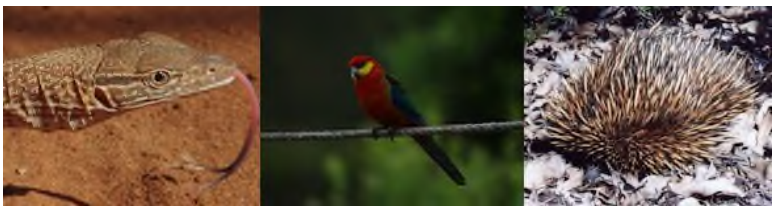
Worsley Alumina Mine Expansion (WME)
Desktop Fauna Assessment

Prepared for: South32 Worsley Alumina Pty Ltd

By BIOSTAT Pty Ltd

May 2019



BIOSTAT Pty Ltd

ABN 87 092 767 032
39 Doris St
North Perth Western Australia 6006
Ph: +61 8 6460 2455
www.biostat.com.au consulting@biostat.com.au

REVISION SCHEDULE

Rev. No.	Date	Description	Prepared/Approved By
a	14/12/2018	Pre-release draft. Information not reviewed, edited or confirmed. Data in this document to be used with care.	EGC
b	18/1/2019	First Draft release. Draft notation advanced to avoid confusion with pre-release draft.	EGC
c	4/2/2019	Near final release. Returned to South32 with edits and responses to comments	EGC
1	8/2/2019	Final Release with figures	EGC
1c	12/2/2019	Minor edits relating to changes in acronyms	EGC
1d	9/5/2019	Update to areas of habitat resulting from a review and refinement of spatial data	EGC

STATEMENT OF LIMITATIONS

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(The 'Project' is defined as the scope of services as set out in the contract and agreed to by BIOSTAT Pty Ltd and the Client.)

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Glossary

Acronym	Description
BBM	Boddington Bauxite Mine
BTC	Boddington Transport Corridor
Bonn	Convention on the Conservation of Migratory Species of Wild Animals
CAMBA	China-Australia Migratory Bird Agreement
CBME	Contingency Bauxite Mining Envelope
DBCA	Department of Biodiversity, Conservation and Attractions
DPaW	Department of Parks and Wildlife
EPBC Act	*Environmental Protection and Biodiversity Conservation Act 1999*
JAMBA	Japan-Australia Migratory Bird Agreement
IUCN	International Union for the Conservation of Nature
MMB	Mornington Mills Block
MEA	Mine Expansion Area (historical survey term)
MNES	Matters of National Environmental Significance
MAR	Worsley Marradong Mine Operations
NBGM	Newmont Boddington Gold Mine
OBC	Overland Belt Conveyor
PHT	Potential Habitat Tree
QIN	Quindanning Mine Operations
RLA	Refinery Lease Area
ROKAMBA	Republic of Korea-Australia Migratory Bird Agreement
SAD	Saddleback Mine Operations
WME	Worsley Mine Expansion
WMDE	Worsley Mining Development Envelope
WMDEC	Combined WMDE and BTC Combined boundary areas

EXECUTIVE SUMMARY

Biostat Pty Ltd (Biostat) was commissioned in 2018 by South32 Worsley Alumina Pty Ltd (South32) to undertake a terrestrial vertebrate fauna survey and review of the proposed Worsley Mine Expansion (WME).

The WME consists of three development envelopes: two in the Boddington area and one in the Collie area of Western Australia:

- the Worsley Mining Development Envelope (WMDEC) covering an area of 27,796 ha from the Saddleback Tree Farm and Newmont Boddington Gold Mine (NBGM) to the North and south to Quindanning;
- the Bauxite Transport Corridor (BTC) covering 4,146 ha of which 3,332 ha overlaps WMDE; and,
- the Contingency Bauxite Mining Envelope (CBME), located at the Refinery Lease Area (RLA) near Collie which covers 747 ha (there is an additional 5 ha "Maintenance Area" within the CBME boundary that will not be considered separately in this report).

In relation to fauna, the area of impact at Boddington is considered the collective area covered by both WMDE and BTC. The combined merged area covered by these two administrative boundaries is 29,362 ha. They will be collectively referred to as the Worsley Mine Development Envelope Combined (WMDEC) for the analysis presented in this document.

This report will detail the adequacy, currency and validity of the data already held by South32 and Newmont Mining (for their NBGM) providing substantiating information for the referral of threatened species under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act). Gaps in knowledge identified during the analysis of data for this report will be highlighted and recommendations made for further assessment, where required.

This report will detail the adequacy, currency and validity of the data already held by South32 and utilise it in providing substantiating information for the referral of threatened species under the EPBC Act. Gaps in knowledge identified during the analysis of data for this report will be highlighted and recommendations made for further assessment, where required.

The data available for the areas under consideration is generally robust and current for its use in impact assessment and of a substantially higher-level than what could be expected if basic guideline methodologies set out for impact assessments are followed.

Data for the WMDEC area, with systematic survey data available for most of the mining operations from 1982 to 2018, provides the necessary spatial-temporal data measure that allow confidence in assessing trends and likelihoods. This is especially relevant for data collected for the Boddington Bauxite Mine (BBM) area within the WMDEC. Certain areas including for the NBGM area, Marradong Timber Reserve (MTR) and for sites along the Overland Belt Conveyor (OBC) could benefit from updated data collection. The most evident gap in data is for the CBME area where systematic biodiversity surveys have not been undertaken since 2001.

The value of systematic survey design and data collection is discussed, and it is recommended that such surveys be preferred over other more typical methods such as passive monitoring or targeted surveys due to their limitations (i.e., short-term, lacking multi-seasonal perspective, speculative, generally poorly designed).

The fauna habitats present in the WME are typical for the bioregion, representing and dominated by, varying form of forest and woodland communities. The majority of the WMDEC consists of a mosaic of agricultural and cleared areas. The remnant native vegetation communities of relatively high quality are present in the northern and western portion of the WMDEC. In some cases, these form contiguous

tracts of native forests and woodlands such as the northern area of NBGM and in the central west area of SAD. There are remnants within agricultural lands as well as rehabilitation of mined areas that form connecting corridors allowing for fauna movements across the landscape.

All native vegetation remnants are of some level of use to much of the fauna dependent on the resources they contain. For example, rehabilitation performs a significant function in supporting fauna species associated with heath habitats. They also provide suitable feeding habitat for black-cockatoos and other nectarivore and granivore species. Stands of tall trees in agricultural lands can provide temporary refuge for volant and to a lesser degree non-volant fauna in their movements in the landscape.

Threatened species listed under the EPBC Act were assessed in relation to:

- Likely habitat utilisation;
- Threatening processes;
- The likelihood of occurrence in the WMDEC and CBME (including known records); and,
- data availability and potential for additional data collection.

Several of the EPBC Act listed Threatened species have been recorded at the WMDEC over time and, recently the kenngoor was added to the list of conservation significant species found in the area. Some of the more cryptic species, quokka and woylie, have been recorded infrequently. Other cryptic species may occur in low densities outside of the focus areas for surveys but still within the boundaries of the WME. By their nature, rare species are difficult to assess due to the lack of data. However, in some cases, the level of data available for assessment is relatively high although focused on areas of mine activity.

Of the threatened species under consideration, all three species of black-cockatoo, woylie, kenngoor, and chuditch have been recorded in the surveys undertaken within the WMDEC boundaries. Black-cockatoo have been recorded breeding at both WMDEC and CBME. The western ringtail possum has been recorded along the OBC in areas close to RLA but not within the CBME. The quokka has been recorded from areas adjoining the RLA (which included the CBME) but not within its boundaries.

From the available information it was possible to determine the likelihood of occurrence of the threatened species within both the WMDEC and CBME. However, it was also evident that there was a need to collect more current information from some areas including CBME and northern NBGM to raise the certainty of likelihood and arrive at a better understanding of fauna distributions and habitat use.

