PHOENIX
ENVIRONMENTAL SCIENCES

Black Cockatoo breeding habitat assessment for the Worsley Mine Expansion Project

Prepared for Worsley Alumina Pty Ltd

March 2023

Final

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Abbreviation	Description
BC Act	*Biodiversity Conservation Act 2016*
BGM	Boddington Gold Mine
CBME	Contingency Bauxite Mining Envelope
CSIRO	Commonwealth Scientific Industrial Organisation
DAWE	Department of Agriculture, Water and the Environment
DBCA	Department of Biodiversity Conservation and Attractions
DBH	Diameter at breast height
DCCEEW	Department of Climate Change, Energy, the Environment and Water
DEC	Department of Environment and Conservation
DSEWPaC	Department of Sustainability, Environment, Water, Population and Communities
DWER	Department of Water and Environmental Regulation
EIA	Environmental Impact Assessment
EN	Endangered
EPBC Act	*Environmental Protection and Biodiversity Conservation Act 1999*
FRTBC	Forest Red-tailed Black Cockatoo
HRZ	High rainfall zone
IBRA	Interim Biogeographic Regionalisation of Australia
IBSA	Index of Biodiversity Surveys for Assessment
IDF	Indicative Disturbance Footprint
MRZ	Medium rainfall zone
NBG	Newmont Boddington Gold
NW	Northwest
PAA	Primary Assessment Area
PHT	Potential habitat trees
RLA	Refinery Lease Area
SRI	Significant Residual Impact
VU	Vulnerable
WA	Western Australia
WAM	Western Australian Museum
WMDE	Worsley Mine Development Envelope

EXECUTIVE SUMMARY

Worsley Alumina Pty Ltd (South32) has requested a black cockatoo breeding habitat assessment for the Worsley Mine Expansion Project (the Project), specifically within the Primary Assessment Area (PAA), which comprises the:

- Worsley Mine Development Envelope (WMDE) – proposed mining expansion in the vicinity of the Boddington Bauxite Mine (BBM)
- Bauxite Transport Corridor (BTC) – located in proximity of the BBM
- Contingency Bauxite Mining Envelope (CBME) – confined to within the Collie Refinery Lease Area (RLA)

Three species of black cockatoo are present in the south-west of WA. All three species are protected under state (*Biodiversity Conservation Act 2016;* [BC Act]) and federal legislation (*Environmental Protection and Biodiversity Conservation Act 1999* [EPBC Act]). All three black cockatoo species are known to feed, and two species (Carnaby's Black Cockatoo and Forest Red-tailed Black Cockatoo (FRTBC) are known to breed within the PAA.

Ten spatial data sets concerning Carnaby's Cockatoo (confirmed breeding areas, unconfirmed and confirmed roosting sites and areas requiring investigation as feeding habitat) were published by the Western Australian Government in 2012. There are no spatial datasets concerning breeding habitat quality/value for the other two species. This study therefore attempted to derive such a product specifically for the PAA, i.e. determining which vegetation types/ fauna habitat types can be considered to be black cockatoo breeding habitat.

The aims of the study were to:

1. Determine via spatial analysis if there are any correlations between vegetation and environmental variables with the three black cockatoo species and their breeding location selection in the south-west of Western Australia, specifically the Northern Jarrah Forest (JAF01) and PAA.
2. Analyse the demographics of potential habitat trees (PHT) within the PAA, compared to other spatially confined studies.
3. Rank habitat types and calculate the area (ha) occurring within the PAA in terms of their relative preference for breeding by black cockatoos to inform the Significant Residual Impact calculations of the Proposal.
4. Estimate the number of breeding trees occurring in the PAA based on historic pre-clearance breeding records, to inform the Significant Residual Impact calculations of the Proposal.

This black cockatoo breeding tree habitat assessment was undertaken in accordance with the Department of Agriculture, Water and the Environment EPBC Act referral guidelines for three threatened black cockatoo species: Carnaby's Cockatoo (Endangered) *Calyptorhynchus latirostris*, Baudin's Cockatoo (Vulnerable) *Calyptorhynchus baudinii*, FRTBC (Vulnerable) *Calyptorhynchus banksii naso* (DoEE 2017).

Black cockatoo habitat tree data was aggregated from various sources. Within the PAA data was provided by South32 from data collected during -pre-clearance surveys and systematic fauna surveys undertaken specifically for the Proposal (Biostat 2020) and long-term vegetation monitoring plots (Mattiske 2020). Beyond the PAA data was aggregated from publicly available sources, Government departments and Phoenix' biological survey database.

Once compiled the data was used in numerous analyses undertaken at two spatial scales:

- The entire dataset of 23,595 PHT from several Interim Biogeographic Regionalisation of Australia (IBRA) regions was used in the various environmental variable analyses, PHT and breeding tree analyses
- A subset of 15,905 PHT from 11 studies from with the JAF01, JAF02 and WAR01 subregions – as the most appropriate to compare with the PAA – used in the PHT demographic analyses.

The demographic analyses determined there to be five size-classes based on the distribution of diameter at breast height (DBH mm). When size was considered across the studies areas, it was found that trees within the PAA were predominantly comprised of trees in size-class 3 (503mm – 826mm DBH), which are considered PHT's (DoEE 2017), but which are typically too small to support black cockatoo breeding (Johnstone *et al.* 2013a). In contrast, the DBH of the tree stock of studies external to the PAA comprised a greater proportion of trees in size-classes 4 and 5.

The demographic analysis also found the forest within the PAA to be comprised of considerably denser stands of trees compared with the external studies and that the PAA is dominated by Jarrah, which has a much lower propensity to form hollows compared to Marri and Wandoo, which were more common elsewhere. The stark difference between the forest tree species ratios, tree age and structure (density) is clearly a result of the extensive and repeated timber harvesting that has occurred within the State Forest blocks (Ernest and Hamilton [CBME]; George, Hedges, Marradong, Quindanning, Saddleback and Wells [WMDE and BTC]) of the PAA, which have been harvested 2-5 times in the last century.

With respect to regional vegetation complexes, of the 59 that occur within the Northern Jarrah Forest, ten have confirmed breeding records and 18 have unconfirmed breeding evidence. Of these, seven occur within the PAA and comprise 90% of the PAA and 95% of the Indicative Disturbance Footprint (IDF).

Thus, on this basis and considering the requirements of each species the entire CBME is considered breeding habitat for FRTBC and Carnaby's, while 95.7% of remnant native vegetation in the WMDE is considered breeding habitat for FRTBC and Carnaby's Cockatoo and to a lesser extent, Baudin's Cockatoo.

When this data is further considered in terms of each species within the IDF almost 6,482 ha is considered High value breeding habitat for Carnaby's Cockatoo, 5,647 ha is High value breeding habitat for FRTBC, and 6,714 ha is considered Low value breeding habitat for Baudin's Cockatoo.

That being said, only limited confirmed breeding in the WMDE has been recorded and no confirmed or suspected breeding has been recorded in the CBME. To date, pre-clearance surveys of 3,322 ha over the last 3 years have recorded only five active nests and other surveys have recorded an additional seven active nests, thus, to date only 12 active nests are known from within the boundaries of the PAA.

Thus, while the remnant vegetation within the PAA is largely considered breeding habitat for the three black cockatoo species, the intensive timber harvesting that has occurred throughout the PAA has rendered the trees largely unsuitable for black cockatoo breeding at present; The majority of trees having been harvested two-three times and in some areas (predominantly in the NBG area and CBME) as many as five harvests have occurred.

Further, extensive research has indicated that Carnaby's Cockatoo breeding predominantly occurs further east in the Wheatbelt, with the JAF01 being an important feeding area for birds moving to and from their main breeding grounds. The breeding requirements of FRTBC and Baudin's Cockatoo, however, are generally still not well understood, both in the Northern Jarrah Forest and elsewhere.

The review of the impacts of fire determined that it has important consequences for the availability of hollows, with recent fires at Waroona-Yarloop-Harvey (2016) and Lower Hotham (2019) having had

significant impacts on known breeding trees. In contrast, large areas of the forest within the PAA have not been burnt for decades, and in almost half the State Forest that intersects the PAA, they have not burnt for over half a century. This is because the companies that have operated in the area over the last 50 years have actively suppressed and controlled fires to protect their mining and rehabilitation assets and in turn likely protected the few hollow bearing trees that have survived the repeated timber harvests.

Given the limitations in the datasets aggregated in this report, and the opposing impacts of timber harvesting and suppression of fire, the most accurate approach to determining the number of breeding trees that may potentially be removed by the Proposal and thus calculating the Significant Residual Impacts is to simply multiply the number of known breeding trees identified in the pre-clearance surveys and other data sources by the area of native vegetation proposed to be impacted within the IDF as undertaken by Phoenix (2021); On this basis it was estimated that up to 244 hollows may occur within the IDF.

1 INTRODUCTION

Worsley Alumina Pty Ltd (South32) has requested a black cockatoo breeding habitat assessment for the Worsley Mine Expansion Project (the Project), specifically within the Primary Assessment Area (PAA), which comprises the:

- Worsley Mine Development Envelope (WMDE) – proposed mining expansion in the vicinity of the Boddington Bauxite Mine (BBM)
- Bauxite Transport Corridor (BTC) – located in proximity of the BBM
- Contingency Bauxite Mining Envelope (CBME) – confined to within the Collie Refinery Lease Area (RLA).

Three species of black cockatoo are present in the south-west of WA. All three species are protected under state (*Biodiversity Conservation Act 2016;* [BC Act]) and federal (*Environmental Protection and Biodiversity Conservation Act 1999* [EPBC Act]) legislation:

- Carnaby's Cockatoo (*Calyptorhynchus latirostris*) – Endangered (EN) (EPBC and BC Acts)
- Baudin's Cockatoo (*Calyptorhynchus baudinii*) – EN (EPBC and BC Acts)
- Forest Red-tailed Black Cockatoo (*Calyptorhynchus banksii naso*) (FRTBC) – Vulnerable (VU) (EPBC and BC Acts).

All three species have been recorded within South32's projects from 1982-2019 with the FRTBC the most common of the three, accounting for approximately half of all individuals observed and Carnaby's Cockatoo the second most prevalent species (Biostat 2020; South32 2020c).

The IDF referred to in this report is not current and was not yet available at the time of writing. The IDF has since been updated to be significantly reduced in size. Therefore, this assessment does not reflect the recent changes made to the IDF.

1.1 BACKGROUND

Ten spatial data sets concerning Carnaby's Cockatoo (confirmed breeding areas, unconfirmed and confirmed roosting sites and areas requiring investigation as feeding habitat) were published by the Western Australian Government in 2012. The methods by which these datasets were derived are provided in Glossop *et al.* (2011). The project did not publish spatial polygons for Carnaby's Cockatoo breeding habitat, but did publish a dataset on known breeding locations within the Jarrah Forest Interim Biogeographic Regionalisation of Australia (IBRA) bioregion. Glossop *et al.* (2011) highlight that Department of Environment and Conservation (DEC) in 2009 produced a spatial dataset for Carnaby's Cockatoo breeding habitat, based on vegetation types. Such a dataset would be ideal for this assessment, however it is not available for use. Glossop *et al.* (2011) provide no explanation as to why no attempt was made to improve on this previously produced government dataset or why it was not published with their publicly available datasets.

While Department of Sustainability, Environment, Water, Population and Communities (DSEWPaC 2012) (now the Department of Climate Change, Energy, the Environment and Water (DCCEEW) has published the modelled distributions of all three species, no publicly available spatial datasets like those for Carnaby's Cockatoo are currently available for Baudin's Cockatoo and FRTBC.

This study is therefore attempting to derive a product similar to that of DEC 2009 (that is not available) specifically for the PAA, i.e. determining which vegetation types/ fauna habitat types can be considered to be black cockatoo breeding habitat. The aims of the study are to:

1. Determine via spatial analysis if there are any correlations between vegetation and environmental variables with the three black cockatoo species and their breeding location selection in the south-west of Western Australia, specifically the Northern Jarrah Forest (JAF01) and PAA.
2. Analyse the demographics of potential habitat trees (PHT) within the PAA and compare to other spatially confined studies included in the dataset.
3. Rank habitat types and calculate the area (ha) occurring within the PAA in terms of their relative preference for breeding by black cockatoos to inform the Significant Residual Impact (SRI) calculations of the Proposal.
4. Estimate the number of breeding trees occurring in the PAA based on historic pre-clearance breeding records, to inform the SRI calculations of the Proposal.

1.2 SCOPE OF WORK

The scope of work included:

1. Collation and spatial assessment of any available spatially confined black cockatoo PHT and 'breeding tree' data, e.g. Western Australian Museum (WAM), Department of Biodiversity, Conservation and Attractions (DBCA), Main Roads, Phoenix' database, Biostat (baseline studies, PHT analysis and tree demographics transects from spatially confined data within the PAA), Mattiske (tree density and tree species recorded in flora monitoring plots) and South32 (pre-clearance baseline data from within the PAA) to determine:
    a) average PHT density within the spatially confined studies to enable demographic analysis
    b) historic number of breeding trees and estimate potential further loss due to the Proposal
    c) compare presence and density of breeding trees with respect to dominant overstorey species and vegetation type and position in landscape
    d) relative rank and area (ha) of breeding habitat within the PAA based on the above derived data and using other spatial variables, such as vegetation type/fauna habitat, elevation, slope, other spatial variables of potential relevance
2. Undertake a brief review of the suitability/success of artificial nest boxes for each of the three black cockatoo species
3. Respond to Department of Water and Environmental Regulation (DWER) and DCCEEW comments on the Worsley Mine Expansion Black Cockatoo breeding habitat assessment report by updating the report.

The scope of this breeding tree habitat assessment was undertaken in accordance with the following DAWE EPBC Act referral guidelines. The definition of PHT is also in alignment with these guidelines.

- EPBC Act referral guidelines for three threatened black cockatoo species: Carnaby's Cockatoo (Endangered) *Calyptorhynchus latirostris*, Baudin's Cockatoo (Vulnerable) *Calyptorhynchus baudinii*, Forest Red-tailed Black Cockatoo (Vulnerable) *Calyptorhynchus banksii naso* (DSEWPaC 2012)

- Revised draft referral guideline for three Threatened black cockatoo species: Carnaby's Cockatoo (Endangered) *Calyptorhynchus latirostris*, Baudin's Cockatoo (Vulnerable) *Calyptorhynchus baudinii*, Forest Red-tailed Cockatoo (Vulnerable) *Calyptorhynchus banksii* naso (DoEE 2017).

1.3 STUDY AREA

The study area for the assessment is primarily the PAA however data from across the southwest of Western Australia was aggregated, being restricted mainly to the Northern Jarrah Forest (JAF01) IBRA sub-region (Williams & Mitchell 2001) and to a lesser extent the Southern Jarrah Forest (JAF02) (Hearn *et al.* 2002b) and Warren (WA01) (Hearn *et al.* 2002a) subregions, to which the PAA is compared in a broad sense.

1.4 ASSESSMENT APPROACH

DoEE (2017) states that "The clearing of breeding habitat is highly likely to have a significant impact" and defines breeding habitat as: "species of trees known to support breeding within the range of the species which either have a suitable nest hollow OR are of a suitable diameter at breast height (DBH) to develop a nest hollow. For most species of trees, suitable DBH is 500 mm."

Under this definition, given that native vegetation in the PAA is dominated by woodlands to open forests of Jarrah/marri and wandoo (Mattiske 2020) it was clear that the majority of native vegetation (with or without intact understory) can be defined as breeding habitat for all three species, as breeding has been recorded locally or within the Northern Jarrah Forest bioregion for all three species.

However, it was also clear from the data acquired by South32 over a long period of time (South32 2020b) and more recently via pre-clearance surveys (South32 2020a) that across the range of fauna habitat types present within the PAA, few breeding trees had been recorded and known breeding events were rare.

In order to assess the environmental impact of development proposals on black cockatoo species in WA typically all PHTs within the development envelope are individually measured (DBH) and recorded (using a GPS), with notes on presence of hollows and hollow size/suitability and breeding evidence. Given the scale of the Proposal however, it was determined that following this standard approach was unrealistic and it was considered likely that breeding trees could easily be missed as there was simply too much ground to cover. It was also evident to South32 that the now routine pre-clearance surveys being conducted (South32 2020a), with their focus on short to medium term future mining areas, was a sound approach to identifying, minimising and mitigating impacts to the species' within the area of current operations.

Further, the State Forest component of both the current operational areas and the PAA have suffered repeated, large-scale disturbances in the form of logging. Once the bauxite had been removed and the land revegetated it would revert to State Forest and again be actively managed first and foremost as a timber resource. As will be demonstrated, the area has been repeatedly cutover (under different management regimes/objectives) over the past 100 years. On top of this the forest has experienced different fire management regimes, imposed first by indigenous communities and more recently by Europeans, which has also had a profound impact on hollow availability. With declining rainfall across the Northern Jarrah Forest over the past 30 years it is likely that fire management will also change into the future.

Thus, it was clear that the assessment of breeding habitat within the PAA needed to take a different approach. Most importantly it was considered necessary that the PAA Jarrah/marri forest and

Wandoo forest/woodland demographics – tree composition, tree age (DBH) and tree density, breeding tree density etc – needed to be investigated as these factors are likely to have a large bearing on the quality of breeding habitat. It was also evident that these factors needed to be compared to areas of native forest that were not actively managed as a timber resource. Put simply we needed to determine what does breeding habitat within the Northern Jarrah Forest look like outside of State Forest (which is subject to impacts from timber harvest operations), does it support more or less black cockatoo breeding?

Given the extensive biological dataset compiled by South32 within the current area of operations (both for flora and fauna) and the extensive spatially explicit PHT surveys conducted for Environmental Impact Assessment (EIA) within the Northern Jarrah Forest over the course of the last decade, it was decided that such an investigation was possible, and that the results would allow for an extrapolated evaluation of the breeding habitat quality (required here and for any offsets calculations) and estimation of the number of breeding trees which could be expected to occur within the PAA (required for EIA and to design mitigation measures), with a degree of confidence suitable for regulators to assess the impacts of the Proposal on the three black cockatoo species.

