foraging resources) have been retained in higher quantities. In contrast, the Marradong, Saddleback and, to a lesser extent, the Quindanning regions of the PAA are associated with the bauxite mine operations, which disturbs comparatively larger areas of land compared to the mining of other minerals (IAI, 2018), and tends to correspond with Jarrah/Marri communities. As such, the BBM in general has a much higher proportion of cleared areas, agricultural land, and infrastructure. Stands of trees found within agricultural areas are generally lacking a native vegetation understorey or have an understorey in poor condition due to grazing or competition with introduced pasture grasses; although these corridors are still important for dispersing young (DPaW, 2017). This has meant less Highly Suitable habitat has been retained overall and in small and fragmented areas at a local scale. Similar to the NGM area, the site condition score of the CBME was assessed as 8 out of 10, reflecting the retention of high-quality habitat outside the refinery operations.

Site Context

The site context scores for the PAA were influenced by the numbat records from 2021 and the current survey, as well as the degree of fragmentation and disturbance present. The high site context score of the NGM (9 out of 10) reflects the recent numbat diggings and scats recorded in the NGM during the current survey, and the extension of suitable habitat from the NGM into the surrounding Dwellingup State Forest to the west and large woodland region to the east. The NGM is known to support other significant species of the region, including chuditch, phascogale, western brush wallaby, and woylie (Biostat, 2021a, 2021b). The context score of the CBME at Collie reflects the retention of a high level of connectivity despite the small size of the area, as the site is functionally contiguous with the adjacent State Forest area; however, species presence at the site is not confirmed.

For the other BBM areas (MAR, SAD, QUIN), the context scores were influenced by the fragmentation of the habitat present, and the fragmentation of the landscape to the east with increasingly larger areas of agricultural lands acting as barriers to animal movements. Numbats have shown that they rarely cross farmland, but often end up in suitable habitat at the edge of cleared land (DPaW, 2017). Saddleback was assessed with the lowest context score, a reflection of the high degree of fragmentation and lack of connection to suitable habitat, lack of confirmed records, and degree of disturbance from the bauxite mine operations and public infrastructure. A lot of rehabilitation undertaken across cleared areas within Saddleback has been undertaken within the past decade (Worsley Alumina, 2022a); currently these areas may support the linkages to the forest blocks to the west through areas of native vegetation more than supporting numbat on a permanent basis. There are also some linkages between the MAR and SAD areas. The Marradong site context score (7 out of 10) reflects the presence of the numbat individual on the periphery of the PAA from 2021 for at a minimum of one year based on observational records; however, the area is in general highly fragmented by mining activity, agricultural land, roads, and infrastructure.

Stocking Rate

Numbat home ranges in general is approximately one pair of established adults per 50 hectares, with similar ranges for both wandoo woodland and jarrah forest but can extend up to 133 ha (Christensen *et al.*, 1984; DPaW, 2017). Outside Western Australia, home ranges were found to be between 25–67 hectares (autumn/winter to summer) at Arid Recovery in South Australia, and 28 (female) to 96.6 ha (males) in Scotia in NSW (Hayward *et al.*, 2015). These home ranges are exclusive within the sexes. In consideration of this, many of the habitat patches remaining in the BBM areas of the PAA are unlikely to support more than one individual as a part of its range or as a transient individual, as reflected by the lower site stocking scores for the MAR, SAD, and QUIN areas (2–4 out of 10). The NGM and CBME stocking rate scores of 5 and 7 out of 10 reflects the generally continuous habitat extension outside the area, with the NGM scoring higher as the species presence is confirmed.

Table 4.2: Habitat quality assessment for numbat across the PAA using the EPBC Environmental Offset Policy Guidelines

Habitat attribute	NGM		MAR		SAD		QUIN		CBME	
	Score	Rationale	Score	Rationale	Score	Rationale	Score	Rationale	Score	Rationale
Condition	**8**	Apart from the pit footprint, most of the habitat within the site is considered of High Suitability to support numbat, with foraging, breeding, protection, and dispersal resources present.	**4**	Although the habitat patches in this area contain some foraging and breeding resources, they are in general degraded, exposed, and lack protective qualities or connectivity to larger patches of habitat.	**3**	Although the habitat patches in this area contain some foraging and breeding resources, they are in general degraded, exposed, and lack protective qualities or connectivity to larger patches of habitat.	**4**	Although the habitat patches in this area contain some foraging and breeding resources, they lack protective qualities or connectivity to larger patches of habitat. The habitat of the vicinity is in general cleared and agricultural lands, with some patches recently rehabilitated and therefore lacking abundant breeding logs.	**8**	Apart from the refinery footprint, most of the habitat within the site is considered of High Suitability to support numbat, with foraging, breeding, protection, and dispersal resources present.
Context	**9**	Secondary evidence of numbat presence was recorded during the current field survey in a rehabilitated area close to undisturbed Jarrah/Marri/*Allocasuarina* habitat which continues outside the PAA boundary for 5-10km to the east. Site is continuous with the Dwelling State Forest along the western boundary, and Youralling State Forest is 10km to the north-east where multiple numbat records were recorded in the 19**8**0's.	**7**	The previous numbat records are in the general Marradong vicinity within the PAA; however, the records are restricted to the periphery away from heavy disturbance. In general, the area is highly fragmented by mining activity, agricultural land, roads, and infrastructure.	**5**	There are no confirmed previous records in the immediate vicinity, as the previous database record from 199**7** is unconfirmed. In general, the area is highly fragmented by mining activity, agricultural land, roads, and infrastructure; however, it retains some links to forests blocks to the west through areas of native vegetation.	**4**	There are no confirmed previous records in the immediate vicinity, as the previous database record from 199**7** is unconfirmed. In general, the area is highly fragmented by mining activity, agricultural land, roads, and infrastructure.	**6**	No known contemporary numbat sighting within the vicinity. Site is in general continuous with the Dwellingup State Forest.
Stocking Rate	**7**	Suitable habitat is adjacent to Dwellingup State Forest and other large patches of suitable habitat. Site has the potential to form part of multiple individuals home range.	**2**	Unsuitable habitat and therefore unlikely to support more than an individual on a transient basis.	**2**	Unsuitable habitat and therefore unlikely to support more than an individual on a transient basis.	**3**	Patches of suitable habitat are present, however due to the small and fragmented nature they are unlikely to support more than an individual on a transient basis. Species presence is not confirmed.	**5**	Suitable habitat is adjacent to Dwellingup State Forest and other large patches of suitable habitat. Site has the potential to form part of an individual's home range; however, species presence is not confirmed.
Overall score	**8**		**4**		**3**		**4**		**6**	

4.2 Offset Properties Habitat Assessment

4.2.1 Desktop Assessment

Previous records

Of the known database records, nine exist within the immediate vicinity of the Collie-based offset properties, in addition to the previously described 2015 record from the Dwellingup State Forest that lies within 10 km of Offsets C (ex-Bulgara and Power-Kennedy) and D (ex-Talbot) (DBCA, 2022b) (Figure 4.1; Appendix C).The Collie-based numbat records are considered historic, dating from 1956 to 1974; however there are two records (museum voucher specimens) within the large Offset F property from 1968, with an additional record immediately south from 1974. The numbat recovery plan (DPaW, 2017) notes that “areas that do not currently contain the species, but did so historically, and are suitable for translocation now or in the future if threat abatement occurs should also be considered important”. As such, the presence of previous records within the largest offset property is of significance and demonstrates the potential value. Other historic records of the Collie area are located within now-cleared agricultural land and the Collie townsite (Figure 4.1).

4.2.2 Ground-truthing Assessment

Biostat (2020) categorised the habitats present across all offset properties (both Direct Offset 1 and 2) into seven types, excluding Cleared areas; Blackbutt Woodlands, Marri/Jarrah on lower slopes, Jarrah/Marri/*Allocasuarina* woodlands, Jarrah/Marri woodlands on slopes, Wandoo Woodlands, Heaths, Flooded Gum Woodlands, Melaleuca Shrublands, and Rehabilitation (both with native species or on agricultural lands) (Figure 4.2; Figure 4.4; Table 4.3). Comparable to the PAA, the habitats covering the greatest proportion of the offset properties are the jarrah and marri-based communities, covering 53.89% in total. Blackbutt woodlands comprised 24.08% of the offset property habitats. The offset properties overlapping the BBM areas (Offsets A, B, H, I, J, L, M, N) in general contain a lower proportion of native vegetation than those located in the Collie region and comprise a higher proportion of cleared and agricultural lands.

Following the field survey, the Jarrah/Marri communities and Wandoo Woodlands were assessed as having suitable quantities and quality of critical habitat elements to support numbat for foraging, breeding, and predator protection, and are considered of High Suitability; (Table 4.3; Figure 4.3; Figure 4.5). Overall, these habitats comprise 58.51% (2,965.59 ha) of the offset properties. This is comparable to the localised conditions present in the PAA, where on local scale habitat patches show high levels of hollow and decaying logs, termite mounds, woody and decomposing debris, and appropriate levels of vegetation cover. Evidence of other digging mammals such as quenda and echidna were recorded within the offset properties, demonstrating the value of the invertebrate resources available.

The Blackbutt Forests, Melaleuca shrublands, and Flooded Gum Woodlands (categorised as Riparian systems by (Biostat, 2020) due to the presence of drainage lines and creeks) are considered of Low suitability for numbat. Hollow abundance and formation is less common in blackbutt stands compared to other associations (Williams, 2001), and larger logs are most likely to produce valuable (i.e. cavities with depth and larger entrance diameters) hollow logs (Williams & Faunt, 1997). Comparable to the current field survey, Biostat (2020) also noted the high density of younger, and therefore with a smaller diameter, trees

present at the site. Overall, the riparian habitat groups appear to have less breeding resources available for numbat. In addition, the canopy cover was extremely dense in patches within the Blackbutt Forest in Offsets E, F, G, J, K, and M, reducing the overall suitability due to the absence of a more open understorey suited for foraging. The habitat is still valuable as part of an individual's home range; however, the core characteristics were less suitable than other habitats. Biostat (2020) noted that numbats will be able to utilise most open woodland and forest habitats within the offset properties with a variety of understory where they have a more open canopy structure.

The Rehabilitation areas on previously agricultural land and Heath habitat within the offset properties have been assessed as Low suitability comparable to the assessment across the PAA, with a general lack of fallen logs and branches that support breeding and nocturnal refuges. The Heath habitats were noted as lacking the mature eucalypts required to create critical breeding logs and refuges to support the species.

Plate 4.7: Example habitat photos from offset properties showing high quality habitat elements (clockwise from top left); jarrah woodland, termite mound and activity, decomposing log, and jarrah woodland.

