Alkimos City Centre and Central (EPBC 2015/7561)

Parks and Recreation Reserve Management Plan

Prepared for
Lendlease
by Strategen

November 2019

strategen
ENVIRONMENTAL

Alkimos City Centre and Central (EPBC 2015/7561)

Parks and Recreation Reserve Management Plan

Strategen is a trading name of
Strategen Environmental Consultants Pty Ltd
Level 1, 50 Subiaco Square Road Subiaco WA 6008
ACN: 056 190 419

November 2019

Limitations

Scope of services

This report ("the report") has been prepared by Strategen Environmental Consultants Pty Ltd (Strategen) in accordance with the scope of services set out in the contract, or as otherwise agreed, between the Client and Strategen. In some circumstances, a range of factors such as time, budget, access and/or site disturbance constraints may have limited the scope of services. This report is strictly limited to the matters stated in it and is not to be read as extending, by implication, to any other matter in connection with the matters addressed in it.

Reliance on data

In preparing the report, Strategen has relied upon data and other information provided by the Client and other individuals and organisations, most of which are referred to in the report ("the data"). Except as otherwise expressly stated in the report, Strategen has not verified the accuracy or completeness of the data. To the extent that the statements, opinions, facts, information, conclusions and/or recommendations in the report ("conclusions") are based in whole or part on the data, those conclusions are contingent upon the accuracy and completeness of the data. Strategen has also not attempted to determine whether any material matter has been omitted from the data. Strategen will not be liable in relation to incorrect conclusions should any data, information or condition be incorrect or have been concealed, withheld, misrepresented or otherwise not fully disclosed to Strategen. The making of any assumption does not imply that Strategen has made any enquiry to verify the correctness of that assumption.

The report is based on conditions encountered and information received at the time of preparation of this report or the time that site investigations were carried out. Strategen disclaims responsibility for any changes that may have occurred after this time. This report and any legal issues arising from it are governed by and construed in accordance with the law of Western Australia as at the date of this report.

Environmental conclusions

Within the limitations imposed by the scope of services, the preparation of this report has been undertaken and performed in a professional manner, in accordance with generally accepted environmental consulting practices. No other warranty, whether express or implied, is made.

Client: Lendlease

Report Version	Revision No.	Purpose	Strategen author/reviewer	Submitted to Client	
				Form	Date
Draft Report	A	Client review	R Chesney / E Payne / J Mitchell / D Walsh	Electronic	12 May 2017
Final Draft Report	B	Client review	R Chesney / E Payne / J Mitchell	Electronic	24 May 2017
Final Draft Report	C	Client review	E Payne / J Mitchell	Electronic	31 May 2017
Final Draft Report	0	DEE review	E Payne / J Mitchell	Electronic	15 Jun 2017
Final Draft Report	D	Client review	E Payne / J Mitchell	Electronic	28 Jun 2017
Final Report	1	DEE Approval	E Payne / J Mitchell	Electronic	06 Jul 2017
Final Draft Report	E	Client Review	E Payne / JMitchell	Electronic	07 July 2017
Final Report	2	DEE Approval	E Payne / J Mitchell	Electronic	17 Jul 2017
Draft Report	F	Client Review	E Payne	Electronic	1 November 2018
Final Draft Report	G	Client review	E Payne / T George	Electronic	1 April 2019
Final Draft Report	H	Client review	L Reid / E Payne	Electronic	21 June 2019
Final Draft Report	I	Client review	E Payne / T George	Electronic	8 July 2019
Final Draft Report	J	Client review	E Payne	Electronic	3 Sept 2019
Final Report	3	DEE Approval	E Payne	Electronic	5 Sept 2019
Final Report	4	DEE Approval	E Payne	Electronic	5 November 2019

Filename: LLC16557_01 R002 Rev 4 - 5 November 2019

Declaration of accuracy

I declare that:

1. To the best of my knowledge, all the information contained in, or accompanying this Parks and Recreation Reserve Management Plan is complete, current and correct.

2. I am duly authorised to sign this declaration on behalf of the approval holder.

3. I am aware that:

a. Section 490 of the *Environment Protection and Biodiversity Conservation Act 1999* (Cth) (EPBC Act) makes it an offence for an approval holder to provide information in response to an approval condition where the person is reckless as to whether the information is false or misleading.

b. Section 491 of the EPBC Act makes it an offence for a person to provide information or documents to specified persons who are known by the person to be performing a duty or carrying out a function under the EPBC Act or the Environment Protection and Biodiversity Conservation Regulations 2000 (Cth) where the person knows the information or document is false or misleading.

c. The above offences are punishable on conviction by imprisonment, a fine or both.

Signed

Full name (please print)

ANTHONY ROWBOTHAM

Organisation (please print)

LENDLEASE

Executive Summary

Lendlease Communities (Australia) Pty Ltd (Lendlease) proposes to develop the following:

- Alkimos City Centre (Lot 9502, Marmion Avenue, Alkimos)
- Central Alkimos (Lot 9501, Marmion Avenue, Alkimos).

The purpose of this Parks and Recreation Reserve Management Plan (PRRMP) is to satisfy the requirements of Condition 3 of EPBC 2015/7561 by:

- providing measures to avoid and mitigate impact on Carnaby's Black-Cockatoo and its habitat prior to, during and post construction
- identifying objectives, interim targets, performance indicators and completion criteria
- providing timeframes for the implementation and completion of the above objectives
- developing a monitoring and reporting program for Carnaby's Black-Cockatoo habitat
- identifying contingency measures
- establishing roles and responsibilities
- providing a map clearly illustrating the area of Carnaby's Black-Cockatoo habitat to be cleared and retained.

The Project Area contains approximately 323.5 ha of potential foraging habitat for the endangered Carnaby's Black Cockatoo (CBC). Of this habitat, approximately 257 ha will be cleared for the development and approximately 66.64 ha retained within Parks and Recreation Reserves (PRR). A total of 103 potential breeding trees (>500mm diameter at breast height [DBH]) have been identified within the Project Area, of these trees a minimum of 16 will be retained within PRR.

An assessment of the potential impacts and risks to Carnaby's Black Cockatoos as a result of the Project has been undertaken. Results of the risk assessment have been used to develop management measures that form part of this PRRMP.

Objectives, interim targets, performance indicators and completion criteria have been developed to manage the PRR; broadly including the following strategies to manage these risks including:

- delineate PRR and clearing boundaries
- restrict access to PRR through fencing or barriers
- install signage to restrict construction workers from entering PRR
- ensure appropriate hygiene measures undertaken for vehicle, plant and equipment to ensure dieback and weeds are not spread
- identify areas containing dieback manage accordingly
- management of existing weeds
- annual monitoring of nesting hollows
- regular monitoring of rehabilitation.

Monitoring activities will be undertaken to determine performance against objectives. Contingency measures will be initiated if monitoring indicates that targets and performance indicators are not being met.

Table of contents

1. Introduction and purpose of the plan 1

1.1 Project description 1
1.1.1 Terminology 1
1.2 Purpose 3
1.3 Land details 4
1.4 Statutory and policy context 6
1.4.1 Alkimos-Eglinton MRS Amendment 1029/33 6
1.4.2 Alkimos-Eglinton District Structure Plan 6
1.4.3 Environment Protection and Biodiversity Conservation Act 1999 6
1.5 Existing environment 6
1.5.1 Vegetation 6
1.5.2 Fauna habitat 7
1.6 Potential impacts and risks 9
1.6.1 Threats to Carnaby's Black Cockatoo and habitat 9
1.6.2 Potential impacts 9

2. Environmental outcomes and completion criteria 11

3. Risk assessment 15

4. Management measures 19

4.1 Implementation 19
4.2 Delineation of areas to be retained 19
4.3 Protection of retained vegetation 20
4.4 Rehabilitation of PRR 20
4.5 Retention and management of Carnaby's Black Cockatoo nesting habitat 23

5. Monitoring 24

5.1 Monitoring program 24
5.2 Data handling and management 27

6. Contingency response, corrective actions 28

7. Review and audit 31

7.1 Compliance reporting 31
7.1.1 PRRMP and technical review and adaptive management 31

8. Environmental management roles and responsibilities 32

8.1 Lendlease Project Manager 32
8.2 Construction Contractor 32
8.3 Environmental Consultant 32
8.4 Rehabilitation Contractor 33
8.5 Pest Control Contractor 33
8.6 Dieback Survey Consultant 33
8.7 Western Australian Planning Commission 33

9. Glossary of terms 34

10. References 35

List of tables

Table 1: Conditions of approval reference table 3
Table 2: Potential impacts on Carnaby's Black Cockatoos 10
Table 3: Objectives, interim targets, performance indicators and completion criteria 12
Table 4: Risk framework 15
Table 5: Likelihood and consequence 15
Table 6: Risk assessment 17
Table 7: Management measures for delineating retention areas 19
Table 8: Management measures for protection of retained vegetation 20
Table 9: Management measures for rehabilitation of PRR 21
Table 10: Management measures for retention and management of black cockatoo nesting habitat 23
Table 11: Monitoring actions 25
Table 12: Contingency measures 28

List of figures

Figure 1: Project Area 2
Figure 2: Parks and Recreation Reserve areas, CBC habitat and revegetation areas 8

List of appendices

Appendix 1 Carnaby's Black Cockatoo primary feeding plants (Groom 2011)
Appendix 2 Artificial hollows for Carnaby's black cockatoo: an investigation of the placement, use, monitoring and maintenance requirements of artificial hollows for Carnaby's black cockatoo (Groom 2010)

1. Introduction and purpose of the plan

Lendlease Communities (Australia) Pty Ltd (Lendlease) proposes to develop the following:

- Alkimos City Centre (Lot 9502, Marmion Avenue, Alkimos)
- Central Alkimos (Lot 9501, Marmion Avenue, Alkimos).

The proposed action was referred under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) to the former Department of the Environment (DotE, now the Department of Environment and Energy [DEE]) on 18 September 2015. The proposed action was determined to be a controlled action requiring assessment via preliminary documentation on 26 November 2015. On 30 March 2017 the proposed action was approved with conditions (EPBC 2015/7561).

1.1 Project description

Alkimos Lots 9501 and 9502 (the Project Area) covers a combined area of 480.4 ha and is located 14 km north of the Joondalup Strategic Metropolitan Centre and 40 km north-west of the Perth CBD (Figure 1). The proposed action involves works pertaining to the provision of an urban regional centre including a commercial centre, residential housing, schools, public amenities and transport routes.

The Project Area is situated within the south-east corner of the Alkimos-Eglinton District Structure Plan (DSP). The Alkimos-Eglinton DSP was assessed and subsequently approved under the *Environmental Protection Act 1986* (EP Act) by the Western Australian Minister for the Environment on 24 April 2006 (Ministerial Statement No.722). Key conservation recommendations resulting from the assessment form the basis for the location of retained vegetation and conservation reserves within the Project Area.

The Project Area contains approximately 323.5 ha of potential foraging habitat for the endangered Carnaby's Black Cockatoo (CBC). Of this habitat, approximately 257 ha will be cleared for the development and approximately 66.64 ha retained within Parks and Recreation Reserves (PRR). A total of 103 potential breeding trees (>500mm diameter at breast height [DBH]) have been identified within the Project Area. Of these trees a minimum of 16 will be retained within PRR and where possible additional trees will be preserved within the development area through incorporation into strategically located public open space and within road reserves. It is noted that 22 of the 103 trees contain potentially suitable hollows for black cockatoos (nesting and roosting activities) and of these 4 will be retained within PRR. An additional 6 trees that do not currently exhibit a DBH above 500 mm, however are considered to be future potential habitat trees (*Eucalyptus gomphocephala* (Tuart) and *E. todtiana* (Coastal Blackbutt)], will be retained within PRR. In addition, a total of 12 nest hollows (transplanted from trees prior to clearing) or artificial nest boxes will be installed strategically within the Project Area in consideration of proximity to foraging habitat.