2 METHODS

Black cockatoo habitat tree data was collected from various sources. Within the PAA data was provided by South32 from data collected during pre-clearance surveys, and systematic fauna surveys undertaken specifically for the Proposal (Biostat 2020; Mattiske 2020). Beyond the PAA, data was aggregated from Phoenix' biological survey database (~20,000 individual tree records; Phoenix 2020b) and publicly available sources, principally:

- Index of Biodiversity Surveys for Assessment (IBSA) website – ~ 650 individual tree records
- Government departments – ~1,000 individual 'tree' records (that being records that could be ascribed to a tree, such as breeding or roosting records).

Once compiled the data was used in numerous analyses undertaken at two spatial scales:

- The entire dataset of 23,595 PHT from several IBRA regions was used in the various environmental variable analyses, PHT and breeding tree analyses
- A subset of 15,905 PHT from with the JAF01, JAF02 and WAR01 subregions – as the most appropriate to compare with the PAA – was used in the PHT demographic analyses.

The PHT and breeding record data came in various forms and levels of detail, e.g. DBH, was accurately measured in some datasets, but only categorised in others. The Phoenix dataset (Phoenix 2020b) includes individual tree DBH (mm) measurements for all 20,448 trees.

Data from DBCA Threatened fauna database outputs and known breeding trees on the data.wa.gov.au website often contained no DBH or even tree species and thus, the tree DBH category was determined according to any descriptive notes or determined to be 'Null' where no notes were provided.

The following definitions were used:

1) A **potential habitat tree** – a tree with a suitable nest hollow **OR** of a suitable DBH to develop a nest hollow, following the specifications of the EPBC Act referral guidelines for black cockatoo species (DoEE 2017; DSEWPaC 2012); where for most tree species DBH >=500 mm, but for Salmon Gum (*E.salmonophloia*) and Wandoo (*E.wandoo*) is >=300 mm (DoEE 2017)

2) A **confirmed breeding tree –** a tree where a breeding event has taken place, as determined by breeding evidence, where such evidence includes:

- eggs or chicks seen in a hollow
- chicks are heard in the nest
- an adult female cockatoo is observed to be brooding eggs or with young (flushed from a hollow).

3) Trees with **evidence of breeding –** might have suitable or potentially suitable hollows however, none of the definitive evidence above has been obtained. Trees in this category include:

- observations of prospecting birds (males and females in or very close to hollows)
- a female flushed from a hollow but upon inspection using a camera, no eggs or chicks are seen
- mating or courtship behaviour
- chewing around the hollow entrance.

In addition, two different types of PHT hollows exist, these are:

- Natural hollows which refer to hollows that have naturally formed in the PHT
- Artificial nest hollows which refer to artificial nest boxes that have been installed in the PHT.

2.1 POTENTIAL HABITAT TREE DEMOGRAPHICS

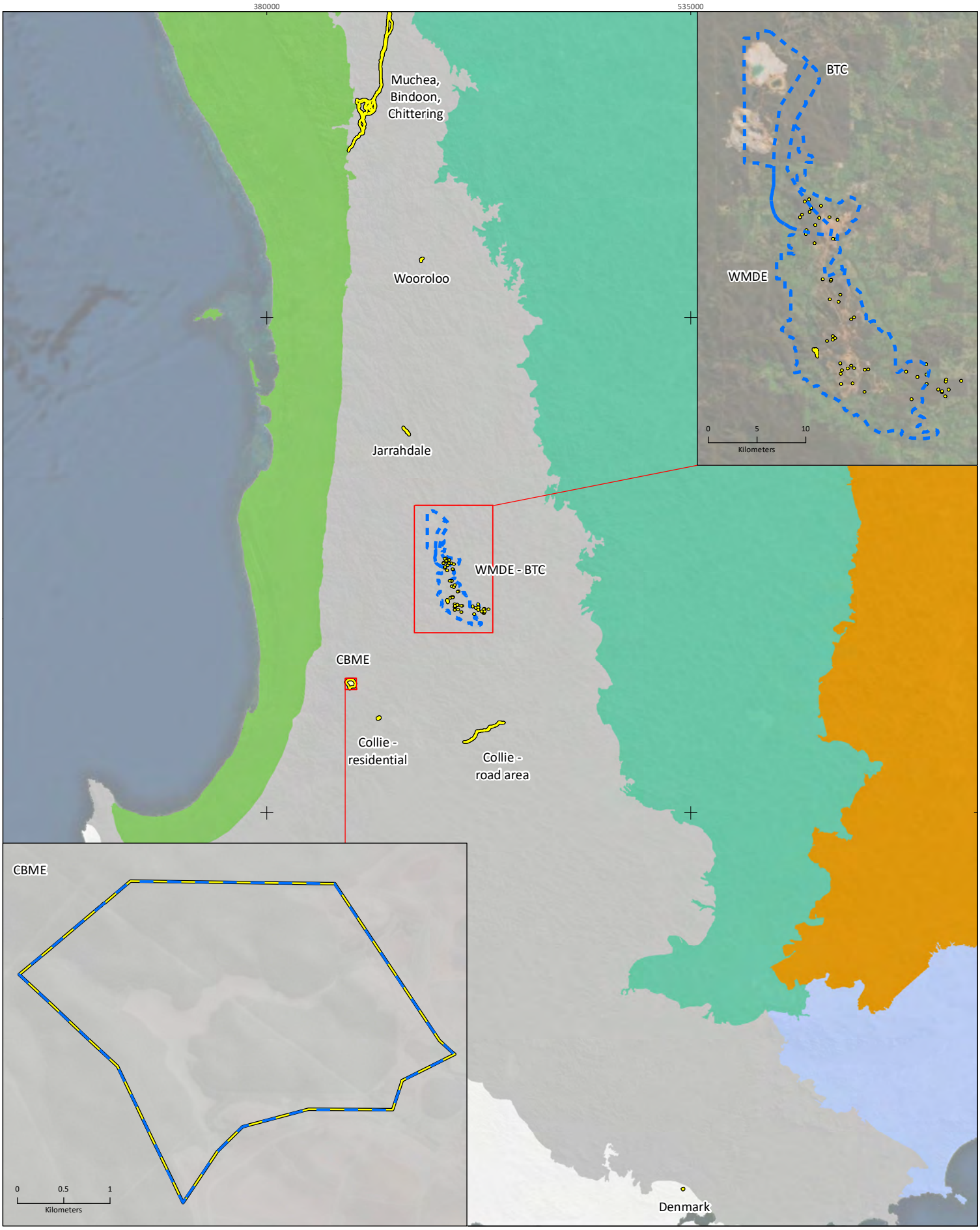
Eleven surveys were incorporated into the PHT demographic analysis, representing 15,905 trees over 4,592.5 ha (Table 2-1). Phoenix' data is all collected in the same way, the others are collected differently:

- Phoenix – all individual tree GPS coordinates recorded and DBH measured (mm)
- Biostat – no tree coordinates recorded but trees counted within a spatially defined transect (200m^2 or 1,000m^2), DBH estimated within three size-class (>300-500mm, >500mm and > 1,000mm)
- South32 - all individual tree GPS coordinates recorded within a spatially defined area and DBH measured (mm)
- Mattiske – no tree coordinates recorded but trees counted within a spatially defined quadrat (400m^2 or 1,600m^2), DBH measured (mm).

Table 2-1 Summary of potential habitat tree data used in demographic analysis

Survey area		IBRA region	Area (ha)	Area (%)	No. trees	Trees (%)
1	Muchea, Bindoon, Chittering	JAF01	4,031.10	87.8%	11,966	75.23%
2	Collie - road	JAF01/JAF02	379.8	8.3%	1,686	10.60%
3	Jarrahdale	JAF01	94.1	2.0%	424	2.67%
4	Collie - residential	JAF01	49.3	1.1%	557	3.50%
5	Wooroolloo	JAF01	14.5	0.3%	68	0.43%
6	Denmark	WAR01	10.8	0.2%	52	0.33%
7	Boddington - WMDE (South32/Phoenix)	JAF01	7.4	0.2%	222	1.40%
8	Boddington - WMDE (Mattiske)	JAF01	3.8	0.1%	209	1.31%
9	Boddington - WMDE (Biostat)	JAF01	1	0.02%	102	0.64%
10	Boddington - WMDE (Biostat/South32)	JAF01	0.44	0.01%	574	3.61%
11	Collie - CBME (Biostat)	JAF01	0.3	0.0%	45	0.28%
PAA subtotal		**1**	**12.94**	**0.33%**	**1,152**	**7.24%**
Grand total		**3**	**4,592.54**	**100.0%**	**15,905**	**100.00%**

These surveys were restricted to the Northern and Southern Jarrah Forest IBRA subregions and one, Denmark, is within the Warren sub-region but is only 1.5 km south of the Southern Jarrah Forest boundary (Figure 2-1).



Sout32 Ltd
Worlsey Mine Expansion Project

Project No	1317-WME-S32-VER
Date	1/09/2021
Drawn by	IN
Map author	JC

0 7.5 15
Kilometers

1:1,800,000 (at A4) GDA 1994 MGA Zone 50

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Survey locations
PAA

IBRA bioregions
- Western Mallee
- Warren
- Swan Coastal Plain
- Jarrah Forest
- Esperance
- Avon Wheatbelt

Figure 2-1

The location of surveys used in the demographic analysis

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The following key steps were undertaken to establish the PHT demographics:

1. The stems per ha and relative abundance of each tree species was summarised.
2. The size demographics (DBH [mm]) of PHT were determined for each survey area in order to compare the size and, by extension, the age of the tree stock in the PAA compared with the other areas.
3. Size-class demographic analysis, which began by plotting the DBH distribution for the PHT dataset. The demographic analysis provides a measure of confidence in the calculated number of known or suspected breeding trees in the PAA. In its simplest form the analysis allowed determination of whether the age of the tree stock is younger, similar or older within the PAA when compared with than the other studies. This provided a path to calculating number of breeding trees in the PAA Indicative Disturbance Footprint (IDF).
4. The resultant histogram size-classes were derived for each PHT record based simply on the natural groupings evident in the data. The size-classes were then summarised and compared for each dataset.

2.2 BREEDING HABITAT VALUE DETERMINATION

Once all data was compiled and analysed as above, it was necessary to determine what vegetation types/fauna habitats in the PAA support black cockatoo breeding and to ascribe a value to those types, in order to inform the SRI calculations. Accordingly, the following criteria were used (where it has been assumed that all remnant vegetation provides foraging habitat, including rehab of age >6 year; and whereby all potential breeding habitat is either within foraging habitat or within very close proximity to foraging habitat, i.e. within 6km of foraging resource):

- High – vegetation complex/vegetation type or fauna habitat has been recorded within the JAF01 to contain trees with confirmed breeding trees, or trees with breeding evidence close to water and foraging habitat
- Medium – vegetation complex/vegetation type or fauna habitat has been recorded within the JAF01 to contain trees with breeding evidence, but no confirmed breeding
- Low – contains trees (dominant or otherwise) known to be used by black cockatoos within the JAF01 for breeding above the DoEE (2017) potential habitat tree criteria (> 300/500mm)
- None – vegetation complex/vegetation type or fauna habitat contains no trees known to support breeding.

2.3 ENVIRONMENTAL VARIABLES

Spatially defined environmental variable data was collected from publicly available sources (Table 2-2) for analysis against the PHT and breeding record data. The environmental variables included distance from water (km), fire data, vegetation type, slope and aspect. The PHT variables included DBH (mm), hollow size (mm) and tree species.

Trees containing artificial nest boxes were included in analyses involving distance from water (km), elevation and aspect, but not for, tree species and fire history.

No statistical measures of the strength of the relationships were derived because the sample size was too small once tree species, natural or artificial hollow type where considered. Instead, the data is discussed in terms of general trends evident.

Table 2-2 Datasets used in the black cockatoo breeding tree analysis

Variable(s)	Source	Data used
Fire history	DBCA (2020b)	This dataset contains state-wide wildfires and prescribed burns with year and cause
Distance to water	Geoscience Australia (2020)	Rivers, creek lines, lakes and swamps
Vegetation type/ fauna habitat	Fine scale (~1:5000): PAA vegetation (Mattiske 2020) and vertebrate fauna habitats (Biostat 2020) Large-scale (1:250,000): Heddle vegetation complexes (Heddle *et al.* 1980) which covers most of the Jarrah Forest bioregion	Biostat's fauna habitat was equated to Mattiske Consulting's vegetation types within the PAA
Elevation, slope and aspect	OpenTopoMap dataset https://tile.opentopomap.org	Elevation, slope and aspect
PHT and associated variables - aggregated dataset from various sources and Phoenix' dataset[1]	(DBCA 2020a; IBSA 2020; Phoenix 2020b; South32 2020b)	PHT locations, DBH, species, species of black cockatoo, evidence of usage
Black cockatoo confirmed and unconfirmed breeding areas	www.data.wa.gov.au	

[1] Due to licence and contractual restrictions, the datasets cannot be individually identified

2.4 BLACK COCKATOO HABITAT ASSESSMENT SURROUNDING THE PAA

Spatially defined environmental data was collected from publicly available sources to determine potential black cockatoo habitat types within 20 km of the PAA.

3 RESULTS

3.1 BLACK COCKATOO BREEDING

The spatial analysis is based on breeding habitat attributes derived from the following review for each species.

3.1.1 Forest Red-tailed Black Cockatoo (*Calyptorhynchus banksii naso*)

This subspecies occurs throughout the forested areas of the south-west and was formerly common north to Gingin, (formerly to Dandaragan), Gidgegannup, and east to Mount Helena, (formerly to Toodyay), Chidlow, Wooroloo, Wundowie, The Lakes, Christmas Tree Well, near Brookton, Bannister, (formerly to Wandering), Mount Saddleback, (formerly to Kojonup), Rocky Gully, the upper King River, Porongurup Range and Green Range. The species is now rare to uncommon and patchily distributed over most of its range (Johnstone *et al.* 2017). Its distribution on the northern Swan Coastal Plain was confined largely to the eastern zone north to Gingin and south to the Armadale-Byford and Serpentine-North Dandalup regions, with small breeding populations at Baldivis, Mundijong, Stake Hill, Karnup and more recently in the Perth area at Murdoch and possibly Perry Lakes (Johnstone *et al.* 2017).

Nests of the FRTBC are typically, but not regularly, clustered in the landscape with social interactions within the flock likely to play a part in the clustering of nests (Johnstone *et al.* 2013b). In many settings, nests were clumped in remnant patches of veteran Marri with 19 nests within a 230 m radius at one site (Johnstone *et al.* 2013a).

A survey of 128 nests (in large tree hollows) found 95% of FRTBC were in living Marri that were older than 209 years and the remainder in dead Marri, live Jarrah, Blackbutt, Bullich (*Eucalyptus megacarpa*), Wandoo and dead trees of unknown species (noting that any large tree may form suitable hollows for breeding) (Johnstone *et al.* 2013b). Marri nest trees had a mean circumference at breast height of 2.76 m, a mean estimated age of 220 years (95% confidence limit 209–231 years) and an average overall height of 20.04 m (Johnstone *et al.* 2013a).

The provision of adequate numbers of veteran Marri in perpetuity for this species is dependent on the retention of clusters of old growth trees (i.e. trees >200 years old) and numbers of trees in the next age bracket (>100 years) to replace the older trees as they are lost through natural processes (Johnstone *et al.* 2013a).

Reliable water sources are particularly important for the FRTBC, owing to a high basal metabolic rate and evaporative water loss. Water sources close to foraging and breeding areas is likely to benefit the FRTBC (Lee *et al.* 2013).

There has been a significant decline in breeding success of the FRTBC at monitored sites in the Northern Jarrah Forest (EPA 2019; Johnstone *et al.* 2017). In 2016 almost no FRTBC were recorded breeding at any of the Western Australian Museum's study sites and no juveniles were recorded in the Northern Jarrah Forest or on the Swan Coastal Plain (Johnstone & Kirkby 2019). There has also been an increase in numbers of this species in the Perth-Peel region from 2005 until present. This change in distribution has been brought about by impacts in its natural range influencing movements of the species (Johnstone *et al.* 2017). Habitat clearing resulting in the scarcity of Jarrah and Marri seed suggests that the FRTBC may become more dependent on some introduced species such as Cape Lilac for food in some areas along the Swan Coastal Plain (Johnstone *et al.* 2017). The altered foraging

behaviour has also led to changes in roosting patterns that will no doubt influence the breeding success of this species (Johnstone *et al.* 2017).

3.1.2 Baudin's Cockatoo (*Calyptorhynchus baudinii*)

Very little breeding information exists for this species (Johnstone *et al.* 2010), however the "extrapolated" breeding distribution of Baudin's is generally described as occurring between Leschenault, Collie and Albany (DoEE 2017). This species is very different to the other two black cockatoos in that it is quite an elusive and a quiet breeder, with nests often difficult to find in the forests (T Kirkby, 2020 pers. comm., 14 April). The Karri forest is the main breeding area for Baudin's Cockatoo but there are also isolated breeding populations in the Jarrah Forest (T Kirkby, 2020 pers. comm., 14 April). The availability of Marri is likely to be important for breeding success of this species (Johnstone & Kirkby 2008b).

In the last 50 years, Baudin's Cockatoo has declined greatly with counts at traditional roosts declining by over 90% since 2009 (Johnstone & Kirkby 2008b; Johnstone & Kirkby 2016). Baudin's Cockatoo has been demonstrated to be less adaptable than Carnaby's and has a lower fecundity, meaning population growth is slower (EPA 2019) and it is therefore more vulnerable to breeding threats.

Regular monitoring of nest sites of Baudin's between 1998-2018 has provided information on the timing of nesting events and providing details of nest trees, distance between nests, fledging success and details of local vegetation, helping provide a profile of a preferred nest site (Johnstone & Kirkby 2019). The conclusion of a study and subsequent research paper on the breeding biology of Baudin's Cockatoo is due to be released in 2020 (T Kirkby, pers. comm., 14 April 2020).

Baudin's Cockatoo has not been definitively recorded breeding within the WMDE, although Biostat (2020 referencing Johnstone and Kirkby 2019) discusses an observation of Baudin's Cockatoo tending to a fledgling at Marradong in January 2007, but where breeding in the area was not confirmed. Thus, any subsequent discussion below for this species relates only to the CBME, which is located at Collie and is within the modelled breeding range of the species.