Table 4.3: Fauna habitats present across the offset properties and numbat habitat suitability assessment

Fauna Habitat		Habitat Code	Offset Area													Biologic Suitability Assessment			Overall Suitability for Numbat	Total Area (ha)
			A	B	C	D	E	F	G	H	I	J	K	L	M	N	Foraging Resources	Breeding Resources	Protection/ Refugia		
Riparian/Wetland	Blackbutt forests on lower slopes	BB				7.72	22.25	924.73	11.63						253.89		Low	Low	Medium	**Low**	1,220.23
	Flooded gum woodlands which may include Jarrah, Marri, *B. littoralis* or Wandoo.	FG								12.07				1.53		18.14	Low		Low	**Low**	31.74
	Melaleuca shrublands on seasonally wet valley floors	MS														34.31	Low		Low	**Low**	34.31
Jarrah/Marri communities	Marri/jarrah on lower slopes. Can exist as a mosaic of vegetation communities including wandoo	JS				58.24		10.13									High	High	High	**High**	68.37
	Jarrah/Marri/*Allocasuarina* woodlands on slopes and ridges. Can exist as a mosaic of vegetation	JC		5.05	26.64	98.91	46.95	710.10	169.31	5.77					136.53		High	High	High	**High**	1,199.24
	Jarrah/Marri woodlands on slopes. Can exist as a mosaic of vegetation communities including wandoo woodlands.	JM	27.68	0.72	9.90	9.67	21.30	854.20	104.97						410.86	24.40	High	High	High	**High**	1,463.69
Wandoo Woodlands	Wandoo woodlands.	WO	47.86	7.31	95.04	52.40				5.80				2.08		92.14	High	Medium	Medium	**High**	302.63
Heath Communities	Heaths including perched heaths.	PH			21.07	2.34											Low			**Low**	23.41
Other	Rehabilitation with native species and rehabilitation as agricultural lands.	RE														50.71	Low		Low	**Low**	50.71
	Cleared lands	CL	1.82					131.76	124.40	44.67		14.06	26.90			1.16				**Nil**	344.78
	Agricultural cleared lands.	CL-Ag		0.03						39.10	19.98			31.95		238.08				**Nil**	329.14
Total Area (ha)			**77.37**	**13.12**	**152.65**	**229.28**	**90.49**	**2630.9**	**410.31**	**107.41**	**19.98**	**14.06**	**26.90**	**35.55**	**801.29**	**458.95**					**5,068.26**

400000 405000 410000 415000

6330000 6325000 6320000 6315000

E

F1

F2 F3 F4

M

F5 F6 F7 J F8

K G1 G2

Worsley Refinery

Worsley

Coalfields Rd

Legend

Primary Assessment Area (PAA)

State Road

Direct Offset 1

Offset Type

Protection

Restoration

Fauna Habitat

Jarrah/ Marri Community

DL

JC

JM

Other

CL

DM

RE

Riparian/ Wetland

BB

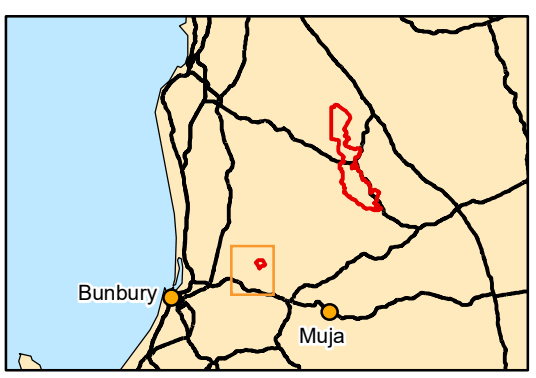
0 1 2 3 Km

Coordinate System: GDA2020 MGA Zone 50
Projection: Transverse Mercator
Datum: GDA2020 Created 15/12/2022

N

biologic Environmental Survey

Scale: 1:60,000



SOUTH32/WORSLEY ALUMINA

Boddington Mine and Offset Properties Targeted Numbat Habitat Assessment

Figure 4.4: Broad fauna habitat (Worsley)

400000 405000 410000 415000

6330000 6325000 6320000 6315000

E

F1

F2 F3 F4

M

F5

F6

F7

J

F8

K

G1

G2

Worsley Refinery

Worsley

Coalfields Rd

Legend

Primary Assessment Area (PAA)

State Road

Direct Offset 1

Offset Type

Protection

Restoration

Numbat Habitat Suitability

High Suitability

Medium Suitability

Low Suitability

Nil Suitability

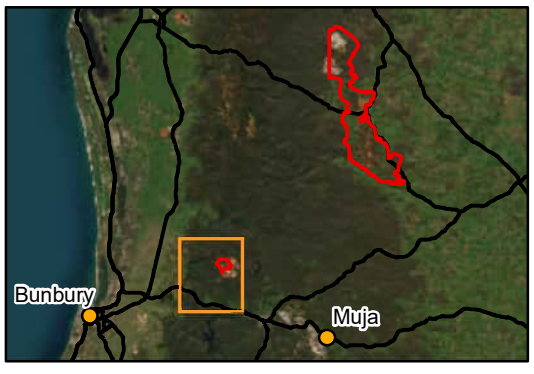
0 1 2 3 Km

Coordinate System: GDA2020 MGA Zone 50
Projection: Transverse Mercator
Datum: GDA2020 Created 14/12/2022

N

biologic Environmental Survey

Scale: 1:60,000



SOUTH32/WORSLEY ALUMINA

Boddington Mine and Offset Properties Targeted Numbat Habitat Assessment

Figure 4.5: Numbat suitability (SW/Worsley areas)

4.2.3 EPBC Habitat Offset Calculations

A habitat quality score was assigned to each of the offset properties surveyed as per the criteria in Table 3.7. With equal weighting assigned to each attribute, overall, the habitat quality scores for the offset properties in relation to numbat ranged between 3 and 8 out of 10, with an average score of 5.6 (Table 4.4).

Site Condition

The site condition scores for the offset properties ranged from 3 to 9 out of 10, reflecting the range of habitat types and land use present across the offsets. All of the offsets have been impacted by logging at some time. “Restoration” properties that are currently degraded agricultural land or cleared areas requiring extensive rehabilitation (e.g. Offsets H, I, and J) scored poorly, (between 3 to 4 out of 10) (Plate 4.8). These sites were primarily located adjacent or overlapping the PAA boundary. Offset properties containing relatively undisturbed woodland communities (e.g. Offsets E, F, G) correspondingly contained critical habitat features suitable to support numbat, such as hollow logs, canopy and understorey coverage, and abundant foraging resources. These sites are concentrated within the Dwellingup State Forest and Harris River State Forest

Plate 4.8: Example of agricultural farmland on an offset property (Offset G), lacking critical habitat elements to support numbat.

Site Context

Site Context scores across the offset properties were assessed between 3 and 8 out of 10. The Site Context scores were influenced not only by the numbat records from 2021 and current survey, but also previous historic records occurring in the Dwellingup State Forest that demonstrate previous suitability to support numbat. Site Context scores were also a reflection of the ecological linkages from the offset to larger expanses of habitat and surrounding land-use. Consequently, Offset properties A and B were assessed as having site context scores comparable to those encompassed by the state forest and national parks (e.g. Offsets E, F, G) despite being comprised of smaller, disturbed remnant vegetation, as they located within 5 km of the 2021 numbat records and are linked to the site by narrow habitat corridors. Fragmentation was considered not only from artificial sources such as mining activity, roads, and infrastructure, but natural

barriers such as river systems (e.g. Hotham River, Murray River), as numbats are not commonly known to cross water. For example, Offset I, overlapping the western side of the PAA, is separated from larger, more suitable habitat patches by the Hotham River.

Stocking Rate

As discussed in section 4.1.3, numbat home ranges are large and exclusive from individuals of other sexes. Many of the offset properties are unlikely to support more than a small number of individuals when considered in isolation; for example, site L (BBM NE 1) is only 35 ha in size, and site I (BBM NE 2) is only 20 ha. However, for those properties encompassed by expansive habitat (e.g. Offsets C (153 ha), D (229 ha), E (90 ha), and F (2242 ha)), their Stocking Rate was scored accordingly between 6 to 7 out of 10. These sites were not scored higher due to the lack of confirmed numbat presence, although previous records exist in Offset F from the 1960's. Corridors of native vegetation with adequate low vegetation cover are important to maintain in agricultural areas as they will be used by dispersing young numbats (DPaW, 2017). Therefore, offsets surrounded by unsuitable habitat, and lacking these corridors to other habitat patches (e.g. Offsets H, I, and J), were scored according to their habitat patch size and the number of individuals that could be supported on a permanent basis. Overall, Stocking Rate scores were scored between 3 to 7 out of 10.

Table 4.4: Habitat quality assessment for numbat across the offset properties (prior to rehabilitation) using the EPBC Environmental Offset Policy Guidelines

Habitat attribute	A - **BBM SE1**		B - **BBM SE 2**		C - **7 Ex-Bulgara and Power-Kennedy**		D - **Ex-Talbot Nth, Ex-Talbot Sth**		E - **North Refinery**		F - **25 Lot 102, 28 Lot 102, 27 Lot 102, 26 Lot 102, 21 Lot 103, 16 Lot 103, 23 Lot 103, 17 Lot 103**		G - **20 Lot 103, SE block - name TBD**	
	Score	**Rationale**	**Score**	**Rationale**	**Score**	**Rationale**	**Score**	**Rationale**	**Score**	**Rationale**	**Score**	**Rationale**	**Score**	**Rationale**
Condition	**6**	Contains appropriate cover (canopy and understorey. Foraging resources present. Breeding resources present. Disturbance from mining, infrastructure, and agriculture	**6**	Contains appropriate cover (canopy and understorey. Foraging resources present. Breeding resources present. Disturbance from mining, infrastructure, and agriculture	**5**	Offset is on the periphery of the Dwellingup State Forest; although disturbance from mining, infrastructure, and agriculture is minimal, the site is in some post-fire recovery. Suitable foraging, breeding, protection, and dispersal characteristics present to support numbat.	**8**	Disturbance from mining, infrastructure, and agriculture is minimal apart from the conveyor road present through the centre. Suitable foraging, breeding, protection, and dispersal characteristics present to support numbat.	**8**	Disturbance from refinery operations, infrastructure, and agriculture is relatively minimal. Suitable foraging, breeding, protection, and dispersal characteristics present to support numbat. Some riparian zones, but overall suitable foraging, breeding, protection, and dispersal characteristics present to support numbat.	**8**	Site is comprised of continuous, suitable habitat with minimal disturbance from mining, agriculture, and infrastructure. Suitable foraging, breeding, protection, and dispersal characteristics present to support numbat.	**5**	The southern half (SE Block) of the site is currently comprised of agricultural farmland and cleared areas, lacking the critical habitat elements required to support numbat. The northern half (20 Lot 10**3**) has appropriate canopy cover; however, foraging and breeding resources and understorey protection is not as optimal as the adjacent State Forest.
Context	**7**	Recent (2021) numbat sighting within **5** km, with small habitat corridors linking site to known contemporary record	**7**	Recent (2021) numbat sighting within **5** km, with small habitat corridors linking site to known contemporary record	**7**	Previous contemporary numbat record from 201**5 8** km south. Site value is with continuous linkage with large network of unfragmented habitat, and not in isolation.	**7**	Site is separated from the northern half of the Dwellingup State Forest by the Murray River; however, connectivity is continuous with the Harris River State Forest to the south, east, and west. Previous contemporary numbat record from 201**5** 10 km south-east.	6	No known contemporary numbat sighting within the vicinity. Site value is with continuous linkage with the Dwellingup State Forest, and not in isolation.	**7**	No known contemporary numbat sighting within the vicinity, however records within the site are known from the 19**6**0's. As well as being 2,242 ha in size, site is also continuous with the Dwellingup State Forest.	**5**	No known contemporary numbat sighting within the vicinity. Site borders the Harris River State Forest to the north and Wellington National Park to the south with some cleared lands between the site and large expanses of suitable habitat.
Stocking Rate	**3**	Relatively small pocket (77 ha) of habitat relatively disconnected from wider expansive vegetation. As such, site is restricted to individuals only and cannot sustain a population.	**3**	Small pocket (13 ha) of habitat relatively disconnected from wider expansive vegetation. As such, site is restricted to individuals only and cannot sustain a population.	**6**	153 ha of habitat encompassed by Dwellingup State Forest. Offset has the potential to form part of multiple individuals home range; however, species presence is not confirmed.	**5**	229 ha of habitat encompassed by Harris River State Forest. Offset has the potential to form part of multiple individuals home range; however, species presence is not confirmed.	**7**	90 ha of habitat encompassed by Dwellingup State Forest. Offset has the potential to form part of multiple individuals home range	**7**	2,242 ha of habitat linked to Dwellingup State Forest and Offset M. Offset has the potential to form part of multiple individuals home range; species presence is not currently confirmed, but previous records exist.	**5**	20 Lot 10**3** has the potential to form part of multiple individuals home range; however, dispersal may be slightly limited. Species presence is not confirmed.
Overall Score	**5**		**5**		**6**		**7**		**7**		**7**		**5**	