In conclusion, the overriding issues in the fauna assessment of the proposed WME are:

1. There is adequate robust information to allow a greater degree of certainty in assessing risk to threatened fauna at the proposed WMDEC.
2. Biodiversity information from CBME will need to be updated. It is recommended that a trapping survey, similar to the 2000-2001 general biodiversity survey, covering all terrestrial vertebrate fauna groups be undertaken, possibly using the same site locations. Targeted surveys are not designed to determine spatial and seasonal variation in species and would prove inadequate to determine the ecosystem functions of the area. However, targeted searches as part of the biodiversity survey could be incorporated to provide additional information.
3. It is likely the project will be referred on the evidence of information on all three species of black-cockatoo.
4. Certain listed species will need continued monitoring including all three black-cockatoo species, chuditch, woylie, kenngoor, and western ringtail possum. These monitoring programs can be incorporated as part of longer-term management strategies. Targeted populations studies are also recommended as part of the monitoring.

5. Connectivity in a fragmented landscape is critical for the longer-term sustainability of ecosystems. This may require active establishment and maintenance of corridors or protection of existing corridor systems.
6. A broader approach is required to undertake management of landscapes at both sites in the proposed WME. Collaboration with all stakeholders would be required to ensure effective ecological management of the landscape.
7. For highest value outcomes enhancement of habitats should commence early in the planning phase to ensure that they are advanced enough to provide the ecological function of the areas they are to replace.
8. Fauna monitoring is a critical component for collating detailed ecological data that will allow for the avoidance, mitigation and management of impacts on threatened species, ecosystems and other fauna within both areas.
9. General systematic biodiversity surveys are recommended for areas of native forests that have not been surveyed previously to obtain a better understanding of the distribution of fauna in the landscape, e.g., areas in the northern section of NBGM.
10. Climate change is an important consideration in the maintenance and management of ecosystems for the conservation of threatened fauna.

1 INTRODUCTION

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2 STATUTORY AND OTHER REQUIREMENTS

This section summarises the various Australian Government and Western Australian Government Acts that cover rare, threatened and vulnerable vertebrate fauna species and was correct at the time of the preparation of this document. However, as changes are made to both State and Australian Government legislation and new treaties are entered, all current documentation regarding rare, threatened and vulnerable fauna should be periodically reviewed for any changes to the status of fauna in each area.

Additionally, in any discussion of rare, threatened or vulnerable species, several aspects require clarification before the significance of these species can be considered in context of the development and operation of any project.

- Resident, habitat-specific rare fauna are much more susceptible to the influences of disturbance than nomadic or migratory species.
- Not all rare species are equally susceptible to disturbance. Some rare species such as the Peregrine Falcon can accommodate the high levels of disturbance present in urban and rural environments.
- The concept of species rarity is a dynamic process considerably influenced by the level of survey work carried out in a location.

2.1 Protected Species – Australian Government

The EPBC Act (Commonwealth of Australia 1999) is administered by the Department of the Environment and Energy (DEE) (https://www.environment.gov.au/epbc) which also administers the international treaties discussed below.

Several animals are covered by the EPBC Act under six categories of threat (S.179: *EPBC Act 1999*):

- extinct (X);
- extinct in the wild (XW);
- critically endangered (CR);
- endangered (EN);
- vulnerable (VU); and,
- conservation dependent (CD).

A range of birds are listed under the Japan-Australia (JAMBA), China-Australia (CAMBA) and Republic of Korea/Australia (ROKAMBA) Migratory Bird Agreements. The main aim of these international agreements is to protect migratory birds and their breeding and/or feeding habitats. An earlier agreement, Bonn Convention (Bonn), binds signatories to the conservation of species of wild animals and aims to conserve terrestrial, marine and avian migratory species throughout their range. There are several birds listed on these international treaties that could occur within the two areas, WMDEC and CBME, and these are discussed in this report.

2.2 Protected Species - Western Australia

In Western Australia, species of conservation significance have historically been protected under the *Wildlife Conservation Act 1950* (*WC Act 1950*) (Government of Western Australia 1950) however are now transferred to the *Biodiversity Conservation Act 2016* (*BC Act 2016*) (Government of Western Australia 2016). The schedules defined under this Act are:

Schedule 1 (CR): *fauna that is rare or likely to become extinct, as critically endangered fauna, are declared to be fauna that is in need of special protection*;

Schedule 2 (EN): *fauna that is rare or likely to become extinct, as endangered fauna, are declared to be fauna that is in need of special protection*;

Schedule 3 (VU): *fauna that is rare or likely to become extinct, as vulnerable fauna, are declared to be fauna that is in need of special protection*;

Schedule 4 (X[1]): *fauna that is presumed to be extinct, are declared to be fauna that is in need of special protection*;

Schedule 5 (IA): *birds that are subject to international agreements relating to the protection of migratory birds, are declared to be fauna that is in need of special protection*;

Schedule 6 (S1): *fauna that are of special conservation need being species dependent on ongoing conservation intervention, are declared to be fauna that is in need of special protection*;

Schedule 7 (S2): *fauna that is in need of special protection, otherwise than for the reasons mentioned in* [previous schedules).

(Schedule definitions are quoted from Wildlife Conservation Act 1950 for consistency and relevance)

[1] A new category, Extinct in the Wild (XW), will be introduced with the next fauna notice in 2019.

This Act is periodically reviewed. The current list of protected fauna can be viewed on the Department of Biodiversity, Conservation and Attractions (DBCA) website (http://www.dpaw.wa.gov.au/plants-and-animals/threatened-species-and-communities).

2.3 Priority Species - Western Australia

There are several species not listed under the *WC Act 1950* that, for various reasons, require attention and these are listed on the DBCA's Priority Fauna List which classifies species as[2]:

- Priority 1 - Poorly-known species with few, poorly known populations on threatened lands.

Taxa which are known from few specimens or sight records from one or a few localities on lands not managed for conservation, e.g. agricultural or pastoral lands, urban areas, active mineral leases. The taxon needs urgent survey and evaluation of conservation status before consideration can be given to declaration as threatened fauna.

- Priority 2 - Poorly-known species with few, poorly known populations on conservation lands.

Taxa which are known from few specimens or sight records from one or a few localities on lands not under immediate threat of habitat destruction or degradation, e.g. national parks, conservation parks, nature reserves, State forest, vacant Crown land, water reserves, etc. The taxon needs urgent survey and evaluation of conservation status before consideration can be given to declaration as threatened fauna.

- Priority 3 - Poorly-known species with several, poorly known populations, some on conservation lands.

Taxa which are known from few specimens or sight records from several localities, some of which are on lands not under immediate threat of habitat destruction or degradation. The taxon needs urgent survey and evaluation of conservation status before consideration can be given to declaration as threatened fauna.

- Priority 4 - Rare, Near Threatened and other species in need of monitoring.

Rare. Taxa which are considered to have been adequately surveyed, or for which sufficient knowledge is available, and which are considered not currently threatened or in need of special protection, but could be if present circumstances change. These taxa are usually represented on conservation lands.

Near Threatened. Taxa that are considered to have been adequately surveyed and that do not qualify for Conservation Dependent, but that are close to qualifying for Vulnerable.

Taxa that have been removed from the list of threatened species during the past five years for reasons other than taxonomy.

- Priority 5 - Conservation Dependent species.

Taxa which are not considered threatened but are subject to a specific conservation program, the cessation of which would result in the species becoming threatened within five years.

The Priority Fauna List does not confer any additional legal protection to the species listed apart from the normal protection afforded to most native animals. It does, however, indicate the need for vigilance during the construction and commissioning of development projects to manage native vegetation and rehabilitation, so that Priority Species do not meet the criteria for listing as Protected Species resulting from that development.

[2] Definitions can be found (https://www.dpaw.wa.gov.au/images/documents/plants-animals/threatened-species/Listings/conservation_code_definitions.pdf)

2.4 Other Classification

The International Union for Conservation of Nature (IUCN: https://www.iucn.org/) aims to assess the conservation status of species, subspecies, varieties and even selected subpopulations on a global scale to highlight taxa threatened with extinction, and therefore promote their conservation.