3.1.3 Carnaby's Cockatoo (*Calyptorhynchus latirostris*)

There is considerable knowledge available on the foraging and breeding ecology of Carnaby's Cockatoo. These two factors are intertwined and critical to the continued breeding success of this species. However, knowledge gaps remain on the impacts of threatening processes, including the carrying capacity of remaining foraging habitat and breeding areas in the northern Avon-Wheatbelt, Geraldton Sandplains and Jarrah Forest IBRA bioregions (EPA 2019). It has been estimated that Carnaby's Cockatoo has disappeared from more than one-third of its historical breeding range because of extensive habitat loss in the Avon-Wheatbelt region (Saunders 1990). Subsequently, the breeding distribution of Carnaby's Cockatoo has shifted westward through the Jarrah Forest region, where it now also breeds (Johnstone & Kirkby 2008a; Johnstone & Storr 1998).

For Carnaby's Cockatoo increased foraging distances have been associated with poor chick health and lower breeding success rates, leading to abandonment of breeding areas because of a lack of food availability (Saunders 1982; Saunders 1990; Saunders & Ingram 1987; Saunders *et al.* 1985). For example, Saunders observed that the chicks of adult birds that had to travel greater distances, up to 12km, to find food, had lower growth rates and fledging success, compared to the chicks of adult birds that had foraging habitat available within 7 km of a nest site (Saunders 1982; Saunders 1990). It has been demonstrated that the proximity of foraging habitat and water is critical to support roosting and breeding sites for this species (Groom 2015; Le Roux 2017; Saunders 1990).

3.2 POTENTIAL HABITAT TREE DEMOGRAPHICS

The PHT DBH distribution is based on the measurement of 16,348 trees; the resultant histogram is shown below (Figure 3-1). The distribution is not Normally Distributed and heavily right skewed as one would expect for measurements of tree diameter; Five size-classes have been determined to be present (Table 3-1).

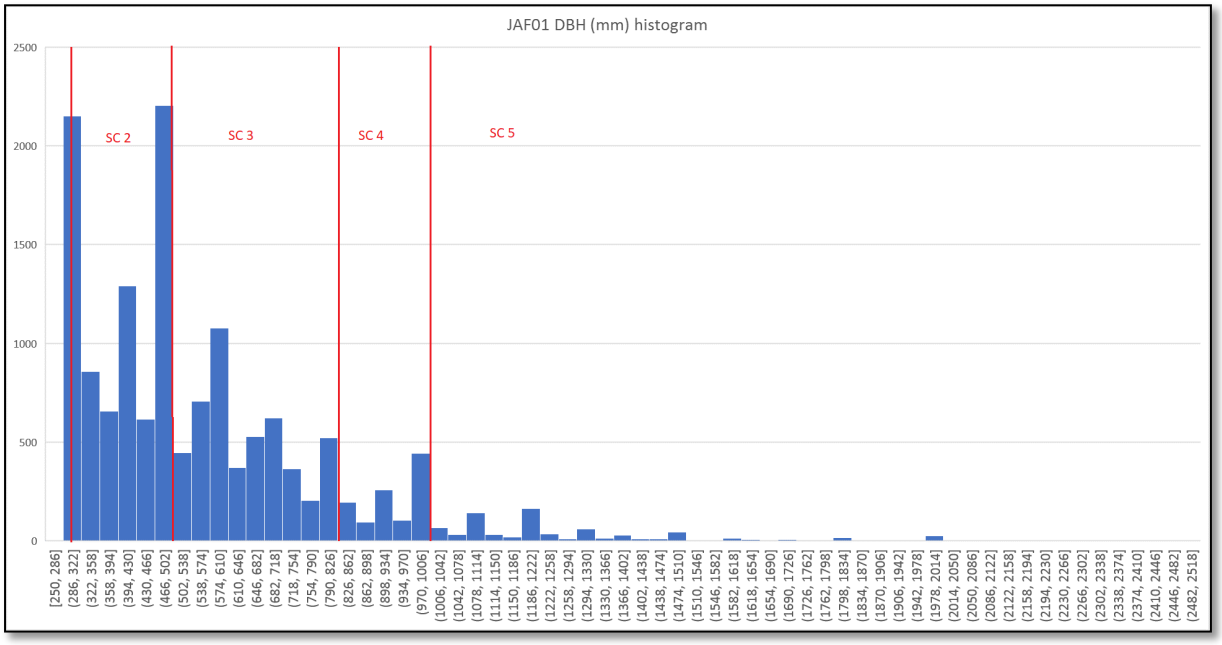


Figure 3-1 **Potential habitat tree DBH histogram**

Table 3-1 **Potential habitat tree size-classes**

Size-class	DBH (mm)	No. of trees	% of trees
1	<300	4	0.03%
2	300 – 502	7988	50.22%
3	503 – 826	5897	37.08%
4	827 – 1006	1261	7.93%
5	>1006	755	4.75%
	Total	**15,905**	**100%**

Johnstone *et al.* (2013a) found that nest trees of all species used by black cockatoos have an average circumference at breast height of 2.79 m (or DBH = 880 mm), thus they occur within size-classes 4 and 5 which accounts for 12.3% of the JAF01 PHT analysed. The percentage of trees in each size-class is shown in Figure 3-2. The data shows that within the PAA between 10% and 33% of the PHT stock is currently of sufficient diameter to support black cockatoo breeding. The data also shows that 20%–80% are greater than the EPBC Act referral guidelines for black cockatoo species (DoEE 2017) diameter criteria (>500mm), but are not yet large enough to support breeding.

In comparison, the roadside studies have a higher proportion of trees of mature, 'breeding diameter' (>=class 4; >827mm): Denmark (~85%), Jarrahdale (~75%), Collie (60%), Wooroloo (55%). This result is to be expected given that a near-majority of the PAA land is State Forest (~42%) which is subject to timber harvesting and has been cutover several times (Figure 3-10) (evident by the majority of trees in class 3 (492 – 826 mm)). Whereas the road-side remnants may have never been cutover and thus a larger proportion of mature trees prevail (classes 4 and 5).

The large dataset of Muchea, Bindoon, Chittering includes tree stock within a range of tenures including road-side remnants, and native vegetation on private land and tree stands in paddocks (where no recruitment occurs), and therefore the size-class distribution is more evenly distributed.

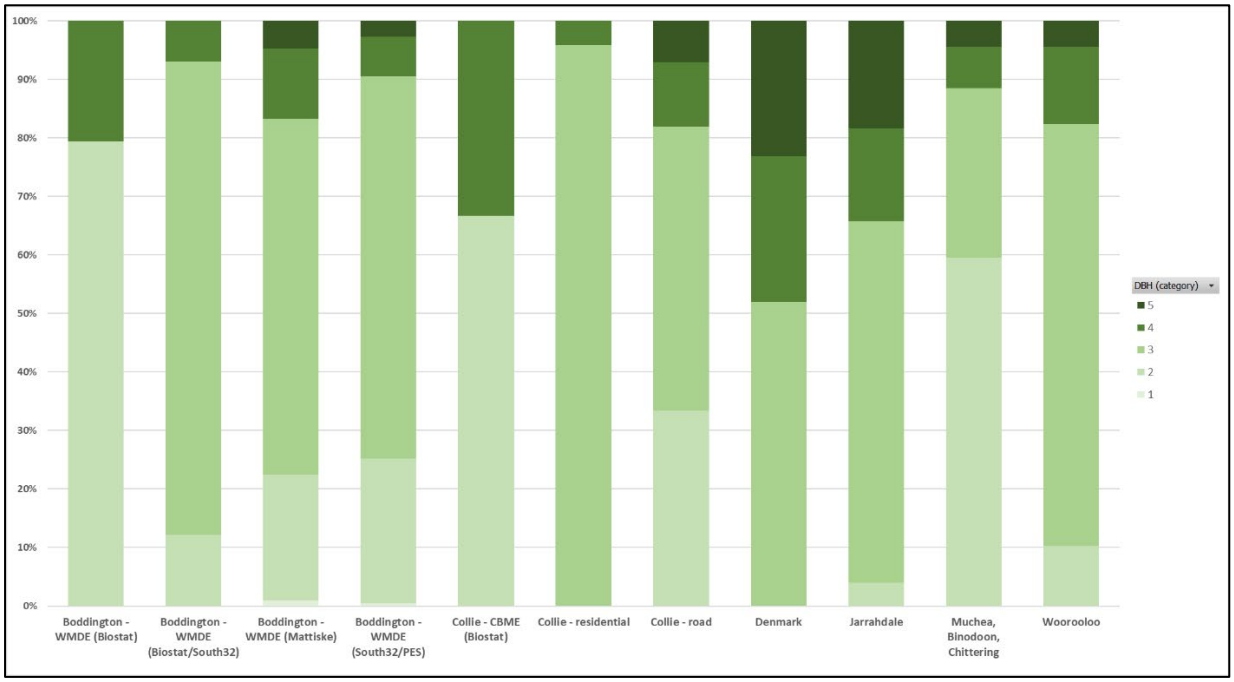


Figure 3-2 Demographics of PHT – percentage of trees in each size category in each study area

A summary of the PHT by tree species and area (ha) for the ten datasets is provided in Table 3-2 and graphically in Figure 3-2 and Figure 3-4. The data shows a marked difference in the density of trees within the PAA (CBME and WMDE/BTC) compared with the five roadside and one residential development studies. The PHT studies from the PAA occur predominantly on State Forest lands (and some agricultural remnants) and thus the significantly higher density is considered a reflection of the planting density targets. However, it is also likely that road-side remnants see lower recruitment due to the presence of a larger stock of mature trees and general disconnection from larger non-linear remnants, which act to prevent successful recruitment and trees from reaching a size where they are measured in such studies (section 2; DoEE 2017; DSEWPaC 2012).

The data overall is dominated by *Eucalyptus marginata* (Jarrah), *Corymbia calophylla* (Marri) and *E.wandoo* (Wandoo). The remaining species comprising less than 10% of PHT typically (Figure 3-3) comprised *Eucalyptus patens* (Blackbutt) and *E.rudis* (Flooded gum). These tree species are included in Figure 3-3 as they occur within the PAA and surrounds typically associated with creek lines and wetter areas. Other minor trees are removed to make the graph more readable. Interestingly, while the Muchea, Bindoon, Chittering dataset represents a clear majority of the dataset and contains a much higher proportion of *E.wandoo* than the other datasets, the density of PHT's is comparable to the other road-side study areas. The most southern dataset, Denmark, is dominated by old, large

C.calophylla trees (Figure 3-3), which provide superior breeding opportunities generally due to more proficient hollow formation.

In contrast to the road-side remnant datasets, the PAA is dominated by *E.marginata* by a factor of >3, compared with *E.wandoo* and *C.calophylla*. Again, this is considered a reflection of the historic timber harvesting practices which have selected *E.marginata* over other species.

Table 3-2 Summary of the PHT trees by tree species and area (ha), rows in grey are studies within the PAA

Study area	Study area (ha)	Stems per ha	*C. calophylla*	*E. sp. indet.*	*E. accedens*	*E. camaldulensis*	*E. diversicolor*	*E. loxophleba*	*E. marginata*	*E. patens*	*E. rudis*	*E. salmonophloia*	*E. sp.*	*E. Wandoo*	Grand total
Boddington - WMDE (Biostat)	1	102.0	22	1					53					26	102
Boddington - WMDE (Biostat/South32)	2.8	205.0	115						257					202	574
Boddington - WMDE (Mattiske)	2.6	80.4	15						125					69	209
Boddington - WMDE (South32/PES)	7.4	30.0	34						188						222
Collie - CBME (Biostat)	0.3	150.0	9						27	9					45
Collie - residential	49.3	11.3	268						251	22			16		557
Collie - road	379.8	4.4	92						420		5		13	1156	1,686
Denmark	10.8	4.8	47				1		4						52
Jarrahdale	94.1	4.5	82						327				15		424
Muchea, Bindoon, Chittering	4031	3.0	2,070	1	550	65		337	355		1,024	16	337	7,211	11,966
Woorooloo	14.5	4.7	34						20				6	8	68
PAA subtotal	**14.1**	**81.7**	**195**	**1**	**0**	**0**	**0**	**0**	**650**	**9**	**0**	**0**	**0**	**297**	**1,152**
Grand total	**4,593.7**	**3.5**	**2,788**	**2**	**550**	**65**	**1**	**337**	**2,027**	**31**	**1,029**	**16**	**387**	**8,672**	**15,905**

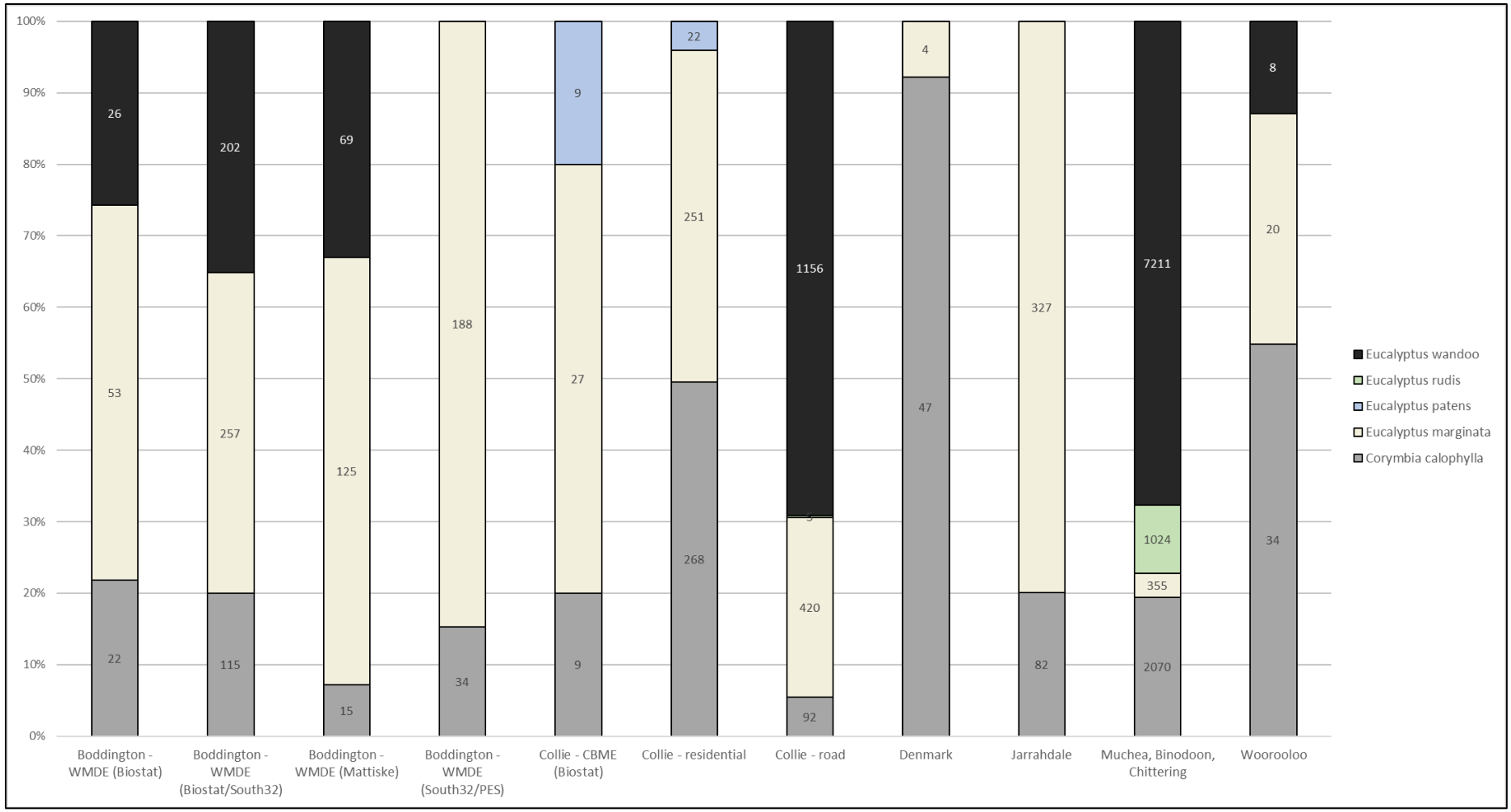


Figure 3-3 Relative abundance of the most common tree species (relative to the PAA) in each study area

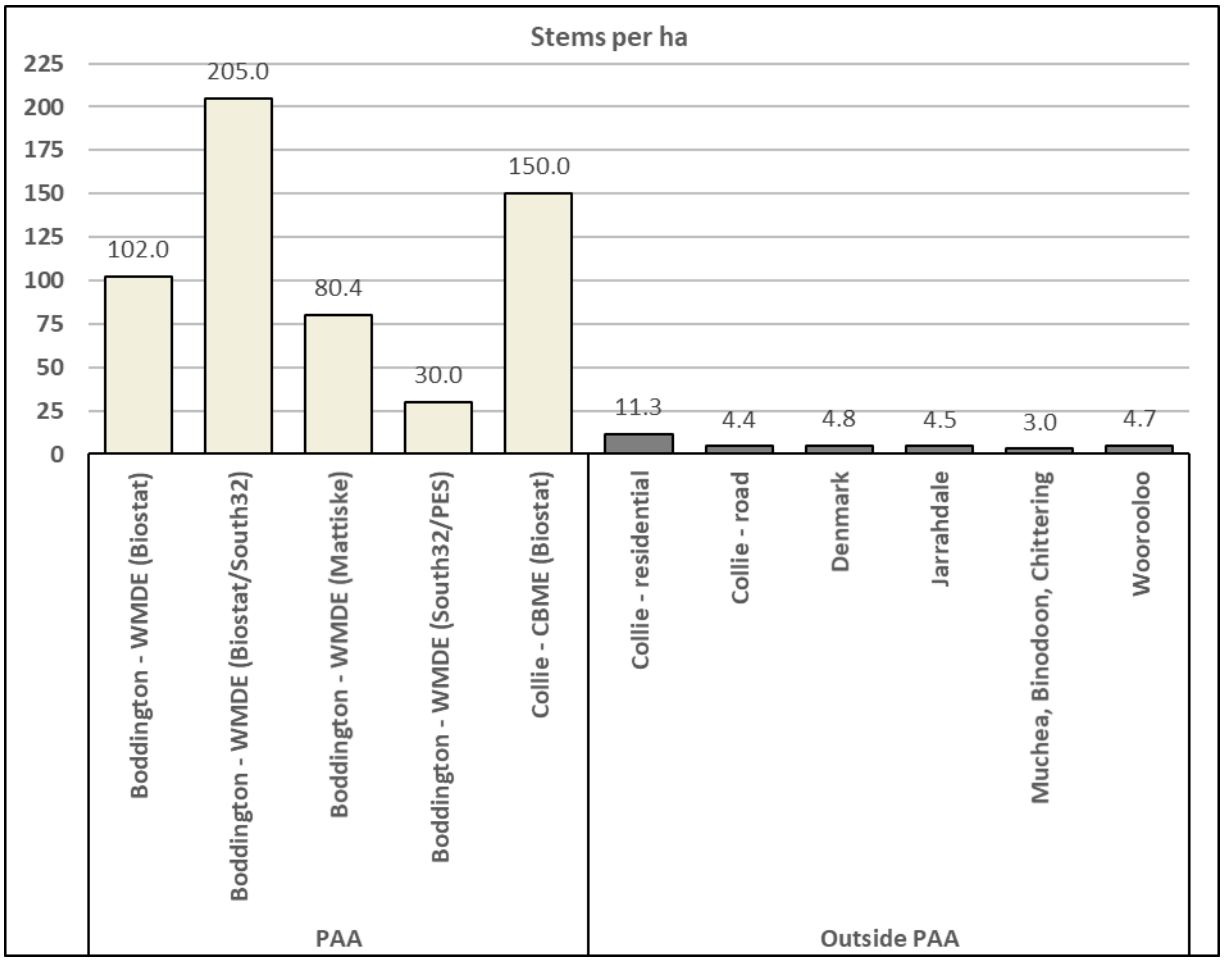


Figure 3-4 **Potential habitat tree density (stems/ha) within each survey area (ha) from three IBRA subregions**

3.3 Spatial Analysis of Black Cockatoo 'Potential Habitat Tree' and 'Breeding Tree' Data

When the entire PHT dataset is analysed (see section 1.4; 23,595 PHT), trees with evidence of nesting consist primarily of Wandoo (87), Marri (20), Jarrah (4) and Flooded Gum (5) (Table 3-3). According to Biostat (2020) the PAA is dominated by Jarrah (43%), Wandoo (23%) and Marri (22%) and this general trend is evident in the data presented here for the transect data (Biostat, South32/Biostat), systematic PHT data (South32/Phoenix) and vegetation plot data (Mattiske Consulting) (Table 3-2).