Habitat attribute	H - **Ex-Nicholls**		I - **BBM NE 2**		J - **Part of Lot 103**		K - **Part of Lot 103**		L - **BBM NE 1**		M - **Part of Lot 100**		N - **Saddleback (Lot 2026)**	
	Score	**Rationale**	**Score**	**Rationale**	**Score**	**Rationale**	**Score**	**Rationale**	**Score**	**Rationale**	**Score**	**Rationale**	**Score**	**Rationale**
Condition	**3**.	Offset is currently comprised of agricultural farmland and cleared areas, lacking the critical habitat elements required to support numbat	**3**	Offset is currently comprised of agricultural farmland and cleared areas, lacking the critical habitat elements required to support numbat.	**3**	Offset is currently comprised of mainly agricultural farmland and cleared areas, lacking the critical habitat elements required to support numbat.	**3**.	Offset is currently comprised of mainly agricultural farmland and cleared areas, lacking the critical habitat elements required to support numbat	**3**	Offset is currently comprised of agricultural farmland and cleared areas, lacking the critical habitat elements required to support numbat.	**9**	Site is comprised of continuous, suitable habitat with minimal disturbance from mining, agriculture, and infrastructure. Suitable foraging, breeding, protection, and dispersal characteristics present to support numbat.	**4**	Site is currently comprised mainly of agricultural farmland and cleared areas, lacking critical habitat elements required. Some marri and jarrah woodland is present on the eastern edge, extending into the Timber Reserve outside the PAA.
Context	**5**	Previous contemporary numbat record from 201**5** 12 km south. Offset adjoins large network of unfragmented habitat on the western half but is predominantly bordered by agricultural land and river (which numbats in general do not utilise).	**3**	Site is separated from the vicinity of the previous numbat record by mining activity and is separated from larger habitat patches by the Hotham River.	**4**	No known contemporary numbat sighting within the vicinity. Site value is with linkage with Offset F, and not in isolation.	**4**	No known contemporary numbat sighting within the vicinity. Site value is with linkage with Offset F, and not in isolation.	**3**	Site is separated from the vicinity of the previous numbat record by mining activity and is separated from larger habitat patches by the Hotham River.	**7**	No known contemporary numbat sighting within the vicinity, however records within the site are known from the 19**6**0's. As well as being 801 ha in size, site is also continuous with the Wellington National Park.	**4**	Site is not in the general vicinity of the previous numbat record or record from current survey. Site has some connectivity to suitable habitat on the eastern edge; however, the connectivity is likely to be impacted by future mining and clearing.
Stocking Rate	**3**	Unsuitable habitat and therefore unlikely to support more than an individual on a transient basis; species presence is not confirmed.	**3**	Unsuitable habitat and therefore unlikely to support more than an individual on a transient basis; species presence is not confirmed.	**3**	Small pocket (14 ha) of habitat. Unsuitable habitat and therefore unlikely to support more than an individual on a transient basis; species presence is not confirmed.	**3**	Small pocket (27ha) of habitat. Unsuitable habitat and therefore unlikely to support more than an individual on a transient basis; species presence is not confirmed.	**3**	Unsuitable habitat and therefore unlikely to support more than an individual on a transient basis; species presence is not confirmed.	**6**	801 ha of habitat attached to Offset F and Wellington National Park. Offset has the potential to form part of multiple individuals home range; species presence is not currently confirmed, but previous adjacent records.	**3**	Predominantly unsuitable habitat and unlikely to support more than an individual on a transient basis; species presence is not confirmed.
Overall Score	**4**		**3**		**3**		**3**		**3**		**8**		**4**	

4.2.4 Habitat Restoration Potential for Numbat

Ten offset sites (or partial offset sites) are proposed to be rehabilitated as part of Worsley Alumina's Biodiversity Offset Plan (BOP) (Worsley Alumina, 2022b) (Table 4.5). Revegetation and restoration of agricultural lands can be difficult due to changes in soil structure, loss of vegetation community structure, and introduced flora (Parsons *et al.*, 2017). As part of the objectives of this assessment, the suitability of ecological restoration for the provision of numbat habitat was assessed through a review of previous translocations, management plans for the species, and peer-reviewed literature (Table 3.3). Translocations of numbats can be successful, as demonstrated by the number of new populations established within Western Australia, South Australia, and New South Wales. As such, these sources of information were used to determine the habitat and contextual factors that supported self-sustaining numbat populations (Appendix A), and if these factors can be controlled through ecological restoration.

Table 4.5: Offset sites to be rehabilitated as part of the BOP (Worsley Alumina, 2022b)

Site	Code	Restoration Area
Direct Offset 1		
BBM SE 1 - name TBD	A	1.82
BBM SE 2 - name TBD	B	0.03
Lot 103	F	623.81
SE block - name TBD	G	292.72
ex-Nicholls	H	173.11
BBM NE 2 - name TBD	I	19.98
Lot 103 (partial)	J	14.06
Lot 103 (partial)	K	26.90
BBM NE 1 - name TBD	L	31.95
Direct Offset 2		
Saddleback Offset	M	239.24

Overall, the factors that most impact the success of maintaining self-sustaining numbat populations are predation, habitat patch size, availability of food and breeding resources, and appropriate vegetation cover (Table 4.6; Appendix A). These factors can be accommodated for and potentially successful in ecological restoration for numbat across not only the sites listed in Table 4.5, but also the offset properties designated as "Habitat Protection" sites and are discussed in brief below. Some relevant actions have already been outlined briefly in the BOP (Worsley Alumina, 2022b) and Threatened Species Management Plan (TSMP) (Worsley Alumina, 2022c) to support other significant species (Table 4.6). The most difficult success factor is retaining and expanding landscape-level connectivity between patch sizes to promote ecological function and suitability for numbat.

- **Predation**

Numbats are routinely predated by raptors; however, predation by introduced species, in particular foxes and cats (*Felis catus*), is a common cause of population declines of translocated populations such as Stirling Range National Park and Dragon Rocks. At the Dryandra Woodland, a sharp increase in numbat sightings was recorded within a few years after fox baiting commenced (Friend & Thomas, 1994). The implementation of predator baiting in undertaking ecological restoration is important to the conservation of the numbat (DPaW, 2017), and should be undertaken within the offset properties as well as adjacent habitat. Implementing predator control in the surroundings of Alcoa bauxite mine boosted the numbers of small marsupials and improved recolonization of rehabilitated areas (Nichols & Grant, 2007).

- **Area size**

Numbats need large areas of natural woodland vegetation because of their relatively large home ranges. Once a juvenile numbat has established its home range after dispersal, that animal remains in or close to that area for the rest of its life (DPaW, 2017). The introduction of numbats to Karakamia Wildlife Sanctuary was unsuccessful as the enclosed area too small to support a viable population (DPaW, 2017; Hayward *et al.*, 2015). Tutanning and Boyagin are considered relatively small in terms of minimum viable population supported and are as such at the risk of extinction, with capacity for only 200 adults at density of 1/25 ha (Friend, 1990) at Tutanning, and 50 individuals at Boyagin (Friend & Thomas, 1994). Offset F, as the largest offset property available, is 2,630 ha across all offset components, approximately the same size as Boyagin as one of the smallest sustaining populations in terms of area.

The size of some offset properties is the major determinant to their ecological value, and in isolation, some offset properties are too small to be considered suitable for numbat, even if the habitat is revegetated. For example, Offsets I and L, are located within the PAA boundary and lack ecological linkages to wider habitat. They are comprised of habitat patches only 35 ha and 20 ha in size, which in isolation are too small to support a single individual's home range, and ecological restoration is limited by the difficulty in providing sufficient area and landscape connectivity and linkage. Connectivity and increased area size is achievable for sites such as Offset H (ex-Nicholls), which is highly degraded but directly connected to Dwellingup State Forest, and Offset G, where the location of the patch adjacent to suitable habitat mitigates the limitation of the area size. Overall, the success of ecological restoration for numbat is limited for many of the offset properties by the difficulty in providing sufficient area and linkages to support the species.

- **Food and breeding resource availability**

Numbats need large areas of natural woodland vegetation because of their relatively large home ranges and limited food resources. Starvation was the main cause of death for the animals translocated to Scotia Sanctuary in 2012, when drought conditions returned to the area (Hayward *et al.*, 2015). As such, ecological restoration for numbat needs to consider actions that retain conditions for termite availability across seasons. In winter, termites are active in small sticks and branch wood laying on the

forest floor, and in galleries under the surface on large logs (Maisey & Bradbury, 1982). During summer, the higher temperatures causes termite activity to move to the underside of larger logs or to pieces of wood partially buried, and numbats change their foraging methods to dig in the soil next to buried wood or base of trees (Maisey & Bradbury, 1982). Successful ecological restoration for foraging resources is achievable if it incorporates not only logs for decomposition, but vegetation that promotes leaf litter and woody branches, or woodchips.

These actions also relate to the retention and addition of breeding resources i.e. hollow logs. The removal of logs for firewood by members of the public was noted during the field survey through observations of freshly cut logs. Localised increases in firewood collection, which targets logs but also involves removal of standing trees, is noted as negatively affecting numbat habitat quality (Seidlitz, 2021). Fire may negatively impact numbats by directly killing them or by reducing the availability of important resources such as logs. In an unpublished experimental study at the Dryandra Woodland, fire was not considered a significant threat to numbats, and surviving individuals continued using their pre-fire home ranges; however, the loss of logs and vegetation cover appeared to increase predation pressures (DPaW, 2017). Therefore the retention of logs and hollows during timber harvesting and burn operation is a key factor in ecological restoration success for numbat. Seidlitz (2021) recommends that forest management should ensure the retention of six to 12 logs (number of logs partially or wholly within a 4 x 50 m transect) during management activities to aid the species' conservation.

- **Appropriate understorey and canopy cover**

In general, rehabilitated lands within mine sites follows a similar trajectory following planting; from bare ground to heath-like habitat through to shrubland, low closed forest, and finally tall forest. The density and richness of mammals in rehabilitated areas are rarely found equal or better than in undisturbed areas (Cristescu *et al.*, 2012). For numbats, which prefer a combination of an open understorey interspersed with thickets (DPaW, 2017), this results in the early succession processes being likely too dense to support foraging except in small clearings (as potentially occurred at VBOD-03 and the current survey numbat record), too little canopy cover for protection from raptor predation, and with too little production of hollows and woody debris until eucalypt species mature. Rehabilitation management such as thinning or burning of dense vegetation might be necessary as rehabilitated areas age (Cristescu *et al.*, 2012). Successful ecological restoration for numbat is therefore a long-term process and difficult to predict, with best-practice methods offering the best chance at providing suitable habitat in the future.

Table 4.6: Key ecological restoration factors for numbat and relevant actions from the BOP and TSMP

Ecological Restoration Factor	Recommendations for ecological restoration success for numbat	Current actions from BOP and TSMP
Predation		
Predation by introduced species, in particular foxes and cats, is a common cause of the decline in population sizes for translocated populations.	• Feral animal control within and outside the offset areas	• Develop and implement a feral predator management program within defined ecological linkages, specific species habitats and surrounds. The intent of this program is to reduce the threatening process of feral predation for ground dwelling critical weight range mammals (e.g. woylie, chuditch, numbat etc).
Area size		
Numbats need large areas of natural woodland vegetation because of their relatively large and exclusive home ranges. Once a juvenile numbat has established its home range after dispersal, that animal remains in or close to that area for the rest of its life (DPaW, 2017).	• Retention of suitable habitat • Connectivity to larger habitat patches to increase total available area.	• Ecological restoration will incorporate strategic benefit (e.g. landscape connectivity, contiguity with existing habitat) • Establishment of dominant vegetation community types comparable with the eastern and northern jarrah forest and constructed fauna habitats (e.g. coarse woody debris) • Clearing will only take place in Ecological Linkages within an allowance for roads, transport, maintenance, and construction activities (not ore mining activities)
Food and breeding resource availability		
Numbats need large areas of natural woodland vegetation to support foraging and breeding resources.	• Retention of logs and hollows during timber harvesting and burn operations. • Increasing landscape complexity by adding dead stags, rocks, log piles and coarse woody debris.	• Establishment of dominant vegetation community types comparable with the eastern and northern jarrah forest and constructed fauna habitats (e.g. coarse woody debris and logs stockpiled during clearing) • Retention and replacement of hollow logs in rehabilitation areas • Construction of fauna habitats in rehabilitation areas in accordance with the Fauna Habitat Construction Standard.
Appropriate understorey and canopy cover		
Most sites where numbats occur and were recorded in the past are characterised by the presence of eucalypt species providing logs and hollows and possibly higher termite densities. Numbats also prefer a combination of an open understorey interspersed with thickets.	• Best-practice rehabilitation methods offer the best chance at providing suitable habitat in the future, including planting of eucalypts as well as understorey species. Some further rehabilitation management (e.g. thinning, burning) might be necessary as rehabilitated areas age.	• The ongoing fauna monitoring program of rehabilitated areas provides direct assessment of the assemblages that change over time as the rehabilitation ages (understorey and overstory development), which provide habitat for different species at different life stages

4.3 Other Recorded Fauna

A total of six additional non-target significant fauna species were recorded during the field survey (Figure 4.6; Appendix D), including:

- chuditch (*Dasyurus geoffroii* – Endangered EPBC Act and BC Act) – a scat was recorded at Site VBOD-03 in the NGM portion of the PAA.
- Carnaby's cockatoo *Zanda latirostris* – Endangered EPBC Act and BC Act)– individuals were sighted flying over the PAA over the course of the field survey.
- forest red-tailed black cockatoo *Calyptorhynchus banksii naso* - Vulnerable EPBC Act and BC Act) - individuals were sighted flying over the PAA over the course of the field survey.
- wambenger (south-western brush-tailed phascogale) *Phascogale tapoatafa wambenger* – Conservation Dependent BC Act)– a scat was recorded at Site VBOD-53 in Offset F, confirmed by laboratory analysis.
- quenda (*Isoodon fusciventer* – Priority 4 DBCA)– multiple diggings attributed to this species were recorded at sites VBOD-02, VBOD-31, and an opportunistic record.
- western brush wallaby (*Notamacropus irma* – Priority 4 DBCA)– individuals of this species were recorded at sites VBOD-23, VBOD-53, and twice opportunistically on driven transects.