There are several animals that are shown on the IUCN Red List that are not listed on any Australian Government or Western Australian Acts. The IUCN Red List does not confer any additional protection over and above that provided to Australia's native animals. However, in the interests of good project management, where possible, conservation of species within a project area will reflect a comprehensive approach to environmental management of that project.

2.5 Significant Fauna Habitats

Australia-wide, a small number of Threatened Ecological Communities (TECs) have been defined in, and are protected by, the EPBC Act. The DBCA has developed a list of TECs specific to Western Australia that include communities in addition to those listed under the EPBC Act. These communities are protected under the BC Act.

Further to these lists and, while not defined under any legislation, some fauna habitats within a project may be defined as locally significant because they (Department of Parks and Wildlife 2013):

- support rare or vulnerable species;
- support specialised or habitat specific fauna;
- are regionally or locally uncommon; or
- are restricted in area.

Such habitats are not protected under any State or Australian Government legislation. In the interests of good project management and, where possible, conservation of such locations within a project will provide the basis for the fauna component of an environmental management plan to be put in place for the duration of a project.

3 NOMENCLATURE, TAXONOMY AND DISTRIBUTION PATTERNS

The literature review conducted prior to the field survey consisted of:

- a search of Australian and State Government vertebrate fauna databases (Protected Matters Search/SPRAT, DEE, and NatureMap, DPaW, respectively);
- a search of other databases including BirdLife Australia, Bird Atlas data and Atlas of Living Australia;
- a review of published literature on the vertebrate fauna of the general area.

The following literature sources have been employed to discuss fauna distribution patterns and ecology in the preparation of this report:

Birds: Barrett et al. 2003; Johnstone & Storr 1998, 2004.

Mammals: Churchill 2008; Jackson & Groves 2015; eds Van Dyck, Gynther & Baker 2013; eds Van Dyck & Strahan 2008.

Amphibians: Tyler & Doughty 2009; Tyler & Knight 2011.

Reptiles: Wilson & Swan 2013.

The nomenclature in this report follows the references listed and more recent taxonomic revisions.

Species listed in this report will adhere to strict taxonomic order as outlined in the references above. The taxonomic order tends to reflect broad guild commonality between species. The more familiar alphabetical listing of species is ecologically irrelevant and hides much of this broader information.

4 METHODS

The focus of this study are matters of national environmental significance (MNES). That is, fauna species that would require referral under Federal legislation as part of the approvals process. It also includes species that may require referral under State legislation.

It should be noted that ecological processes and species distributions do not recognize artificial boundaries (i.e., administrative boundaries such as local government boundaries, development envelopes, etc.) and assessments are undertaken on a local and regional basis. This is an important aspect of determining the applicability of the information in relation to the landscapes being assessed.

4.1 Data Assessment

The WMDEC area consists of four sections in which fauna investigations have been focused since 1982 (Figure 1):

- South32 Marradong Operations (MAR);
- South32 Saddleback Operations (SAD);
- South32 Quindanning Timber Reserve Operations (QIN); and,
- Newmont Mining Ltd Newmont Boddington Gold Mine (NBGM).

These sections do not define ecological boundaries and fauna will move between them. However, the use of these sections as geographical reference points is intended to facilitate discussions in this document. The CBME is contained within the RLA.

4.1.1 Existing Data

South32 and NBGM hold substantial fauna data collected for the SAD, MAR, and QIN areas that has been collected primarily through multi-seasonal systematically designed surveys since 1982. The data base contains over 25,000 observations from a diverse number of sites and collected over 36 years. There is less data available for the CBME, also held by South32, although there have been several assessments in and around RLA since the systematic multi-seasonal surveys of 2000-2001. In addition, studies were undertaken in habitats alongside the 50km conveyor belt (OBC) that carries ore from SAD and MAR to the refinery.

Survey data from NBGM was made available for this survey and contained systematic survey data primarily collected by Ninox Wildlife Consulting contracted to Newmont Mining and previous owners of the mine.

All data sets contained material collated by other consultancies/research groups undertaking investigations on behalf of the mine owners since they began.

This data will be collated and assessed for its currency and relevance to the assessment. This data set will be collectively referred to as the “survey data”.

4.1.2 Database searches

Database search through the DBCA NatureMap, for threatened species records for search areas centred around WMDEC and CBME were undertaken using the following search centroid coordinates:

Area	Central Point (latitude, longitude WGS84)
WMDEC	-32.88669256, 116.4222041
CBME	-33.225464, 116.040507

A search of the Matters of National Environmental Significance was undertaken using the same centroids to identify those fauna species of greatest concern and likely to be considered as triggers for referral (Appendix 1).

Buffers were applied to these points dependent on the data availability:

Database	WMDEC Buffer	CBME Buffer
Threatened species search, including black-cockatoo breeding, roosting and foraging data	50km	15km
Protected matters search	30km	15km
Australian Living Atlas	30km	15km

Data from these searches was combined to provide a list of species for the WME proposal. As with other data used in this assessment, the more recent data (i.e., from the last 20 years) was considered the more relevant in the analysis. However, historical data did provide temporal context for locally extirpated species.

4.1.3 Literature Review

All survey reports relating to the WMDEC and CBME areas were reviewed as background reference for this study. Other material relevant to this study were also included in the desktop assessment.

4.2 Reconnaissance Survey

A field assessment of additional areas not accessed during the earlier assessment in 2015 was to be undertaken between 12-17 November 2018. Standardised habitat descriptions, potential habitat tree assessments and searches for signs or individuals of threatened species were to be carried out in these areas. The survey was undertaken by two experienced field ecologists, Eddy Cannella and Andrew McCreery (Table 1).

Table 1 Team members for the fauna assessment.

Name	Position	Experience	Tasks
Eddy Cannella	Senior Zoologist	>29 years of experience	Field assessment, Data analysis, Report preparation
Andrew McCreery	Assisting Zoologist	>7 years of experience	Field assessment

During the survey, access to some of the land parcels could not be obtained, therefore, the survey was reduced from 5 days to 1 day and only 2 of the 3 areas were assessed.