Only two confirmed breeding trees with natural hollows in JAF01 had DBH recorded. They were 300mm and 810mm; the 300mm record is likely to be an error (both are smaller than that documented by Johnstone *et al.* (2013a)). DBH of trees with breeding evidence in JAF01 ranged between 300 and 1,650 mm, with an average of 794 mm, and a median of 755 mm. Overall 95% of trees were between 300 mm and 1,200 mm DBH (Table 3-3); again, smaller than that documented by Johnstone *et al.* (2013a). However, these are not trees with confirmed breeding records.

Table 3-3 PHT species recorded in surveys in the JAF01 sub-region

Tree species	Confirmed breeding trees		PHT with evidence of breeding		PHT	
	JAF01	All data	JAF01	All data	JAF01	All data
Wandoo	7	9	80	110	8,731	10,821
Marri	4	4	16	205	2,882	4,284
Jarrah	1	1	3	5	7,970	2,852
Flooded Gum	0	0	5	6	1,050	1,698
Powderbark Wandoo	2	2	8	8	567	606
Salmon Gum	0	2	1	33	17	702
York Gum	0	0	0	0	337	1027
River Red Gum	0	1	0	2	65	197

A total of 23,595 PHT records were obtained from black cockatoo surveys in the southwest of WA including 20,448 from Phoenix' survey data. A total of 356 trees from the compiled dataset do not have coordinates and thus cannot be located and analysed spatially.

PHT spanned six IBRA regions with most records coming from the Jarrah Forest (17,653) (16,302 from the Northern Jarrah Forest sub-region, JAF01 and 763 from the Southern Jarrah Forest sub-region, JAF02), followed by Avon-Wheatbelt (3,110) and Swan Coastal Plain (2,708) (Table 3-4). Across all IBRA regions 706 trees have recorded evidence of breeding activity. In the Jarrah Forest, 154 trees have evidence of breeding activity of which 141 are located within the JAF01. A total of 59 PHT are recorded as having a confirmed breeding event take place in JAF01, 28 are natural breeding hollows and 31 artificial nesting hollows.

Carnaby's Cockatoos account for 46 of the 59 confirmed breeding records in the Northern Jarrah Forest (however 31 are from artificial hollows), nine are of FRTBC, two are of Baudin's Cockatoo and two do not specify species. The two Baudin's Cockatoos and nine FRTBC confirmed breeding records are from natural hollows. Thus, to date, nesting records from JAF01 are sparse.

Table 3-4 Summary of black cockatoo habitat trees in the dataset

IBRA region	Number of potential habitat trees	Number of trees with breeding evidence	Number confirmed breeding
Avon-Wheatbelt	3,110	77	31
Jarrah Forest	17,653 (JAF01: 16,311, JAF02: 1,342)	154 (JAF01: 141, JAF02: 13)	60 (JAF01: 59, JAF02: 1)
Geraldton Sandplains	62	61	58
Warren	59	6	2
Swan Coastal Plain	2,708	407	4
Esperance Plains	3	1	0
Total	**23,595**	**706**	**155**

3.4 PRE-CLEARANCE SURVEY DATA

Worsley undertakes pre-clearance surveys to identify black cockatoo breeding habitat within proposed clearing boundaries. When conducting pre-clearance surveys for black cockatoo species (South32 2020a), trees with hollows considered to have some potential to support cockatoo breeding are rated and subsequently inspected for those rated >=4 (Table 3-5). Further detail regarding survey methodology and management are provided in the Worsley pre-clearance black cockatoo habitat procedure (South32 2020a).

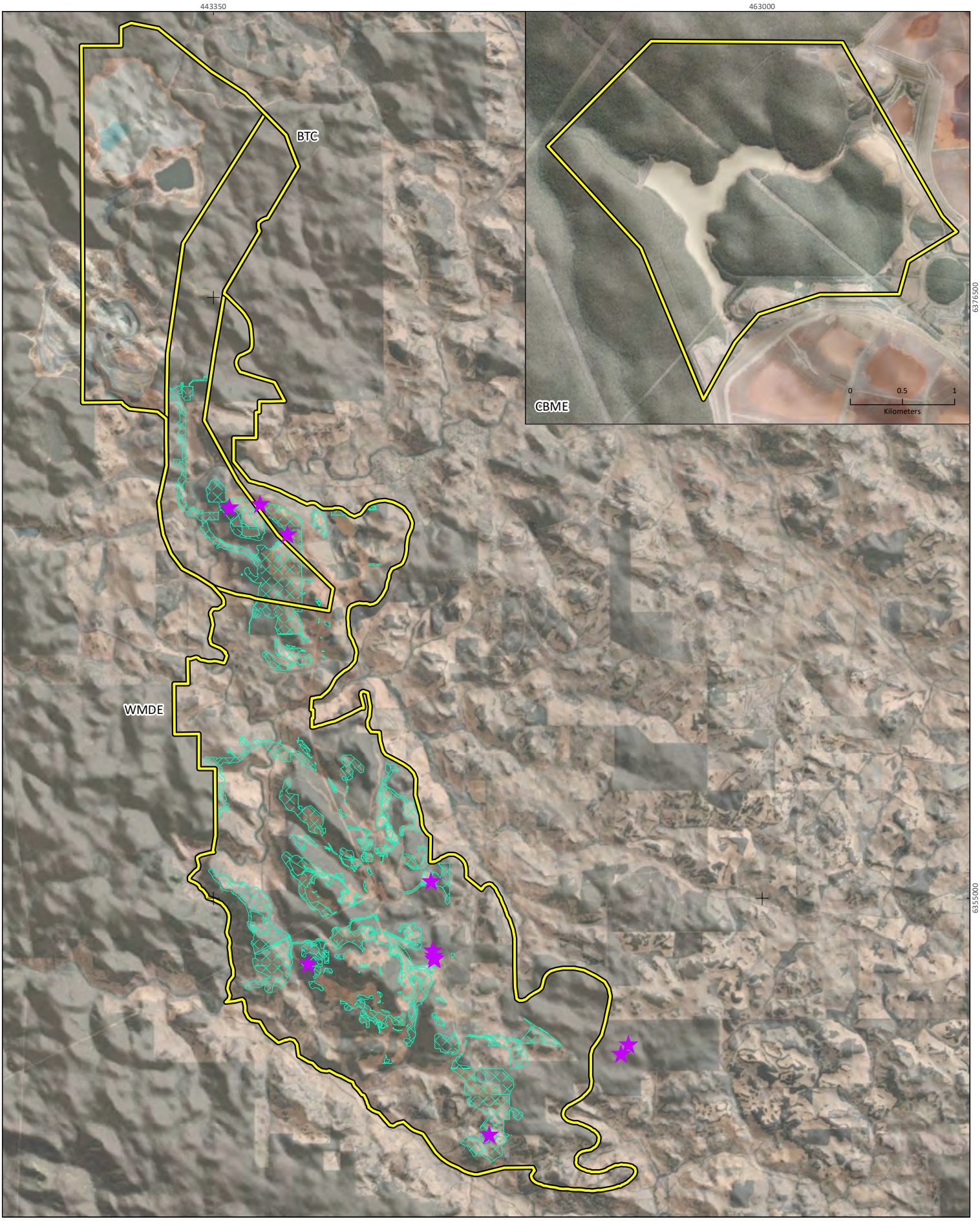
Table 3-5 Worsley black cockatoo pre-clearance survey potential habitat tree rating system

Rating	Potential	Description
10	Confirmed	Adult on nest, chick in nest.
9	Extremely high	Extremely high potential. High confidence in evidence of use i.e. visible fresh chewing around and at entrance to hollow, smooth entrance into hollow, scat line inside hollow, mulch material in base of hollow. Hollow attributes suitable for black cockatoo breeding i.e. entrance greater than 10cm diameter, depth of hollow greater than 80cm. If above criteria met then pole camera/drone used to confirm. Specific images to be sent to experts and were confirmed as a black cockatoo hollow, the rating is elevated to 10.
8	High	Moderate to high confidence in evidence of use. Likely chewing at hollow entrance. Hollow attributes suitable for black cockatoo breeding. Pole camera/drone to confirm.
7	Moderate to high	Possible chewing at hollow entrance. Hollow attributes suitable for black cockatoo breeding. Pole camera/drone to confirm.
6	Moderate	Hollow entrance and attributes suitable for BC breeding. Pole camera/drone to confirm.
5	Moderate	Hollow entrance and attributes on the limits of what may be considered suitable for BC breeding. Pole camera/drone to confirm. Pole camera/drone - Not possible to view inside hollow. Too high (usually >20 - 25m) or not possible to view hollow.
4	Low to moderate	No visible evidence of chewing or breeding activity. Hollow entrance suitable. Depth questionable. Pole camera/drone to confirm.

Rating	Potential	Description
3	Low	Hollows present, however, likely unsuitable by location, type or size. DBH moderate to high.
2	Low	Hollows present, however, likely unsuitable by location, type or size. DBH moderate.
1	Low	Hollows present, however, likely unsuitable by location, type or size. DBH low.
0	None	No breeding potential at the time of survey.

The data in Table 3-6 is largely derived from the Worsley black cockatoo internal pre-clearance dataset from surveys of 3,322.9 ha captured between July 2017 and June 2020 (Figure 3-5). The dataset also includes some historic South32 breeding records and breeding records obtained during baseline fauna surveys by Biostat (2020) conducted for this Proposal. No clearing has been undertaken in the CBME and therefore the CBME is not shown in Figure 3-5.

The data indicates that Jarrah with hollows are rarely rated higher than Low and no Jarrah with confirmed breeding have been recorded. Marri and Wandoo therefore represent the only species where black cockatoo breeding has been confirmed (n = 12), with an additional 15 trees of these species being rated as High and 100 trees rated as Medium. Trees of unknown species (dead) comprise 105 Medium-High potential breeding trees.



South32 Ltd
Worsley Mine Expansion Project

Project No	1317-WME-S32-VER
Date	1/09/2021
Drawn by	IN
Map author	JC

0 2.5 5
Kilometers

1:175,000 (at A4) GDA 1994 MGA Zone 50

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PAA

10 year plan clearing areas 2017 - 2022

Breeding trees

Figure 3-5

Pre-clearance survey boundaries (July 2017-June 2020)

PHOENIX ENVIRONMENTAL SCIENCES

Table 3-6 South32 black cockatoo pre-clearance and historical records dataset

Tree rating	Jarrah	Marri	Wandoo	Dead/not recorded	Total
Confirmed (10)	0	6	6	0	**12**
High (8 - 9)	2	13	2	16	**33**
Medium (5 - 7)	5	76	24	89	**194**
Low (1 - 4)	31	90	22	9	**152**
No Potential (0)	241	20	0	22	**283**
Total	**279**	**205**	**54**	**136**	**674**

The Worsley pre-clearance data of Table 3-6 is further analysed in terms of vegetation and habitat type in Table 3-7. Between July 2017 and June 2020, a total of 356 PHT with hollows were assessed for their potential to support black cockatoo breeding and five were found to support active breeding (Table 3-7). The breeding events were found to be occurring within three fauna habitats:

- Jarrah/Marri on slopes (2)
- Jarrah/Marri/Allocasuarina (2)
- Wandoo woodlands (1)

Interestingly, while Wandoo and Marri trees are the only known species to support breeding in the WMDE, only one breeding event has been recorded from Wandoo woodland in the last three years; this is because in that time Wandoo woodlands have historically rarely been cleared for bauxite mining by Worsley and therefore less area of Wandoo woodlands have required to be assessed as part of pre-clearance processes by the operation.

When the data is considered spatially it is evident that recorded breeding within the WMDE occurs at a density of 0.001 trees/ha.

Table 3-7 South32 black cockatoo pre-clearance PHT dataset for the years FY2017–FY2020

Vegetation code (Mattiske 2020)	Fauna habitat/code	Area surveyed (ha) (FY2017 - FY2020)	PHT rating					
			0	1-4	5-7	8-9	10	Total
A	Melaleuca shrublands on seasonally wet valley floors (MS)	6.8						0
A1								0
A2	*Melaleuca, E. rudis* woodlands on seasonally wet valley floors (MW)							0
AC	*E. rudis* woodlands which may include Jarrah, Marri, Banksia or Wandoo. Riparian community (FG)							0
AD								0
AX		12.9						0
AY		24.5						0
AY/D	Mosaic of Marri/Jarrah on lower slopes and *E. rudis* riparian community (FG/DL)							0
B	Jarrah/Marri valley floors/swamps							0
CL	Cleared Land (CL)	83.9						0

Vegetation code (Mattiske 2020)	Fauna habitat/code	Area surveyed (ha) (FY2017 - FY2020)	PHT rating					
			0	1-4	5-7	8-9	10	Total
CL – Ag		670.3						0
CL – Other		0.4						0
CQ	Blackbutt woodlands on lower slopes (BB)							**0**
CW								**0**
L		0.8						**0**
Q								**0**
W								**0**
DAM	Dam/open water body (DM)							**0**
D	Marri/Jarrah on lower slopes (DL)	71.4		10	7			**17**
DG								**0**
E								**0**
SW								**0**
G1	Heath/perched heath (PH)	0.2						**0**
G2		1.2				1		**1**
G3		0.8						**0**
G4	Mallee (ML)	2						**0**
H	Jarrah/Marri on slopes (JM)	291.1	1	11	15	3	1	**31**
H1		25.3			2			**2**
H2		111.1	1					**1**
HG		17.6						**0**
R								**0**
T								**0**
TS								**0**
Z		194.8	89		17		1	**107**
M	Wandoo woodlands (WO)	159.2	2		7		1	**10**
M2		1.2						**0**
MG		22.7						**0**
Y		9.1						**0**
YG	Wandoo woodlands[1] (WO)							**0**
P	Jarrah/Marri/Allocasuarina (JC)	901	76	23	23	3	2	**127**
PS		2.4						**0**
PW								**0**
S		608.3	1	29	24	5		**59**
SP								**0**
ST		33.2				1		**1**
PL	Plantations (PL)	20						**0**
PL -Ag		0.2						**0**
Rehab	Rehabilitation (RE)	50.3						**0**
Rehab – Ag		0.2						**0**

Vegetation code (Mattiske 2020)	Fauna habitat/code	Area surveyed (ha) (FY2017 - FY2020)	PHT rating					
			0	1-4	5-7	8-9	10	Total
	Total Area (ha)	3322.9	170	73	95	13	5	356

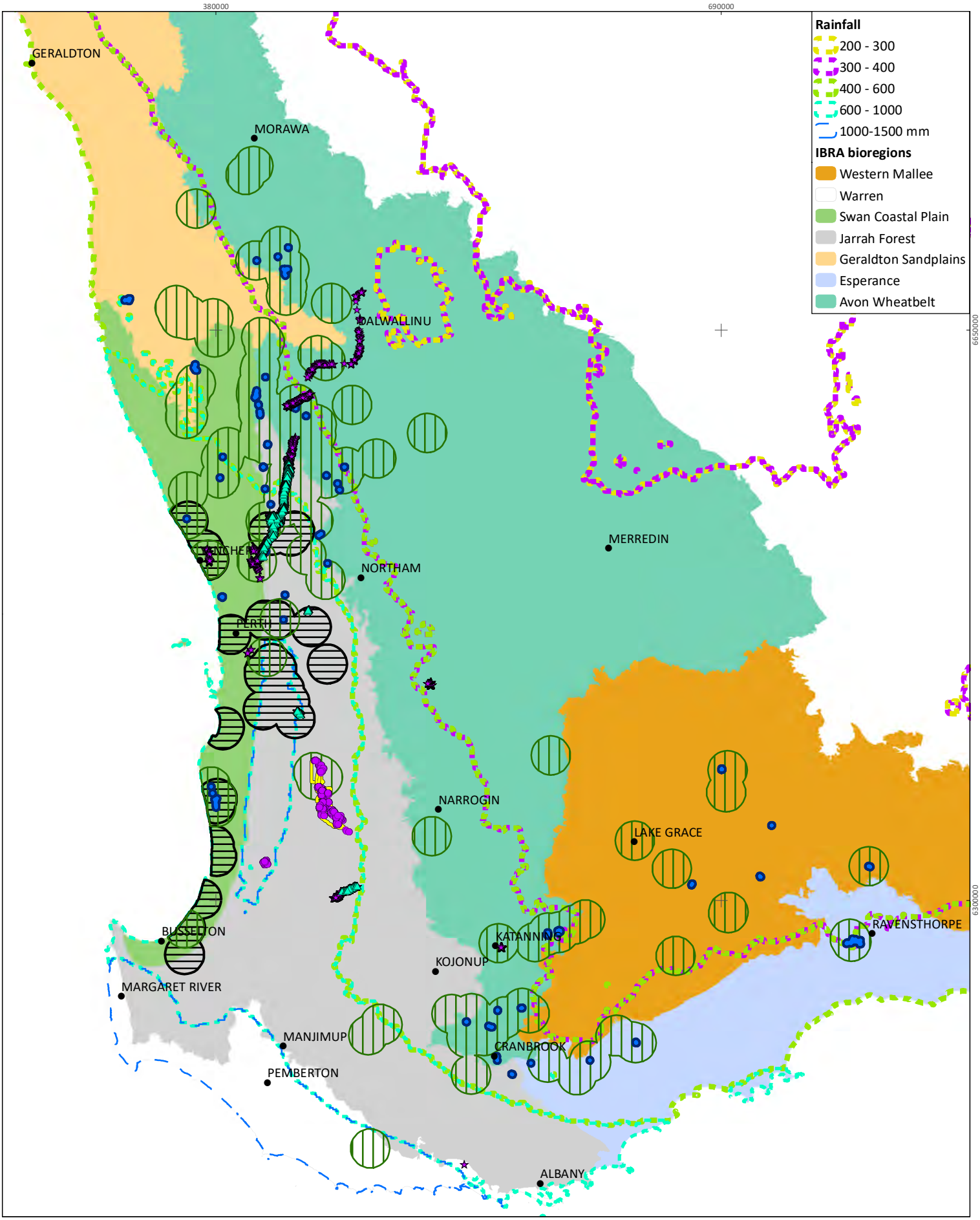
3.5 VEGETATION, FAUNA HABITATS AND BLACK COCKATOO BREEDING HABITAT VALUE

The black cockatoo breeding datasets are shown in Figure 3-6. The figure shows that over 50% of the PAA (northern half) represents breeding area for Carnaby's' Cockatoo. This dataset is based on a limited number of confirmed breeding records with a buffer applied (unknown distance) to mask the exact location to protect the location.