The value of the PAA and offset properties for significant species other than numbat are discussed extensively in previous fauna surveys (Biostat, 2017, 2018, 2020, 2021a, 2021b, 2021c), with management actions and offset values discussed in Worsley Alumina (2022b); as such, they are not discussed here in detail as per the scope of the study.

400000 420000 440000 460000

6380000 6360000 6340000 6320000

Newmont Gold Mine
Bannister Rd
Marradong Rd
Albany Hwy
Ranford
Boddington
Pinjarra Williams Rd
Marradong
Yalup Brook
Waterous
Wagerup
Yarloop
Cookernup
South Western Hwy
Harvey
Wokalup
Saddleback
Quindanning
Worsley Refinery
Coalfields Rd
Worsley
Allanson
Collie

C L M I A B H C N D1 D2 E F1 F2 F3 F4 F5 M F6 J F7 F8 K G1 G2

Legend

- Primary Assessment Area (PAA)
- Indicative Disturbance Footprint
- State Road

Direct Offset 1
Offset Type
- Protection
- Restoration

Direct Offset 2
Offset Type
- Protection
- Restoration

Significant Fauna
Quenda
- Digging

Wanbenger brush- tailed phascogale
- Scat

Western brush wallaby
- Individual (alive)

Western quoll, Chuditch
- Scat

0 3 6 9 12 Km

Coordinate System: GDA2020 MGA Zone 50
Projection: Transverse Mercator
Datum: GDA2020 Created 14/12/2022

N

biologic Environmental Survey

Scale: 1:257,000

Perth
Bunbury
Muja

SOUTH32/WORSLEY ALUMINA

Boddington Mine and Offset Properties Targeted Numbat Habitat Assessment

Figure 4.6: Other significant fauna recorded in the Study Area

4.4 Potential Limitation and Constraints

The EPA (2020) outlines several potential limitations and constraints which have the potential to affect results of terrestrial vertebrate fauna surveys (Table 4.7). Based on these criteria, there were no significant limitations which impeded the ability to achieve the desired outcomes of the assessment, which are in line with those recommended by the EPA for the level of survey undertaken.

Table 4.7: Survey limitations and constraints

Potential limitation or constraint	Limitation	Applicability to this survey
Availability of data and information	No	There has been numerous basic and targeted previous vertebrate fauna survey undertaken across both the PAA and offset properties, dating back several decades (Bamford Consulting Ecologists, 2021; Biostat, 2017, 2018, 2020, 2021a, 2021b; Ninox, 2003). Numerous research programs and studies on numbat have been conducted within the local region such as at the Dryandra Woodland, Boyagin Nature Reserve, and Batalling Forest Block (Christensen, 1975; Christensen *et al.*, 1984; Connell & Friend, 1985; Friend & Thomas, 1994; Hayward *et al.*, 2015; Maisey & Bradbury, 1982; Moseby *et al.*, 2011) as well as on interstate translocated populations (Hayward *et al.*, 2015; Moseby *et al.*, 2011; Vieira *et al.*, 2007). Recent work on sign surveys has also been published (Seidlitz, 2021; Seidlitz *et al.*, 2021a; Seidlitz *et al.*, 2021b; Thorn *et al.*, 2022). Overall, numbat ecology, populations, and habitat are well studied and understood, and as such adequate data and information was available to complete the assessment.
Competency/experience of the survey team, including experience in the bioregion surveyed	No	The zoologists who undertook the survey have extensive survey experience within the region and are familiar with and competent in the fauna sampling methods outlined. Sian Thorn was present on the field survey, and has extensive experience in numbat sign surveys following recent PhD studies (Thorn *et al.*, 2022).
Scope (groups sampled and whether any constraints affect this)	No	The survey was completed in line with the scope of a terrestrial vertebrate fauna survey (EPA, 2020). All components of the survey were completed over the field survey period.
Timing, weather and season	Partial	The survey timing coincided with the period of juvenile numbat dispersal (November to early December) (DPaW, 2017), and therefore the time of maximum numbat abundance when detection is most likely. The rainfall experienced on the first day of the survey partially reduced the ability to record secondary signs (scats, tracks, and diggings) made prior to the rainfall. The conditions experienced were considered suitable to assess the suitability of habitat for numbat, as foraging and breeding resources would not have been detrimentally affected by climatic conditions leading up to the field survey.
Disturbance that may have affected results	No	The primary disturbances to the Study Area are the mining activity, previous agricultural land use, and road network, which fragment the habitat present and limit the fauna that can be reside or disperse through the area. However, these disturbances were not considered to constrain the survey methods and are a feature of the Study Area, having been present for decades.

Potential limitation or constraint	Limitation	Applicability to this survey
Proportion of fauna identified, recorded, or collected	No	All observed fauna were either identified at the point of observation, or unconfirmed scat material was sent to a laboratory for species identification.
Adequacy of the survey intensity and proportion of survey achieved	No	A numbat habitat assessment survey was undertaken across the Study Area. It is considered that the work is of a sufficient level to meet EPA requirements and the objectives of the survey given the previous survey effort undertaken and the proposed level of disturbance. The entire PAA and each offset property were traversed on foot or by vehicle, with all tasks achieved within the allotted field time.
Access problems	No	The majority of the Study Area was traversed either by vehicle or foot. The main disturbance to the Study Area is the presence of mining activity that limited access to some areas of the PAA; however, habitat assessments and targeted searches were undertaken in all suitable habitat patches, and escorts from the mine provided where needed. Some tracks and access points to offset properties were difficult to access; however, alternative routes were available. Overall, remoteness or access was not considered a limitation.
Problems with data and analysis	No	No issues with data or analysis were experienced. Unconfirmed scat material was sent to a laboratory for species identification.

5 CONCLUSION

A numbat habitat assessment survey for numbat was undertaken across the Study Area, comprising the Primary Assessment Area (PAA) and offset properties associated with the Worsley Alumina Boddington mine. The fauna survey was completed over four days from the 24th to 27th October 2022. Key outcomes from the numbat habitat assessment survey were:

Primary Assessment Area

- There is now the recorded occurrence of the species on multiple occasions within the PAA. This includes the presence of scats and diggings within the NGM in the northern section of the Study Area during the current survey, 12 km from the previous record in 2021. The record was made within a patch of rehabilitated habitat encompassed by Jarrah/Marri/*Allocasuarina* woodland. Possible conclusions include:
    - permanent residency by a single individual previously recorded in 2021 (of unknown origin) within the Study Area in the areas north of Hotham River, supporting the potential for portions of the PAA to provide suitable habitat for the species to permanently occur;
    - the presence of a new individual from either known (e.g. Dryandra Woodland, Batalling Forest) or unknown (e.g. Dwellingup State Forest, Youralling State Forest) populations; or
    - the presence of a dispersed or dispersing juvenile numbat representing offspring from 2021 records of the species.
- Localised patches of habitat within the PAA are suitable to support numbat across Jarrah/Marri, Wandoo, and Mallee vegetation communities, containing the critical habitat features of hollow logs, foraging resources, and protection/refugia. This is particularly true across the NGM and CBME areas, where smaller disturbance footprints from the gold mining and bauxite refinery operations have meant more Highly Suitable habitat (particularly Jarrah/Marri communities) has been retained. When considering habitat quality on a landscape level in regard to the EPBC Offset Policy, the higher overall habitat scores of the NGM and CBME at Collie reflects not only the higher retention of suitable habitat, but a greater level of connectivity, as the sites are functionally contiguous with the adjacent State Forest area.
- In contrast, the Marradong, Saddleback and to a lesser extent the Quindanning regions of the PAA are associated with the bauxite mine operations, which disturbs comparatively larger land areas compared to the mining of other minerals and tends to correspond with Jarrah/Marri communities. As such, the BBM in general has a much higher proportion of cleared areas, agricultural land, and infrastructure. The overall habitat suitability for numbat across the Marradong, Saddleback, and Quindanning regions of the PAA was also reduced due to a lack of connectivity to the greater landscape area such as Dwellingup State Forest and resulting overall patch size.

Offset Properties

- Large offset properties containing relatively undisturbed woodland communities (e.g. Offsets E, F, G) correspondingly contained critical habitat features suitable to support numbat in significant quantities, such as hollow logs, canopy and understorey coverage, and abundant foraging resources.
- When considering the EPBC Offset Policy, the offset properties on average were assessed as having a higher habitat quality score; this was a reflection that many of the sites were encompassed by the Dwellingup State Forest, Harris River State Forest, and Wellington National Park (e.g. Offsets E, F, G) and as such retain landscape-level connectivity, as well as proximity to contemporary and historic numbat records.
- Site Context scores were influenced not only by the numbat records from 2021 and current survey, but also previous historic records occurring in the Dwellingup State Forest that demonstrate previous suitability to support numbat. For Offset sites A and B, located within 5 km of the 2021 numbat records (where the individual was observed residing for a year) and linked to the site by narrow habitat corridors, the sites were assessed as having as site context scores almost comparable to those patches of greater size and condition.
- Overall, although the offset properties are generally of better habitat condition than the PAA, many of the sites are unlikely to support more than a single or small number of individuals when considered in isolation, except for those properties surrounded by expansive habitat.

Ecological Restoration Suitability

- Overall, the factors that most impact the success of maintaining self-sustaining numbat populations are predation, habitat patch size, availability of food and breeding resources, and appropriate vegetation cover. These factors can be accommodated for and successful in ecological restoration for numbat across not only for some sites listed for restoration, but also the offset properties designated as “Habitat Protection” sites.
- The most difficult success factor is retaining and expanding landscape-level connectivity between patch sizes to promote ecological function and suitability for numbat.