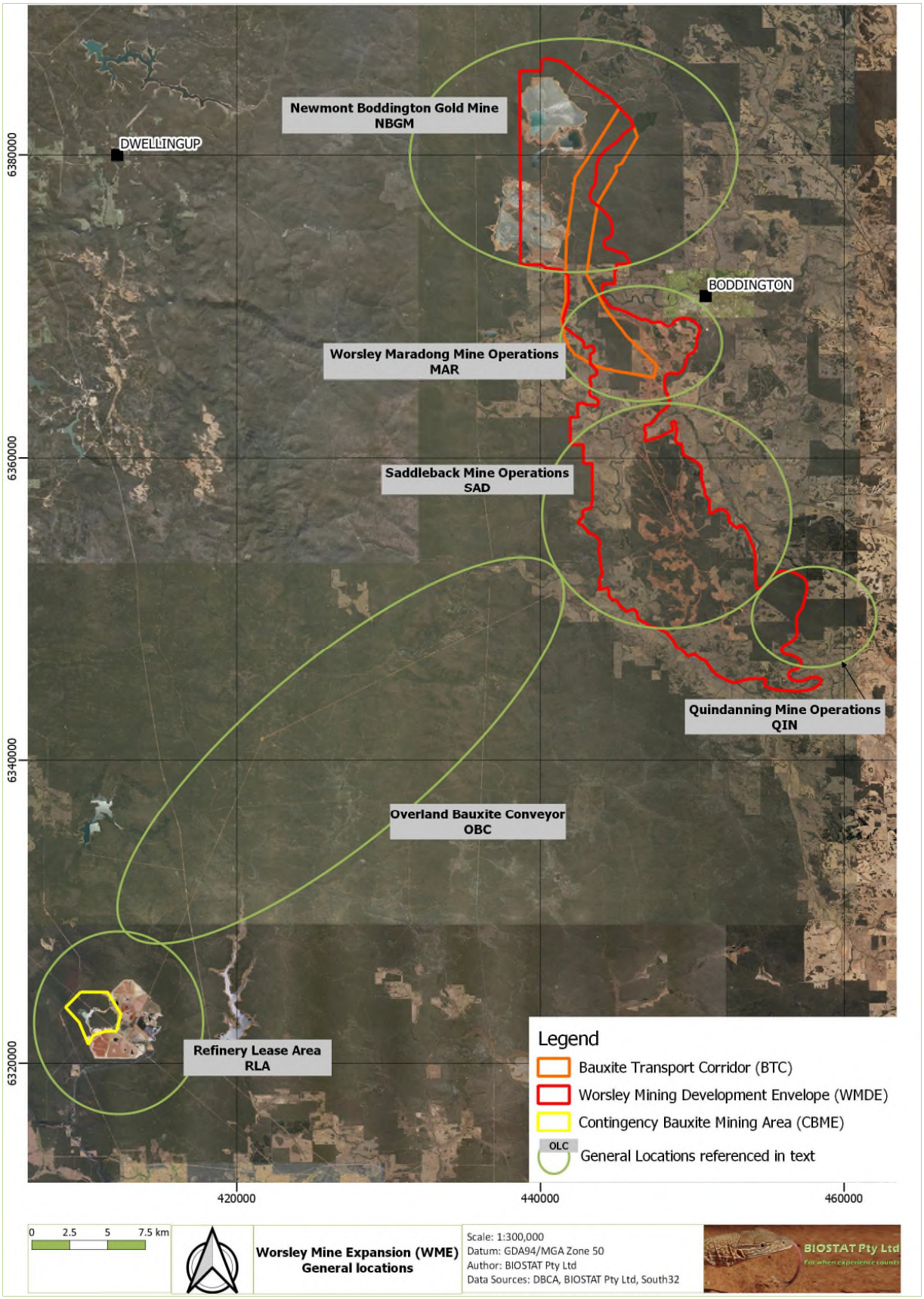

Figure 1 Locations in WME project area referred to in text.

5 RESULTS AND DISCUSSION

5.1 Data Currency and Relevance

5.1.1 Literature Review

Twenty-four reports describing the fauna assemblages of the WMDEC and CBME areas were identified and collated for the review (Table 2). Two additional reports of surveys along the conveyor belt linking the two areas together were also included as they report on fauna assemblages within similar habitats. All but four of the projects were undertaken by Ninox Wildlife Consulting. Biodiversity surveys were undertaken at SAD, NBGM and RLA areas from the earliest point in their developments (circa 1982). BIOSTAT continued the implementation of Worsley's rehabilitation fauna monitoring program since 2014.

Most of these are unpublished internal reports, although the "Phase Two" at BBM (Worsley Alumina Pty Ltd 1985) and the "Gold Mine Project" at NBGM (Worsley Alumina Pty Ltd 1999) studies were made available publicly at the time (both out of print). Two reports are currently in preparation for survey work undertaken in 2017-2018 at SAD and QIN. In addition, a "Phase" report is also in the process of being prepared which will undertake an assessment of fauna at SAD from surveys undertaken over the last 10 years (BIOSTAT Pty Ltd in prep.) .

Eighteen of the documents report on the results of multi-seasonal systematic biodiversity surveys. It is important to note that well designed biodiversity surveys that focus on systematic and repeatable collection of data that investigate both spatial and temporal variability, provide substantially more robust data than is possible using other techniques such as single season trapping surveys, targeted surveys or site assessments. Furthermore, the methodology employed in these studies was relatively consistent with only minor alterations in physical design and the addition of equipment, such as trail cameras, ultrasonic recorder, as these became available and relevant to the focus of the studies. The data resulting from such surveys lend themselves to vigorous statistical analysis and can be used to benchmark and characterise ecosystems with a greater level of certainty. In this capability, these survey designs exceed the robustness and scientific rigour of the requirements usually associated with Level 1 and Level 2 survey requisites.

It was not possible to source all the original reports for fauna surveys at the NBGM prior to 1999 although the data is still held by South32. A "Phase" document published in 1999 (Worsley Alumina Pty Ltd 1999) contained an analysis of all data collected to that point as an investigation into the biological aspects of NBGM. Systematic seasonal studies were undertaken in 2003 and 2012 (Ninox Wildlife Consulting 2003, 2012d) to investigate alternative rock waste areas as part of the NBGM mine expansion. A biodiversity assessment was undertaken in 2011-2012 in an area potentially designated for the expansion of the large northern tailings dam (Ninox Wildlife Consulting 2012a). The most recent study at NBGM consisted of the translocation and salvage of fauna at sites being cleared for the expansion of the waste dump (Ninox Wildlife Consulting 2016).

The first MAR survey (Ninox Wildlife Consulting 2007b) focused on the eastern portion of the Marradong Timber Reserve (MTR). A second survey of the western portion of the MTR was undertaken in 2012 (Ninox Wildlife Consulting 2012c). Most of MTR has been cleared and mined with rehabilitation undertaken on some areas in the eastern portion.

There has been a substantial level of effort concentrated on SAD, the major bauxite mine area. Surveys include pre-mining areas (Ninox Wildlife Consulting 1992, 1997, 1998a; Worsley Alumina Pty Ltd 1985), monitoring programs to evaluate the progress of rehabilitation in relation to fauna assemblages (BIOSTAT Pty Ltd 2015b, 2018; Ninox Wildlife Consulting 2006, 2012b), and comprehensive research investigations using compilations of environmental data (BIOSTAT Pty Ltd in prep.; Ninox Wildlife Consulting 1992; Worsley Alumina Pty Ltd 1985).

Table 2 Reports of fauna surveys undertaken at PBA and EBMA.

Area	Location	Researchers	Year	Report Title	Level of Assessment
WMDEC	**NBGM**		1999	Worsley Alumina Boddington Gold Mine Project. Flora and Fauna Studies.	A compilation and analysis of baseline surveys undertaken to 1998.
			2003	The vertebrate fauna of the Boddington Gold Mine[3]	3 season systematic trapping survey with systematic area search bird surveys.
			2012	Vertebrate fauna survey within Newmont Boddington Gold Mine: An assessment of potential waste rock disposal areas.	
			2012	A vertebrate fauna survey within the Saddleback Treefarms area. Newmont Boddington Gold Mine. An assessment of potential residue disposal areas.	
			2016	Vertebrate fauna translocation program from the waste rock dump extension area to be developed within Newmont Boddington Gold Mine.	An intensive 2 month trapping program to translocate all terrestrial vertebrate fauna caught during the period prior to the clearing of vegetation.
	MAR		2007	Vertebrate fauna survey of Marradong Timber Reserve 2006-2007.	3 season systematic trapping survey with systematic area search bird surveys.
			2012	Vertebrate fauna survey of Marradong Timber Reserve 2012.	
	SAD	Ninox Wildlife Consulting	1985	Worsley Alumina Project. Flora and Fauna Studies, Phase Two.	A compilation and analysis of data collected to 1985.
			1992	Phase Three: Vertebrate Fauna Studies, 1991-1992.	A compilation and analysis of data collected to 1992.
			1997	A vertebrate fauna survey of the proposed Northern Saddleback mining area 1996-1997.	3 season systematic trapping survey with systematic area search bird surveys.
			1998	A vertebrate fauna survey of the proposed Southern Saddleback mining area 1997-1998.	
			2003	Monitoring of vertebrate fauna within forest & rehabilitation at the Boddington Bauxite Mine 2002 – 2003	
			2007	Monitoring of vertebrate fauna within forest & rehabilitation at the Boddington Bauxite Mine 2006 – 2007	
			2012	Monitoring of vertebrate fauna within forest & rehabilitation at the Boddington Bauxite Mine 2009-2011 including comparisons with previous sampling.	
		BIOSTAT Pty Ltd	2015	Vertebrate fauna monitoring, Boddington Bauxite Mine 2014-2015.	
			In prep	Vertebrate fauna monitoring, Boddington Bauxite Mine 2017-2018	
	QTR	Ninox Wildlife Consulting	2002	The vertebrate fauna of the Quindanning Timber Reserve	
		BIOSTAT Pty Ltd	In prep	Biodiversity survey of the Quindanning Timber Reserve 2017-2018 (working title)	

[3] The original focus of this study was on a 3-season survey. Due to the unexpectedly large number of Chuditch caught (47 over the entire survey period) during the initial survey, extra sites and additional survey events were undertaken purely to monitor the population of this species.