Fifty-nine vegetation complexes (Heddle *et al.* 1980) occur within JAF01. Trees with evidence of breeding occur within 18 of these (31%) and ten vegetation complexes (17%) have confirmed breeding records (Table 3-8). Seven vegetation complexes that occur within the PAA (Ce, Ck, D4, Mi, Pn, Y5 and Y6) comprise over 90% of the PAA and 95% of the IDF; all but one (Ce) have recorded confirmed black cockatoo breeding. At the scale of this dataset, the data suggests over 95% of the PAA can be considered as black cockatoo breeding habitat.

At the finer site-specific scale, trees with evidence of breeding have been recorded from seven of the vegetation types (Mattiske 2020)/fauna habitat types (Biostat 2020) and confirmed breeding trees are known from four vegetation types (Mattiske 2020)(D, H2, M, Y) and five fauna habitat types (Biostat 2020) (BB, DL, JC, JM and WO) (Table 3-9).

Six fauna habitats represent High value breeding habitat for Carnaby's Cockatoo (Table 3-9; Table 3-10), and accordingly 22% of such habitat in the PAA is proposed to be impacted by the Proposal. For FRTBC High value breeding habitat is represented by five fauna habitats (Table 3-9; Table 3-10), of which 19% in the PAA is proposed to be impacted by the Proposal (Table 3-10). There is no High or Moderate value breeding habitat for Baudin's Cockatoo in the PAA (Figure 3-9; Table 3-10); Low value habitat for Baudin's Cockatoo represents 43% of the PAA, the loss of habitat under the Proposal represents 23% loss of Low value breeding habitat within the PAA.



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PAA

Black cockatoo breeding sites based on recorded breeding events buffered (DBCA, indicative dataset)

- Black cockatoo breeding sites buffered
- Carnaby's Cockatoo confirmed breeding areas
- Carnaby's Cockatoo unconfirmed breeding areas

PHT records (Phoenix and S32 only)

- South32
- Phoenix (JAF01 IBRA region)
- Phoenix all other records

Figure 3-6

Black cockatoo potential breeding habitat

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Table 3-8 Summary of black cockatoo breeding records in vegetation complexes of the Northern Jarrah Forest

Vegetation complex (Heddle *et al.* 1980)	Brief description	No. of PHT	No. of confirmed breeding trees	Proportion of confirmed breeding hollows/PHT[1]	No. of trees with evidence of breeding	Proportion hollows with evidence of breeding/ PHT[1]	PAA (%)	IDF (%)
Bindoon (Bi)	Wandoo and Powderbark woodland with a generally sparse *Acacia* understory on slopes of a valley	2,816	0	0	4	0.1%	0	0
Cooke (Ce)	Open eucalypt spp. woodland with spare understory	10	0	0	1	10%	8.8%	7.6%
Coolakin (Ck)	Marri/Jarrah/Wandoo woodland/forest over proteaceous species	2,174	8	0.4%	24	1.1%	12.3%	9.9%
Dwellingup (D1)	Marri/Jarrah tall forest of with proteaceous understory, generally undulating	234	0	0	1	0.4%	1.1%	1.5%
Dwellingup (D2)	Marri/Jarrah Forest with proteaceous and Allocasuarina understory, generally undulating	117	1 (19)	0.9%	2 (19)	1.9%	0	0
Dwellingup (D4)	Marri/Jarrah woodland/forest with proteaceous understory	304	1	0.3%	1	0.3%	32.2%	40.3%
Michibin (Mi)	*Eucalyptus*, *Allocasuarina* or *Acacia* spp. woodland with low understory	794	2	0.3%	8	1%	16.4%	13.0%
Mogumber (Mb)	Jarrah/Marri woodland with proteaceous understory	179	0 (4)	0	(4)	2.4%	0	0
Moondah (Mh)	No description	113	0 (1)	0	0 (1)	0	0	0
Murray 1 (My1)	*Eucalyptus* forest with *Banksia* on lower or mid-slopes of a valley	101	1	1%	1	1%	1.3%	1.1%
Murray 2 (My2)	*Eucalyptus* spp. woodland/ forest with low shrub to herbaceous understory	236	0	0	0	0	0	0
Nooning (No)	Flooded gum and Melaleuca open forest on a seasonally inundated and waterlogged area	1,170	0	0	5 (3)	0.4%	0	0

Vegetation complex (Heddle *et al.* 1980)	Brief description	No. of PHT	No. of confirmed breeding trees	Proportion of confirmed breeding hollows/PHT[1]	No. of trees with evidence of breeding	Proportion hollows with evidence of breeding/ PHT[1]	PAA (%)	IDF (%)
Pindalup (Pn)	*Eucalyptus* spp. woodland/forest with low shrub herbaceous understory	992	3	0.3%	12	1.2%	7.0%	8.7%
Swamp (S)	Low lying seasonally waterlogged area	349	0		2	0.6%	3.0%	1.0%
Williams (Wi)	*Eucalyptus*, *Casuarina*, or *Melaleuca* woodland on a seasonally inundated and/or waterlogged valley floor or floodplain	80	0	0	0	0	4.2%	0.8%
Yarragil 1 (Yg1)	Jarrah/Marri/Blackbutt woodland/forest with a proteaceous understory generally on undulating valley lower slopes	27	0	0	1	3.7%	0.1%	0.1%
Yalanbee (Y5)	Jarrah/Marri woodland with proteaceous understory on undulating slopes	600	5	0.8%	10	1.7%	5.0%	10.5%
Yalanbee (Y6)	Wandoo/Marri woodland and proteaceous understory on undulating, uplands	4,150	4 (2)	0.1%	39 (2)	0.9%	7.9%	5.3%
Total		**9,095**	**25**	**0.51%**	**115**	**1.78%**	**100%**	**100%**

* Shading indicates vegetation complexes included in analyses.
* Figures in bracket represent artificial hollows. These complexes were analysed as they occur in the PAA.
* Mattiske plot data not included as breeding evidence was not recorded, which would therefore skew the analysis.

Table 3-9 Summary of PHT and breeding evidence in relation to vegetation type and fauna habitats in the PAA

x = not breeding habitat, L = Low value breeding habitat, M = Moderate value breeding habitat, H = High value breeding habitat

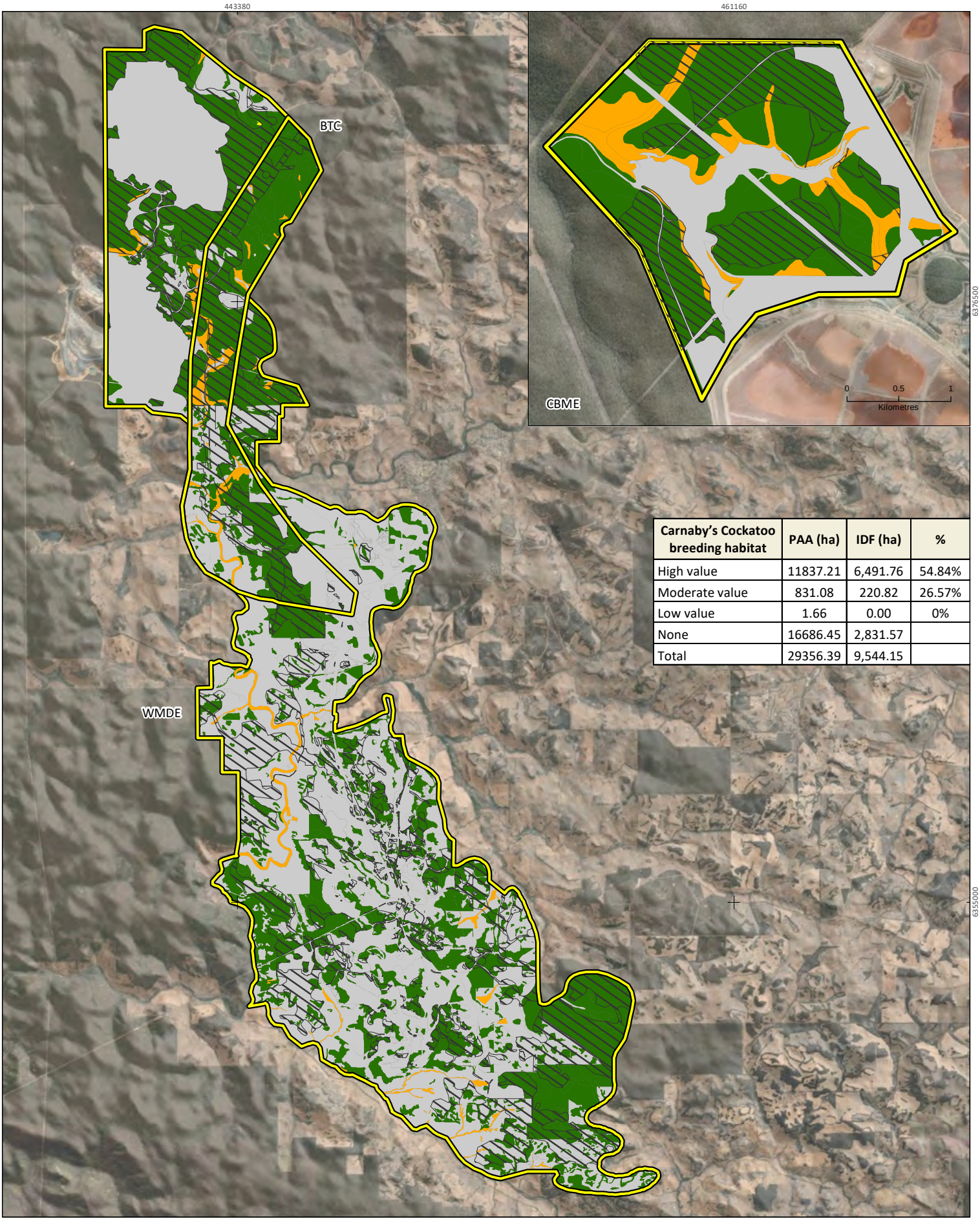
Veg. type codes (Mattiske 2020)	Fauna habitat description (Biostat 2020)	No. of PHT in PAA	No. of confirmed breeding trees in PAA (IDF)	Proportion of confirmed breeding hollows/PHT	No. of trees with evidence of breeding	Proportion hollows with evidence of breeding/ PHT	Potential breeding habitat		
							Carnaby's Cockatoo	Baudin's Cockatoo	FRTBC
A	*Melaleuca* shrublands on seasonally wet valley floors	0	0	0	0	0	×	×	×
A1		0	0	0	0	0	×	×	×
A2	*Melaleuca* and *E. rudis* woodlands on seasonally wet valley floors	0	0	0	0	0	L	×	×
AC	*E. rudis* woodlands which may include Jarrah, Marri, *Banksia* or Wandoo. Riparian community.	0	0	0	0	0	M	L	L
AD		0	0	0	0	0	M	L	L
AX		19	0	0	0	0	M	L	L
AY		31	0	0	0	0	M	L	L
AY/D	Mosaic of Marri/Jarrah on lower slopes and *E. rudis* riparian community	29	0	0	0	0	M	L	L
B	Jarrah/Marri valley floors/swamps	0	0	0	0	0	H	L	H
CL	Cleared Land	38	0	0	0	0	×	×	×
CL – Ag		1	0	0	0	0	×	×	×
CL – Other		0	0	0	0	0	×	×	×
DAM	Dam/open water body	0	0	0	0	0	×	×	×

Veg. type codes (Mattiske 2020)	Fauna habitat description (Biostat 2020)	No. of PHT in PAA	No. of confirmed breeding trees in PAA (IDF)	Proportion of confirmed breeding hollows/PHT	No. of trees with evidence of breeding	Proportion hollows with evidence of breeding/ PHT	Potential breeding habitat		
							Carnaby's Cockatoo	Baudin's Cockatoo	FRTBC
D	Marri/Jarrah on lower slopes	184	1 (1)	0.5%	1(1)	0.5%	H	L	H
DG		0	0	0	0	0	H	L	H
E		0	0	0	0	0	H	L	H
G/G1	Heath/perched heath	20	0	0	0	0	×	×	×
G2		0	0	0	0	0	×	×	×
G3		0	0	0	0	0	×	×	×
G4	Mallee	0	0	0	0	0	×	×	×
H	Jarrah/Marri on slopes	105	0	0	1	1%	H	L	H
H1		9	0	0	0	0	H	L	H
H2		41	1	2.4%	2	4.9%	H	L	H
HG		0	0	0	0	0	H	L	H
R		0	0	0	0	0	H	L	H
T		0	0	0	0	0	H	L	H
TS		81	0	0	0	0	H	L	H
Z		184	0	0	0	0	H	L	H
CQ	Blackbutt woodlands on lower slopes	18	0	0	0	0	M	L	L
CW		0	0	0	0	0	M	L	L
L		32	0	0	0	0	M	L	L
M	Wandoo woodlands	157	2(1)	1.3%	2(1)	1.3%	H	L	L

Veg. type codes (Mattiske 2020)	Fauna habitat description (Biostat 2020)	No. of PHT in PAA	No. of confirmed breeding trees in PAA (IDF)	Proportion of confirmed breeding hollows/PHT	No. of trees with evidence of breeding	Proportion hollows with evidence of breeding/ PHT	Potential breeding habitat		
							Carnaby's Cockatoo	Baudin's Cockatoo	FRTBC
M2		0	0	0	0	0	H	L	✓
MG		8	0	0	0	0	H	L	✓
Y		128	1(1)	0.8%	4(1)	3.1%	H	L	✓
YG		3	0	0	0	0	H	L	✓
PL	Plantations	0	0	0	0	0	×	×	×
PL -Ag		0	0	0	0	0	×	×	×
P	Jarrah/Marri/Allocasuarina	163	0	0	0	0	H	L	H
PS		6	0	0	0	0	H	L	H
PW		0	0	0	0	0	H	L	H
S		217	0	0	0	0	H	L	H
SP		0	0	0	0	0	H	L	H
ST		202	0	0	1	0.5%	H	L	H
Q	Blackbutt woodlands on lower slopes	39	0	0	1	2.6%	L	L	L
W		0	0	0	0	0	L	L	L
Rehab	Rehabilitation	0	0	0	0	0	×	×	×
Rehab – Ag		0	0	0	0	0	×	×	×
SW	Marri/Jarrah on lower slopes	0	0	0	0	0	H	L	H
Average	**Using only those with >0%**			**1.25**		**1.74**			

Table 3-10 Black cockatoo breeding habitat value summary for the PAA and IDF

Breeding habitat value	Carnaby's Cockatoo				Baudin's Cockatoo				FRTBC			
	PAA (ha)	PAA (%)	IDF	IDF (% of PAA)	PAA (ha)	PAA (%)	IDF	IDF (% of PAA)	PAA (ha)	PAA (%)	IDF	IDF (% of PAA)
High value	11,850	40%	6,482	22%	0	0%	0	0%	9,172	31%	5,647	19%
Moderate value	824	3%	232	1%	0	0%	0	0%	0	0%	0	0%
Low value	2	<0.1%	0	0%	12,676	43%	6,714	23%	3,516	12%	1,071	4%
None	16,681	57%	2,831	10%	16,681	57%	2,831	10%	16,668	57%	2,827	10%
Total	**29,356**	**100%**	**9,545**	**33%**	**29,356**	**100%**	**9,545**	**33%**	**29,356**	**100%**	**9,545**	**33%**



Carnaby's Cockatoo breeding habitat	PAA (ha)	IDF (ha)	%
High value	11837.21	6,491.76	54.84%
Moderate value	831.08	220.82	26.57%
Low value	1.66	0.00	0%
None	16686.45	2,831.57	
Total	29356.39	9,544.15	