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7 APPENDICES

Appendix A – Summary of previous numbat translocations and factors affecting success

Location	Original/ Translocated	Self-sustaining?	Population	Cause of habitat suitability/unsuitability		
				Introduced Species Predation	Area size	Food
Dryandra	Original extant population	Yes	50-10	Population had declined dramatically in late 1970s, coinciding with increase in fox numbers. An increase in numbat population was observed following fox control. (Friend & Thomas, 1994). Predation by native species and cats are known to occur (Friend & Thomas, 2003)	Yornaning water reserve (two sightings and other signs) is close to Dryandra for forest to act as source of colonisers.	No constraint information available, but unlikely to be a factor
Brookton Highway Block (East of Dryandra)	Extension of original population. Small reserve, but close to State Forest, which acts as source of colonisers (Connell & Friend, 1985)	Yes. Irregular sightings.			Close to Dryandra for forest to act as source of colonisers.	No constraint information available, but unlikely to be a factor
Upper Warren, including Tone-Perup/ Kingston/ Palgarup, Balban, Boyicup, Dwalgan, Dudijup, Yeticup forest blocks	Original extant population	Yes	>100 (DPaW, 2017) Estimated to be the largest (from 200 to 500 mature individuals) but is relatively understudied compared with the Dryandra population (Thorn *et al.*, 2022)		Very large area incorporating numerous connecting forest blocks.	No constraint information available, but unlikely to be a factor
Boyagin 2,000 ha plus 3,000 ha.	Reintroduced	Yes	50-100 (Hayward *et al.*, 2015).	After reintroductions of individuals, of the 13 predation events, five were by foxes, four by raptors, and five unknowns.	A population established, and now been recorded in the western block, separated from eastern block by 500m of farmland (Friend & Thomas, 1994). By 1990, individuals had spread to use all suitable habitat (Friend & Thomas, 1994). Relatively small in terms of minimum viable population supported, room for only 200 adults at density of 1/25 ha (Friend, 1990)	No constraint information available, but unlikely to be a factor
Karroun Hill 300,000 ha	Reintroduced Skeletal remains at Karroun in 1977 and anecdotal evidence.	No longer present	0	Heavy cat predation (Friend & Thomas, 2003) (Hayward *et al.*, 2015). By 1994, of the 50 known deaths, 44 involved predation – of known predators, 10 due to raptors, four to cats, three to foxes, and one to dingo (Friend & Thomas, 1994).	Reintroduced populations could expand to the north and east into uncleared habitat on vacant crown land and pastoral leases (Friend & Thomas, 1994)	No constraint information available, but unlikely to be a factor
Tutanning Reserve 2,000 ha	Reintroduced	Yes	<50	Three females released in 1987 – two killed by raptors in first month (Friend & Thomas, 1994).	Small area, danger of extinction. Same for two other locations in Pingelly area (Connell & Friend, 1985). Min area to support 50 numbats (Friend & Thomas, 1994).	No constraint information available, but unlikely to be a factor
Batalling Forest (Muja State Forest) 40km from CBME 14,000 ha	Reintroduced	Yes	50-100	Fox control by baiting has been carried out there since 1990. The current fox baiting regime is six times per year with aerial baiting, supplemented by monthly ground baiting along a route through the core area. (DPaW, 2017)	The forest extends 50 km west and 200 km north of the release site and although all forests within 25 km of the release site was thoroughly searched by aircraft for radio-collared animals, over half of the numbats released were never located again. It is likely that many animals dispersed well beyond the search area. (DPaW, 2017)	No constraint information available, but unlikely to be a factor
Dragon Rocks Nature Reserve 33,000 ha	Reintroduced	Yes	<50	Fox control commenced at Dragon Rocks Nature Reserve shortly before the first release of numbats there. It is likely that the observed increase in feral cat numbers a few years later caused the initially high numbat density to fall to the low levels seen there today (DPaW, 2017).		No constraint information available, but unlikely to be a factor
Stirling Range National Park 115,920 ha	Reintroduced	Unknown	Unknown	At Stirling Range, fox control was difficult to maintain in wet seasons (Hayward *et al.*, 2015). Although a quarterly aerial baiting regime was in place, the ground baiting program was hampered by inundation of management tracks in winter and movement restrictions due to plant disease hygiene requirements (DPaW, 2017). The greatest number of recorded mortalities was from predation by birds of prey (DPaW, 2017)	No constraint	No constraint information available, but unlikely to be a factor
Cocanarup Timber Reserve 5,452 ha	Reintroduced	Unknown	Unknown	Wide range of predators, including birds of prey, foxes, cats, chuditch, monitors and pythons combined to critically limit population growth (Hayward *et al.*, 2015). The last numbat tracking-collar was recovered on 6 July 2012, but sadly the owner had succumbed to predation. Another animal was seen in 2013. Since then there have been no records in the reserve.	No constraint	No constraint information available, but unlikely to be a factor

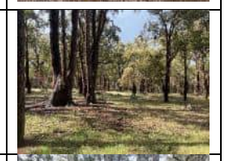
Location	Original/ Translocated	Self-sustaining?	Population	Cause of habitat suitability/unsuitability		
				Introduced Species Predation	Area size	Food
Karakamia Sanctuary 280 ha	Reintroduced	No	0	No constraint	Enclosed area too small to support a viable population (Hayward *et al.*, 2015). Due to its small size, Karakamia could only support a few animals and stochastic factors led to eventual extinction (DPaW, 2017).	No constraint information available, but unlikely to be a factor
Dale Conservation Park (northern jarrah forest) 5,798 ha	Reintroduced	No	0	Greater fox predation pressure may have led to the eventual failure of the translocation (DPaW, 2017).	Most animals dispersed too far from the release site to form a breeding population (Hayward *et al.*, 2015). At Mt Dale Conservation Park in the northern jarrah forest, the lack of barriers to initial dispersal away from the release site led to the scattering of individuals far from each other. A few numbats ended up together in an area of suitable habitat and prospered, so the site was used for subsequent releases.	No constraint information available, but unlikely to be a factor
Arid Recovery Reserve, SA (20km north of Roxby Downs) 6,000 ha	Reintroduced	No	0	The trial at Roxby Downs produced some promising results, but only five animals were released and three, including both females, were taken by raptors within eight months (Bester & Rusten, 2009) (Moseby *et al.*, 2011). Two males were still alive 18 months after release; the other three were taken by an unknown bird of prey. No cat/fox/rabbits present. Short term success, not medium term success.	No constraint	No constraint information available, but unlikely to be a factor
Yookamurra Sanctuary (South Australia) 5,108 ha	Reintroduced	Yes	< 50	1092 ha of remnant mallee woodland and associated vegetation is surrounded by an electrified fence, completed in 1992 and declared free of foxes, feral cats and rabbits the next year. (DPaW, 2017). Predation by native species (Friend & Thomas, 2003)	No constraint	No constraint information available, but unlikely to be a factor
Scotia Sanctuary (NSW) 65,000 ha	Reintroduced	Yes	>100	Predation by raptors (primarily brown goshawk (Accipiter fasciatus) as many carcasses were found either within or below nests) was attributed as the main cause of death for the 2011 captive-bred animals	No constraint	Starvation was the main cause of death for the 2012 animals, when drought conditions returned (Hayward *et al.*, 2015)

Appendix B – Fauna habitat assessments undertaken during the current field survey

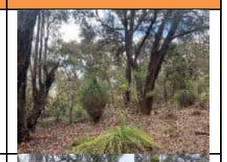
Site	Latitude	Longitude	Habitat type (field)	Landform	Aspect	Slope	Soil type	Soil avail-ability	Out-cropping	Veg litter	Woody debris	Rocky cracks crevices	Burrowing suitability	Hollows <10cm	Hollows >10cm	Water presence	Last fire	Disturbances	Habitat condition	Habitat photo
VBOD-001	-32.7330	116.3626	Jarrah Woodland	Undulating Low Hills	West	Moderate	Loamy Sand	Few Small Patches	Limited Outcropping	Many Small Patches	Few Large Patches	Low	Very High	Moderate	Scarce	Scarce	Moderate (3 to 5 yr.)	Mining Exploration, Road/ Access Track	0.8	
VBOD-002	-32.8251	116.4083	Jarrah Woodland	Hillslope	South/ West	Moderate	Loam	Few Large Patches	Negligible	Evenly Spread	Many Small Patches	Nil	Very High	Common	Common	None	Old (6+ yr.)	Mining Exploration, Road/ Access Track	0.6	
VBOD-003	-32.7323	116.3680	Jarrah Woodland	Undulating Low Hills	South/ West	Low	Loamy Sand	Many Small Patches	Limited Outcropping	Many Large Patches	Few Large Patches	Low	Very High	Scarce	Scarce	Prone to Pooling	Old (6+ yr.)	Rubbish/ Litter	0.6	
VBOD-004	-32.8302	116.3935	Melaleuca Thicket	Major Drainage Line	South	Low	Loam	Scarce	Negligible	None Discernib le	Few Large Patches	Nil	Moderate	Moderate	Moderate	Permanent	Old (6+ yr.)	Cattle Grazing, Weed Invasion	0.2	
VBOD-005	-32.7315	116.3682	Jarrah Woodland	Undulating Low Hills	South/ West	Low	Loamy Sand	Few Small Patches	Limited Outcropping	Evenly Spread	Few Large Patches	Nil	Very High	Scarce	Scarce	Scarce	Old (6+ yr.)	None Discernible	0.8	
VBOD-006	-32.8288	116.3958	Wandoo Woodland	Hillslope	South	Moderate	Loam	Few Small Patches	Minor Outcropping	Evenly Spread	Many Large Patches	Nil	High	Scarce	Moderate	None	Old (6+ yr.)	Cattle Grazing, Logging, Road/ Access Track	0.4	
VBOD-007	-32.7809	116.3875	Marri Woodland	Undulating Low Hills	North	Low	Loamy Sand	Scarce	Negligible	Evenly Spread	Many Small Patches	Nil	Very High	Scarce	Scarce	Scarce	Old (6+ yr.)	Road/ Access Track, Weed Invasion, farming	0.6	
VBOD-008	-32.8396	116.3984	Paddock	Footslope	South	Low	Loam	Scarce	Negligible	None Discernib le	None Discerni ble	Nil	Low	None	None	Permanent	Old (6+ yr.)	Cattle Grazing, Weed Invasion	0.1	
VBOD-009	-32.7815	116.3989	Jarrah Woodland	Undulating Low Hills	North/ East	Low	Clayey Sand	Many Large Patches	Minor Outcropping	Few Small Patches	Many Small Patches	Low	Very High	Scarce	Scarce	Scarce	Old (6+ yr.)	Road/ Access Track, Farming	0.6	
VBOD-010	-32.8287	116.4430	Jarrah Woodland	Hillslope	South/ West	Moderate	Loam	Many Small Patches	Limited Outcropping	Scarce	Many Large Patches	Nil	Moderate	Moderate	Moderate	None	Old (6+ yr.)	Cattle Grazing, Logging, Weed Invasion	0.4	

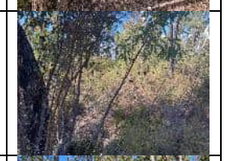
Site	Latitude	Longitude	Habitat type (field)	Landform	Aspect	Slope	Soil type	Soil avail-ability	Out-cropping	Veg litter	Woody debris	Rocky cracks crevices	Burrowing suitability	Hollows <10cm	Hollows >10cm	Water presence	Last fire	Disturbances	Habitat condition	Habitat photo
VBOD-011	-32.7635	116.4001	Jarrah Woodland	Undulating Low Hills	South	Low	Clay Loam	Many Small Patches	Limited Outcropping	Many Small Patches	Many Small Patches	Nil	Very High	Scarce	Scarce	Scarce	Old (6+ yr.)	Mining Exploration, Road/ Access Track	0.8	
VBOD-012	-32.8582	116.4470	Banksia Woodland	Hillslope	South	Moderate	Loam	Few Small Patches	Negligible	Evenly Spread	Many Large Patches	Nil	High	Scarce	Scarce	None	Old (6+ yr.)	Mining Exploration, Road/ Access Track	0.8	
VBOD-013	-32.7390	116.3891	Jarrah Woodland	Undulating Low Hills	East	Low	Clay Loam	Scarce	Limited Outcropping	Evenly Spread	Many Small Patches	Nil	Very High	Scarce	Moderate	Scarce	Old (6+ yr.)	Mining Exploration, Road/ Access Track, Logging	0.6	
VBOD-014	-32.8631	116.4452	Jarrah Woodland	Hillslope	South	Low	Loam	Many Small Patches	Negligible	Evenly Spread	Many Small Patches	Nil	High	Scarce	Scarce	None	Old (6+ yr.)	Mining Exploration, Road/ Access Track	0.8	
VBOD-015	-32.7233	116.3894	Jarrah Woodland	Undulating Low Hills	South/ East	Low	Clay Loam	Scarce	Limited Outcropping	Evenly Spread	Many Small Patches	Nil	Very High	Scarce	Scarce	Scarce	Old (6+ yr.)	Road/ Access Track	0.8	
VBOD-016	-32.8504	116.4518	Marri Woodland	Hillslope	South/ East	Low	Loam	Scarce	Negligible	Evenly Spread	Many Large Patches	Nil	Moderate	Moderate	Moderate	None	Old (6+ yr.)	Buildings, Road/ Access Track	0.8	
VBOD-017	-32.6895	116.3926	Jarrah Woodland	Undulating Low Hills	South/ West	Low	Clay Loam	Scarce	Limited Outcropping	Evenly Spread	Many Large Patches	Nil	Very High	Scarce	Scarce	Scarce	Old (6+ yr.)	Mining Exploration	0.8	
VBOD-018	-32.8446	116.4553	Marri Woodland	Hillslope	South/ East	Low	Loam	Scarce	Negligible	Evenly Spread	Many Large Patches	Nil	Moderate	Moderate	Moderate	None	Old (6+ yr.)	Mining Exploration, Road/ Access Track	0.8	
VBOD-019	-32.6776	116.3792	Jarrah Woodland	Undulating Low Hills	South	Low	Clayey Sand	Few Small Patches	Limited Outcropping	Many Large Patches	Few Small Patches	Nil	Very High	Scarce	Scarce	Prone to Pooling	Old (6+ yr.)	Mining Exploration, Road/ Access Track	0.8	
VBOD-020	-32.8700	116.4187	Jarrah Woodland	Hillcrest/ Upper Hillslope	Flat	Flat	Loam	Many Large Patches	Limited Outcropping	Evenly Spread	Many Large Patches	Nil	High	Common	Moderate	None	Old (6+ yr.)	Cattle Grazing, Road/ Access Track	0.6	