Area	Location	Researchers	Year	Report Title	Level of Assessment
RLA	**CBME**	Ninox Wildlife Consulting	2002	The vertebrate fauna of the Refinery Lease Area and Mornington Mills Block	3 season systematic trapping survey with systematic area search bird surveys.
			2007	An Assessment of the Presence of the Western Ringtail Possum at the Worsley Alumina Pty Ltd Refinery, near Collie, Western Australia	Desktop assessment undertaken using field data.
		Bamford Consulting Ecologists	2011	Conservation significant fauna and habitat tree survey. Proposed BRDA cleared areas, Worsley Alumina Refinery	Targeted surveys for species of conservation significance.
		BIOSTAT Pty Ltd	2015	Vegetation Clearing: Fauna Assessment	Habitat and fauna assessment of small areas at the edge of EBMA.
			2016	RDA1 Baseline Vertebrate Fauna Monitoring 2015 South 32 Worsley Alumina Refinery	Baseline 2 season survey of a rehabilitated tailings dam to the east of MMB
Additional Studies[4]		Ninox Wildlife Consulting	1998	Vertebrate Fauna of the Overland Conveyor Corridor 1997-1998	3 season systematic trapping survey with systematic area search bird surveys. Included specific studies to determine fauna movements across the conveyor.
			2004	A Vertebrate Fauna Survey of the Overland Conveyor Corridor between the Boddington Bauxite Mine and Refinery Lease Area near Collie, Western Australia	
			2010	A Vertebrate Fauna Survey of the Overland Conveyor Corridor 2009 - 2010	

[4] These studies included sites located close to both WMDE and CBME and in State Forests between the two areas.

Systematic biodiversity surveys of the Quindanning Timber Reserve (QTR) were undertaken in 2000-2001 (Ninox Wildlife Consulting 2002) and 2017-2018 (BIOSTAT Pty Ltd in prep.). The most recent survey replicated the original study by using the same survey sites. Changes in methodology in addition to the original trapping grid design and included the use of Funnel Traps, Trail Cameras, Ultrasonic Recorders and Bioacoustic Recorders.

Three surveys were completed for the OBC in 1998, 2004, and 2010 (Ninox Wildlife Consulting 1998b, 2004, 2010). The survey area is within the State Forest between the CBME and WMDEC and represent a relatively contiguous area of remnant habitats. The survey focus was on the potential impact of the Overland Belt Conveyor on fauna movements but also compared fauna assemblages between upland (hills) and lowland (valley) habitats. Systematic bird surveys were not undertaken on the second and third studies along the conveyor and the focus was directed to a live trapping design.

The reports outlined the results of surveys but also interpreted the data to define the quality of habitats, the use of surveyed habitats by fauna, and the observed seasonal variations in relative abundance of fauna. Unlike less robust survey methods, systematic repeatable survey results in quantitative data that can be analysed to make it possible to support interpretations of ecosystems processes (Cochran 2007). In the case of the monitoring program undertaken at SAD, the extensive level of data collected over a decade provides a very strong assessment of terrestrial vertebrate fauna ecology.

The quantity and currency of surveys at the RLA are not comparable to the WMDEC area. Only one multi-seasonal survey has been undertaken at the CBME in 2000-2001 (systematic surveys were carried out in the RLA area prior to construction in 1982). Since then several smaller surveys have been carried out in other areas associated with the RLA but not within the CBME (e.g., BIOSTAT Pty Ltd 2014, 2015a). Further investigations of the CBME are recommended to update and improve understanding of the fauna within this area. To update the available data, the preferred level of assessment at this site would ideally be a repeat of the multi-seasonal survey undertaken in 2000-2001, possibly utilising the same survey sites.

The floristics and vegetation structure covering most of the WMDEC and CBME have been surveyed extensively over a similar period (i.e., 1982 to the present). This report will make use of the vegetation community mapping undertaken by Mattiske Consulting Pty Ltd (Mattiske Consulting Pty Ltd 2018).

Several articles have been published in peer reviewed journals have resulted from projects undertaken at NBGM and QIN (Table 3). The focus of research at NBGM was in black-cockatoo ecology and included investigations into foraging and breeding activities in and around the mine. Other articles included research notes on chuditch (*Dasyurus geoffroii*) and *Phascogale* sp. at NBGM and QIN, respectively.

Currently, there is research continuing at NBGM and BBM on black-cockatoo species habitat utilisation through Murdoch University. This research has identified substantial roosting sites across the area in addition to resource usage patterns.

The available information from the reports and published articles is substantial and can provide a robust assessment of the fauna of the WMDEC. Further investigations of the CBME are required. As indicated earlier, to fully understand the fauna and habitat use of the CBME, a repeat of the previous systematic survey methodology is recommended. This would allow for a direct comparison of data that could not occur if, for example, targeted surveys are employed in the investigations.

Table 3 Peer reviewed published articles resulting from research projects at BBM and NBGM.

Authors[5]	Year of Publication	Title
Cannella, Browne-Cooper, Fairbairn, & Turpin	2018	Possible sympatry between kenngoor (*Phascogale calura*) and wambenger (*Phascogale tapoatafa wambenger*)
Cannella & Henry	2017	A case of homing after translocation of chuditch, *Dasyurus geoffroii* (Marsupialia: Dasyuridae)
Doherty, Wingfield, Stokes, Craig, Lee, Finn & Calver	2016	Successional changes in feeding activity by threatened cockatoos in revegetated mine sites
Lee, Finn & Calver	2013	Feeding activity of threatened black cockatoos in mine-site rehabilitation in the jarrah forest of south-western Australia
Lee, Finn & Calver	2013	Ecology of black cockatoos at a mine-site in the eastern jarrah-marri forest, western Australia
Biggs, Finn, Taplin & Calver	2011	Landscape position predicts distribution of eucalypt feed trees for threatened black-cockatoos in the northern jarrah forest, Western Australia
Lee, Finn & Calver	2010	Mine-site revegetation monitoring detects feeding by threatened black-cockatoos within 8 years

5.1.2 Data Currency and Relevance

A substantial set of data has been collated for this analysis. They have come from several sources with varying levels of adequacy and robustness. There are limitations inherent in any data set:

- The database held by South32 is continuously curated by BIOSTAT Pty Ltd. As errors are encountered they are corrected, or the record omitted if information is not available to allow correction. The same level of confidence for other data sets is unknown and are assumed to be adequate.
- Survey data is point location specific. Records from other sources tend to be correlated with accessibility to areas. For example, there are many occasions where records are aligned with tracks or roads. This can result in gaps in the landscape lacking any data. Therefore, the likelihood of occurrence of a species in the wider landscape is a result of extrapolation based primarily on the availability of suitable habitats.

Long-term and biodiversity monitoring are important in understanding the dynamic and stochastic nature of ecosystems (Lindenmayer 2012; Lindenmayer & Likens 2018). It is very important that seasonal (temporal) and landscape (spatial) variability is measured to assist in understanding fauna utilisation of the landscape and changes that may have occurred to influence that landscape use. Additionally, long-term studies are very important in surveying for rare or elusive species whose detection rates, by their very nature, are low (Thompson 2013).

Generally, by their very nature, designs for short-term surveys, such as targeted surveys or site assessments, provide a simplistic overview of ecosystems within landscapes. Short-term surveys tend to inordinately rely on the investigators knowledge of the survey area, especially in the interpretation of the limited data usually obtained from such surveys. The interpretation can be compromised if the investigator is unfamiliar with the ecosystems in the area or lack the understanding of ecological variation they may encounter. Short-term surveys are characterised by:

- lower levels of detection of rare and threatened species;
- inability to assess variability in fauna distributions and relative abundances in the landscape;
- lack the ability to consider environmental processes and interactions between fauna groups in landscapes;
- inability to assess seasonal variations in fauna use of landscapes; and,
- have a limited ability to investigate interactions of environmental factors in ecosystems

[5] Full details can be found in section *8 References*

As indicated previously, most of data for the WME is derived from robust systematic surveys designed specifically to allow repeatable standardised data collection. The use of similar designs and similar methodologies across investigations provide robust data that can be used in direct comparisons. Data collected at WME sites are maintained by both South32 and BIOSTAT Pty Ltd.