The Project will be developed over the next 20-30 years, with development of Alkimos Central taking place over 7-12 years. The initial Precinct will be developed over 16 stages. Clearing commenced on 26 September 2017 and construction of Stage 1 commenced in November 2017. Construction of Stage 16 is proposed to commence in June 2022 and completed by November 2022. The proposed staging schedule will be subject to further refinement as development progresses. Alkimos City will be developed over the next 20-30 years.

1.1.1 Terminology

For the purpose of this document, the following terminology will be used:

- Project Area (defined above)
- Parks and Recreation Reserve (PRR) areas (illustrated in Figure 2)
- Development Area (covering the portion of the Project Area subject to development, i.e. outside the PRR areas)
- Rehabilitation Areas (portions of PRR areas subject to rehabilitation works).

Figure 1: Project Area

Scale 1:40,000 at A4

0 250 500 750 1,000 1,250 m

Coordinate System: GDA 1994 MGA Zone 50
Note that positional errors may occur in some areas
Date: 18/05/2017
Author: JCrute
Source: Aerial image: ESRI online, approx. 2010.

Legend

- Project area
- Lot 3 Romeo Road, Alkimos EPBC Referral LSP
- Peet Alkimos LSP
- South Alkimos LSP
- Road

strategen ENVIRONMENTAL
info@strategen.com.au
www.strategen.com.au

Path: Q:\Consult\2016\LLC\LLC16557\ArcMap_documents\LLC16557_G001_R002_RevA_F001.mxd

1.2 Purpose

The purpose of this Parks and Recreation Reserve Management Plan (PRRMP) is to satisfy the requirements of Condition 3 of EPBC 2015/7561 by:

- providing measures to avoid and mitigate impact on Carnaby's Black-Cockatoo and its habitat prior to, during and post construction
- identifying objectives, interim targets, performance indicators and completion criteria
- providing timeframes for the implementation and completion of the above objectives
- developing a monitoring and reporting program for Carnaby's Black-Cockatoo habitat
- identifying contingency measures
- establishing roles and responsibilities
- providing a map clearly illustrating the area of Carnaby's Black-Cockatoo habitat to be cleared and retained.

How this PRRMP addresses Condition 3 and sub-conditions of EPBC 2015/7561 is detailed in Table 1 below.

Table 1: Conditions of approval reference table

Ref	Cond.	Plan reference	Condition requirement	How the plan addresses the condition requirements and commitments
1	3	N/A refer below	To mitigate impacts to Carnaby's Black-Cockatoos, the person taking the action must prepare and submit a Parks and Recreation Reserve Management Plan (PRRMP), for the approval of the Minister.	This PRRMP has been prepared to address condition 3. Refer to rows below regarding how condition 3 sub-conditions have been addressed.
2			The person taking the action must not commence clearing unless the Minister has approved the PRRMP.	Construction commenced on 26 September 2017.
3			In relation to the PRR, the PRRMP must include, but is not limited to:	N/A – refer to rows below.
4	3a	Section 4.1 Section 4.2 Section 4.3	Zoning and tenure arrangements.	Zoning and tenure arrangements are described in the sections referenced.
5	3b	Section 4.2 Section 4.3	Measures to physically delineate 66.64 ha of Carnaby's Black Cockatoo habitat that will be retained within the Parks and Recreation Reserve.	Carnaby's Black-Cockatoo habitat will be delineated as described in the sections referenced.
6	3c	Section 4.4	An outline of how Carnaby's Black-Cockatoo habitat will be rehabilitated.	CBC habitat will rehabilitated through a range of measures described in the sections referenced.
7	3d	Section 2.	Objectives, interim targets and completion criteria for the rehabilitation, including site preparation works, seedling planting program, success rates and details of replanting requirements, if success rates are not achieved.	Objectives, interim targets, performance indicators and completion criteria are provided in the sections referenced.

Ref	Cond.	Plan reference	Condition requirement	How the plan addresses the condition requirements and commitments
8	3e	Section 4.2 Section 4.3 Hygiene management measures to be undertaken during construction activities are summarised in the Construction Environmental Management Plan	Management measures including fencing, access controls, weed and pest management, and the control of *Phytophthora cinnamomi* (dieback) spread.	Management measures addressing fencing, access controls, weed and pest management and the control of *Phytophthora cinnamomi* (dieback) spread are described in the section referenced.
9	3f	Section 4.5, Section 5	Management of nesting hollows, including hollows removed and relocated prior to clearing, and artificial nesting boxes: i) a total of 12 artificial nest boxes or nesting must be installed within the project area ii) The construction, positioning and erection of the artificial nest boxes must be in accordance with the WA DEC Publication "Artificial hollows for Carnaby's black cockatoo" (Groom, 2010) iii) The artificial nest boxes must be inspected at least annually to check for condition and evidence of black cockatoo usage for a period of five years. Repair of damage/deterioration, removal of bee colonies, replacement of mulch and/or sacrificial chewing posts, must be undertaken prior to the next breeding season.	Management and inspection measures for artificial hollows are described in the sections referenced.
10	3g	Section 4.5, Section 5	Timeframes for implementing the above measures.	Timeframes are described in the sections referenced.
11	3h	Section 5 Section 6	Performance indicators that measure the effectiveness of measures to mitigate impacts to Carnaby's Black-Cockatoos.	Performance indicators are described in the sections referenced.
12	3i	Section 5 Section 6	Details of performance monitoring, reporting and contingency measures if interim targets, completion criteria and performance indicators are not met.	Performance monitoring and contingency measures, and reporting requirements, are described in the sections referenced.
13	3j	Section 8	Descriptions of the roles and responsibilities of personnel associated with implementation of each of the above measures.	Roles and responsibilities are described in the section referenced.
14	N/A	Section 4.1	If the Minister approves the PRRMP then the approved PRRMP must be implemented.	Lendlease will continue to be responsible for implementation of this PRRMP as the EPBC Act approval holder.

1.3 Land details

The Project Area is located 40 km northwest of Perth, Western Australia, intersected by Marmion Avenue, with the future Mitchell Freeway extension forming the eastern boundary, on Lots 9501, 9502 of deposited plan 400279 (Figure 1).

The Project Area forms part of the 2660 ha Alkimos-Eglinton District, located 40 km northwest of Perth and is zoned for urban and open space purposes under the Metropolitan Region Scheme. The proposed action complements the previously referred 226 ha residential and community development at Lot 1004, 80L Romeo Road and 2611 Marmion Avenue, Alkimos, WA (Alkimos Beach; EPBC 2011/5902), which commenced in 2012. Alkimos Beach and additional approved developments within the surrounding Alkimos area are presented in Figure 1.

1.4 Statutory and policy context

1.4.1 Alkimos-Eglinton MRS Amendment 1029/33

The Eglinton/South Yanchep Project area is located within the wider Alkimos-Eglinton District which was the subject of MRS Amendment 1029/33. This MRS Amendment was assessed by the Environmental Protection Authority (EPA) under s 48A of the EP Act, approved by the Minister for Environment on 24 April 2006 (Ministerial Statement 722), and gazetted by the WA Government on 23 June 2006.

The result of the EPA assessment was the identification of regionally significant areas of the site, principally identified for their geoheritage and biodiversity values. Therefore, the Environmental Conditions for MRS Amendment 1029/33 published by the WA Minister for the Environment, requires the inclusion of the regional significant areas in Parks and Recreation and Public Purpose zonings in the MRS and states that these areas shall only be used for '*conservation, landscape and complimentary purposes'*.

1.4.2 Alkimos-Eglinton District Structure Plan

Following from the MRS Amendment the Project area was also subject to the Alkimos-Eglinton District Structure Plan (DSP), adopted by the Western Australian Planning Commission (WAPC) in August 2009.

The DSP outlines the broad principles for the management of the three Alkimos-Eglinton Regional Open Space (ROS) areas (PRR within the Project Area) as follows:

- to be preserved for conservation, landscape and complimentary purposes
- to preserve the majority of the ROS in its natural state, allowing for retention of representative examples of the vegetation, flora and habitats currently present on the site
- to provide linkages across the site for fauna movement, contributing to the protection of biodiversity
- to provide adequate and appropriate public access to ROS for sustainable passive recreation and protect the values of the ROS from uncontrolled pedestrian access by provided Dual Use Paths (DUP) in and through the ROS that connect to the DUP network in the adjacent areas
- to erect appropriate fencing to discourage uncontrolled access
- to create a clear boundary between the ROS and private land
- to design edges between ROS and adjacent urban areas to minimise disturbance to the ecological values of the ROS
- to protect the linkage values and biodiversity values of the ROS.

1.4.3 Environment Protection and Biodiversity Conservation Act 1999

The EPBC Act referral was submitted to DotE on 18 September 2015. The Project was determined to be a controlled action (EPBC 2015/7561), requiring assessment via preliminary documentation on 26 November 2015. On 12 December 2016, DEE issued a proposed approval decision for endorsement by Lendlease. The EPBC Act approval was issued on 30 March 2017. This PRRMP has been prepared in accordance with condition 3 of the EPBC 2015/7561 approval, as indicated in Table 1.

1.5 Existing environment

1.5.1 Vegetation

The flora and vegetation of the Project Area has been surveyed as part of the larger Alkimos – Eglinton area as documented in Trudgen and Keighery (1990), Armstrong (1996), ATA Environmental (2002) and ATA Environmental (2005) (all cited in Emerge 2013) (Figure 5).

A detailed field survey was carried out by Emerge Associates in October 2012 to assess the vegetation association and condition across the Project Area (Emerge 2013). Thirty three vegetation associations were identified and the Project Area was found to be dominated by two broad groups (Emerge 2013):

- *Melaleuca* spp. / *Lomandra maritima* / *Xanthorrhoea preissii* / *Acacia* spp. heath on dune systems
- *Eucalyptus* spp. / *Banksia* spp. woodlands in lower lying areas and limestone.

The detailed field survey found that the vegetation condition was highly variable, ranging from Completely Degraded (middle of the Project Area) to Excellent (northern section). The PRR was generally in Very Good condition and also comprised the best quality areas of parabolic dune vegetation (EcoLogical 2011).

1.5.2 Fauna habitat

Carnaby's Black Cockatoo

Carnaby's Black Cockatoos (*Calyptorhynchus latirostris)* are endemic to the south-west of Western Australia. They mainly occur in uncleared remnant native eucalypt woodlands, especially those that contain Salmon Gum, Wandoo, and in shrubland or kwongan heathland dominated by *Hakea, Dryandra, Banksia* and *Grevillea* species (Department of Sustainability Environment Water Population and Communities [DSEWPaC] 2012a). Current data on distribution of this species shows that there are numerous records along the Northern Swan Coastal Plain, including records in and around the Project Area.

Habitat within the Project Area

Thirty-three vegetation associations have been identified across the Project Area, consisting of two broad groups (Emerge 2013):

- *Melaleuca* spp. */Lomandra maritima/ Xanthorrhoea preissii/ Acacia* spp. heath on dune systems
- *Eucalyptus* spp. /*Banksia* spp. woodlands in lower lying areas and limestone.