Site	Latitude	Longitude	Habitat type (field)	Landform	Aspect	Slope	Soil type	Soil avail-ability	Out-cropping	Veg litter	Woody debris	Rocky cracks crevices	Burrowing suitability	Hollows <10cm	Hollows >10cm	Water presence	Last fire	Disturbances	Habitat condition	Habitat photo
VBOD-021	-32.7133	116.3576	Jarrah Woodland	Undulating Low Hills	South/ East	Low	Clay Loam	Few Small Patches	Limited Outcropping	Evenly Spread	Few Small Patches	Low	High	Scarce	Scarce	Prone to Pooling	Old (6+ yr.)	Road/ Access Track, Dieback	0.8	
VBOD-022	-32.9066	116.4050	Paddock	Footslope	Flat	Flat	Loam	None Discernible	Negligible	None Discernible	None Discernible	Nil	Nil	None	None	None	Old (6+ yr.)	Farming	0.1	
VBOD-023	-32.7305	116.3497	Jarrah Woodland	Undulating Low Hills	South/ West	Moderate	Clay Loam	Few Small Patches	Limited Outcropping	Many Large Patches	Many Small Patches	Nil	Very High	Scarce	Moderate	Prone to Flooding	Old (6+ yr.)	None Discernible	0.8	
VBOD-024	-32.9274	116.4130	Jarrah Woodland	Drainage Area/ Floodplain	Flat	Flat	Loam	Scarce	Negligible	Evenly Spread	Many Large Patches	Nil	Moderate	Moderate	Moderate	Permanent	Old (6+ yr.)	Cattle Grazing, Mining Exploration, Road/ Access Track	0.4	
VBOD-025	-32.6821	116.3964	Pine Plantation	Undulating Low Hills	North/ East	Low	Clay Loam	Many Large Patches	Limited Outcropping	Few Small Patches	Evenly Spread	Nil	High	None	None	Scarce	Old (6+ yr.)	Road/ Access Track, Logging	0.4	
VBOD-026	-32.9411	116.4075	Wandoo Woodland	Hillslope	South/ West	Moderate	Loam	Many Large Patches	Limited Outcropping	Evenly Spread	Few Large Patches	Nil	High	Scarce	Moderate	None	Old (6+ yr.)	Cattle Grazing, Road/ Access Track	0.6	
VBOD-027	-32.7595	116.3883	Jarrah Woodland	Undulating Low Hills	South	Low	Clay Loam	Many Small Patches	Limited Outcropping	Many Large Patches	Few Large Patches	Nil	Very High	Scarce	Moderate	Scarce	Moderate (3 to 5 yr.)	Frequent Fire, Road/ Access Track	0.8	
VBOD-028	-32.9438	116.4218	Wandoo Woodland	Hillslope	South/ West	Moderate	Loam	Few Small Patches	Negligible	Evenly Spread	Many Small Patches	Nil	High	Scarce	Scarce	None	Old (6+ yr.)	None Discernible	1.0	
VBOD-029	-32.9230	116.3795	paddock with scattered marri and Xanthorrhoea	Undulating Low Hills	East	Moderate	Clayey Sand	Scarce	Negligible	Evenly Spread	Few Small Patches	Nil	Moderate	Scarce	Scarce	Scarce	Old (6+ yr.)	Cattle Grazing, Road/ Access Track, Weed Invasion	0.4	
VBOD-030	-32.9676	116.4224	Jarrah Woodland	Hillcrest/ Upper Hillslope	Flat	Flat	Loam	Few Small Patches	Limited Outcropping	Evenly Spread	Many Large Patches	Nil	High	Scarce	Moderate	None	Old (6+ yr.)	Road/ Access Track	1.0	

Site	Latitude	Longitude	Habitat type (field)	Landform	Aspect	Slope	Soil type	Soil avail-ability	Out-cropping	Veg litter	Woody debris	Rocky cracks crevices	Burrowing suitability	Hollows <10cm	Hollows >10cm	Water presence	Last fire	Disturbances	Habitat condition	Habitat photo
VBOD-031	-32.9517	116.3916	Jarrah Woodland	Hillslope	South/ East	Moderate	Clay Loam	Scarce	Minor Outcropping	Many Large Patches	Few Small Patches	Low	Moderate	Scarce	Scarce	Scarce	Moderate (3 to 5 yr.)	Road/ Access Track	0.8	
VBOD-032	-32.9411	116.5021	Paddock	Hillslope	South/ West	Moderate	Loam	None Discernible	Negligible	None Discernible	None Discernible	Nil	High	None	None	None	Old (6+ yr.)	Cattle Grazing, Road/ Access Track, Weed Invasion	0.1	
VBOD-033	-33.2167	116.0428	jarrah woodland changing to wandoo. no Xanthorrhoea	Sand Plain	Flat	Flat	Loamy Sand	Scarce	Limited Outcropping	Evenly Spread	Few Large Patches	Nil	Very High	None	None	Scarce	Old (6+ yr.)	Mining Exploration, Road/ Access Track, Logging	0.6	
VBOD-034	-32.9725	116.4979	Jarrah Woodland	Hillcrest/ Upper Hillslope	South	Flat	Loam	Few Small Patches	Negligible	Evenly Spread	Many Large Patches	Nil	High	Scarce	Scarce	None	Old (6+ yr.)	Cattle Grazing, Weed Invasion	0.4	
VBOD-035	-33.2307	116.0475	Jarrah Woodland	Undulating Low Hills	North/ West	Low	Loamy Sand	Few Small Patches	Limited Outcropping	Evenly Spread	Many Large Patches	Nil	Very High	Moderate	Scarce	Scarce	Old (6+ yr.)	Mining Exploration, Road/ Access Track	0.8	
VBOD-036	-32.9755	116.5062	Jarrah Woodland	Hillcrest/ Upper Hillslope	South	Flat	Loam	Few Small Patches	Negligible	Evenly Spread	Many Large Patches	Nil	High	Scarce	Scarce	None	Old (6+ yr.)	Weed Invasion	0.4	
VBOD-037	-33.1787	116.0228	Jarrah Woodland	Undulating Low Hills	North	Low	Loamy Sand	Few Small Patches	Negligible	Evenly Spread	Many Small Patches	Nil	Very High	Scarce	Scarce	Permanent	Old (6+ yr.)	None Discernible	0.8	
VBOD-038	-32.9664	116.5375	Jarrah Woodland	Hillcrest/ Upper Hillslope	Flat	Flat	Loam	Few Small Patches	Negligible	Evenly Spread	Many Large Patches	Nil	High	Moderate	Moderate	None	Old (6+ yr.)	Road/ Access Track	1.0	
VBOD-039	-33.2315	116.0320	Jarrah Woodland	Sand Plain	Flat	Flat	Loamy Sand	Scarce	Limited Outcropping	Evenly Spread	Few Large Patches	Nil	Very High	None	None	Scarce	Old (6+ yr.)	Mining Exploration, Road/ Access Track, Logging	0.6	

Site	Latitude	Longitude	Habitat type (field)	Landform	Aspect	Slope	Soil type	Soil avail-ability	Out-cropping	Veg litter	Woody debris	Rocky cracks crevices	Burrowing suitability	Hollows <10cm	Hollows >10cm	Water presence	Last fire	Disturbances	Habitat condition	Habitat photo
VBOD-040	-32.9773	116.5215	Jarrah Woodland	Hillcrest/ Upper Hillslope	Flat	Flat	Loam	Few Small Patches	Negligible	Evenly Spread	Many Large Patches	Nil	High	Moderate	Moderate	None	Old (6+ yr.)	Clearing, Mining Exploration, Road/ Access Track	0.6	
VBOD-041	-33.1739	116.0343	Jarrah Woodland	Undulating Low Hills	South	Low	Loamy Sand	Scarce	Negligible	Evenly Spread	Many Large Patches	Nil	Very High	Scarce	Moderate	Scarce	Old (6+ yr.)	Road/ Access Track	0.8	
VBOD-042	-32.8498	116.4251	Rehab	Hillcrest/ Upper Hillslope	Flat	Flat	Loam	Evenly Spread	Limited Outcropping	None Discernib le	Many Large Patches	Nil	Very High	None	None	None	Old (6+ yr.)	Mining Exploration, Rehab, Road/ Access Track, Weed Invasion	0.1	
VBOD-044	-32.8954	116.4380	Jarrah Woodland	Hillcrest/ Upper Hillslope	Flat	Flat	Loam	Few Large Patches	Negligible	Evenly Spread	Many Large Patches	Nil	Very High	Moderate	Moderate	None	Old (6+ yr.)	Mining Exploration, Road/ Access Track	0.8	
VBOD-045	-33.2744	116.0012	Jarrah Woodland	Undulating Low Hills	North/ West	Moderate	Loamy Sand	Scarce	Negligible	Evenly Spread	Many Large Patches	Nil	Very High	Scarce	Scarce	Prone to Pooling	Old (6+ yr.)	Feral pig present, logging	0.8	
VBOD-046	-32.9181	116.4644	Jarrah Woodland	Footslope	South/ West	Low	Loam	Few Large Patches	Negligible	Evenly Spread	Many Large Patches	Nil	High	Moderate	Moderate	None	Old (6+ yr.)	Mining Exploration, Road/ Access Track	0.8	
VBOD-047	-33.2725	115.9934	Jarrah Woodland	Undulating Low Hills	North/ West	Moderate	Loamy Sand	Scarce	Negligible	Many Large Patches	Few Large Patches	Nil	High	Scarce	Scarce	Scarce	Old (6+ yr.)	Road/ Access Track	0.8	
VBOD-048	-32.9382	116.4804	Jarrah Woodland	Footslope	West	Low	Loam	Few Large Patches	Limited Outcropping	Evenly Spread	Many Large Patches	Low	High	Scarce	Moderate	None	Old (6+ yr.)	Mining Exploration, Rehab, Road/ Access Track	0.8	
VBOD-049	-33.2764	115.9912	Jarrah Woodland	Undulating Low Hills	North/ West	Moderate	Loamy Sand	Scarce	Negligible	Many Large Patches	Few Large Patches	Nil	High	Scarce	Scarce	Scarce	Old (6+ yr.)	Road/ Access Track	0.8	
VBOD-050	-32.9562	116.4660	Pit	Hillcrest/ Upper Hillslope	East	Moderate	Loam	Evenly Spread	Negligible	None Discernib le	None Discerni ble	Nil	Very High	None	None	None	Old (6+ yr.)	Mining, Mining Exploration, Road/ Access Track	0.1	