Furthermore, the surveys integrate the temporal variation with multi-seasonal events being mandatory components in their design. This level of robustness increases the understanding of ecosystems and the way fauna interacts in those systems. It also raises the level of certainty in interpretation well beyond what is possible with data derived from non-systematic survey design methods, especially single effort surveys (e.g., site assessments, single season trapping or targeted surveys).

The level of survey effort for different survey methods using the available documentation (Table 2), but only for the last 20 years, was calculated for all areas (Table 4). The methods employed include:

- **Live Trapping** – this involves the use of fenced pit traps, cage and box traps, and funnel traps. These are deployed in a standard grid pattern at sites. Monitoring sites in rehabilitation and some forest control areas at BBM are permanent and re-used on cyclic schedule. The number of nights traps are opened changed from 6 nights to 7 nights in 2000. Survey effort shown in the table is calculated as trap nights.
- **Systematic Bird Surveys** – these have developed from distance transect surveys employed until the mid-1990s by Ninox Wildlife Consulting and later replaced with timed area searches. The bird surveys are carried out a minimum of 5 days at each site and the timing of the searches is rotated within the morning period. Systematic bird surveys are likely to identify most bird species within a site as opposed to opportunistic or single survey methods. Survey effort is calculated as minimum total hours.
- **General Searches** – searches of habitats, including sites that are being trapped, is a standard design feature of all systematic surveys. It is calculated as the minimum total number of personnel hours for each area (usually a minimum of 2 hours). These general searches involve hand searches for reptiles and other small mammals, and searches for signs of activity such as nesting, tracks and scats. The use of highly experienced personnel in the field ensured a high level of search efficacy which captured all signs of activity regardless of which terrestrial vertebrate fauna group.
- **BC (black-cockatoo) Targeted Surveys** – due to the increasing vulnerability status of the three black-cockatoo species (*Calyptorhynchus banksii naso*, forest red-tailed black-Cockatoo; *Calyptorhynchus latirostris*, Carnaby's black-cockatoo; *Calyptorhynchus baudinii*, Baudin's black-cockatoo) in Western Australia, standardised Federal survey guidelines were established in an effort to provide a level of certainty in the manner in which surveys could be assessed (Department of Environment and Energy 2017; Department of Sustainability, Environment, Water, Populations and Communities 2012). These guidelines have been used in several of the more recent surveys where it was deemed necessary. Guidelines provide a minimum set of goals and aims to be achieved. Not all survey methodologies suggested in guidelines result in robust data that could increase the level of certainty in determining impacts. Survey effort shown in the table is calculated as minimum total hours.
- **Other Targeted Surveys** – at various times since 1982, searches targeting specific species were undertaken during the projects. These included targeted searches for black-cockatoo species, chuditch, quenda (*Isoodon fusciventris*), western ring-tail possum (*Pseudocheirus occidentalis*), and common brushtail possum (*Trichosurus vulpecula hypoleucus*) searches. The effort in these searches is calculated as for General Searches and were in in addition to those searches.
- **Bat Survey** – until the advent of electronic recording equipment, Bat surveys were undertaken using Mist Nets or Harp Traps and only in situations where suitable locations could be found (i.e., farm dams, small creek line). These methods were replaced with Anabat (Titley Scientific) and, later, SongMeter Systems (Wildlife Acoustics) with much improved identification

capabilities of the microbat species. Survey effort shown in the table is calculated as recording nights.

- **Bioacoustic Recording** – as with the bat surveys, bioacoustic recording (BAR) is utilised to record audible calls made by night birds (owls in particular) and frogs. In addition, they can be used to identify the presence and dial cycle of species such as black-cockatoo. Survey effort is shown in the table calculated as recording days.
- **Passive Survey** – The evolution of trail cameras (Infra-red triggered) has allowed their deployment in fauna surveys. The variation in technical abilities of cameras makes them extremely difficult to use in a systematic manner. There are also issues in using these cameras for certain groups of fauna such as birds and smaller ground-dwelling and fossorial species. To 2018, the use of trail cameras is purely as an adjunct to opportunistic assessment. Survey effort shown in the table is calculated as recording days.
- **Habitat Tree Surveys –** As part of the environmental regulatory process, it is required that Potential Habitat Trees (PHT), as outlined in the referral guideline (Department of Sustainability, Environment, Water, Populations and Communities 2012), are located prior to any vegetation clearing for mine operations. This information is used to avoid or mitigate potential impacts for trees that may hold suitable hollows for black-cockatoos. Both mining companies, South32 and NBGM, collect and maintain this data. The value of this data is limited by its coverage in the landscape with the focus being in areas identified for vegetation clearing. However, the data can provide an indication of the distribution of PHT within specific locations.

The chronosequence of survey effort is displayed in Table 4 for the last 20 years of activity in the WMDEC and RLA areas. The survey effort in all sites within the WMDEC area is substantial and recent, especially at SAD. In most cases close to 50% of the survey effort has been since 2008, i.e., in the last 10 years.

The intensity of the surveys undertaken in each of the areas resulted in 68,185 individuals recorded from 180 species of terrestrial vertebrate fauna (birds, herpetofauna and mammals) during systematic surveys (Table 5). This does not include individuals recorded opportunistically that added another 9 species of bird, 1 species of native mammal, and 4 species of reptile and a total of 3,727 individuals recorded.

Additional data on black-cockatoos and standardised habitat assessments were carried out for the earlier assessment of Mine Expansion Areas (BIOSTAT Pty Ltd 2017). The data collected included transects for PHT, standardised fauna habitat assessments, bioacoustic recording and ultrasonic recordings.

Although the volume of data for the WMDEC is substantial, it was highlighted in the previous section, information for CBME is not as current or extensive. It is recommended that further investigations of this area be undertaken using robust systematic survey designs.

The expansive long-term fauna data presented in this document to support the referral documentation is regarded as substantial, current and relevant to the project.

Table 4 Survey effort at the various sites of the proposed WMDEC and CBME areas since 1998.

Area and Trapping Method	Survey year[6] 1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	Totals
NBGM																						
Live Trapping					11,040										14,602				12,046			**37,688 Trap Nights**
Systematic Bird Survey					150										202.5							**352.5 Minimum Hours**
General Searches					160																	**160 Minimum Hours**
Other Targeted Survey					30																	**30 Minimum Hours**
BC Targeted Survey															48							**48 Minimum Hours**
SAD																						
Live Trapping	7,200					6,480				6,912				6,080				7,450			7,755	**41,877 Trap Nights**
Systematic Bird Survey	100					120				120				120				70			70	**600 Minimum Hours**
General Searches	120					96												66			10	**302 Minimum Hours**
Bat Survey																		24			68	**92 Recording Nights**
Bioacoustic Recording																		6			18	**24 Recording Days**
Passive Survey																		58			349	**407 Recording Days**
MAR																						
Live Trapping										3,528					5,040							**8,568 Trap Nights**
Systematic Bird Survey										70					70							**140 Minimum Hours**
General Searches										42					30							**72 Minimum Hours**
Other Targeted Survey										42					30							**72 Minimum Hours**
QIN																						
Live Trapping				7,200																	6,825	**14,025 Trap Nights**
Systematic Bird Survey				100																	60	**160 Minimum Hours**
General Searches				120																	110	**230 Minimum Hours**
Other Targeted Survey				30																		**30 Minimum Hours**
Bat Survey																					60	**60 Recording Nights**
Bioacoustic Recording																					10	**10 Recording Days**
Passive Survey																					260	**260 Recording Days**

[6] This is the year in which the last of the survey events occurred

Area and Trapping Method	Survey year[6]																					Totals
	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	
RLA																						
Live Trapping				9,600														952				**10,552 Trap Nights**
Systematic Bird Survey				150														31.5				**181.5 Minimum Hours**
General Searches				160										40			30	48				**278 Minimum Hours**
Other Targeted Survey				30																		**30 Minimum Hours**
Bat Survey																		6				**6 Recording Nights**
Bioacoustic Recording																		12				**12 Recording Days**
Passive Survey																		56				**56 Recording Days**
OBC																						
Live Trapping	7,776					7,334							7,776									**22,896 Trap Nights**
Systematic Bird Survey	135																					**135 Minimum Hours**
General Searches	81																					**81 Minimum Hours**
Bat Survey	10																					**10 Recording Nights**

Table 5 Species abundance and species richness for each year since 1998.