Foraging habitat

A total of 323.5 ha of potential foraging habitat for CBC are situated within the 480.4 ha Project Area, (Strategen 2015). Of this habitat, approximately 257 ha will be cleared for the development and approximately 66.64 ha retained in PRR (Figure 2).

Potential breeding trees

A detailed tree survey was undertaken in August 2014 assessing the 178 trees identified in the Project Area (Paperbark Technologies 2014). Of these 178 trees, the survey found 22 trees exhibiting existing tree hollows.

Figure 2: Parks and Recreation Reserve areas, Carnaby's Black Cockatoo habitat and revegetation areas

Scale 1:18,000 at A4

0 100 200 300 400 m

Coordinate System: GDA 1994 MGA Zone 50

Note that positional errors may occur in some areas

Date: 29/06/2017

Author: JCrute

Source:

Legend

- Habitat tree locations
- Parks and Recreation Reserve
- Project area boundary
- Potential rehabilitation areas

strategen ENVIRONMENTAL

info@strategen.com.au
www.strategen.com.au

Path: Q:\Consult\2016\LLC\LLC16557\ArcMap_documents\LLC16557_G002_R002_RevB_F002.mxd

1.6 Potential impacts and risks

An assessment of the potential impacts and risks to Carnaby's Black Cockatoos as a result of the Project, including potential risks to the retained CBC habitat within PRR has been undertaken. Results of the risk assessment have been used in developing management measures that form part of this PRRMP.

1.6.1 Threats to Carnaby's Black Cockatoo and habitat

Threats to Carnaby's Black Cockatoos are described in the *EPBC Act referral guidelines for three threatened black cockatoo species* (DSEWPaC 2012b) and summarised as follows:

Habitat loss and degradation, including:

- loss and isolation of mature, hollow-bearing trees necessary for breeding
- lack of or loss of younger age class trees required to replace old trees that die or are destroyed, leading to a shortage of hollows in the future
- loss, degradation and fragmentation of foraging habitat[1]
- removal of native vegetation corridors, restricting the birds' ability to migrate across the landscape
- loss, degradation and isolation of night roost sites and surrounding feeding or watering habitat
- loss and degradation of habitat by secondary impacts such as introduction of dieback caused by *Phytophthora cinnamomi* (and other plant diseases), weed invasion which can affect seed set, and hydrological changes (such as flooding, drainage or salinity).

Interactions with humans, including:

- death or injury when hit by cars or trucks, particularly road constructions that concentrate birds
- at roadsides to feed on roadside vegetation and spilt grain, or drink from rainwater retained as puddles on roadsides
- death or injury from crop protection measures which may trap or injure birds, or prohibit them from accessing nearby native vegetation
- disturbance to birds from noise, light, vibrations and fumes
- shooting of birds (for example where they are coming into conflict with humans over fruit or nut crops)
- poaching of birds and eggs.

Adverse impacts from invasive species, including:

- competition for nest hollows with European honeybees and invading bird species
- injury and death from European honeybees.

1.6.2 Potential impacts

Potential impacts to Carnaby's Black Cockatoos as a result of the Project were identified and assessed as part of the EPBC Act approvals process. The key impacts as described in Table 2 have been derived from a review of threats to Carnaby's Black Cockatoos (as described in Section 1.6.1 above). In order to ensure that potential impacts and associated Project risks have been effectively translated into the implementation phase of the Project an assessment, a risk assessment has been undertaken (Table 2).

[1] This is particularly important in breeding areas: removal of vegetation around breeding sites, and the removal of native vegetation corridors that connect breeding and foraging sites, reduces the amount of food available to breeding birds and can affect chick survival rates. Breaks of more than 4 km have been shown to prevent breeding birds reaching resources.

Table 2: Potential impacts on Carnaby's Black Cockatoos

Impact	Description
Degradation of PRR through unrestricted and/or unauthorised access*	Access to the PRR by unauthorised or unrestricted access may result in degradation to the PRR.
Habitat impacts through introduction and / or spread of dieback	The Project has the potential to introduce and / or spread dieback (*Phytophthora cinnamomi*) into Parks and Recreation Reserves and across the Project area, which could lead to the decline in vegetation health and the resulting displacement of CBCs, as well as increasing the risk of further infestation. Soil containing dieback may be transported on machinery and equipment used during clearing operations.
Habitat impacts through introduction and / or spread of weeds	The Project has the potential to introduce and / or spread weeds into Parks and Recreation Reserves which could lead to the decline in vegetation health and the resulting displacement of CBCs. Habitat contained in Parks and Recreation Reserves within the Proposal Area is considered to be at risk of establishment of invasive species through edge effects. Soil containing weed and seed matter may be transported on machinery and equipment used during clearing operations.
Degradation of CBC nesting hollows within PRR areas	Nesting hollows or sacrificial chewing posts (in the case of artificial hollows) may become damaged by natural processes (rusting of attachments, rotting of timber), or may be used by pest or feral species e.g. bees, rainbow lorikeets, galahs and corellas.
Damage to rehabilitation due to trampling, grazing, soil erosion or poor establishment of rehabilitation	Rehabilitation may be grazed by rabbits or kangaroos or be trampled or damaged if unauthorised access occurs. Rehabilitation may establish poorly for a range of reasons, including soil erosion.

*Note: For the purpose of this PRRMP 'unauthorised access' refers to access to the PRR by Lendlease personnel and its contractors as well as members of the public. While every attempt will be made by Lendlease to control unauthorised access by the public, it has no jurisdiction over the public. For the avoidance of doubt, 'unauthorised access' is any access within the area not approved by the LL Project Manager (i.e. ‘authorised access’ will be permitted).

2. Environmental outcomes and completion criteria

Management measures to avoid or reduce impacts to Matters of National Environmental Significance (MNES) are primarily focussed on habitat avoidance/protection and habitat creation/enhancement measures to be undertaken as part of on-site mitigation measures.

An area of 66.64 ha of on-site CBC habitat will be protected in perpetuity as PRR, comprising approximately 19% of foraging habitat within the Proposal Area (323.5 ha), along with a minimum of 16 potential breeding trees including four with hollows. This land is strategically located to provide habitat linkage values between nearby conservation estates and Bush Forever sites (Yanchep National Park to the north; Neerabup National Park to the south and Bush Forever sites 129 and 130 surrounding the Proposal Area). The PRR will be managed by the WAPC in the short-term, after which the intention is for management requirements to be transferred by the WAPC to the City of Wanneroo (CoW) or Department of Biodiversity, Conservation and Attractions (DBCA) ('handover', refer to Section 4.1 for description of the expected handover process).

Objectives, interim targets, performance indicators and completion criteria for the following key environmental outcomes have been developed in order to comply with EPBC Act approval condition 3 and are provided in Table 3.

Table 3: Objectives, interim targets, performance indicators and completion criteria

Environmental outcome	Objective	Interim target	Performance indicators	Completion criteria
Delineation of retained vegetation	To ensure no more than 257 ha of potential CBC habitat is cleared from the Project Area.	No more than 257 ha of potential CBC habitat is cleared from the Project Area.	No clearing outside of approved boundary.	No more than 257 ha of potential CBC habitat is cleared from the Project Area following the completion of clearing activities.
	To ensure no clearing within the 66.64 ha of CBC retained within the PRR.	A minimum of 66.64 ha of CBC habitat is retained within the area identified as retained vegetation in Figure 2.	No clearing within the 66.64 ha of CBC retained within the PRR.	A minimum of 66.64 ha of CBC habitat is retained within the area identified as retained vegetation in Figure 2 following PRR handover.
	To ensure appropriate access restrictions to PRR are maintained.	If construction is immediately adjacent to the PRR, temporary and/or permanent delineation measures* must be installed along the entire stage boundary and at least 50 m from the edge of the stage clearing footprint, prior to clearing of that stage.	No evidence of unauthorised access to PRR. Installation of PRR delineation measures*.	All PRR permanent delineation measures* are installed on handover of the PRR.
Protection of retained vegetation	To ensure the ongoing protection of and prevent future expansion into retained vegetation.	Consultation with WAPC and the proposed managing body is commenced within one year from the commencement of clearing.	Vegetation is protected in perpetuity as a conservation reserve.	Vegetation to be retained is protected in perpetuity and ceded to WAPC and reserved as conservation by handover.
	To maintain the health and condition of native vegetation within the PRR+.	Monitoring shows: • a decreasing trend in significant weed density • no spread of significant plant pathogens • a decrease in predation by significant pests.	No evidence of vegetation decline as a result of significant weeds, pests and plant pathogens^.	After completion of the 5-year rehabilitation maintenance period, monitoring shows: • significant weed density is lower than it was prior to the commencement of construction works • no spread of significant plant pathogens, when compared to pre-construction monitoring • no evidence of widespread predation by significant pests, when compared to pre-construction monitoring.

Environmental outcome	Objective	Interim target	Performance indicators	Completion criteria
Rehabilitation of retained vegetation	To manage weeds, pests and plant pathogens within the rehabilitation area.	No damage to rehabilitation planting by weeds, pests and plant pathogens.	No or minor evidence of: • grazing on seedlings planted as part of rehabilitation activities • vegetation decline as a result of weeds and plant pathogens.	Five years from the commencement of rehabilitation#, rehabilitated areas are determined to be self-sustaining and free of weed species and pests.
	Rehabilitate a minimum 5 ha of degraded vegetation using plants known to be primary feeding plants CBCs.	Seed will be collected from 50 ha of CBC habitat proposed to be cleared within the Project Area, at the appropriate time of year.	Seed collected from vegetation within Project Area.	Seed collected from 50 ha of CBC habitat prior to clearing.
		Monitoring shows rehabilitated vegetation is tracking toward 1.6 plants/m2.	Seedlings known to be primary feeding plants for Carnaby's Black Cockatoo, as listed in Groom (2011) and other publications as well as other key species typical of the relevant vegetation type are growing within the rehabilitation area.	A minimum of 1.6 plants/m² established within rehabilitation areas, with at least 1 plant/10 m2 being a primary feeding species for Carnaby's Black Cockatoo, five years from the commencement of rehabilitation#.
		Initial seed and seedling mix includes: • overstorey and mid/understorey species • at least 15 species overall • at least two primary feeding species for Carnaby's Black Cockatoo.	Rehabilitation comprises a diverse mix of species, including overstorey and mid/understorey and primary feeding species for Carnaby's Black Cockatoo.	Five years from the commencement of rehabilitation, established plants include: • overstorey and mid/understorey species • at least 8 species overall • at least two primary feeding species for Carnaby's Black Cockatoo.
Retention and management of CBC nesting habitat	To install 12 nesting hollows in the Project Area.	Trees with suitable hollows and those proposed to receive nest boxes identified, marked and removed prior to clearing. Construction, positioning and erection of the artificial nest boxes to be in accordance with the WA DEC Publication "Artificial hollows for Carnaby's black cockatoo" (Groom, 2010; Appendix 2).	Suitable nesting hollows are removed and retained for relocation/installation.	Twelve artificial nesting boxes and/or relocated nesting hollows installed within the Project Area within two years from the commencement of clearing.

Environmental outcome	Objective	Interim target	Performance indicators	Completion criteria
	To ensure relocated/artificial hollows remain in suitable condition for black cockatoo usage.	All installed hollows are to be inspected at least annually and to be found in good condition. Repairs to hollows as a result of damage and/ or deterioration must be undertaken, bee colonies removed if required and mulch and/ or sacrificial chewing posts replaced prior to the next breeding season.	Inspections show hollows are in good condition and/or are being used by CBC.	The Project Area contains 12 viable artificial and/or relocated nesting hollows in good condition for a period of five years.