Site	Latitude	Longitude	Habitat type (field)	Landform	Aspect	Slope	Soil type	Soil avail-ability	Out-cropping	Veg litter	Woody debris	Rocky cracks crevices	Burrowing suitability	Hollows <10cm	Hollows >10cm	Water presence	Last fire	Disturbances	Habitat condition	Habitat photo
VBOD-052	-32.9846	116.4692	Jarrah Woodland	Hillslope	North/ East	Moderate	Loam	Many Small Patches	Negligible	Evenly Spread	Few Large Patches	Nil	High	Scarce	Moderate	None	Old (6+ yr.)	Mining Exploration, Road/ Access Track	0.8	
VBOD-053	-33.2876	116.0041	Jarrah Woodland	Undulating Low Hills	South	Low	Loamy Sand	Few Small Patches	Negligible	Evenly Spread	Many Small Patches	Nil	Very High	Scarce	Scarce	Scarce	Old (6+ yr.)	Mining Exploration, Road/ Access Track	0.6	
VBOD-054	-32.9814	116.4870	Rehab	Hillslope	East	Low	Loam	Evenly Spread	Negligible	None Discernible	None Discernible	Nil	High	None	None	None	Old (6+ yr.)	Rehab, Road/ Access Track	0.2	
VBOD-055	-33.2990	116.0049	Jarrah Woodland	Undulating Low Hills	West	Low	Loamy Sand	Scarce	Negligible	Evenly Spread	Few Small Patches	Nil	High	Scarce	Scarce	None	Old (6+ yr.)	Road/ Access Track, Rubbish/ Litter	0.8	
VBOD-056	-32.9546	116.4785	Jarrah Woodland	Hillslope	West	Low	Loam	Many Small Patches	Negligible	Evenly Spread	Many Small Patches	Nil	High	Scarce	Scarce	None	Old (6+ yr.)	Mining Exploration, Rehab, Road/ Access Track	0.6	
VBOD-058	-32.9549	116.4771	Wandoo Woodland	Footslope	Flat	Low	Loam	Many Large Patches	Negligible	Evenly Spread	Many Large Patches	Nil	High	Moderate	Moderate	None	Old (6+ yr.)	Mining Exploration, Road/ Access Track	1.0	
VBOD-059	-33.2982	115.9982	pasture	Undulating Low Hills	East	Low	Loamy Sand	Scarce	Negligible	Scarce	None Discernible	Nil	High	None	None	None	Old (6+ yr.)	Cattle Grazing, Weed Invasion	0.4	
VBOD-060	-33.0036	116.5054	Jarrah Woodland	Hillslope	South	Low	Loam	Many Small Patches	Negligible	Evenly Spread	Many Large Patches	Nil	High	Common	Common	None	Old (6+ yr.)	Logging, Mining Exploration, Road/ Access Track	0.8	
VBOD-061	-33.2839	115.9945	Jarrah Woodland	Undulating Low Hills	North	Low	Loamy Sand	Many Small Patches	Negligible	Evenly Spread	Many Small Patches	Nil	High	Scarce	Scarce	None	Moderate (3 to 5 yr.)	Road/ Access Track, Logging	0.6	
VBOD-062	-33.0161	116.5214	Jarrah Woodland	Hillslope	South	Low	Loam	Many Small Patches	Negligible	Evenly Spread	Many Large Patches	Nil	High	Moderate	Common	None	Old (6+ yr.)	Logging, Mining Exploration, Road/ Access Track	0.8	

Site	Latitude	Longitude	Habitat type (field)	Landform	Aspect	Slope	Soil type	Soil avail-ability	Out-cropping	Veg litter	Woody debris	Rocky cracks crevices	Burrowing suitability	Hollows <10cm	Hollows >10cm	Water presence	Last fire	Disturbances	Habitat condition	Habitat photo
VBOD-063	-33.2756	115.9827	Jarrah Woodland	Undulating Low Hills	North	Low	Loamy Sand	Many Small Patches	Negligible	Evenly Spread	Many Small Patches	Nil	High	Scarce	Scarce	None	Moderate (3 to 5 yr.)	Road/ Access Track, Logging	0.6	
VBOD-064	-32.9651	116.4600	Rehab	Hillslope	West	Moderate	Loam	Few Small Patches	Negligible	Evenly Spread	Scarce	Nil	High	None	None	None	Old (6+ yr.)	Mining Exploration, Rehab, Road/ Access Track	0.2	
VBOD-065	-33.2829	115.9763	Jarrah Woodland	Undulating Low Hills	North	Low	Loamy Sand	Many Small Patches	Negligible	Evenly Spread	Few Small Patches	Nil	High	Scarce	Scarce	None	Moderate (3 to 5 yr.)	Road/ Access Track, Logging	0.6	
VBOD-066	-32.9396	116.4636	Jarrah Woodland	Hillslope	South	Moderate	Loam	Many Small Patches	Negligible	Evenly Spread	Many Large Patches	Nil	High	None	Scarce	None	Old (6+ yr.)	Mining Exploration, Rehab, Road/ Access Track	0.6	
VBOD-067	-33.2709	115.9739	Jarrah Woodland	Undulating Low Hills	North	Low	Loamy Sand	Many Small Patches	Negligible	Evenly Spread	Few Small Patches	Nil	High	Scarce	Scarce	None	Moderate (3 to 5 yr.)	Road/ Access Track, Logging	0.6	
VBOD-068	-32.9304	116.4467	Jarrah Woodland	Hillslope	North	Low	Loam	Scarce	Negligible	Evenly Spread	Evenly Spread	Nil	High	None	Scarce	None	Old (6+ yr.)	Mining Exploration, Rehab, Road/ Access Track	0.6	
VBOD-069	-33.2879	115.9709	Jarrah Woodland	Undulating Low Hills	South/ West	Low	Loamy Sand	Scarce	Negligible	Evenly Spread	Few Small Patches	Nil	High	Scarce	Scarce	Prone to Pooling	Old (6+ yr.)	Road/ Access Track	0.8	
VBOD-070	-33.0018	116.3118	Jarrah Woodland	Hillslope	South/ West	Moderate	Loam	Scarce	Negligible	Many Small Patches	Many Small Patches	Nil	High	Scarce	Moderate	Scarce	Old (6+ yr.)	Mining Exploration, Road/ Access Track, Weed Invasion	0.8	
VBOD-071	-33.0018	116.3118	Jarrah Woodland	Hillslope	South/ West	Moderate	Loam	Scarce	Negligible	Many Small Patches	Many Small Patches	Nil	High	Scarce	Moderate	Scarce	Old (6+ yr.)	Mining Exploration, Road/ Access Track, Weed Invasion	0.8	
VBOD-072	-33.2823	115.9672	Jarrah Woodland	Undulating Low Hills	South/ West	Low	Loamy Sand	Scarce	Negligible	Evenly Spread	Few Small Patches	Nil	High	Scarce	Scarce	Prone to Pooling	Old (6+ yr.)	Road/ Access Track	0.8	

Site	Latitude	Longitude	Habitat type (field)	Landform	Aspect	Slope	Soil type	Soil avail-ability	Out-cropping	Veg litter	Woody debris	Rocky cracks crevices	Burrowing suitability	Hollows <10cm	Hollows >10cm	Water presence	Last fire	Disturbances	Habitat condition	Habitat photo
VBOD-073	-33.0094	116.2963	Jarrah Woodland	Hillslope	West	Low	Loam	Few Small Patches	Negligible	Evenly Spread	Many Large Patches	Nil	High	Scarce	Moderate	Permanent	Old (6+ yr.)	Dam, Mining Exploration, Road/ Access Track	0.8	
VBOD-074	-33.2754	115.9567	Jarrah Woodland	Undulating Low Hills	South/ West	Low	Loamy Sand	Scarce	Negligible	Evenly Spread	Few Small Patches	Nil	High	Scarce	Scarce	Prone to Pooling	Old (6+ yr.)	Road/ Access Track	0.8	
VBOD-075	-33.0115	116.3086	Jarrah Woodland	Hillslope	North	Low	Loam	Few Small Patches	Negligible	Evenly Spread	Few Large Patches	Nil	High	Scarce	Moderate	None	Old (6+ yr.)	Mining Exploration, Road/ Access Track	0.8	
VBOD-076	-33.2635	115.9617	Gastrolobium thicket with scattered jarrah	Undulating Low Hills	North/ West	Moderate	Loamy Sand	Scarce	Minor Outcropping	Few Small Patches	Many Small Patches	Low	Moderate	Scarce	Scarce	Prone to Flooding	Old (6+ yr.)	Road/ Access Track, Rubbish/ Litter	0.6	
VBOD-078	-33.2346	115.9894	Jarrah Woodland	Hillslope	Flat	Low	Loam	Few Small Patches	Negligible	Evenly Spread	Many Small Patches	Nil	Very High	None	Scarce	None	Old (6+ yr.)	Road/ Access Track	0.8	
VBOD-080	-33.2252	115.9706	Jarrah Woodland	Medium Drainage Line	South/ West	Moderate	Silty Clay Loam	Few Small Patches	Negligible	Evenly Spread	Many Small Patches	Nil	Very High	Scarce	Scarce	Permanent	Old (6+ yr.)	Road/ Access Track	0.8	
VBOD-082	-33.2276	115.9597	Jarrah Woodland	Hillslope	South/ West	Moderate	Loam	Scarce	Negligible	Evenly Spread	Many Large Patches	Nil	Very High	Moderate	Moderate	None	Old (6+ yr.)	Road/ Access Track	1.0	
VBOD-084	-33.2448	115.9492	Jarrah Woodland	Hillslope	South/ West	Moderate	Loam	Scarce	Negligible	Evenly Spread	Many Large Patches	Nil	Very High	Scarce	Scarce	None	Old (6+ yr.)	Road/ Access Track	0.8	
VBOD-086	-33.2455	115.9699	Jarrah Woodland	Hillslope	South/ West	Low	Loam	Few Small Patches	Negligible	Evenly Spread	Many Large Patches	Nil	Very High	Scarce	Scarce	None	Old (6+ yr.)	Road/ Access Track	0.8	
VBOD-088	-33.2378	115.9649	Jarrah Woodland	Hillcrest/ Upper Hillslope	Flat	Flat	Loam	Scarce	Negligible	Evenly Spread	Many Large Patches	Nil	Very High	Moderate	Moderate	None	Old (6+ yr.)	Road/ Access Track	1.0	

Site	Latitude	Longitude	Habitat type (field)	Landform	Aspect	Slope	Soil type	Soil avail-ability	Out-cropping	Veg litter	Woody debris	Rocky cracks crevices	Burrowing suitability	Hollows <10cm	Hollows >10cm	Water presence	Last fire	Disturbances	Habitat condition	Habitat photo
VBOD-090	-33.2438	115.9827	Jarrah Woodland	Hillcrest/ Upper Hillslope	Flat	Flat	Loam	Scarce	Negligible	Evenly Spread	Many Large Patches	Nil	Very High	Moderate	Moderate	None	Old (6+ yr.)	Road/ Access Track	1.0	
VBOD-092	-33.2501	115.9953	Marri Woodland	Hillslope	South/ West	Low	Loam	Scarce	Negligible	Many Large Patches	Many Large Patches	Nil	Very High	Moderate	Moderate	None	Old (6+ yr.)	Road/ Access Track	1.0	
VBOD-094	-33.2620	115.9713	Jarrah Woodland	Granite Outcrops/ Domes	South/ West	Moderate	Loam	Few Small Patches	Moderate Outcropping	Evenly Spread	Many Large Patches	Moderate	Moderate	Scarce	Scarce	None	Old (6+ yr.)	Road/ Access Track	1.0	
VBOD-096	-33.3276	116.0484	Jarrah Woodland	Undulating Low Hills	Flat	Flat	Loam	None Discernible	Negligible	Evenly Spread	Many Large Patches	Nil	Very High	Scarce	Moderate	None	Old (6+ yr.)	Rail, Road/ Access Track	0.8	
VBOD-098	-33.3232	116.0375	Jarrah Woodland	Undulating Low Hills	Flat	Flat	Loam	None Discernible	Negligible	Evenly Spread	Many Large Patches	Nil	Very High	Scarce	Moderate	None	Old (6+ yr.)	Rail, Road/ Access Track	0.8	
VBOD-100	-33.3199	116.0332	Jarrah Woodland	Undulating Low Hills	East	Low	Loam	None Discernible	Negligible	Evenly Spread	Many Large Patches	Nil	Very High	Common	Common	None	Old (6+ yr.)	Farming, Road/ Access Track, Weed Invasion	0.8	
VBOD-102	-33.3114	116.0165	Jarrah Woodland	Hillslope	South/ West	Low	Loam	Scarce	Negligible	Evenly Spread	Many Large Patches	Nil	Very High	Scarce	Scarce	None	Old (6+ yr.)	Cattle Grazing, Road/ Access Track	0.6	
VBOD-104	-33.3137	116.0268	Jarrah Woodland	Undulating Low Hills	West	Low	Loam	Few Small Patches	Negligible	Evenly Spread	Few Large Patches	Nil	Very High	Scarce	Scarce	None	Moderate (3 to 5 yr.)	Cattle Grazing, Road/ Access Track	0.6	

Appendix C – Previous numbat records from database searches

Atlas of Living Australia database records (restricted to 10 km accuracy)