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PAA
IDF

Breeding habitat rating
High
Moderate
Low
None

Figure 3-7

Carnaby's Cockatoo breeding habitat value in the PAA

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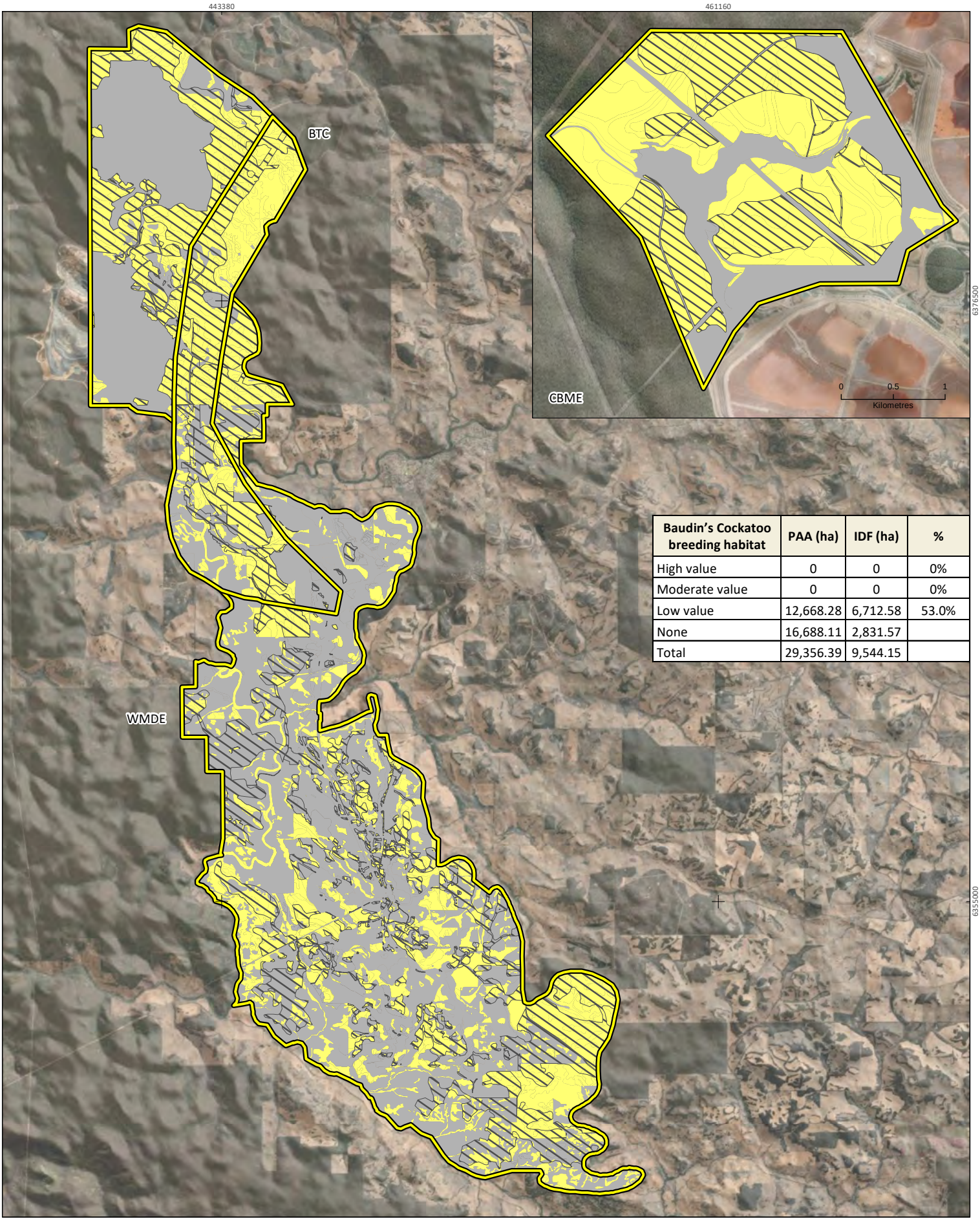

Baudin's Cockatoo breeding habitat	PAA (ha)	IDF (ha)	%
High value	0	0	0%
Moderate value	0	0	0%
Low value	12,668.28	6,712.58	53.0%
None	16,688.11	2,831.57	
Total	29,356.39	9,544.15	

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PAA
IDF

Breeding habitat rating

Low
None

Figure 3-8

Baudin's Cockatoo breeding habitat in the PAA

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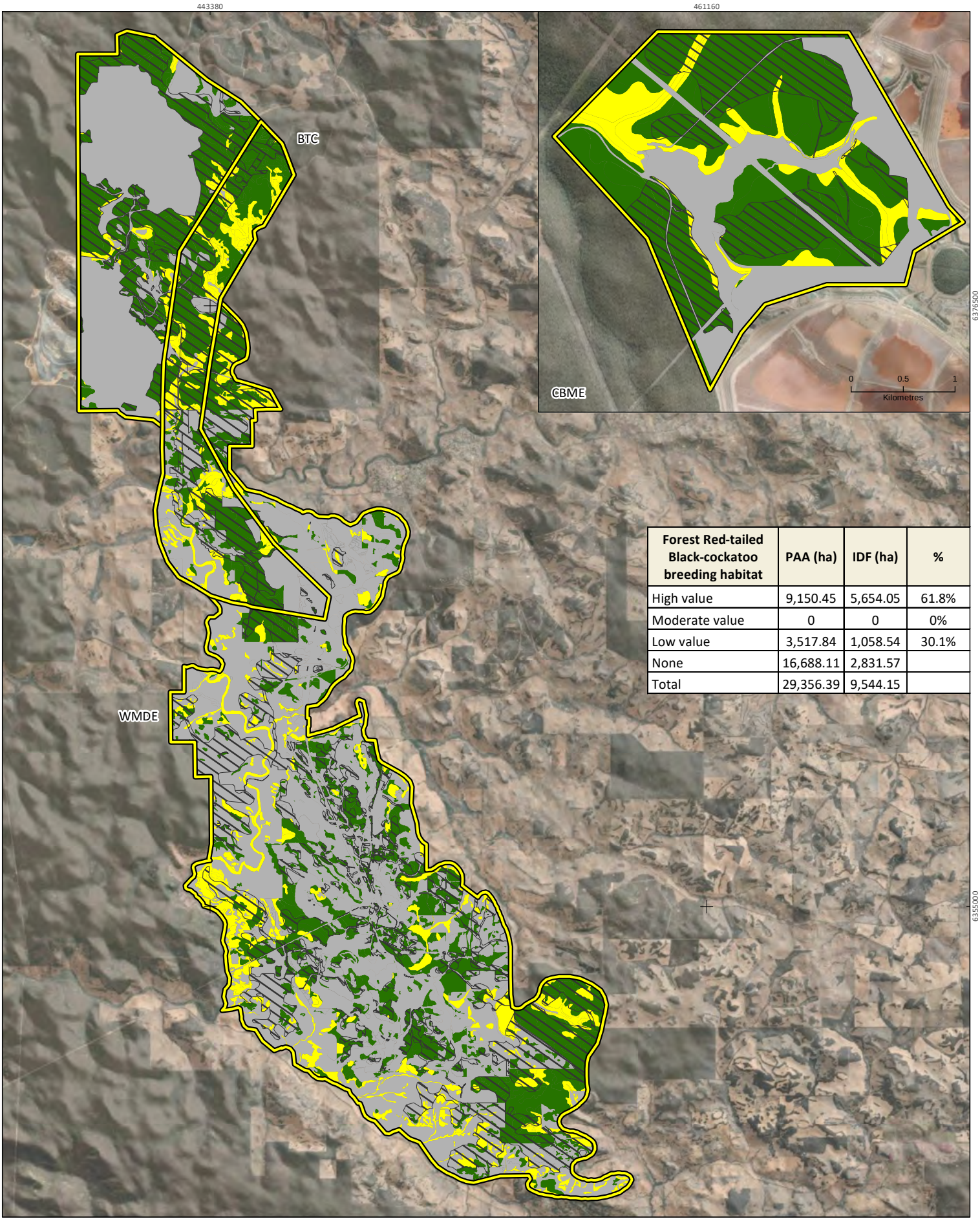

Forest Red-tailed Black-cockatoo breeding habitat	PAA (ha)	IDF (ha)	%
High value	9,150.45	5,654.05	61.8%
Moderate value	0	0	0%
Low value	3,517.84	1,058.54	30.1%
None	16,688.11	2,831.57	
Total	29,356.39	9,544.15	

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Kilometers

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PAA
IDF

Breeding habitat rating

High
Low
None

Figure 3-9

Forest Red-tailed Black Cockatoo breeding habitat value in the PAA

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3.6 OTHER CONSIDERATIONS RELATED TO BLACK COCKATOO BREEDING HABITAT AND AVAILABILITY OF BREEDING HOLLOWS

3.6.1 Silviculture in the Jarrah Forest

Johnstone *et al.* (2013a) found that nest trees of all species used by black cockatoos have an average circumference at breast height of 2.79 m (DBH = 0.88 m), a mean estimated age of 222 years and a mean overall height of 20.24 m. This provides some context with which to accompany the text below and the DSEWPaC (2012) potential habitat tree guideline criteria for Jarrah and Marri (i.e. >50cm), aimed at retaining a stock of trees with the potential to develop hollows.

Large areas of the Northern Jarrah Forest have been managed for forestry since 1870's, the Southern Jarrah Forest was not logged until the 1940's. The ~150 years of active forestry have seen a number of different systems and methods applied (Bradshaw 2015). Between 1870 and 1920 uncontrolled clear-felling of the western side of the Northern Jarrah Forest took place. From 1920 to 1940 Group selection was the most commonly employed system, where mature trees were targeted and few left standing. By the end of this period 169,000 ha had been logged, treated for regeneration or thinned; a program made possible by a large Great Depression workforce (Bradshaw 2015).

From 1940 demand for timber increased due to the post-war (WWII) reconstruction requirements in Europe. Several sawmills were established in the Southern Jarrah Forest for the first time (Bradshaw 2015). By the 1950's methods had changed, whereby the least thrifty trees (i.e. mature trees were selected), thus the logged area (ha) increased, but the overall intensity of forestry practices decreased. At this time, it aimed to open up the forest and provide access for fire control. This practice continued until the mid-1960's and resulted in multi-aged stands but stands with few mature trees.

From the mid-1960's heavy fuel loads had accumulated which made it difficult to use prescribed burns safely and indeed to reduce fuel loads where it was safe (i.e. the fuel load was too wet to burn) (Harris 1975). Up until this point forestry management had attempted to protect the regrowth timber resources from fire; following the highly destructive 1961 Dwellingup fire prescribed burning was increased and timber forests were no longer afforded a fire-free protection period. The effects of this change on hollow development are unknown.

'Jarrah dieback' (*Phytophthora cinnamomi*) as it was historically called was identified in 1965. This led to further changes in forestry practices: the area logged was reduced to reduce infection risk; all sawlogs were removed from harvested areas from 1970; and culls were not removed and there was no attempt to create distinct gaps for regeneration (Bradshaw 2015).

Around the same time, in 1962 bauxite mining in the Northern Jarrah Forest began. Until 1988 dieback resistant exotic eucalypt species were used in rehabilitation (Bradshaw 2015).

During the late 1970s and early 1980's Marri were woodchipped and thus a more intensive timber harvesting method was deployed (Bradshaw 2015).

The resultant stands from the period of the mid-1960's through to the mid-1980' were typically multi-aged resulting from the removal of single trees and some large groups of saplings with any habitat trees that had withstood the previous 100 years of different timber harvesting systems and methods, being retained (Bradshaw 2015).

It was not until the end of this period that other, competing forest uses began to impact forestry management practices, such as for wildlife protection, water quality and catchment protection and recreation (Bradshaw 2015).

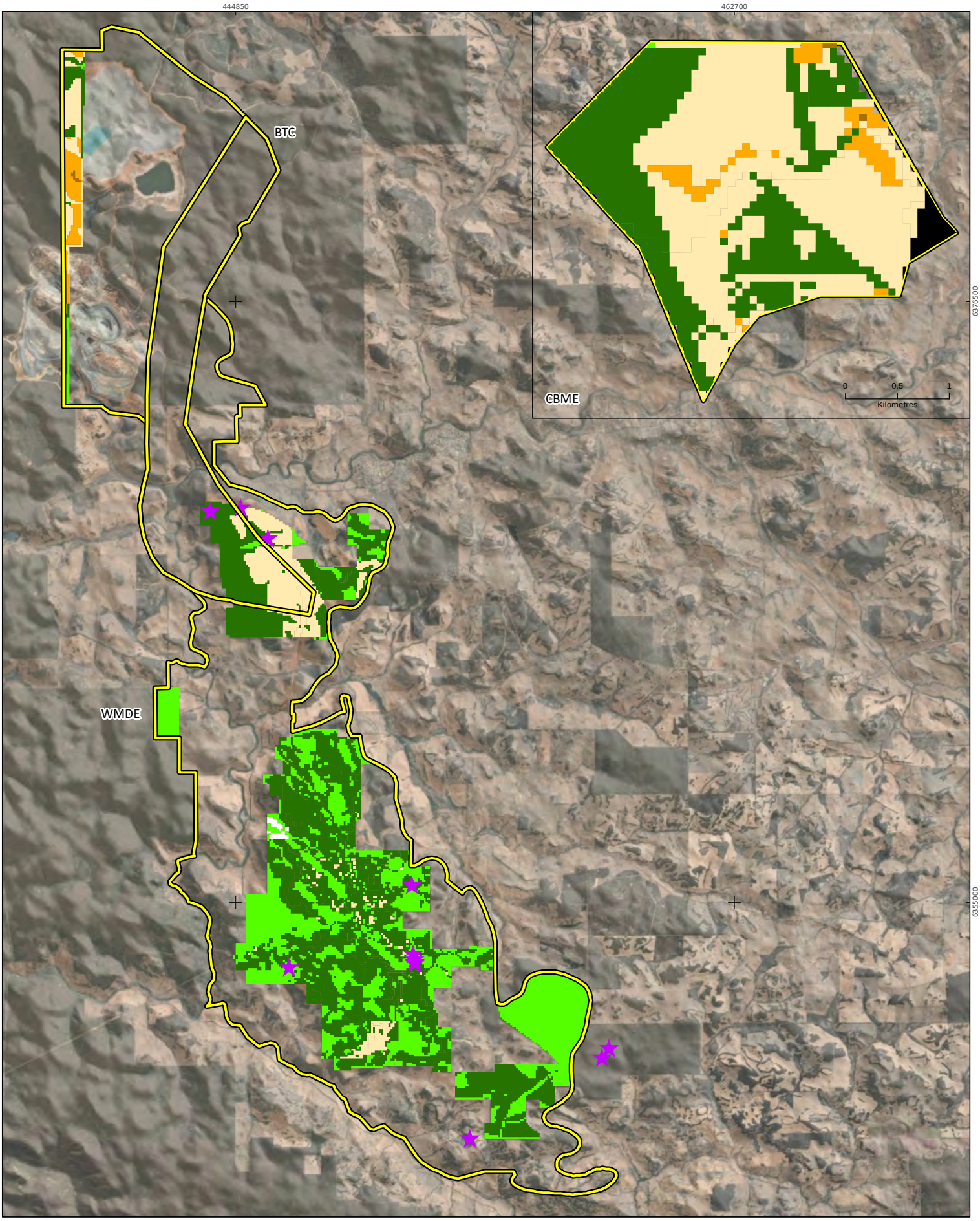
In previous regimes, 'legacy tree retention' (the retention of individuals or groups of trees or patches of older forest) was practiced, which most closely approximates the retention of 'habitat trees' as practiced today. However, in subsequent years legacy tree retention areas were actively targeted and thus old growth trees that would have provided hollows for cockatoo species were lost.

Where mature trees of breeding diameter (>880mm) are retained as 'habitat trees', on the next rotation no new habitat trees will necessarily be added, thus within only a few rotations under the current practices, the vast majority of habitat trees will have been lost. This has important implications for black cockatoos within State Forest, particularly those areas actively mined for bauxite as a majority of the trees are removed to allow mining. That being said, Worsley do preserve habitat including habitat trees either as Protected Areas (preferred) under the Protected Areas Procedure or occasionally, individual trees on a case-by-case basis, e.g. approximately 1250 ha of habitat is protected from bauxite mining (through the Protected Areas Procedure) of which the majority is either Wandoo or Jarrah/Marri. Additionally, pod mining means boundaries can be modified to a degree and where appropriate.

Currently much of the land sought for bauxite mining under the Proposal is State Forest (~3,600 ha; ~53% of the IDF) which has been managed for timber production under various planting, maintenance and fire management, and harvesting protocols, as detailed above, for a long time. Within the Jarrah Forest bioregion under current protocols, harvesting of trees occurs no earlier than 71 years. The harvest history, according to data supplied by DBCA to South32 is shown in Figure 3-10. The data shows that the majority of forest within the PAA has been harvested at least once. Harvesting within the WMDE has been variable, with harvesting at Saddleback having been extensive and repeated (2-3 times), and less intensive at Marradong (1-2 times). Around the Newmont Boddington Gold Mine (west), harvesting has occurred as many as five times. At the CBME harvesting has also been extensive, with the entire area having been harvested at least two times and as many as five times.

The harvest history is evident in the demographic analyses where it was shown that tree density (stems/ha) is much greater within the PAA compared with the studies from road-side remnants (Figure 3-2; Figure 3-4)

Given the general silvicultural history detailed above for the Jarrah Forest and the specific PAA harvest history shown in Figure 3-10, the lack of recorded breeding trees in the PAA (12 in total) is not surprising.



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PAA
Breeding trees

Harvest frequency
- Five times
- Four times
- Three times
- Twice
- Once
- No occurrence
- No data

Figure 3-10

S32 PAA harvest history since 1920

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3.6.2 The impacts of fire

According to the DBCA fire history dataset large areas of the PAA have not burnt since the 1970's (Figure 3-11), this is principally because the mining companies operating in the area have acted to protect their assets.

Nearby however controlled and uncontrolled fires have been extensive. An unknown number of potential breeding and foraging trees were lost in the 2019 Lower Hotham fire for example, with approximately 52,000 ha burnt (Landgate 2019). This area is approximately 1-10km south-west of the PAA. This has placed pressure on the remaining potential breeding trees in and surrounding the PAA, specifically for Carnaby's and the FRTBC who have been recorded nesting in Nanga Brook (approximately 23km west of the PAA) and Dwellingup (approximately 22km north-west from PAA) (T Kirkby, 2020 pers. comm., 16 April).