* Permanent and temporary PRR delineation measures as described in Table 8 (e.g. fencing, signage and other access restrictions/deterrents).

^ Significance in this instance are defined as weeds, pests and plant pathogens that have serious impact on bushland, including Declared Pests under the BAM Act, Weeds of National Significance, Dieback and rabbits or others identified during monitoring.

The commencement of rehabilitation is defined as the first round of weed control within proposed rehabilitation areas.

+ Monitoring to confirm health and condition of native vegetation within the PRR will be undertaken within the 50 m buffer area adjacent to active construction areas. Monitoring will be undertaken annually in spring following commencement of construction until completion of 5-year rehabilitation maintenance period. The 5-year maintenance perios is a continuous period of 5 years during which the completion criteria are attained/maintained.

3. Risk assessment

A qualitative risk assessment has been undertaken using the methods, definitions and matrix described in the *Environmental Management Plan Guidelines* (Department of the Environment 2014). The risk framework is presented in Table 4 and the definitions for the qualitative measure of likelihood and consequence are presented in Table 5. The risk matrix is presented in Table 6.

Table 4: Risk framework

		Consequence				
		Minor	**Moderate**	**High**	**Major**	**Critical**
Likelihood	**Highly Likely**	**Medium**	**High**	**High**	**Severe**	**Severe**
	Likely	**Low**	**Medium**	**High**	**High**	**Severe**
	Possible	**Low**	**Medium**	**Medium**	**High**	**Severe**
	Unlikely	**Low**	**Low**	**Medium**	**High**	**High**
	Rare	**Low**	**Low**	**Low**	**Medium**	**High**

Table 5: Likelihood and consequence

Likelihood	Consequence
Qualitative measure of likelihood (how likely is it that this event/circumstances will occur after management actions have been put in place/are being implemented)	
Highly likely	Is expected to occur in most circumstances
Likely	Will probably occur during the life of the project
Possible	Might occur during the life of the project
Unlikely	Could occur but considered unlikely or doubtful
Rare	May occur in exceptional circumstances
Qualitative measure of consequences (what will be the consequence/result if the issue does occur)	
Minor	Minor risk of failure to achieve the plan's objectives. Results in short term delays to achieving plan objectives, implementing low cost, well characterised corrective actions.
Moderate	Moderate risk of failure to achieve the plan's objectives. Results in short term delays to achieving plan objectives, implementing well characterised, high cost/effort corrective actions.
High	High risk of failure to achieve the plan's objectives. Results in medium-long term delays to achieving plan objectives, implementing uncertain, high cost/effort corrective actions.
Major	The plan's objectives are unable to be achieved, with significant legislative, technical, ecological and/or administrative barriers to attainment that have no evidenced mitigation strategies.
Critical	The plan's objectives are unable to be achieved, may include widespread and severe environmental harm, with no evidenced mitigation strategies.

Project risks were determined based on key project impacts identified as part of the EPBC Act assessment process. Qualitative measures of likelihood and consequences were determined to establish a risk ranking in accordance with the risk framework (Table 4). Potential risks were ranked to determine inherent risk arising from a potential impact prior to the implementation of mitigation/management measures. Although all impacts/risks were ranked as having a low residual risk, mitigation measures have been identified for each key impact/risk identified (summarised further in Section 4). The outcomes of the risk assessment are presented in Table 6 including the key mitigation/management measures that have been discussed further in Section 4.

This page is intentionally blank

Table 6: Risk assessment

Environmental / management outcome	Performance indicators	Risk related event or circumstance	Likelihood	Consequence	Risk level	Management measures	Residual likelihood	Residual consequence	Residual risk level	Detection/monitoring activity/ies	Contingency response	Feasible/effective corrective actions
Delineation of retained vegetation	No clearing outside of approved boundary.	Clearing outside of the clearing boundaries resulting in more than 257 ha of CBC habitat to be cleared.	Possible	Moderate	Medium	Section 4	Unlikely	Moderate	Low	Section 5	Section 6	High
	No clearing within the 66.64 ha of CBC retained within the PRR.	Lack of integrity of PRR fencing, signage and other access restrictions/deterrents.	Possible	Moderate	Medium	Section 4	Rare	Minor	Low	Section 5	Section 6	High
	No evidence of unauthorised access to PRR. Installation of PRR delineation measures.	Access to the PRR by unauthorised or unrestricted access (site personnel, members of the general public) may result in degradation to the PRR.	Possible	Moderate	Medium	Section 4	Unlikely	Moderate	Low	Section 5	Section 6	High
Protection of retained vegetation	Vegetation is protected in perpetuity as a conservation reserve.	Agreement not reached with WAPC/Conservation Commission regarding ceding of PRR.	Possible	Moderate	Medium	Section 4	Unlikely	Moderate	Low	Section 5	Section 6	High
	No evidence of vegetation decline as a result of significant weeds, pests and plant pathogens.	The Project has the potential to introduce and / or spread weeds into Parks and Recreation Reserves which could lead to the decline in vegetation health and the resulting displacement of CBCs. Habitat contained in Parks and Recreation Reserves within the Proposal Area is considered to be at risk of establishment of invasive species through edge effects. Soil containing weed and seed matter may be transported on machinery and equipment used during clearing operations.	Possible	Minor	Low	Section 4	Rare	Minor	Low	Section 5	Section 6	High
		The Project has the potential to introduce and / or spread dieback (*Phytophthora cinnamomi*) into Parks and Recreation Reserves and across the Project area, which could lead to the decline in vegetation health and the resulting displacement of CBCs, as well as increasing the risk of further infestation. Soil containing dieback may be transported on machinery and equipment used during clearing operations.	Possible	Moderate	Medium	Section 4	Rare	Moderate	Low	Section 5	Section 6	High
Rehabilitation of retained vegetation	No or minor evidence of: • grazing on seedlings planted as part of rehabilitation activities • vegetation decline as a result of weeds and plant pathogens.	Rehabilitation may be grazed by rabbits or kangaroos or be trampled or damaged if unauthorised access occurs. Rehabilitation may establish poorly.	Possible	Moderate	Medium	Section 4	Rare	Minor	Low	Section 5	Section 6	High
	Seed collected from vegetation within Project Area.	Seed unable to be collected from 50 ha of CBC habitat due to insufficient seed available.	Possible	Moderate	Medium	Section 4	Unlikely	Moderate	Low	Section 5	Section 6	High
	Seedlings known to be primary feeding plants for CBC, as listed in Groom (2011) and other publications as well as and other key species typical of the relevant vegetation type are growing within the rehabilitation area.	Rehabilitation monitoring shows poor representation of CBC plant species in rehabilitation.	Possible	Moderate	Medium	Section 4	Unlikely	Moderate	Low	Section 5	Section 6	High
	Degraded areas planted with native species including primary feeding species for CBC.											

Environmental / management outcome	Performance indicators	Risk related event or circumstance	Likelihood	Consequence	Risk level	Management measures	Residual likelihood	Residual consequence	Residual risk level	Detection/monitoring activity/ies	Contingency response	Feasible/effective corrective actions
	Rehabilitation comprises a diverse mix of species, including overstorey and mid/understorey and primary feeding species for CBC.											
Retention and management of CBC nesting habitat	Suitable nesting hollows are removed and retained for relocation/installation.	Less than 12 translocated / artificial nesting hollows installed within the Project Area by handover.	Unlikely	Moderate	Low	Section 4	Rare	Minor	Low	Section 5	Section 6	High
	Inspections show hollows are in good condition and/or are being used by Carnaby's Black Cockatoos.	Nesting hollows or sacrificial chewing posts (in the case of artificial hollows) may become damaged by natural processes (rusting of attachments, rotting of timber), or may be used by pest or feral species e.g. bees or rainbow lorikeets.	Likely	Minor	Low	Section 4	Rare	Minor	Low	Section 5	Section 6	High

4. Management measures

4.1 Implementation

Ownership of the PRR has been transferred to the WAPC, however Lendlease will continue to be responsible for implementation of this PRRMP as the EPBC Act approval holder. Retained vegetation will be vested in the WAPC and retained for conservation (PRRMP 1).

4.2 Delineation of areas to be retained

Delineation of 66.64 ha of Carnaby's Black-Cockatoo habitat to be retained within PRR areas is important during the construction phase as well as post construction. If retained CBC habitat is not adequately delineated, it may become degraded through trampling, predation by feral animals/domestic pests and the introduction/spreading of weeds. Relevant management measures are provided in Table 7.

Table 7: Management measures for delineating retention areas

PRRMP item	Action	Timing	Responsibility
2	Delineate areas of PRR along clearing boundaries through the installation of survey pegs and/or temporary fencing along the entire stage boundary.	Prior to clearing (each stage where adjacent to PRR)	Construction contractor
3	Install permanent fencing to delineate PRR.	Prior to the commencement of work on site, where site works are adjacent (up to 50 m) of the PRR	Construction contractor
4	Restrict access to unwanted tracks in PRR areas through the installation of appropriate fencing or barriers.	During construction	Construction contractor
5	Provide GPS co-ordinates of areas approved to be cleared and those required to be retained to the contractor to ensure no unapproved clearing is undertaken.	During construction	Project Manager
6	Install appropriate temporary signage to restrict unauthorised access to the PRR.	Pre and during construction	Construction contractor
7	Install permanent signage to encourage public education and awareness on: • where to access the PRR, if applicable • the importance of retained bushland • the detrimental effects of rubbish, weeds and pathogens on biodiversity • the importance of keeping to the designated walking tracks, if applicable.	During and post-construction up until handover	Project Manager / Construction contractor

4.3 Protection of retained vegetation

The PRR will be protected through the provisions of the Metropolitan Region Scheme as ROS. Management will be vested in the WAPC, with ongoing management to be undertaken by the WAPC initially, and then transferred to CoW or DBCA for future ongoing management through the creation of a management order to CoW. Relevant management measures are provided in Table 8.

Table 8: Management measures for protection of retained vegetation

PRRMP item	Action	Timing	Responsibility
Tenure and zoning			
8	Vegetation to be retained is protected in perpetuity and vested with WAPC and reserved as conservation to be managed by CoW or Parks and Wildlife.	Lendlease will continue to be responsible for implementation of this PRRMP as the EPBC Act approval holder.	Project manager.

4.4 Rehabilitation of PRR

Rehabilitation of a minimum 5 ha of degraded vegetation will be undertaken within PRR areas, incorporating restoration activities, including direct seeding and/or infill planting, fencing, weed and pest control.

Seed will be collected from 50 ha of CBC habitat for use in revegetation. The optimal timing for seed collection for the majority of species is between October and April; however, seed is typically present for some species outside of this time. Excess seed collected during clearing will be made available to DBCA or a suitable third party on agreement of DBCA/the third party and in accordance with relevant licence conditions, for use in ongoing rehabilitation works.

To maximise the potential for rehabilitation success, the area(s) that are subject to rehabilitation will be prepared by:

- undertaking weed control
- removing rubbish or other debris, if required
- placing brushing and / or mulch or other suitable measures to assist in stabilising the rehabilitation area and preventing erosion, as required.

Any areas suitable for direct seeding will be subject to soil preparation, e.g. scarification, if required. Seed will be treated to break dormancy factors, as appropriate for species (e.g. smoke treatment, scarification).

Seedlings will be propagated in an accredited nursery from seed collected from the Project Area, or if insufficient seed is available, local provenance seed (collected from within a 50 km radius of the Project Area). This radius may need to be extended if restrictions on seed collection exist at the time seed collection is required.