Year	Observation Method	General Area	Latitude	Longitude
2007	Human Observation	PAA, Dryandra, and Batalling	-32.7	116.8
2020	Human Observation	PAA, Dryandra, and Batalling	-32.7	116.9
2020	Human Observation	PAA, Dryandra, and Batalling	-32.7	117
2020	Human Observation	PAA, Dryandra, and Batalling	-32.7	117
2020	Human Observation	PAA, Dryandra, and Batalling	-32.7	116.9
2022	Human Observation	PAA, Dryandra, and Batalling	-32.8	117
2020	Human Observation	PAA, Dryandra, and Batalling	-32.7	116.9
2014	Human Observation	PAA, Dryandra, and Batalling	-32.7	116.9
2021	Human Observation	PAA, Dryandra, and Batalling	-32.7	117
2021	Human Observation	PAA, Dryandra, and Batalling	-32.8	117.1
2020	Human Observation	PAA, Dryandra, and Batalling	-32.7	116.9
2021	Human Observation	PAA, Dryandra, and Batalling	-32.7	116.9
2017	Human Observation	PAA, Dryandra, and Batalling	-32.7	116.9
2019	Human Observation	PAA, Dryandra, and Batalling	-32.7	116.9
2015	Human Observation	PAA, Dryandra, and Batalling	-32.8	116.9
2022	Human Observation	PAA, Dryandra, and Batalling	-32.7	117
2021	Human Observation	PAA, Dryandra, and Batalling	-32.8	116.9
2021	Human Observation	PAA, Dryandra, and Batalling	-32.7	116.8
2021	Human Observation	PAA, Dryandra, and Batalling	-32.7	116.9
2022	Human Observation	PAA, Dryandra, and Batalling	-32.6	116.9
2021	Human Observation	PAA, Dryandra, and Batalling	-32.8	116.8
2022	Human Observation	PAA, Dryandra, and Batalling	-32.7	116.9
2019	Human Observation	PAA, Dryandra, and Batalling	-32.7	116.9
2019	Human Observation	PAA, Dryandra, and Batalling	-32.8	116.9
2021	Human Observation	PAA, Dryandra, and Batalling	-32.8	117
2007	Human Observation	PAA, Dryandra, and Batalling	-32.8	116.8
2015	Human Observation	PAA, Dryandra, and Batalling	-32.8	116.9
2021	Human Observation	PAA, Dryandra, and Batalling	-32.8	116.9
2022	Human Observation	PAA, Dryandra, and Batalling	-32.6	117
2021	Human Observation	PAA, Dryandra, and Batalling	-32.6	117
2022	Human Observation	PAA, Dryandra, and Batalling	-32.7	117
2019	Human Observation	PAA, Dryandra, and Batalling	-32.7	117
2021	Human Observation	PAA, Dryandra, and Batalling	-32.8	116.9
2022	Human Observation	PAA, Dryandra, and Batalling	-32.7	116.8
2020	Human Observation	PAA, Dryandra, and Batalling	-32.8	116.9
2017	Human Observation	PAA, Dryandra, and Batalling	-32.6	117
2022	Human Observation	PAA, Dryandra, and Batalling	-32.8	116.9
2022	Human Observation	PAA, Dryandra, and Batalling	-32.7	116.9
2022	Human Observation	PAA, Dryandra, and Batalling	-32.8	116.9
2021	Human Observation	PAA, Dryandra, and Batalling	-32.8	116.9
2015	Human Observation	PAA, Dryandra, and Batalling	-32.8	116.9
2022	Human Observation	PAA, Dryandra, and Batalling	-32.9	117
2019	Human Observation	PAA, Dryandra, and Batalling	-32.8	117

Year	Observation Method	General Area	Latitude	Longitude
2021	Human Observation	PAA, Dryandra, and Batalling	-32.8	116.9
2019	Human Observation	PAA, Dryandra, and Batalling	-32.7	116.9
2022	Human Observation	PAA, Dryandra, and Batalling	-32.8	117
2015	Human Observation	PAA, Dryandra, and Batalling	-32.6	117
2021	Human Observation	PAA, Dryandra, and Batalling	-32.8	117
2022	Human Observation	PAA, Dryandra, and Batalling	-32.9	117.2
1935	Preserved Specimen	PAA, Dryandra, and Batalling	-32.9	117.2
1935	Preserved Specimen	PAA, Dryandra, and Batalling	-32.9	117.2
1954	Preserved Specimen	PAA, Dryandra, and Batalling	-32.8	116.9
1927	Preserved Specimen	PAA, Dryandra, and Batalling	-32.7	117.1
1927	Preserved Specimen	PAA, Dryandra, and Batalling	-32.7	117.1
1928	Preserved Specimen	PAA, Dryandra, and Batalling	-32.7	117.1
1927	Preserved Specimen	PAA, Dryandra, and Batalling	-32.7	117.1
1926	Preserved Specimen	PAA, Dryandra, and Batalling	-32.7	117.1
2022	Preserved specimen	PAA, Dryandra, and Batalling	-32.8	115.9
1937	Preserved Specimen	PAA, Dryandra, and Batalling	-33	116.9
1943	Preserved Specimen	PAA, Dryandra, and Batalling	-32.9	117.2
1929	Preserved Specimen	PAA, Dryandra, and Batalling	-32.9	117.2
1936	Preserved Specimen	PAA, Dryandra, and Batalling	-32.9	117.2
1961	Preserved Specimen	PAA, Dryandra, and Batalling	-32.7	115.8
1943	Preserved Specimen	PAA, Dryandra, and Batalling	-32.9	117.2
Historic (no date)	Preserved Specimen	PAA, Dryandra, and Batalling	-32.7	116.6
Historic (no date)	Preserved Specimen	PAA, Dryandra, and Batalling	-32.7	116.6
1990	Preserved Specimen	PAA, Dryandra, and Batalling	-32.9	117.2
1929	Preserved Specimen	PAA, Dryandra, and Batalling	-33	116.9
1974	Preserved Specimen	PAA, Dryandra, and Batalling	-32.7	116.5
1944	Preserved Specimen	PAA, Dryandra, and Batalling	-32.9	117.2
1966	Preserved Specimen	PAA, Dryandra, and Batalling	-32.7	117.2
1943	Preserved Specimen	PAA, Dryandra, and Batalling	-32.9	117.2
1929	Preserved Specimen	PAA, Dryandra, and Batalling	-33	116.9
Historic (no date)	Preserved Specimen	PAA, Dryandra, and Batalling	-32.7	116.6
1968	Preserved Specimen	PAA, Dryandra, and Batalling	-33.3	116
1973	Preserved Specimen	PAA, Dryandra, and Batalling	-33.3	116
1943	Preserved Specimen	PAA, Dryandra, and Batalling	-32.9	117.2
1943	Preserved Specimen	PAA, Dryandra, and Batalling	-32.9	117.2
1929	Preserved Specimen	PAA, Dryandra, and Batalling	-33	116.9
Historic (no date)	Preserved Specimen	PAA, Dryandra, and Batalling	-33.2	116
1967	Preserved Specimen	PAA, Dryandra, and Batalling	-32.7	116.5
1928	Preserved Specimen	PAA, Dryandra, and Batalling	-33.3	116.7
1937	Preserved Specimen	PAA, Dryandra, and Batalling	-33	116.9
1944	Preserved Specimen	PAA, Dryandra, and Batalling	-32.7	116.5
1941	Preserved Specimen	PAA, Dryandra, and Batalling	-32.9	117.2
1937	Preserved Specimen	PAA, Dryandra, and Batalling	-33	116.9
1964	Preserved Specimen	PAA, Dryandra, and Batalling	-32.8	116.9
1968	Preserved Specimen	PAA, Dryandra, and Batalling	-33.3	116

Year	Observation Method	General Area	Latitude	Longitude
1941	Preserved Specimen	PAA, Dryandra, and Batalling	-32.6	117.1
1937	Preserved Specimen	PAA, Dryandra, and Batalling	-33	116.9
Historic (no date)	Preserved Specimen	PAA, Dryandra, and Batalling	-32.8	117
1929	Preserved Specimen	PAA, Dryandra, and Batalling	-33	116.9
2021	Preserved Specimen	PAA, Dryandra, and Batalling	-32.8	117
1937	Preserved Specimen	PAA, Dryandra, and Batalling	-33	116.9
1991	Preserved Specimen	PAA, Dryandra, and Batalling	-32.6	117.1
1929	Preserved Specimen	PAA, Dryandra, and Batalling	-33	116.9
1981	Preserved Specimen	PAA, Dryandra, and Batalling	-32.8	117
1966	Preserved Specimen	PAA, Dryandra, and Batalling	-32.8	117
2001	Preserved Specimen	PAA, Dryandra, and Batalling	-32.8	117
1942	Preserved Specimen	PAA, Dryandra, and Batalling	-32.6	117.1
1990	Preserved Specimen	PAA, Dryandra, and Batalling	-32.8	117
Historic (no date)	Preserved Specimen	PAA, Dryandra, and Batalling	-32.8	117
1966	Preserved Specimen	PAA, Dryandra, and Batalling	-32.8	117
1939	Preserved Specimen	PAA, Dryandra, and Batalling	-33.2	116.8
1981	Preserved Specimen	PAA, Dryandra, and Batalling	-32.8	117
1987	Preserved Specimen	PAA, Dryandra, and Batalling	-32.6	117.1
1967	Preserved Specimen	PAA, Dryandra, and Batalling	-32.8	117
1966	Preserved Specimen	PAA, Dryandra, and Batalling	-32.8	117
Historic (no date)	Preserved Specimen	PAA, Dryandra, and Batalling	-32.8	117
1982	Preserved Specimen	PAA, Dryandra, and Batalling	-32.8	117
1962	Preserved Specimen	PAA, Dryandra, and Batalling	-32.6	117.1
1990	Preserved Specimen	PAA, Dryandra, and Batalling	-32.8	117
Historic (no date)	Preserved Specimen	PAA, Dryandra, and Batalling	-32.6	116.8
1989	Preserved Specimen	PAA, Dryandra, and Batalling	-32.6	117.1
1990	Preserved Specimen	Collie	-32.8	117
1989	Preserved Specimen	Collie	-32.8	117
1982	Preserved Specimen	Collie	-32.8	117
1929	Preserved Specimen	Collie	-32.6	116.6
1982	Preserved Specimen	Collie	-32.8	117
1941	Preserved Specimen	Bunbury	-32.6	117.1
1944	Preserved Specimen	Bunbury	-33.3	115.9

*note that the DBCA Threatened and Priority Fauna records are not provided here due to data permissions

Appendix D – Significant fauna recorded during the current survey

Latitude	Longitude	Site	Name	Conservation Status	Date	Observation Method	Record Type
-32.7322	116.3677	VBOD-03	*Myrmecobius fasciatus*, Numbat, Walpurti	EN (EPBC, BC Act)	24/10/2022	Targeted Search	Scat
-33.2743	116.0018	VBOD-45	*Zanda latirostris,* Carnaby's Black Cockatoo	EN (EPBC, BC Act)	26/10/2022	Targeted Search	Individual (alive)
-33.2743	116.0014	VBOD-45	*Calyptorhynchus banksii naso,* Forest red-tailed black cockatoo	VU (EPBC, BC Act)	26/10/2022	Targeted Search	Individual (alive)
-32.7321	116.3679	VBOD-03	*Dasyurus geoffroii,* Western Quoll, Chuditch	VU (EPBC, BC Act)	24/10/2022	Targeted Search	Scat
-32.9767	116.5217	Opp	*Isoodon fusciventer,* Quenda	P4 (DBCA)	24/10/2022	Targeted Search	Digging
-32.8251	116.4083	VBOD-02	*Isoodon fusciventer,* Quenda	P4 (DBCA)	24/10/2022	Targeted Search	Digging
-32.9513	116.3906	VBOD-31	*Isoodon fusciventer,* Quenda	P4 (DBCA)	25/10/2022	Targeted Search	Digging
-32.7637	116.4003	VBOD-23	*Notamacropus Irma,* Western Brush Wallaby	P4 (DBCA)	24/10/2022	Targeted Search	Individual (alive)
-32.7752	116.3953	Opp	*Notamacropus Irma,* Western Brush Wallaby	P4 (DBCA)	24/10/2022	Targeted Search	Individual (alive)
-32.7238	116.3895	Opp	*Notamacropus Irma,* Western Brush Wallaby	P4 (DBCA)	24/10/2022	Targeted Search	Individual (alive)
-33.2739	115.9883	VBOD-53	*Notamacropus Irma,* Western Brush Wallaby	P4 (DBCA)	26/10/2022	Targeted Search	Individual (alive)
-33.2876	116.0044	VBOD-53	*Phascogale tapoatafa wambenger*, Wambenger	CD (BC Act)	26/10/2022	Targeted Search	Scat