		Systematic Records Only						
Year	Area	Total Abundance	Total Species Richness	Bird Species Richness	Native Mammal Species Richness	Introduced Mammals Species Richness	Frog Species Richness	Reptile Species Richness
1998	**OBC**	**719**	73	35	8	3	5	22
	SAD	**1,256**	69	40	10	3	1	15
1999	***No surveys undertaken***							
2000	**QIN**	**1,825**	84	53	9	3	6	13
	RLA	**1,945**	76	46	7	3	3	17
2001	**NBGM**	**2,622**	94	71	6	1	1	15
	QIN	**3,105**	79	50	7	5	3	14
	RLA	**5,271**	84	49	9	5	7	14
2002	**NBGM**	**3,330**	78	50	7	5	7	9
	SAD	**2,482**	69	43	9	4		13
2003	**OBC**	**212**	22		8	3	6	5
	SAD	**3,157**	79	48	10	4	5	12
2004	**OBC**	**234**	26	1	8	3		14
2005	***No surveys undertaken***							
2006	**MAR**	**989**	64	37	7	2	2	16
	SAD	**3,774**	85	57	8	3		17
2007	**MAR**	**990**	63	37	9	3	2	12
	SAD	**1,467**	73	48	8	3		14
2008	***No surveys undertaken***							
2009	**OBC**	**413**	36	2	6	2	7	19
	SAD	**1,696**	70	41	7	4	1	17
2010	**OBC**	**310**	25	1	6			18
	SAD	**342**	50	26	5	4	3	12
2011	**NBGM**	**931**	62	35	8	1	9	9
	SAD	**1,577**	61	44	5	3		9
2012	**NBGM**	**1,471**	81	42	9	1	4	25
	NBGM	**2,328**	89	49	8	1	7	24
	MAR	**1,224**	65	36	8	1		20
2013	***No surveys undertaken***							
2014	**SAD**	**3,348**	86	52	8	3	4	19
2015	**SAD**	**2,345**	77	51	7	5	1	13

Systematic Records Only								
Year	Area	Total Abundance	Total Species Richness	Bird Species Richness	Native Mammal Species Richness	Introduced Mammals Species Richness	Frog Species Richness	Reptile Species Richness
	RLA	**835**	46	29	4	4	3	6
2016	**NBGM**	**1,209**	27		7	1	1	18
2017	**SAD**	**2,646**	90	52	13	3	2	20
	QIN	**2,892**	81	49	7	5	4	16
2018	**SAD**	**5,258**	86	49	16	6	5	10
	QIN	**5,982**	84	52	16	5	1	10
Grand Total		**68,185**	**180**	**98**	**24**	**8**	**13**	**37**

5.2 Landscape Types and Fauna Habitats

Most animals are more influenced by vegetation community physical structure and soil types than plant assemblages *per se*. Faunal assemblage distributions are generally aligned to vegetation community and landscape function at the scale in which the fauna exists. Wider ranging species, whose home ranges may be measured in km^2, are unlikely to discriminate between the sometimes-subtle distinctions that characterise floristic differences between associations. The smaller spatially confined species rely on microhabitat characteristics such as soil types, humic contents, ground cover, patch radiant values which are often not considered as important to wider ranging species. In anthropogenic modified environments, specifically agricultural areas, the amount and quality of habitats and the diversity of habitats are the more important determinants in biodiversity (Gardiner et al. 2018; Redlich et al. 2018; Sawatzky, Martin & Fahrig 2019).

5.2.1 Overview of WMDEC Habitats

The previous assessment of a subset of the WMDEC area identified a total of 16 major landscape type (Table 6) using available vegetation community mapping data and a field assessment of habitats (BIOSTAT Pty Ltd 2017). A table of fauna habitats and their vegetation community equivalents is provided in Appendix 2 and photographic examples of the habitats are provided in Appendix 3. These 16 landscape types have been categorised into 5 major fauna habitat types that reflect landscape position and general habitat function similarities.

The WMDEC covers a large area, approximately 2,8610 ha, containing mostly cleared lands (approximately 12,662 ha) within a primarily wheat and crop farming district (Figure 2). These cleared lands represent highly homogenous landscape types with generally poor values for native fauna.

In the agricultural lands within these cleared landscapes are stands of remnant native trees. For this study, these remnants have been classified under the appropriate vegetation community categorisation shown in Table 6. The remnants represent ubiquitous features of agricultural lands and have been retained generally as shelter belts for stock. They are characterised as:

- Generally consisting of stands of trees, with various combinations of jarrah/marri/blackbutt/flooded gum/wandoo (dependent on their position in the landscape);
- usually in varying levels of condition and of relatively homogenous age cohort (e.g., Plates 1 and 2: Appendix 3);
- lacking a native vegetation understorey;
- if native understorey exists, it is sparse and in very poor condition due to grazing; and,
- ground cover is dominated by introduced pasture grasses and grain species.

These stands, however, provide a resource for native fauna, especially volant fauna (i.e., birds and bats). They can act as supplementary foraging resource or provide breeding/denning/roosting habitat. Remnants can also provide some level of connectivity within the landscape allowing for movements of individuals or flocks between more suitable habitats.

Conversely, introduced predators, such as fox (*Vulpes vulpes*) and cat (*Felis catus*), benefit from the less complex and homogeneity of agricultural landscapes (Carter & Luck 2013; May & Norton 1996; White et al. 2006). This can increase the risk of depredation within these “in-field” remnants and in areas where agricultural areas are adjacent to more complex and higher quality native vegetation communities.

Plantations within agricultural systems are either established for commercial properties or to create shelter belts/feed shrubs for livestock and are predominantly of Tasmanian blue gum (*Eucalyptus globulus*). They can provide additional foraging resource and some limited connectivity, if adjacent to relatively undisturbed habitats. In most cases it would be unlikely that plantation trees would reach a point where hollows would form prior to harvesting. Plantations should only be considered as a last

resort temporary low quality refuge for resource enhancement (e.g., Arnold 2003; Davies Jr. & Recher 2012).

Riparian, wetland and mesic valley systems, including the Hotham River and its tributaries, are located through the WMDEC landscape (Figure 3: Plates 3, 4, 5: Appendix 3). Although the main Hotham River branch has been excluded from the WMDEC by a 100m buffer, it remains part of the extended drainage ecosystems in the areas via direct physical connections or proximity to vegetation communities and associated wetlands. The deeper pools that support water for substantial periods act as refuge for aquatic species as well as frog, waterfowl and the native mammals such as rakali (*Hydromys chrysogaster*). The role of riparian and mesic systems and the landscape connectivity they represent requires both upstream and downstream level impacts to be assessed and managed.

The vegetation communities that exist along the tributaries range from melaleuca woodlands and heaths (MW and MS), jarrah/marri/flooded gum riparian woodlands (FD), and flooded gum woodlands (FG). Additional mesic habitats that are occasionally associated with riparian systems habitats include blackbutt and jarrah-marri communities (BB and JS). These occur in lower slopes and valleys in the landscape and can sometimes be seasonally inundated.

The largest of these communities are the flooded gum woodlands (FG: 699 ha) and the melaleuca shrublands (MW: 135 ha). The former is associated with the Hotham River and its drainage tributaries of while the melaleuca shrublands form distinct habitats throughout the WMDEC however with the largest concentration at QIN.