Degraded areas will be planted and seeded to achieve a density of at least 1.6 plants/m^2. The planting mix will include both CBC foraging and habitat species as well as other non-foraging species found within the same communities in order to achieve the completion criteria (Table 3). Relevant management measures are provided in Table 9.

Table 9: Management measures for rehabilitation of PRR

PRRMP item	Action	Timing	Responsibility
Contractor engagement			
9	Appoint an experienced revegetation contractor(s) to undertake seed collection, weed control and other site preparation, and direct seeding/seedling planting.	Prior to the seed collection season (approximately October–April) before clearing commences	Project manager
10	Appoint an experienced pest control contractor to undertake measures to control pest fauna (i.e. grazing fauna such as rabbits), based on monitoring results.	Prior to commencement of planting	Project manager
11	Appoint a suitably qualified dieback consultant to undertake baseline dieback assessment of the PRR.	Prior to the commencement of work on site, where site works are adjacent (up to 50 m) of the PRR	Project manager
12	Induct all personnel working on site in relation to the following: restricted and/or 'no-go' areas, including the PRR and other areas of protected vegetation identified on site key requirements of the PRRMP (including measures to protect CBC, hygiene measures etc) key requirements of the Construction Environmental Management Plan (CEMP), relevant to protection of the PRR.	Prior to commencing work on site	Project manager / Construction contractor
Baseline assessment			
13	Establish three permanent baseline vegetation monitoring quadrats as described in Table 11.	Prior to rehabilitation works (refer to Table 11)	Rehabilitation contractor
Weed and pathogen control			
14	Undertake weed control at least twice within PRR rehabilitation areas.	Prior to direct seeding / seedling planting and/ or commencement of rehabilitation activities	Rehabilitation contractor
15	Weed control methods to be in accordance with industry standards (e.g. RIAWA^, DBCA standards).	During weed control	Rehabilitation contractor
16	Control methods for any weeds listed as Declared Pests to be undertaken in accordance with guidelines of the Department of Agriculture and Food WA.	During weed control	Rehabilitation contractor
17	Undertake ongoing maintenance weed control.	Biannually for five years from the initial planting completion date, or as advised by rehabilitation contractor	Rehabilitation contractor
18	Engage suitably qualified dieback consultant to conduct baseline dieback survey of the rehabilitation areas.	Prior to rehabilitation works	Project manager
19	Conduct baseline dieback survey within PRR rehabilitation areas to establish any areas where dieback infestations currently occur.	Prior to rehabilitation works	Dieback survey consultant
20	If vehicles are required to enter PRR rehabilitation areas, all vehicles, machinery and equipment will be free of mud and soil prior to entering retained vegetation to prevent introduction and spread of weeds and pathogens.	During construction and rehabilitation works	PAll personnel

PRRMP item	Action	Timing	Responsibility
21	TEnsure that records of vehicles, equipment and equipment hygiene are keptthroughout the project..	During construction and rehabilitation works	Project manager/Rehabilitation contractor
22	Ensure any materials (soil, mulch etc) brought into PRR rehabilitation areas is certified dieback free.	During rehabilitation works	Project manager
Pest control			
23	Conduct pest control in PRR, based on monitoring detecting significant pest presence.	Ongoing as required	Pest control contractor subcontracted to the Rehabilitation contractor
Seed collection			
24	Compile list of appropriate species to be planted in rehabilitation areas based on flora and vegetation surveys and baseline assessment.	Prior to seed collection	Rehabilitation contractor
25	Collect seed from 50 ha of CBC habitat within the Project area, targeting any suitable CBC foraging species that pertain to the vegetation types within the rehabilitation area	October to April^	Rehabilitation contractor
26	If sufficient seed is not available from within the Project Area, additional collection areas within 50 km of the Project Area will be sourced.	December to March prior to seeding	Project manager / Rehabilitation contractor
27	Appropriate licences to be obtained from DBCA for seed collection.	Prior to seed collection	Rehabilitation contractor
Seedling planting			
28	Determine areas suitable for rehabilitation.	Prior to seedling planting	Rehabilitation contractor
29	Propagate seedlings from seed collected from Project Area*.	September to May following seed collection	Rehabilitation contractor
30	Undertake seedling planting including an initial seed/seedling mix of: • at least 15 species • two primary CBC feeding species • a mix of overstorey and mid/understorey species as appropriate.	During seedling planting	Rehabilitation contractor
31	Protect seedlings with tree guards if required or apply other suitable measures, i.e. perimeter exclusion fencing and baiting etc.	During seedling planting	Rehabilitation contractor
32	Ensure all plants used in rehabilitation are suitable as foraging, breeding or roosting habitat for Carnaby's black-cockatoo as listed by Groom (2011; Appendix 1) or other species suitable for the vegetation types being rehabilitated within PRR areas.	During rehabilitation	Rehabilitation contractor
33	Procure seedlings of suitable provenance to conduct top-up planting in any areas not meeting density of 1.6 plants/m²..	When monitoring indicates a density of 1.6 plants/m² has not been met	Rehabilitation contractor
Direct seeding			
34	Determine whether any areas are suitable for direct seeding.	Prior to seeding	Rehabilitation contractor
35	Determine seed mix based on target vegetation type, seed availability and planned seedling program.	Prior to seeding	Rehabilitation contractor
36	Treat seed to break dormancy factors, as appropriate for species.	Prior to seeding	Rehabilitation contractor

PRRMP item	Action	Timing	Responsibility
37	Prepare soil with any methods necessary to increase germination success (e.g. scarification), as required.	Prior to seeding	Rehabilitation contractor
38	Place mulch or brushing where appropriate to increase success of revegetation, in any areas subject to erosion.	Prior to seeding	Rehabilitation contractor
39	Undertake direct seeding based on seed mix, in consideration of target vegetation type, seed availability and planned seedling program.	During seeding	Rehabilitation contractor

*Refer to note above regarding provenance if inadequate quantities of seed available from Project Area.
^Timing of seed collection may extend into other months depending on species, seasonal conditions and site conditions, based on the advice of the Rehabilitation Contractor.
#Optimal timing for seed sowing for most seedlings is October–December to produce robust seedlings by the usual planting times in winter, so preferable for seed collection to occur the previous spring/summer to maximise species diversity and avoid inferior seedlings.

4.5 Retention and management of Carnaby's Black Cockatoo nesting habitat

A total of 12 nesting hollows will be either created or translocated into PRR areas to enhance breeding habitat.

Potential nesting hollows in the Development Area will be salvaged from trees proposed to be cleared, and these will be translocated to suitable trees within PRR areas. Additionally, nest boxes will be installed within the PRR to enhance breeding habitat therein. Relevant management measures are provided in Table 10.

Table 10: Management measures for retention and management of black cockatoo nesting habitat

PRRMP Item	Action	Timing	Responsibility
40	Identify and mark trees with hollows to be removed and relocated to PRR areas.	Prior to clearing of Project Area	Project manager / Environmental consultant
41	Remove hollows from trees identified as having hollows suitable for relocation.	Prior to clearing of Project Area	Construction contractor
42	Engage contractor to undertake hollow construction and installation works.	During rehabilitation works	Project manager
43	Install relocated natural hollows and artificial nesting boxes within PRR areas in accordance with requirements outlined in Groom (2010; Appendix 1).	During rehabilitation works	Construction contractor / environmental consultant
45	Where necessary, hollows will be repaired, cleared of bee colonies and any other actions to ensure condition is maintained.	When monitoring indicates hollows are damaged or otherwise unviable for use by CBC	Construction contractor / Environmental consultant
46	Hollows will be inspected prior to and upon completion of the CBC breeding season for condition and evidence of black cockatoo usage.	Bi-annually (prior to and on completion of the CBC breeding season [July to December])	Environmental consultant

5. Monitoring

5.1 Monitoring program

A monitoring program has been developed focusing on monitoring of the following items:

- retained CBC habitat within PRR areas
- opportunistic monitoring of the presence and abundance of CBC
- rehabilitation in degraded areas of the PRR.

The following monitoring actions have been developed to enable an assessment of the effectiveness of the management actions (Table 11).

Table 11: Monitoring actions

Monitoring objective	Performance Indicators	Monitoring parameter	Frequency/timing	Location	Responsibility
To delineate retained vegetation	No clearing outside approved boundary. No clearing within the 66.64 ha of CBC retained within the PRR. No evidence of unauthorised access to PRR. Installation of PRR delineation measures*.	Condition of fencing to delineate the area of retained vegetation, and barriers used to block unwanted access tracks.	Fortnightly for the first 6 months following commencement of clearing and then quarterly thereafter during construction	Around the PRR near clearing boundaries	Construction contractor
		Approved clearing boundaries.	Fortnightly during clearing, or as otherwise required by regulatory authorities as part of construction site inspections	Clearing boundaries	Construction contractor
		Total area cleared.	Annually during construction after clearing has commenced	Project Area	Construction contractor
		Evidence of unauthorised access within the PRR, e.g. observations of unauthorised vehicles or machinery, damage to fencing.	Opportunistically during other PRR inspections	Around the PRR	Construction contractor
		Integrity of PRR fencing, signage and other access restrictions/deterrents.	Fortnightly for the first 6 months following commencement of clearing and then quarterly thereafter during construction	Around the PRR	Construction contractor
To protect retained vegetation	Vegetation is protected in perpetuity as a conservation reserve.	Status of retained vegetation.	At handover to CoW or DBCA	PRR areas	Project manager
	No evidence of vegetation decline as a result of significant weeds, pests and plant pathogens.	Establish three permanent baseline vegetation monitoring quadrats* within remnant native vegetation of the same vegetation type as rehabilitation areas to determine: • native species composition of remnant native vegetation within PRR areas to determine suitable species for use in rehabilitation • list of CBC foraging, roosting and nesting habitat species present within remnant native vegetation within PRR areas to determine suitable species for use in rehabilitation • baseline levels of weed infestation including list of weed species currently present within PRR areas • to inform general PRR condition monitoring.	Prior to seed collection	PRR areas	Rehabilitation contractor
		Establish other permanent quadrats or transects* as required to assist PRR condition monitoring and maintenance.	As required	PRR areas	Environmental consultant

Monitoring objective	Performance Indicators	Monitoring parameter	Frequency/timing	Location	Responsibility
		Vegetation health within 50 m adjacent to the construction area within the PRR including: • weed density • significant plant pathogens • predation by significant pests.	Annually in spring following commencement of construction until completetion of 5 year rehabilitation maintenance period	PRR areas (permanent quadrats to be established within the 50 m buffer area adjacent to active construction).	Project manager
To rehabilitate PRR areas	Seed collected from vegetation within Project Area.	Monitoring of seed collection records.	Annually, during planting/direct weeding	N/A	Rehabilitation contractor
	Seedlings known to be primary feeding plants for CBC, as listed in Groom (2011) and other publications as well as key species typical of the relevant vegetation type are growing within the rehabilitation area. No evidence or minor evidence of: • grazing on seedlings planted as part of rehabilitation activities • vegetation decline as a result of weeds and plant pathogens.	Establish three permanent baseline vegetation monitoring quadrats (10 m by 10 m) within remnant native vegetation of the same vegetation type as rehabilitation areas to determine: • native species composition of remnant native vegetation within PRR areas to determine suitable species for use in rehabilitation • list of CBC foraging, roosting and nesting habitat species present within remnant native vegetation within PRR areas to determine suitable species for use in rehabilitation • baseline levels of weed infestation including list of weed species currently present within PRR areas • to inform general PRR condition monitoring.	Monitoring annually in spring following rehabilitation, for five years	Permanent monitoring quadrats within rehabilitation areas	Rehabilitation contractor
		Percentage cover of weed species within vegetation monitoring quadrats within the retained vegetation.			
	Rehabilitation comprises a diverse mix of species, including overstorey and mid/understorey and primary feeding species for CBC.	Undertake monitoring of: • overstorey and mid/understorey species (number and species types) • number of primary feeding species for CBC.	Monitoring annually in spring following rehabilitation, for five years	Permanent monitoring quadrats within rehabilitation areas	Project manager (via environmental consultant)
To retain and manage CBC nesting habitat	Suitable nesting hollows are removed and retained for relocation/installation.	Number of nesting hollows installed within the Project Area.	During hollow monitoring (bi-annually)	Project Area	Environmental consultant
	Inspections show hollows are in good condition and/or are being used by CBCs.	CBC presence within nesting hollows.	Bi-annually (prior to and on completion of the CBC breeding season [July to December])		
		Evidence of damage/deterioration, presence of bee colonies.			