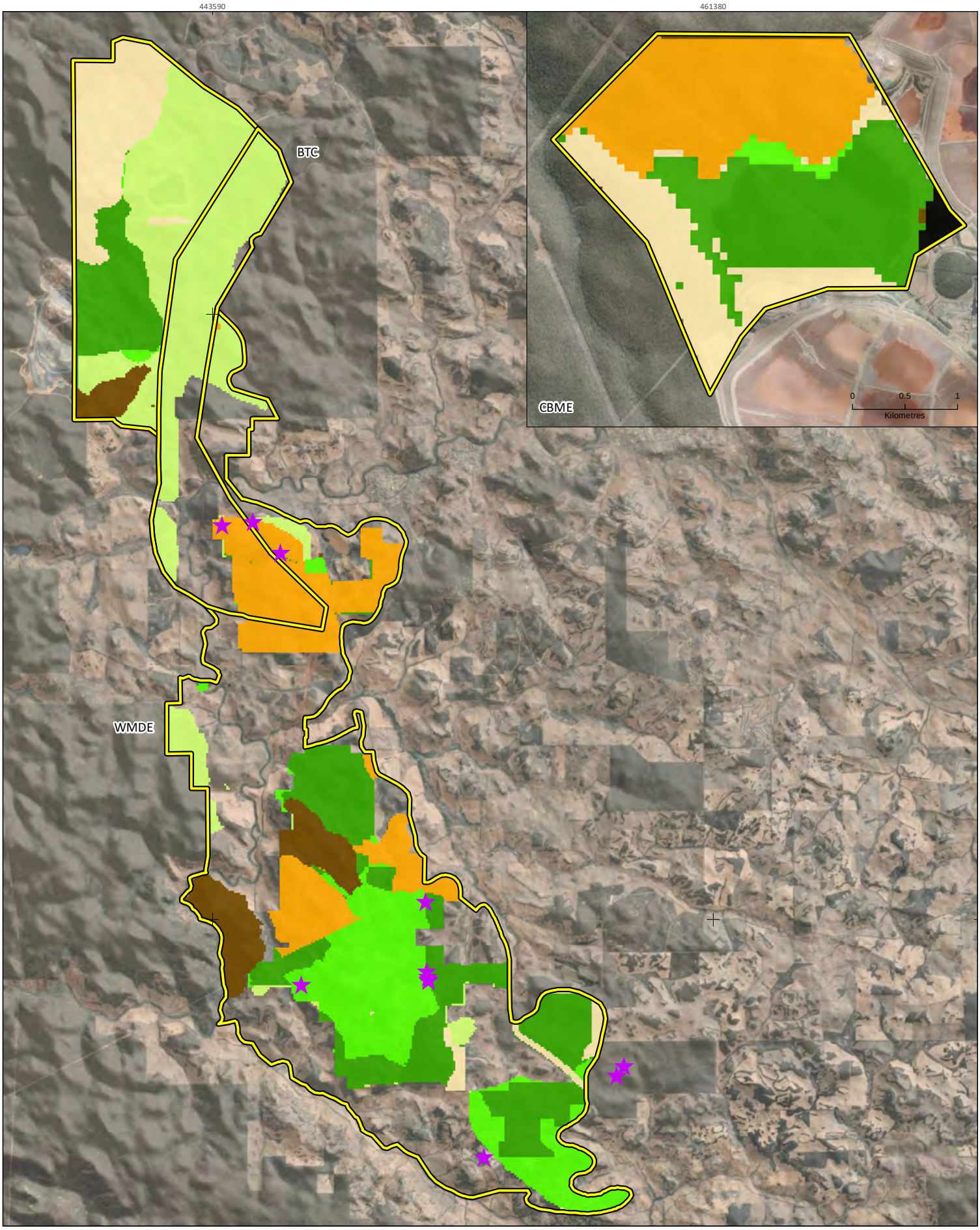
The 2016 Waroona-Yarloop-Harvey wildfire approximately 40km west of the PAA burnt approximately 69,000 ha including extensive areas of Jarrah-Marri forest and remnant nesting trees on road verges (Johnstone *et al.* 2017). Twelve known black cockatoo nesting hollows were burnt in this fire. This same wildfire also swept through the nearby Alcoa Larego forest block (Nanga Road) and destroyed a total of 19 of 41 known cockatoo hollows (Johnstone *et al.* 2017). This also equated to the loss of about 80– 90% of foraging habitat for the small resident FRTBC flocks in that region, resulting in these birds needing to forage well outside their normal home range to survive (Johnstone *et al.* 2017).

Fire is thus one of the biggest threats to the loss of veteran and stag Marri trees as these species have a tendency to form hollows quicker and will burn right to the ground (T Kirkby, 2020 pers. comm., 14 April). Thus, the active fire suppression practiced by Worsley (as evident in Figure 3-11) is highly advantageous to black cockatoo breeding in the PAA and immediate surrounds.

3.6.3 Loss of nearby foraging habitat

The intactness and connectivity of feeding habitat surrounding breeding areas affects nestling weights and fledging rates (Saunders 1977; Saunders 1986). In fragmented landscapes, the ability of parent birds to fly to feeding areas is hampered in that adequate feed may not be provided to nestlings. This results in a failed or compromised breeding attempt (Saunders 1977; Saunders 1986). The availability of Jarrah and Marri seed as a main, native foraging resource in close proximity (within 6 km) to known nesting habitat is becoming increasingly scarce in many areas in the face of habitat modification, climate change and fire (Johnstone *et al.* 2017). Recent fires have seen the loss of 5,200 ha of Jarrah and Marri forest surrounding the PAA habitat (Landgate 2019). The loss of this nearby habitat is critical to the survival of nesting black cockatoos that may utilise this area.

In the context of bauxite mining, rehabilitated areas are a significant foraging resource for black cockatoos (Doherty *et al.* 2016; Lee *et al.* 2010) and offer supplementary sources to that lost from fires and mining. In the immediate area of the PAA, there are significant undisturbed and rehabilitation foraging resources adjacent to and in close proximity to breeding habitat and thus loss of foraging habitat is not considered to be a limitation to black cockatoo breeding within the PAA.



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PAA

Breeding trees

Fire history

- 2009 - 2017
- 2000 - 2009
- 1990 - 1999
- 1980 - 1990
- 1974 - 1980
- <1960 - 1972
- No data

Figure 3-11

PAA fire history (<1960 - 2017)

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3.7 POTENTIAL BLACK COCKATOO HABITAT SURROUNDING THE PAA

Figures and data produced in this analysis are indicative and based on best available data. Assumptions have been made where information is not available.

Land within 20 km of the PAA can be attributed to four primary uses: natural environments, agriculture, infrastructure, and water. These four land uses have been assigned to three potential black cockatoo habitat types: 'drinking habitat', 'movement corridors' and 'foraging, roosting and breeding habitat' (Figure 3-12).

3.7.1 Drinking habitat

Drinking habitat suitable for black cockatoo species consists of all fresh surface water features, including but not limited to reservoirs, farm dams, swamps, rivers and lakes. For this analysis, only water features likely to be perennial were considered.

Approximately 321.2 ha of drinking habitat was found within the PAA, and 5,475.26 ha within 20 km of the PAA (Figure 3-13; Figure 3-14). Approximately 5.96ha occurs within the IDF (Figure 3-13; Figure 3-14).

Approximately 259.23 ha of drinking habitat is found within WMDE and BTC (Figure 3-13). The largest water feature is the Hotham River, which runs through the central portion of WMDE. The remining water features within the WMDE & BTC are mainly small dams, predominantly concentrated in areas used for agriculture.

Drinking habitat surrounding WMDE and BTC is concentrated to the east where land is mainly used for agriculture; these water features are primarily small farm dams (Figure 3-13). The Murray River and Lake Banksiadale also lie within 20 km west of the WMDE and BTC, both of which are considered important black cockatoo drinking habitat due to the scarcity of other permanent water features in their vicinity and the presence of potential breeding, foraging and roosting habitat surrounding them.

Approximately 61.96 ha of drinking habitat is found within CBME (Figure 3-14). A large fresh water dam used for refinery operations is in the centre of the CBME and makes up all of the drinking habitat within the CBME. Within 20 km of the CBME lies Stirling Dam, Harvey Dam, Lake Ballingall and Wellington Dam (Figure 3-14). Benger Swamp lies to the west of the CBME within Benger Swamp Nature Reserve. Like the WMDE and BTC, drinking habitat surrounding the CBME is common in agricultural areas as small farm dams.

It is likely that other water features are present that were not captured by available data; for example, black cockatoos have been found to utilise horse drinking troughs (Rycken 2019) which are not illustrated in Figure 3-13 and Figure 3-14. Therefore, figures and data produced by this analysis are indicative.

3.7.2 Foraging, roosting and breeding habitat

Natural environments surrounding the PAA likely provide foraging, roosting, and breeding habitat for black cockatoos. Natural environments include nature reserves, national parks, conservation areas, residual native cover, production native forests, wood production forestry and grazing of native vegetation.

Potential foraging, roosting, and breeding habitat within 20 km of the WMDE and BTC is primarily located west of the PAA (Figure 3-12). To the east, the landscape is largely used for agriculture; as such, remnant vegetation suitable for foraging, roosting, or breeding habitat is fragmented and less

available (Figure 3-12). Regarding the CBME, areas within 20 km to the northeast and south of the PAA are likely to provide suitable foraging, roosting, and breeding habitat. To the west and southeast of the CBME, land is generally used for agriculture and infrastructure (Figure 3-12).

Natural environments in close proximity to drinking habitat is critical to ensuring successful breeding (DAWE 2022). Black cockatoos rely on watering points usually within 2 km of night roost sites (DAWE 2022); as such, natural environments that lie within 2 km of drinking habitat are considered particularly important foraging, roosting, and breeding habitat.

3.7.3 Movement corridors

Agricultural areas may include plantation forests, grazing pastures, cropping, land in transition, degraded land from agricultural practices and orchards. Infrastructure includes any area highly modified from its natural state, including but limited to roads, mining, airports, housing, and manufacturing.

As black cockatoos are highly mobile, agriculture and infrastructure areas are considered potential movement corridors for black cockatoos (Figure 3-12). It is unlikely black cockatoos will drink, forage, roost, or breed in agricultural or infrastructure areas. Such areas are concentrated to the east of the WMDE and BTC, and west and southeast of the CBME (Figure 3-12).

425200

6412000

6328000

WMDE - BTC

CBME

0 1.5 3
Kilometers

CBME

Black cockatoo records

- *Calyptorhynchus banksii naso*
- *Calyptorhynchus baudinii*
- *Calyptorhynchus latirostris*
- *Calyptorhynchus sp.* 'white-tailed black cockatoo'

Stuart Simmmonds
Worsely Mine Expansion Project

Project No	1553
Date	15/03/2023
Drawn by	FK
Map author	BQ

0 10 20
Kilometers

1:400,000 (at A3) GDA 1994 MGA Zone 50

- PAA
- Roosting sites
- State forests
- Other DBCA Managed Lands
- IDF
- Black cockatoo nesting trees

Black cockatoo habitat types

- Foraging, roosting and breeding habitat
- Movement corridors
- Drinking habitat

Figure 3-12a

Black cockatoo records and potential habitat types within 20 km of the PAA

PHOENIX ENVIRONMENTAL SCIENCES

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425200

6412000

6328000

WMDE and BTC

0 5 10
Kilometers

Black cockatoo records

- *Calyptorhynchus banksii naso*
- *Calyptorhynchus baudinii*
- *Calyptorhynchus latirostris*
- *Calyptorhynchus sp.* 'white-tailed black cockatoo'

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Project No	1553
Date	15/03/2023
Drawn by	FK
Map author	BQ

0 10 20
Kilometers

1:500,000 (at A3) GDA 1994 MGA Zone 50

- Black cockatoo nesting trees
- Roosting sites
- PAA
- State forests
- Other DBCA Managed Lands
- IDF

Black cockatoo habitat types

- Foraging, roosting and breeding habitat
- Movement corridors
- Drinking habitat

Figure 3-12b

Black cockatoo records and potential habitat types within 20 km of the PAA

PHOENIX ENVIRONMENTAL SCIENCES

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425200

6412000

6328000

MUNDALUP POOL

DARNMINNING POOL

CROSSING POOL

THIRTY FOUR MILE BROOK

CANNING RESERVOIR

WUNGONG RESERVOIR

CAMBALLING WATERHOLE

HOTHAM RIVER

HOTHAM RIVER

SERPENTINE DAM

MURRAY RIVER

HOTHAM RIVER

HOTHAM RIVER

HORSE POOL

WMDE and BTC

0 5 10

Kilometers

WMDE - BTC

LAKE BANKSIADALE

KENNEDY POOL

MUNDALUP POOL

WARKELENY POOL

DARNMINNING POOL

THIRTY FOUR MILE BROOK

CAMBALLING WATERHOLE

HOTHAM RIVER

MURRAY RIVER

HORSE POOL

SWAN POND

DUCK POND

LAKE CLIFTON

BOUNDARY LAKE

LAKE POLLARD

LAKE MOYANUP

LAKE NAVARINO

LAKE KABBAMUP

MARTINS TANK LAKE

LAKE YALGORUP

LAKE HAYWARD

LAKE NEWNHAM

SOUTH YALUP LOWER DAM

LAKE PRESTON

LAKE BROCKMAN

HARVEY DAM

LAKE JOSEPHINE

STIRLING DAM

22 MILE POOL

NALYERIN LAKE

YOURDAMUNG LAKE

LAKE BALLINGALL

CBME

BRUNSWICK RIVER

COLLIE RIVER

MUNGALUP DAM

WELLINGTON DAM

MINNINGUP POOL

Western Australia

PERTH

Stuart Simmmonds

Worsely Mine Expansion Project

Project No	1553
Date	15/03/2023
Drawn by	FK
Map author	BQ

0 10 20

Kilometers

1:500,000 (at A3) GDA 1994 MGA Zone 50

PAA

Lakes and Rivers

IDF

Drinking habitat

Figure 3-13

Black cockatoo drinking habitat within and surrounding the WMDE and BTC

PHOENIX ENVIRONMENTAL SCIENCES

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425200

6412000

6328000

CANNING RESERVOIR

CBME

0 1.5 3
Kilometers

WMDE - BTC

MURRAY RIVER

KENNEDY POOL

MUNDALUP POOL

LAKE BANKSIADALE

SWAN POND

DUCK POND

LAKE CLIFTON

BOUNDARY LAKE

LAKE POLLARD

LAKE MOYANUP

LAKE NAVARINO

MARTINS TANK LAKE

LAKE YALGORUP

LAKE HAYWARD

LAKE NEWNHAM

SOUTH YALUP LOWER DAM

LAKE KABBAMUP

LAKE PRESTON

LAKE BROCKMAN

WARKELENY POOL

DARNMINNING POOL

THIRTY FOUR MILE BROOK

CAMBALLING WATERHOLE

HOTHAM RIVER

MURRAY RIVER

HORSE POOL

HARVEY DAM

LAKE JOSEPHINE

STIRLING DAM

22 MILE POOL

NALYERIN LAKE

YOURDAMUNG LAKE

LAKE BALLINGALL

CBME

BRUNSWICK RIVER

COLLIE RIVER

MAMINE SWAMP DAM

MUNGALUP DAM

WELLINGTON DAM

MINNINGUP POOL

Western Australia

PERTH

Stuart Simmmonds
Worsely Mine Expansion Project

Project No	1553
Date	15/03/2023
Drawn by	FK
Map author	BQ

0 10 20
Kilometers

1:400,000 (at A3) GDA 1994 MGA Zone 50

PAA

Lakes and Rivers

IDF

Drinking habitat

Figure 3-14

Black cockatoo drinking habitat within and surrounding the CBME

PHOENIX ENVIRONMENTAL SCIENCES

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4 DISCUSSION

This study aimed to determine which vegetation complexes and fauna habitat types in the PAA represent breeding habitat and the relative value of each to the three species of black cockatoos. It also aimed to estimate the number of breeding trees that might be removed by the Proposal in order for the SRI to be calculated. This has been achieved.

However, limitations with the dataset for the PAA and indeed, the broader JAF01 (due to its significant history of large-scale harvesting and depauperate accompanying relevant data gathered and published by management agencies to draw upon), means the number of confirmed breeding trees that potentially occur, is difficult to definitively determine. While the South32 pre-clearance survey data from over 3,300 ha is the most comprehensive available to consider past losses, data from the Proposal IDF is more limited, and with a greater area of Wandoo potentially impacted, a conservative approach to the SRI calculations is needed.

While DSEWPaC (2012) has published maps concerning the modelled distribution of all three black cockatoo species, no publicly available spatial datasets concerning breeding habitat extent have been produced for any of the species. DEC did produce a breeding habitat spatial dataset in 2009 (see Glossop *et al.* 2011) based on vegetation complexes (Heddle *et al.* 1980), but that is not publicly available.

This study undertook a spatial analysis of confirmed breeding trees with vegetation complexes and expanded it to include trees with evidence of breeding and to a number of environmental variables. PHT demographics were also investigated as a way of comparing the size-class of trees in the PAA with other nearby spatially constrained surveys and the results strongly indicate that forest structure within the PAA is very different to the other areas in the dataset; being composed of younger, smaller trees, occurring at much higher densities and dominated by Jarrah (*Eucalyptus marginata*), which is less dominant elsewhere and rarely forms hollows of sufficient size to support black cockatoo breeding.

Data captured over 30 years of fauna studies within the PAA area have recorded all three black cockatoo species feeding within the PAA, with FRTBC and Carnaby's being most common within the WMDE and FRTBC and Baudin's Cockatoo being most common in the CBME. Confirmed breeding events/trees have all also been recorded for all three species in the WMDE; there are no confirmed breeding events/trees identified from within the CBME at this stage, and this may be a result of the intensive timber harvesting that has taken place there (Figure 3-10).

In this study of the Jarrah Forest, 166 trees have evidence of breeding activity of which 141 are located within JAF01 and 59 trees were recorded as having a confirmed breeding event take place (28 in natural hollows and 31 in artificial hollows). This is likely an underestimate.