The jarrah-marri communities (DL, JC, JM) cover a substantial area of the WMDEC (approximately 8,808 ha) (Figure 4). The differentiation between these communities relates to their position in the landscape and the associated soil type and soil structure (Plates 6, 7, 8: Appendix 3). Most these habitats are found within the MAR, QIN and NBGM. In many cases, these Jarrah/Marri woodlands have been logged at some time and tend to support trees of similar age cohorts with minimal variation. A substantial portion of these habitat types has been cleared for mining in the SAD area, as they tend to correspond to the presence of bauxite ore. The largest contiguous remnants of these habitats exist at NBGM and QIN and form forest complexes that include other major habitat types such as wandoo woodlands. A large area remains at MAR although areas of this remnant are proposed to be cleared as part of the expansion of mining operations at Marradong.

Generally, most upper slope and ridge jarrah/marri communities (JC/JM) are found on rockier soils and tend to have a lower tree layer characterised by the presence of bull banksia (*Banksia grandis*). Rocky lateritic outcrops or granite capping is common within these habitats. Understorey consists primarily of low shrubs and native grasses. Where they occur on mid and lower slopes (JM/JC/DL), these communities tend to be located on more humic soils with a relatively denser shrub understorey.

The presence of western sheoak (*Allocasuarina fraseriana*) is an important landscape characteristic for these jarrah/marri communities. These areas have the potential to support populations of wambenger (*Phascogale tapoatafa*) and kenngoor (*Phascogale calura*). Additionally, western sheoak fruit is a component of the food resource types for black-cockatoo.

These habitats represent large but fragmented areas within WMDEC. In this type of landscape their role is to provide refuge for fauna as breeding, denning/roosting and foraging habitats. More importantly, they provide a means for movements across the fragmented landscape. Connectivity is a critical aspect for the sustainability of viable populations within the landscape and should be a prime consideration in impact assessments that may result in greater fragmentation and reduced connectivity.

Table 6 Areas of fauna habitats identified in the WMDEC.

Fauna Habitats		Fauna Habitat Code	General Fauna Type	WMDEC Area (ha)*	WMDE Area (ha)*	BTC Area (ha)*
Blackbutt woodlands on lower slopes		**BB**	**Riparian/Wetland and associated communities**	34	34	27
Mosaic of marri/jarrah on lower slopes and flooded gum riparian communities		**FD**		5	5	5
Flooded gum woodlands riparian community.		**FG**		699	640	253
Jarrah/marri valley floors/swamps		**JS**		<1ha	<1ha	0
Melaleuca shrublands on seasonally wet valley floors		**MS**		135	126	40
Flooded gum/Melaleuca shrublands on seasonally wet valley floors		**MW**		2	2	0
Marri/jarrah on lower slopes		**DL**	**Jarrah/marri communities**	409	399	152
Jarrah/marri/Allocasuarina woodlands on slopes and ridges		**JC**		4,987	4,945	1,138
Jarrah/marri woodlands on slopes		**JM**		3,412	3,151	730
Low *Eucalyptus* woodland over low shrubs		**ML**	**Mallee woodlands**	14	12	2
Wandoo woodlands		**WO**	**Wandoo communities**	2,675	2,426	581
Heaths including perched heaths		**PH**	**Heath communities**	149	149	10
Rehabilitation	**Rehabilitation not in Agricultural Areas**	**RE**	**Others**	2,977	2,977	45
	Rehabilitation in Agricultural Areas	**RE – Ag**		27	3	26
Plantations	**Plantations not in Agricultural Areas**	**PL**		178	178	0
	Plantations in Agricultural Areas	**PL – Ag**		244	243	1
Dam		**Dam**		1	1	0
Cleared Lands	**Cleared Lands not in Agricultural Areas**	**CL**		6,127	6,126	396
	Cleared Lands in Agricultural areas	**CL – Ag**		6,535	6,378	739
			Grand Total	**28,610**	**27,796**	**4,145**

** figures should be used as approximation for relative comparisons.*

The wandoo woodland habitat is a common feature of the region covering approximately 2,675 ha (Figure 5). These areas occur on sandy to clay soils and can be found in all elevations in the landscape. Lower storeys and ground cover can vary widely, including *Xanthorrhoea* sp, *Acacia* sp and *Hakea* sp (Plates 9 and 10: Appendix 3). All the areas visited during the assessment show signs of previous logging, characterised by the relative uniformity in tree age cohorts even in areas that had not been logged for many decades (e.g., eastern portions of QIN).

Wandoo form hollows readily, which makes these habitats an important component in the biodiversity of the landscape. The flowers and fruit also provide a feeding resource for several vertebrate fauna species. Most of the wandoo woodlands, as with other native remnants, have been logged and display relatively homogenous age cohort demographics.

Heaths and perched heaths occur infrequently in the landscape (Figure 5). Areas of heath are found in the NBGM, MAR and in a small area associated with the Conveyor Belt travelling between SAD and the RLA. Heaths tend to occur on shallow soils usually over granite cap-rock. They offer a distinct habitat type within the landscape. The high diversity of flowering plant species in such habitats is favoured by such fauna as honey possum, *Tarsipes rostratus*, as well as other nectarivores and insectivores (e.g., honeyeaters, *Sminthopsis* sp, *Chiropterans*, etc.).

There are several other habitats which are of varying ecological value. Rehabilitated areas (RE) form an important component of the landscape with approximately 2,997 ha (including 27 ha of rehabilitated areas on agricultural landscapes) completed to 2018[7]. Their value to fauna is further enhanced if they form part of the landscape connectivity joining less disturbed habitats. Within the controlled operations in mine sites, rehabilitated areas tend to progress along a relatively predictable path as they mature; from bare ground to heath-like habitat through to shrubland, low closed forest, and finally tall forest. After 5-8 years, these areas are useful foraging resource for black-cockatoo species, nectarivores and granivores (Lee, Finn & Calver 2010a).

Dams are present throughout the WMDEC. They are artificial and, in most cases, non-permanent water sources. They do provide an additional water source for many native species and can act as temporary refugia for waterfowl.

Even with the level of fragmentation and the poor quality of some of the remnants within the WMDEC, the local area supports relatively diverse fauna assemblages. This includes threatened species such as all three black-cockatoo species, chuditch, kenngoor, woylie (*Bettongia penicillata ogilbyi*), and others, which reflects not only the resilience of these species, but also the importance of remnant vegetation.

One component that could not be assessed for WMDEC assessment was the impact of fire. All efforts are made to minimise fire on mine leases and prescribed burning is not part of the management plan for the mine site areas. However, bush-fires have erupted in the WMDEC area at different times especially in the State Forest areas at the western boundaries. The lack of fire over a long period has altered the structure of remnant forest blocks within the WMDEC mine area and are different to areas of similar vegetation communities outside lease boundaries. This difference has not been quantified and is an area of special interest for management and conservation purposes.

A more definitive determination of the quality of all habitats within the WMDEC will have to be undertaken as areas are earmarked for development. On a general basis, all habitats of native and remnant vegetation are likely to be utilised by fauna where resources are available. In the first instance, the *prima facie* case would require that these habitats be considered relatively high value and of importance to all fauna, including threatened fauna. For example, all remnants found in agricultural areas, containing mature trees have the potential to develop hollows and can become important nesting sites, and rehabilitated mine lands can provide suitable foraging resource for numerous volant

[7] This figure is of rehabilitation undertaken by Worsley Alumina on their BBM and MTR leases. It does not include rehabilitation undertaken at NBGM or in other lands not in control of South32.

and non-volant species. In both cases the actual value of these areas could be said to be greater than would be suggested at a superficial level.

The true ecological value of habitats for any species, however, is determined by many other factors including on-going management activities and, importantly, connectivity in the landscape. Although the level of information available for this study is relatively comprehensive, it is focused to very specific areas within WMDEC (i.e., mining and mining infrastructure footprints), making it difficult to generalise over the larger WMDEC area. Therefore, the determination of habitat value must be undertaken at a more detailed level for each species for WMDEC in its entirety and will require further field survey and verification.