*Quadrats will be permanent for the duration of the rehabilitation works untilachievement of completion criteria, i.e. 5 years.

5.2 Data handling and management

Data collected by the Environmental Consultant, Revegetation Consultant and/or any other specialists in the course of monitoring activities will be provided to the Lendlease Project Manager who will ensure all data and records are stored and maintained to inform reporting, review and compliance assessments. Numerical data will preferably be stored using Microsoft Excel and spatial data in shapefile format or similar widely used formats.

Data will be provided to the Lendlease Project Manager upon submission of monitoring reports.

6. Contingency response, corrective actions

Contingency measures will be initiated if monitoring indicates that interim targets, completion criteria and performance indicators are not being met. Table 12 outlines trigger levels relating to each environmental outcome and subsequent interim targets, performance indicators and contingency measures. Given the environmental outcomes and objectives of the PRRMP relate to the protection of CBC habitat, the contingency measures in this section are used as the 'environmental emergency procedures' referred to in DotE 2014, i.e. serious environmental incidents such as hydrocarbon spills are considered by Strategen as negligible risk.

Table 12: Contingency measures

Trigger level	Contingency action	Responsibility
Delineation of retained vegetation		
More than 257 ha of CBC habitat cleared	• Determine extent of additional clearing. • Report additional clearing (breach of condition 1 of EPBC 2015/7561) to DEE. • Undertake required remedial measures as determined by DEE.	Project manager
Clearing of more than 66.64 ha of CBC earmarked for retention within the PRR	• Determine extent of clearing of CBC habitat within PRR. • Report clearing of more than 66.64 ha of CBC habitat within PRR (breach of condition1 and 3 of EPBC 2015/7561) to DEE. • Undertake required remedial measures as determined by DEE.	Project manager
Unrestricted access, or unauthorised access by Lendlease contractors or members of the public	• Determine how access was gained and, if possible, the likely time of access. • Implement remedy, which could include: - repair fence/s - erect signs to highlight prohibited access - review education measures (e.g. inductions, toolbox/site meetings and communications) - re-induct contractors including revision of induction as required - reiterate to contractors the importance of not entering the PRR unless authorised, through toolbox meetings, training sessions etc. • Monitor success of control.	Project manager
Integrity of temporary and/or permanent fencing compromised	• Determine how integrity was compromised, if possible. • Determine if additional measures required to prevent reoccurrence. • Undertake maintenance of fencing and implement additional measures as required. • Monitor success of measures undertaken.	Project manager
Protection of retained vegetation		
Introduction of a new significant weed species within retained vegetation within the PRR	• Map the distribution of the newly introduced significant weed species. • Identify activities that may have potentially introduced the significant weed species. • Plan and implement a significant weed control program (may involve seeking advice from relevant authorities). • Apply hygiene control and education measures.	Rehabilitation contractor / environmental consultant
Observations indicate presence of dieback in previously uninfested areas of PRR	• Identify potential sources of dieback spread and determine likely cause. • Update mapped distribution of dieback affected areas. • Undertake dieback control -control methods may include phosphite treatment to minimise the spread of dieback. • Review success of dieback control methods and continue monitoring. • Review and update management plan accordingly.	Rehabilitation contractor / environmental consultant

Trigger level	Contingency action	Responsibility
Increase in distribution, abundance or density/cover of a significant weed species within the PRR	• Map the revised extent of the significant weed species within the site. • Identify activities that may have potentially increased the abundance, distribution or density/cover of significant weed species. • Plan and implement a significant weed control program (may involve seeking advice from relevant authorities). • Apply hygiene control and education measures.	Rehabilitation contractor / environmental consultant
Incorrect hygiene procedures being undertaken by work machinery at authorised access points into retained vegetation	• Determine why appropriate hygiene procedures were not followed. • Implement remedy, which could include: - educating employees on appropriate hygiene measures - erect signs to highlight prohibited access. • Review education measures (e.g. inductions, toolbox/site meetings and communications). • Monitor success of control.	Project manager
Increase in abundance and/or distribution of significant pest grazing animals within PRR	• Investigate cause. • Review control measures and procedures. • Re-inform all personnel of any changes to control procedures. • Implement remedial and/or revised control measures. • Implement of a pest animal control program. • Monitor outcome.	Rehabilitation contractor / environmental consultant
Rehabilitation of retained vegetation		
Introduction of a new weed species within rehabilitation areas	• Map the distribution of the newly introduced weed species. • Identify activities that may have potentially introduced the weed species. • Plan and implement a weed control program (may involve seeking advice from relevant authorities). • Apply hygiene control and education measures.	Rehabilitation contractor
Observations indicate presence of dieback in previously uninfested rehabilitation areas	• Identify potential sources of dieback spread and determine likely cause. • Update mapped distribution of dieback affected areas. • Undertake dieback control -control methods may include phosphite treatment to minimise the spread of dieback. • Review success of dieback control methods and continue monitoring. • Review and update management plan accordingly.	Rehabilitation contractor
Increase in distribution, abundance or density/cover of a weed species within rehabilitation areas	• Map the revised extent of the weed species within the rehabilitation area. • Identify activities that may have potentially increased the abundance, distribution or density/cover of weed species. • Plan and implement a weed control program (may involve seeking advice from relevant authorities). • Apply hygiene control and education measures.	Rehabilitation contractor
Increase in abundance and/or distribution of pest grazing animals within rehabilitation areas	• Investigate cause. • Review control measures and procedures. • Re-inform all personnel of any changes to control procedures. • Implement remedial and/or revised control measures. • Implement of a pest animal control program. • Monitor outcome.	Rehabilitation contractor
1.6 plants/m^2 (with at least 1 plant/10 m^2 being a primary feeding species for Carnaby's Black) not established within rehabilitation areas, five years from the commencement of rehabilitation	• Investigate cause (e.g. presence of dieback, pest infestation, weed infestation, erosion). • Implement relevant measures to prevent decline in species numbers. • Conduct supplementary seeding/planting as advised by revegetation contractor. • Continue monitoring as required by this PRRMP.	Rehabilitation contractor

Trigger level	Contingency action	Responsibility
Less than 8 species of which two are primary feeding species for CBC are established in rehabilitation areas, five years from the commencement of rehabilitation	• Investigate cause (e.g. presence of dieback, pest infestation, weed infestation, erosion). • Implement relevant measures to prevent decline in diversity. • Conduct supplementary seeding/planting as advised by revegetation contractor. • Continue monitoring as required by this PRRMP.	Rehabilitation contractor
Retention and management of CBC nesting habitat		
Damage to nesting hollows, translocated / artificial nesting hollows or sacrificial chewing posts	• Investigate cause. • Implement relevant measures to prevent further damage, if possible. • Repair any damage as per relevant guidance published by Groom (2010; Appendix 2) or upon advice by suitably experienced fauna expert. • Continue monitoring as required by this PRRMP.	Environmental consultant
Less than 12 translocated / artificial nesting hollows installed within the Project Area by handover	• Investigate cause. • Identify additional trees that could receive a nest hollow. • Install nest hollows as required.	Environmental consultant
Feral species inhabiting nesting hollows	• Implement measures to remove feral species using suitably experienced expert (dependent on species present). • Once feral species are removed, ensure nesting hollow remains viable for use by CBC (may require advice from suitably experienced fauna expert). • Continue monitoring as required by this PRRMP.	Environmental consultant

7. Review and audit

7.1 Compliance reporting

Condition 7 of EPBC 2015/7561 requires that the following reporting is undertaken:

> *Within 3 months of every 12 month anniversary of the commencement of the action, the person taking the action must publish a report on their website addressing compliance with each of the conditions of this approval, including implementation of any management plans as specified in the conditions. Documentary evidence providing proof of the date of publication and non-compliance with any of the conditions of this approval must be provided to the Department at the same time as the compliance report is published. Reports must remain on the website for the life of the approval. The person taking the action must continue to comply with this condition until such time as agreed in writing by the Minister.*

The report required for condition 7 will assess conformance with the actions described in this PRRMP, to substantiate implementation of the plan as required by condition 2. The annual report will be informed by monitoring data and reports as generated in implementing the program described in Section 8.

In addition to findings of the annual compliance audit, the compliance report will include the findings of any relevant environmental assessments, such as dieback assessments, including any adaptive management response(s).

7.1.1 PRRMP and technical review and adaptive management

PRRMP review shall be initiated:

- following significant incidents
- where monitoring indicates that performance is not being achieved against KPIs
- periodically every 12 months.

Technical review of and evaluation of the monitoring program will be undertaken annually as part of the PRRMP to ensure monitoring parameters, timing, location and outputs are addressing all key risk areas and management plan objectives adequately. The review will be undertaken by Lendlease and the Environmental Consultant with advice from technical specialists as appropriate (e.g. dieback, vegetation and fauna specialists).

To ensure uncertainty is reduced over time, and that plan outcomes/performance indicators are achieved, the following will be evaluated during review stages and incorporated into revisions of the PRRMP:

- new and relevant data/information gained as a result of implementing the plan or from external sources (e.g. academic literature, EPBC Act policy statements)
- effectiveness of PRRMP coordination, scheduling, monitoring, risk management, auditing and reporting activities
- risks, including in response to the risk level, changing circumstances or the results from implementing corrective actions
- effectiveness of management measures with significant levels of uncertainty, relatively long implementation timeframes, and upon which the plan is highly dependent
- consequences of significant environmental incidents.

8. Environmental management roles and responsibilities

All contractors and staff will be required to operate in accordance with this PRRMP. Key personnel and responsibilities are described in the following sections:

8.1 Lendlease Project Manager

The primary responsibilities of the Project Manager include:

- act as primary liaison between DEE, City of Wanneroo (CoW), WAPC, DBCA and contractors
- engage suitably qualified contractors to implement the PRRMP as required
- ensure all contracts contain relevant PRRMP provisions and check these provisions are undertaken
- review reports provided by the contractors as required
- ensure all site personnel are aware of the requirements of the PRRMP
- report to DEE in accordance with Condition 3 of EPBC 2015/7561
- act as the key 'Emergency Contact', responsible for implementation of emergency response procedures (detailed in Section 6)
- technical review of and evaluation of the monitoring program.

8.2 Construction Contractor

The primary responsibilities of the Construction Contractor include:

- assist the project manager to ensure construction activities do not adversely affect black cockatoo habitat within the retained vegetation area
- ensure all site personnel are aware of the requirements of the PRRMP and related plans
- provide support to the Project Manager as required during the construction phase
- maintain relevant records and provide reports on clearing activities to the Project Manager including:
    - map describing the areas of clearing and locations of delineation works that have occurred
    - key construction dates
    - environmental incidents, relevant (e.g. toolbox) meeting minutes and environmental observations (e.g. of feral fauna or black cockatoos).