Trees with evidence of breeding occur within 18 JAF01 vegetation complexes (Heddle *et al.* 1980) while confirmed breeding records are known from ten vegetation complexes (17% of Jarrah Forest complexes).

At the scale of the PAA, the Williams regional vegetation complex (Wi; *Eucalyptus*, *Casuarina*, or *Melaleuca* woodland on a seasonally inundated and/or waterlogged valley floor or floodplain) is the only complex that has not recorded confirmed breeding or evidence of breeding, for the three black cockatoo species. This system occurs in association with the Hotham River and its main tributaries, separating the NBG from the Marradong area; aligning with the analysis of slope which suggested that breeding tends to occur in flat to moderately-sloping terrain (Appendix 1). This area was also completely lacking Wandoo and was relatively low in Marri, the two most prolific hollow forming trees in JAF01.

Confirmed breeding in the Jarrah Forest has been most commonly recorded from the Yalanbee system (Y5 and Y6; Jarrah/Marri/Wandoo woodland with proteaceous understory on undulating slopes) which dominates the Marradong area (which has been extensively cleared for mining) and Quindanning area (which contains large areas of intact forest and agricultural lands and to date has not been impacted by mining). The Yalanbee system does not occur in the CBME.

The vegetation complex that most commonly support breeding after Yalanbee is the Coolakin system (Ck; Marri/Jarrah/Wandoo woodland/forest over proteaceous species), which occurs extensively in the southern two-thirds of the WMDE but is absent from the CBME.

Breeding (confirmed or unconfirmed evidence) has also been commonly recorded from the Pindalup and Dwellingup systems, which occur widely in the NBG and Saddleback areas of the WMDE (which has been extensively cleared for mining). The Dwellingup system comprise around 30% of the CBME. In addition to the Dwellingup system the CBME is comprised on Murray1 and Yarragil 1 complexes both of which have minimal breeding evidence.

The remaining ten vegetation complexes are all known (confirmed breeding events) or suspected (breeding evidence documented for a tree) to support black cockatoo breeding.

Thus, on this basis, 100% of the CBME is considered breeding habitat for FRTBC and Baudin's in particular, while 95.7% of remnant native vegetation in the WMDE is considered breeding habitat for FRTBC and Carnaby's Cockatoo and to a lesser extent, Baudin's Cockatoo.

In terms of fauna habitat (Biostat 2020) trees with confirmed breeding or evidence of breeding have been recorded from five fauna habitats (BB, DL, JC, JM and WO), which equates to 40.76% and 68.42% of the PAA and IDF respectively. When this data is further considered in terms of each species within the IDF almost 6,482 ha is considered High value breeding habitat for Carnaby's Cockatoo, 5,647 ha is considered High value breeding for FRTBC. There is no High value breeding habitat for Baudin's Cockatoo within the PAA and IDF as all habitat present is considered to be Low value (6,714 ha).

That being said, only limited confirmed breeding in the WMDE has been recorded and no confirmed or suspected breeding has been recorded in the CBME. Thus while the remnant vegetation within the PAA is largely considered breeding habitat for the three black cockatoo species, the reality is that the intensive timber harvesting that has occurred throughout the PAA has rendered the trees largely unsuitable for black cockatoo breeding, with the majority having been harvested two-three times and in some areas (predominantly in the NBG area and CBME) as many as five harvests have occurred (Figure 3-10). Further, research has indicated that Carnaby's cockatoo breeding predominantly occurs north (Geraldton Sandplain bioregion), south and east of the study area (DoEE 2017; EPA 2019; Johnstone *et al.* 2010; Saunders 1986; Saunders *et al.* 2014a), with the JAF01 being an important feed area for birds moving to and from their main breeding grounds. While the breeding requirements of FRTBC and Baudin's Cockatoo generally, are still not well understood.

Lastly, the PHT demographic analysis clearly demonstrated the stark difference between the structure of the state forests in which Worsley operates and the other datasets analysed (predominantly road-side remnants). That is, the PAA is comprised predominantly densely positioned, younger Jarrah trees (which rarely form hollows) occurring at a 3:1 ratio with Wandoo and Marri (which are much better at forming hollows).

Given the limitations in the datasets aggregated in this report, and the opposing impacts of timber harvesting and suppression of fire, the most accurate approach to determining the number of breeding trees that may potentially be removed by the Proposal and thus calculating the Significant Residual Impacts is to simply multiply the number of known breeding trees identified in the pre-clearance surveys and other data sources by the area of native vegetation proposed to be impacted within the IDF as undertaken by Phoenix (2021); On this basis it was estimated that up to 244 hollows

may occur within the IDF, and a further 586 having potential to become suitable for black cockatoo breeding, assuming they are not lost to natural attrition.

4.1 HABITAT SURROUNDING THE PAA

Potential black cockatoo habitat types within 20 km of the PAA includes drinking, foraging, roosting, breeding, and movement corridors.

Reliable drinking sources are important for black cockatoo species, particularly foraging, roosting and breeding individuals (Groom 2015; Le Roux 2017; Lee *et al.* 2013; Rycken 2019; Saunders 1990). Black cockatoos rely on watering points, usually within 2 km of night roost sites (DAWE 2022). Thus, drinking habitat located in natural environments (particularly west of the WMDE and BTC and north and east of the CBME) is considered to be of particular importance for the preservation of black cockatoos due to the to the scarcity of other permanent water features in these forested areas and its proximity to potential breeding, foraging and roosting habitat. The scarcity of drinking habitat in these areas is particularly noteworthy when compared to how concentrated drinking habitat is in agricultural areas. It is likely that black cockatoos also utilise semi-permanent or smaller water features that were not captured by available data.

Regarding the PAA, a total of 321.2 ha of drinking habitat occurs, including small farm dams and ~600 m of the Hotham River. None of these water features are restricted or limited within the PAA, and all water features that lie within the IDF are located within 2 km of other water sources outside the IDF. Thus, removal of drinking habitat within the IDF may result in increased flying distances from nesting or roost sites but is unlikely to have a significant adverse effect on black cockatoo species at a local or regional scale.

Although it appears a high proportion of area surrounding the PAA has been cleared for agricultural purposes, small vegetation corridors remain which maintain habitat connectivity between conservation reserves, national parks, and other large areas of natural environment. Vegetation connecting foraging resources, breeding habitat and night roosting habitat are essential for maintaining black cockatoo habitat connectivity across landscapes, and allow black cockatoos to access resources across their range (DAWE 2022).

While remanent natural vegetation outside the PAA is considered potential breeding habitat for the three black cockatoo species, intensive timber harvesting that has occurred throughout state forests may have rendered trees largely unsuitable for black cockatoo breeding. Suitable breeding habitat is likely to be more prominent in areas that have not undergone timber harvesting, such as national parks.

4.2 USE OF ARTIFICIAL NEST BOXES

From the literature review (Appendix 2) mixed results with respect to use of artificial nest boxes by each of the black cockatoo species has been documented. A decade ago Groom (2010) reviewed use of 239 artificial nest boxes by Carnaby's Cockatoo and reported that greatest success was in the northern Wheatbelt and in the case of southern areas, artificial hollows placed in existing breeding areas saw some success. Groom (2010) concluded that artificial hollows should be installed in proximity to known breeding hollows.

Carnaby's Cockatoo appears to readily take up a range of artificial nest boxes (Phoenix 2020a; Saunders *et al.* 2020). Tony Kirkby reports that they effectively nest in artificial nest boxes throughout their range (T. Kirkby, pers. comm., 14 April 2020).

Artificial nest box success for the two 'forest' species however has been limited. The large-scale study by Groom (2010) reported no nesting by FRTBCs or Baudin's Cockatoo (Groom 2010) in artificial nest boxes. Most relevant to the Proposal, recent trials at the Boddington Gold Mine (BGM) (Newmont Boddington Gold Pty Ltd 2014) failed to record successful breeding by either FRTBC or Baudin's Cockatoo. Murdoch University researchers concluded that the lack of breeding within installed nesting boxes is due to the presence of sufficient hollows within forested areas surrounding the BGM (Newmont Boddington Gold Pty Ltd 2014). However, there is little evidence of widespread breeding of these species in the PAA and indeed the forest demographics suggest a much lower number of breeding size trees.

Further south and more recently, nest box installation for the Greenbushes lithium mine (GHD 2018) has also failed to record successful breeding by either FRTBC or Baudin's Cockatoo. To date, one piece of evidence of successful breeding of FRTBC in artificial nest boxes was able to be sourced; a wooden nest box and a PE tube, at Bedfordale, approximately 58km NW of the PAA (Johnstone & Kirkby 2019).

The PAA appears to support breeding of both FRTBC and Carnaby's Cockatoo, but limited potential for breeding of Baudin's Cockatoo (and further only limited to the CBME). Given the success of artificial nest boxes with Carnaby's Cockatoo elsewhere, there is a high level of confidence that loss of breeding hollows for this species as a result of implementation of the Proposal can be offset/mitigated through installation of nest boxes. The same cannot however be said of FRTBC and Baudin's Cockatoo, indeed the evidence suggests that artificial nest boxes cannot be relied on to offset or mitigate impacts to these two species.

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Appendix 1 Environmental variable analysis

Due to the small sample size for confirmed breeding trees once various factors are considered, statistical test such as the Pearson's correlation coefficient could not be used and thus only general trends can be described. Accordingly, the results below have little bearing on the determination of breeding habitat analysis and have thus been retained here as an appendix.

Elevation

Average elevation of confirmed breeding trees in the Northern Jarrah Forest was 218 m and the range was between 124 and 337 m above sea-level. For natural confirmed breeding hollows, the average was 241 m, with a range between 124–337 m. The elevation of the PAA ranges between approximately 200 and 590 m above sea-level but the majority of the PAA is below 350 m above sea-level.

Slope

Natural confirmed breeding hollows were typically recorded in flat to moderate-sloping terrain; with only two confirmed breeding trees being located in steep terrain in JAF01. The terrain in the PAA consists of a variety of slopes, from flat and gently sloping hilltops, to low and moderate slopes and steep valleys. Mining for bauxite typically occurs on the cemented laterite hilltops and upper slopes, where slope angle is lowest.

Trees with artificial nesting hollows were not included in the analysis because of the bias towards placing nest boxes in easily accessed flat areas.

Aspect

The aspect of confirmed breeding trees with natural nesting hollows in JAF01 trended towards trees on west-facing moderate slopes (12 trees) or flat hilltop areas (11). For all hollow types, trees on west-facing slopes (23 trees) or flat areas (24) dominated again. West-facing and no aspect is possibly more preferred but does not appear to be an impediment to breeding. The aspect of slopes in the PAA generally follows the trend of the Darling Range, with the ranges tending in a NW/SE direction.

Fire

Based on the DBCA (DBCA 2020b) fire history dataset in JAF01, fire has affected 14 confirmed breeding trees with natural hollows. Most fires are prescribed burns and all fires have occurred between 1940 and 1991.The most recent fire to affect a confirmed breeding tree is in 1990.

Approximately 20% of the PHT's in JAF01 have been affected by fire, 3% of these have been affected in the last 10 years.

Distance to water

The average distance to water (major and minor rivers/creeks, and lakes) for black cockatoo confirmed breeding trees in the JAF01 is 1,959 m and the median is 2,574 m, for both natural and artificial nesting hollows.

For Carnaby's Cockatoo the distance of confirmed breeding trees ranged from 58 m to 4,340 m.

Baudin's Cockatoo confirmed breeding trees were 228 and 1,149 m to nearest water.

FRTBC confirmed breeding trees ranged from 1,149 – 3,565 m to water and Carnaby's Cockatoo ranged from 58 m to 4340 m.

Parameter	Three black cockatoo species		Carnaby's Cockatoo		Baudin's Cockatoo		FRTBC	
	Mean (m)	Median (m)	Min. dist. (m)	Max. dist. (m)	Min. dist. (m)	Max. dist. (m)	Min. dist. (m)	Max. dist. (m)
Confirmed breeding trees	1,959	2,574	58	4,340	228	1,149	1,149	3,365

Rainfall

With respect to annual rainfall, 50 of the confirmed natural and artificial breeding hollows are situated in the 600 – 1,000 mm per year high rainfall zone (HRZ) and eight are located in the 400- 600 mm medium rainfall zone (MRZ); the latter are all situated at the foothills of the Darling Scarp. One confirmed breeding hollow in the HRZ is on the border of the very high rainfall zone (1,000-1,500 mm/p.a.; VHRZ) and is a natural nest belonging to one of the two Baudin's Cockatoo records.

All six FRTBC records occur in the HRZ. Of the 38 Carnaby's Cockatoo breeding records, 30 occur in the HRZ with the remaining eight occurring in the MRZ at the foothills to the Darling Scarp.

Of the potential breeding trees in the JAF01, approximately 1145 (70%) are located in the HRZ, 4,082 (25%) in the MRZ,) and 77 (4 5%) in the VHRZ.

The WMDE is situated in the HRZ zone and the CBME is situated in the VHRZ.

Appendix 2 Review of the suitability /success of artificial nest boxes for black cockatoo species in WA

Breeding activity census for Carnaby's Cockatoo 2018- 2020

Phoenix has been undertaking a breeding activity census for Carnaby's Cockatoo within and surrounding Muchea North. The census began in 2017 surveying natural nesting hollows and existing artificial hollows and in 2018, an additional 39 artificial nest boxes were installed (Phoenix 2019, 2020a). The artificial nesting hollows were installed during the 2018-2019 breeding season and so the combined two first breeding season census' served as a baseline for future comparison. The third survey (2019-2020 breeding season) recorded a higher number of artificial nesting hollows with both confirmed breeding events and evidence of nesting activity other than in the natural nesting hollows (Phoenix 2020a). Three of the four confirmed breeding events were observed in the artificial nesting hollows, and these were also the three that had successful outcome (a chick that hatched and had fledged) (Phoenix 2020a). An additional ten artificial nesting hollows had evidence of nesting which was also higher than the natural nesting hollows of which six hollows had evidence of nesting activities (Phoenix 2020a). All of the artificial nesting hollows were in good condition and none required any maintenance. This is a good indication that the artificial nesting hollows are providing a suitable alternative to natural nesting hollows for Carnaby's Cockatoo in the Muchea area (Phoenix 2020a). Ongoing monitoring is planned every season until 2027.

Coomallo Creek study for Carnaby's Cockatoo 2020

Carnaby's Cockatoo have been known to effectively nest in artificial nest boxes throughout their range. (T Kirkby, 2020 pers. comm., 14 April). The ecology of one breeding population of Carnaby's Cockatoo in Coomallo Creek (northern Wheatbelt) has been studied from 1969 - until present. A recent study on this population (2011-2018) focusing on the use of artificial hollows for these birds showed that up to 45 of 68 artificial hollows were successfully used for breeding from 2011-18 (Saunders *et al.* 2020). It is important to note that in this study, the fire at the end of the 2009 breeding season and the subsequent increase in the number of breeding attempts provided a strong justification for augmenting and installing nesting hollows (Saunders *et al.* 2020). The rapid increase in the number of breeding attempts after the repair of derelict natural hollows in 2011 and the installation of artificial hollows in 2011 was mostly a result of accommodating breeding birds displaced from habitat destroyed by the 2009 fire (Saunders *et al.* 2014b) and also the result of young birds being able to breed. This study shows that Carnaby's Cockatoo readily accepts artificial PVC nest hollows (Saunders *et al.* 2020).

Black Cockatoo Research Project - Final Report for Housing Authority 2019

Since the 1990's trials on the use and effectiveness of artificial nest hollows for black cockatoos has been ongoing and the monitoring of wooden nest boxes and PE pipe tubes has continued at a number of sites in the south-west (Johnstone & Kirkby 2019).

A study on the effectiveness of artificial nest hollows for the two forest species, FRTBC and Baudin's Cockatoo is continuing. In 2018, FRTBCs were recorded breeding in a wooden nest box and in a PE tube at Bedfordale and young were fledged from both nests (Johnstone & Kirkby 2019).

Newmont Boddington Gold (NBG) artificial nest box trial 2014

Murdoch University researchers and NBG installed 24 artificial nest hollows (of two differing designs) within NBG tenements and surrounding areas. Both the 'cockatube' or wooden box artificial nest hollows were used at the sites. Although monitoring to date has not identified use of these hollows, monitoring will continue in order to assess their long-term efficiency. Research on the use of artificial nesting boxes in the NBG area suggests that one of the primary reasons for no use to date is the presence of sufficient hollows within forested areas surrounding the NBG (Newmont Boddington Gold

Pty Ltd 2014). This is supported by the high level of artificial nest hollow success observed in Wheatbelt areas of WA where natural hollows are limited as a result of large-scale clearing (Newmont Boddington Gold Pty Ltd 2014).

Greenbushes project - Talison Lithium Australia 2014-2015

In 2014 and 2015, 30 artificial black cockatoo breeding hollows were installed in Greenbushes by Talison Lithium Australia as part of another project, these hollows have been subsequently monitored and maintained by the Blackwood Basin Group to date. The FRTBC and Carnaby's Cockatoo have been recorded feeding in the area and there are several nests recorded in the area by one black cockatoo species, possibly the FRTBC (GHD 2018). Presently, there has been no utilisation of the artificial breeding hollows by black cockatoos (GHD 2018). Talison has committed to maintaining and monitoring these hollows while they are viable for up to 8 years from installation until at least the end of 2023. Monitoring of these artificial nest boxes coincides with the peak breeding season of black cockatoos (between September and December) (GHD 2018).

Artificial hollows study for Carnaby's Cockatoo 2010

Groom (2010) investigated the design, construction, and placement of artificial hollows for Carnaby's Cockatoo by assessing 239 different artificial hollows in varying locations in south-west WA. Greatest success was in the northern Wheatbelt where a large number of natural breeding records were recorded in close proximity to artificial hollows, however in the case of southern areas, artificial hollows placed in existing breeding areas saw some artificial hollows being utilised while others were not (Groom 2010). Based on this study, the presence of known breeding should be a key consideration when selecting sites for artificial hollows. During this study no artificial hollows were recorded as being used by FRTBC or Baudin's Cockatoos (Groom 2010).

Further information related to artificial hollow usage

According to T Kirkby, 2020 pers. comm., 14 April, the FRTBC have not been known to utilise nest boxes in the Jarrah Forest and there are no current records of Baudin's Cockatoo utilising nest boxes for breeding.