8.3 Environmental Consultant

The primary responsibilities of the Environmental Consultant include

- identify trees with hollows in the Development Area to be removed and relocated
- monitor nesting hollows
- monitor rehabilitation works
- technical review of and evaluation of the monitoring program.

8.4 Rehabilitation Contractor

The primary responsibilities of the Rehabilitation Contractor include:

- maintain relevant records and provide progress activity reports to the Project Manager which include details of activities undertaken, including, for example:
  - weed control details (herbicide name, volumes, method, date and location, weather conditions, other relevant observations)
  - planting (species, numbers planted, date and location of planting, conditions and other relevant observations [e.g. presence of rabbits, litter, erosion])
- ensure all rehabilitation personnel are aware of the requirements of the PRRMP and related management plans
- ensure rehabilitation activities meet performance targets
- provide support to the project manager and DBCA as required during the construction phase
- monitor rehabilitation works in conjunction with the environmental consultant.

8.5 Pest Control Contractor

The primary responsibilities of the Pest Control Contractor include:

- maintain relevant records and provide progress activity reports to the Rehabilitation Contractor which include details of activities undertaken
- conduct any measures required for controlling rabbits or other feral fauna.

8.6 Dieback Survey Consultant

The Dieback Survey Consultant will be suitably qualified and registered with the DBCA. The primary responsibilities of the Dieback Survey Consultant include:

- conduct baseline survey of the PRR areas to determine the location of any existing dieback infestations
- provide a report and map to inform hygiene management and location of rehabilitation works.

8.7 Western Australian Planning Commission

It is proposed that the primary responsibility of WAPC includes:

- provide for the long term management and protection of habitat within the PRR.

9. Glossary of terms

CEMP	Construction Environmental Management Plan
CoW	City of Wanneroo
DBH	Diameter at breast height
DEE	Department of Environment and Energy (Cth)
Development Area	Lots 9501 and 9502 Marmion Avenue, Alkimos, excluding Parks and Recreation Reserves
DotE	Department of the Environment (Cth; former)
DSEWPaC	Department of Sustainability, Environment, Water, Population and Communities (Cth; former)
DSP	District Structure Plan
EP Act	Environment Protection Act 1986 (WA)
EPA	Environment Protection Authority (WA)
EPBC Act	Environmental Protection and Biodiversity and Conservation Act 1999 (Cth)
LandCorp	Western Australian Land Authority
Lendlease	Lendlease Communities (Australia) Pty Ltd
MNES	Matters of National Environmental Significance
MRS	Metropolitan Region Scheme
DBCA	Department of Biodiversity, Conservation and Attractions
Project Area	Lots 9501 and 9502 Marmion Avenue, Alkimos
PRR	Parks and Recreation Reserve
PRRMP	Parks and Recreation Reserve Management Plan
RIAWA	Revegetation Industry Association of Western Australia
ROS	Regional Open Space
WAPC	Western Australian Planning Commission

10. References

Department of Sustainability, Environment, Water, Population & Communities (DSEWPaC) 2012a *Calyptorhynchus latirostris–Carnaby's Black-Cockatoo, short billed black-cockatoo*, (SPRAT), [Online], Available at *http://www.environment.gov.au/cgi-bin/sprat/public/publicspecies.pl?taxon_id=59523* [3 May 2017].

Department of Sustainability, Environment, Water, Population and Communities (DSEWPaC) 2012b, *EPBC Act Referral Guidelines for three threatened Black-Cockatoo species*, DSEWPaC, [Online], Available from: http://www.environment.gov.au/system/files/resources/895d4094-af63-4dd3-8dff-ad2b9b943312/files/referral-guidelines-wa-black-cockatoo.pdf [3 May 2017].

Department of the Environment 2014, *Environmental Management Plan Guidelines*, Australian Government, [Online], Available from: http://www.environment.gov.au/system/files/resources/21b0925f-ea74-4b9e-942e-a097391a77fd/files/environmental-management-plan-guidelines.pdf [9 May 2017].

EcoLogical 2011, *Referral of proposed action: Alkimos LSP Lot 1004, Alkimos WA*, report prepared for Lendlease Communities (Alkimos) Pty Ltd, March 2011.

Emerge 2013, *Vegetation Association and Condition, Alkimos City Centre and Central Alkimos*, report prepared for Lendlease Communities (Alkimos) Pty Ltd, April 2013.

Groom 2010, *Artificial hollows for Carnaby's black cockatoo: an investigation of the placement, use, monitoring and maintenance requirements of artificial hollows for Carnaby's black cockatoo*, [Online], Department of Environment and Conservation, Available from: https://www.dpaw.wa.gov.au/images/documents/plants-animals/threatened-species/carnabys/Research_into_the_success_of_artificial_hollows_for_Carnabys_cockatoo.pdf [8 May 2017].

Groom 2011, *Plants Used by Carnaby's Black Cockatoo*, prepared by Christine Groom, Department of Environment and Conservation, April 2011.

Paperbark Technologies 2014, *Tree Survey at Alkimos City and Central Land*, 2014.

Strategen Environmental (Strategen) 2015, *Alkimos City Centre and Central Environment Protection and Biodiversity Conservation Act 1999 Referral,* unpublished report prepared for Lendlease Communities (Alkimos) Pty Ltd, September 2015.

Appendix 1
Carnaby's Black Cockatoo primary feeding plants (Groom 2011)

Plants Used by Carnaby's Black Cockatoo

Department of Environment and Conservation

Our environment, our future

List prepared by Christine Groom, Department of Environment and Conservation 15 April 2011

For more information on plant selection or references used to produce this list please visit the Plants for Carnaby's Search Tool webpage at www.dpaw.wa.gov.au/apps/plantsforcarnabys/index.html

	Used for						Soil type					Soil drainage				
Species	**Feeding**	**Nesting**	**Roosting**	**Priority for planting for Carnaby's**	**Growth form**	**Flower colour**	**Clayey**	**Gravelly**	**Loamy**	**Sandy**	**Sun exposure**	**Well drained**	**Poorly drained**	**Waterlogged**	**Salt affected**	**Origin**
Acacia baileyana (Cootamundra wattle)*	■			Low	Tree	Yellow	■		■		○ ◗	■	■	■		Australian native
Acacia pentadenia (Karri Wattle)	■			Low	Tree	Cream			■		○ ◗ ●	■				WA native
Acacia saligna (Orange Wattle)	■			Low	Tree	Yellow			■	■	○ ◗	■	■			WA native
Agonis flexuosa (Peppermint Tree)	■			Low	Tree	White		■		■	○ ◗ ●	■	■			WA native
Araucaria heterophylla (Norfolk Island Pine)	■			Low	Tree	Green				■	○ ◗ ●	■				Exotic to Australia
Banksia ashbyi (Ashby's Banksia)	■			Medium	Tree or Tall shrub	Yellow, Orange				■	○ ◗	■				WA native
Banksia attenuata (Slender Banksia)	■			High	Tree	Yellow			■	■	○ ◗	■				WA native
Banksia baxteri (Baxter's Banksia)	■			Medium	Tall shrub	Yellow	■		■	■	○ ◗	■				WA native
Banksia carlinoides (Pink Dryandra)	■			Medium	Medium or small shrub	White, cream, pink	■		■	■	○ ◗	■				WA native
Banksia coccinea (Scarlet Banksia)	■			Medium	Tree	Red		■	■	■	○ ◗	■				WA native
Banksia dallanneyi (Couch Honeypot Dryandra)	■			Low	Medium or small shrub	Orange, brown			■	■	○	■				WA native
Banksia ericifolia (Heath-leaved Banksia)	■			Medium	Tall shrub	Orange			■	■	○	■				Australian native
Banksia fraseri (Dryandra)	■			Medium	Medium or small shrub	Orange		■		■	○ ◗	■				WA native
Banksia gardneri (Prostrate Banksia)	■			Low	Medium or small shrub	Orange	■	■	■	■	○ ◗	■				WA native
Banksia grandis (Bull Banksia)	■			High	Tree	Yellow		■	■	■	○ ◗	■				WA native
Banksia hookeriana (Hooker's Banksia)	■			Medium	Tall shrub	Orange				■	○ ◗	■				WA native
Banksia ilicifolia (Holly Banksia)	■			High	Tree	Cream				■	○ ◗	■				WA native
Banksia kippistiana (Dryandra)	■			Medium	Medium or small shrub	Yellow		■		■	○ ◗	■				WA native
Banksia leptophylla	■			Low	Medium or small shrub	Yellow				■	○ ◗	■				WA native
Banksia littoralis (Swamp Banksia)	■			High	Tree	Yellow	■	■	■	■	○ ◗	■				WA native
Banksia menziesii (Firewood or Menzie's Banksia)	■			High	Tree	Yellow, pink, red				■	○ ◗	■				WA native
Banksia mucronulata (Swordfish Dryandra)	■			Medium	Medium or small shrub	Yellow	■		■	■	○ ◗	■				WA native
Banksia nivea (Honeypot Dryandra)	■			High	Medium or small shrub	Orange		■		■	○ ◗	■				WA native
Banksia nobilis (Golden Dryandra)	■			Medium	Tall shrub	Orange	■	■	■	■	○	■				WA native
Banksia praemorsa (Cut-leaf Banksia)	■			Medium	Tall shrub	Red, yellow, green				■	○	■				WA native
Banksia prionotes (Acorn Banksia)	■			High	Tree	Orange				■	○	■				WA native

Species	Used for			Priority for planting for Carnaby's	Growth form	Flower colour	Soil type				Sun exposure			Soil drainage				Origin
	Feeding	Nesting	Roosting				Clayey	Gravelly	Loamy	Sandy	○	◒	●	Well drained	Poorly drained	Waterlogged	Salt affected	
Banksia quercifolia (Oak-leaved Banksia)	■			Medium	Tall shrub	Brown			■	■	○			■				WA native
Banksia sessilis (Parrot Bush)	■			High	Tree	Cream		■		■	○	◒		■				WA native
Banksia speciosa (Showy Banksia)	■			High	Tree	Yellow	■			■	○	◒		■				WA native
Banksia squarrosa (Pingle)	■			High	Tall shrub	Yellow	■	■	■	■	○			■				WA native
Banksia tricuspis (Lesueur Banskia or Pine Banksia)	■			Medium	Tree	Orange				■	○	◒		■				WA native
Banksia undata (Urchin or Cut-leaf Dryandra)	■			High	Tall shrub	Yellow	■	■	■	■	○	◒		■				WA native
Banksia verticillata (Granite Banksia)	■			Low	Tree	Yellow			■	■	○	◒		■				WA native
Brassica campestris (Canola, Rape)**	■			Low	Herb	Yellow			■	■	○	◒	●	■				Exotic to Australia
Callistemon viminalis (Captain Cook Bottlebrush)	■			Medium	Tall shrub	Red	■	■	■	■	○			■				Australian native
Callitris sp.	■			Medium	Tree		■		■	■	○			■				WA native
Carya illnoinensis (Pecan)	■			Low	Tree	Yellow			■	■	○	◒		■				Exotic to Australia
Casuarina cunninghamiana (River Sheoak)*	■			Low	Tree	Red	■	■	■	■	○			■	■	■		Australian native
Citrullus lanatus (Pie or Afghan Melon)*	■			Low	Scrambler, climber or percher	Yellow	■	■	■	■	○			■				Exotic to Australia
Corymbia calophylla (Marri)	■	■	■	High	Tree	Cream	■	■	■	■	○	◒		■	■			WA native
Corymbia ficifolia (Red Flowering Gum)	■			Medium	Tree	Red		■	■	■	○			■				WA native
Corymbia haematoxylon (Mountain Marri)	■			Medium	Tree	White				■	○			■				WA native
Corymbia maculata (Spotted Gum)			■	Low	Tree	White		■			○			■				Australian native
Darwinia citriodora (Lemon-scented Darwinia)	■			Low	Medium or small shrub	Red, orange, yellow		■			○	◒		■				WA native
Diospryros sp. (Sweet Persimmon)	■			Low	Tree				■	■	○			■				Exotic to Australia
Eremophila glabra (Tarbush)	■			Low	Tall shrub	Various	■		■	■	○	◒		■				WA native
Erodium aureum (Corkscrew Grass or Storksbill)*	■			Low	Herb	Pink			■	■	○			■				Exotic to Australia
Erodium botrys (Corkscrew Grass or Storksbill)*	■			Low	Herb	Purple					○			■				Exotic to Australia
Eucalyptus caesia (Silver Princess)	■			Medium	Tree	Pink			■		○			■				WA native
Eucalyptus camaldulensis (River Red Gum)			■	Low	Tree	Cream, yellow	■				○				■	■	■	Australian native
Eucalyptus citriodora (Lemon Scented Gum)	■		■	Medium	Tree	Red		■	■		○			■				Australian native
Eucalyptus diversicolor (Karri)		■		Low	Tree	Cream			■	■	○			■				WA native
Eucalyptus globulus (Tasmaniam Blue Gum)			■	Low	Tree	White	■	■	■		○			■				Australian native
Eucalyptus gomphocephala (Tuart)	■	■	■	High	Tree	White			■	■	○			■				WA native
Eucalyptus grandis (Flooded Gum, Rose Gum)			■	Low	Tree	White, cream	■		■	■	○			■				Australian native
Eucalyptus longicornis (Red Morrell)		■		Low	Tree	White	■		■		○			■				WA native
Eucalyptus loxophleba (York Gum)	■	■		Low	Tree	White		■	■	■	○			■				WA native
Eucalyptus marginata (Jarrah)	■		■	Medium	Tree	White	■	■	■	■	○			■				WA native
Eucalyptus occidentalis (Swamp Yate)		■		Low	Tree	Cream	■		■		○				■	■		WA native
Eucalyptus patens (Blackbutt)	■		■	Medium	Tree	White	■	■	■	■	○			■				WA native
Eucalyptus pleurocarpa (Tallerack)	■			Medium	Tree	White				■	○			■				WA native

Species	Used for			Priority for planting for Carnaby's	Growth form	Flower colour	Soil type				Sun exposure			Soil drainage				Origin
	Feeding	Nesting	Roosting				Clayey	Gravelly	Loamy	Sandy	○	◒	●	Well drained	Poorly drained	Waterlogged	Salt affected	
Eucalyptus preissiana (Bell-fruited Mallee)	■			Medium	Tree	Yellow		■	■	■	○			■	■			WA native
Eucalyptus robusta (Swamp Mahogany)	■		■	Medium	Tree	White	■	■	■	■	○			■	■	■	■	Australian native
Eucalyptus rudis (Flooded Gum)			■	Low	Tree	White	■		■	■	○			■				WA native
Eucalyptus salmonophloia (Salmon Gum)	■	■		High	Tree	White	■	■		■	○			■				WA native
Eucalyptus salubris (Gimlet)		■		Medium	Tree	White, cream		■	■	■	○			■				WA native
Eucalyptus todtiana (Coastal Blackbutt or Prickley Bark)	■			Medium	Tree	White				■	○			■				WA native
Eucalyptus wandoo (Wandoo)	■	■	■	High	Tree	White	■	■	■	■	○			■				WA native
Ficus sp. (Fig)	■			Low	Tree		■		■	■	○	◒	●	■				Australian native
Grevillea armigera (Prickly Toothbrushes)	■			Medium	Tall shrub	Green, yellow, black		■		■	○	◒		■				WA native
Grevillea bipinnatifida (Fuschia Grevillea)	■			Medium	Medium or small shrub	Red	■	■	■	■	○	◒		■				WA native
Grevillea hookeriana (Red Toothbrushes)	■			Medium	Tall shrub	Red		■	■	■	○			■				WA native
Grevillea hookeriana subsp. apiciloba (Black Toothbrushes)	■			Medium	Medium or small shrub	Black				■	○			■				WA native
Grevillea paniculata (Kerosene Bush)	■			Medium	Tall shrub	White	■	■	■	■	○	◒		■				WA native
Grevillea paradoxa (Bottlebrush Grevillea)	■			Medium	Medium or small shrub	Cream, pink		■	■	■	○			■				WA native
Grevillea petrophiloides (Pink Poker)	■			Medium	Tall shrub	Pink		■		■	○			■				WA native
Grevillea robusta (Silky Oak)	■			Medium	Tree	Orange	■		■	■	○			■				Australian native
Hakea auriculata	■			Medium	Tall shrub	White		■	■	■	○	◒		■				WA native
Hakea candolleana	■			Medium	Medium or small shrub	White	■		■	■	○			■				WA native
Hakea circumalata (Coastal Hakea)	■			Medium	Medium or small shrub	White, pink	■	■		■	○	◒		■				WA native
Hakea commutata	■			Medium	Medium or small shrub		■	■	■	■	○	◒		■		■		WA native
Hakea conchifolia	■			Medium	Medium or small shrub	White, cream, pink		■	■	■	○			■				WA native
Hakea costata (Ribbed Hakea)	■			Medium	Medium or small shrub	White		■	■	■	○			■				WA native
Hakea cristata (Snail Hakea)	■			Medium	Medium or small shrub	White		■	■		○	◒		■				WA native
Hakea cucullata (Snail Hakea)	■			Medium	Tall shrub	Pink		■	■	■	○			■				WA native
Hakea cyclocarpa (Ramshorn)	■			Medium	Medium or small shrub	White	■	■	■		○	◒		■				WA native
Hakea eneabba	■			Medium	Medium or small shrub	Yellow			■	■	○			■				WA native
Hakea erinacea (Hedgehog Hakea)	■			Medium	Medium or small shrub	Cream	■	■	■	■	○	◒		■				WA native
Hakea falcata (Sickle Hakea)	■			Medium	Tall shrub	White	■	■	■	■	○	◒			■	■		WA native
Hakea flabellifolia (Fan-leaved Hakea)	■			Medium	Medium or small shrub	Brown		■	■	■	○			■				WA native
Hakea gilbertii	■			Medium	Medium or small shrub	White	■	■	■	■	○			■				WA native
Hakea incrassata (Golfball or Marble Hakea)	■			Medium	Medium or small shrub	Cream		■	■	■	○	◒		■				WA native
Hakea lasiantha (Woolly Flowered Hakea)	■			Medium	Tall shrub	White		■	■	■	○	◒		■				WA native
Hakea lasianthoides	■			Medium	Tall shrub	White	■	■	■			◒		■				WA native
Hakea laurina (Pin-cushion hakea)	■			Medium	Tree	Red	■	■		■	○	◒		■				WA native
Hakea lissocarpha (Honeybush)	■			Medium	Medium or small shrub	White		■	■	■	○	◒		■				WA native

Species	Used for			Priority for planting for Carnaby's	Growth form	Flower colour	Soil type				Sun exposure	Soil drainage				Origin
	Feeding	Nesting	Roosting				Clayey	Gravelly	Loamy	Sandy		Well drained	Poorly drained	Waterlogged	Salt affected	
Hakea megalosperma (Lesueur Hakea)	■			Medium	Medium or small shrub	White, cream, pink, red		■		■	○	■				WA native
Hakea multilineata (Grass Leaf Hakea)	■			Medium	Tall shrub	Pink	■	■	■	■	○ ◓	■				WA native
Hakea obliqua (Needles and Corks)	■			Medium	Tall shrub	White			■	■	○	■				WA native
Hakea oleifolia (Dungyn or Olive-leaved Hakea)	■			Medium	Tree	White	■	■	■	■	○	■				WA native
Hakea pandanicarpa subsp. crassifolia (Thick-leaved Hakea)	■			Medium	Tall shrub	Cream		■	■	■	○ ◓	■				WA native
Hakea polyanthema	■			Medium	Medium or small shrub	White		■	■	■	○	■				WA native
Hakea petiolaris (Sea Urchin Hakea)	■			Medium	Tall to medium shrub	Cream, pink		■	■	■	○ ◓	■				WA native
Hakea preissii (Needle Tree)	■			Medium	Tall shrub	Yellow	■	■	■	■	○	■		■	■	WA native
Hakea prostrata (Harsh Hakea)	■			High	Tall to mediumshrub	White	■	■	■	■	○	■				WA native
Hakea psilorrhyncha	■			Medium	Tall shrub	Cream			■	■	○	■				WA native
Hakea ruscifolia (Candle Hakea)	■			Medium	Tall shrub	White		■	■	■	○ ◓	■				WA native
Hakea scoparia (Kangaroo Bush)	■			Medium	Tall shrub	Cream	■	■	■	■	○ ◓	■				WA native
Hakea smilacifolia	■			Medium	Medium or small shrub	White		■	■	■	○	■				WA native
Hakea spathulata	■			Medium	Medium or small shrub	Red			■	■	○	■				WA native
Hakea stenocarpa (Narrow-fruited Hakea)	■			Medium	Medium or small shrub	White	■	■	■	■	○ ◓	■	■			WA native
Hakea sulcata (Furrowed Hakea)	■			Medium	Medium or small shrub	White		■	■	■	○ ◓	■		■		WA native
Hakea trifurcata (Two-leaved Hakea)	■			High	Tall shrub	White		■	■	■	○ ◓ ◓	■				WA native
Hakea undulata (Wavy-leaved Hakea)	■			High	Tall shrub	White	■	■	■	■	○ ◓	■	■			WA native
Hakea varia (Variable-leaved Hakea)	■			Medium	Tall shrub	White	■	■	■	■	○ ◓	■	■	■		WA native
Helianthus annuus (Sunflower)*	■			Low	Herb	Yellow					○	■				Exotic to Australia
Hibiscus sp. (Hibiscus)	■			Low	Tall shrub	Various					○ ◓ ◓	■				Exotic to Australia
Isopogon scabriusculus	■			Medium	Medium or small shrub	Pink		■	■	■	○	■				WA native
Jacaranda mimosifolia (Jacaranda)	■			Low	Tree	Blue, purple			■	■	○ ◓	■				Exotic to Australia
Jacksonia furcellata (Grey Stinkwood)	■			Medium	Tall shrub	Orange				■	○ ◓	■				WA native
Lambertia inermis (Chittick)	■			Medium	Tree	Red, orange, yellow		■	■	■	○ ◓	■				WA native
Lambertia multiflora (Many-flowered Honeysuckle)	■			Medium	Medium or small shrub	Orange, yellow	■	■		■	○	■				WA native
Liquidamber styraciflua (Liquid Amber)	■			Medium	Tree	Green					○ ◓	■				Exotic to Australia
Lupinus sp. (Lupin)*	■			Low	Herb	Yellow, blue					○	■				Exotic to Australia
Macadamia integrifolia (Macadamia)	■			Medium	Tree	White		■	■	■	○	■				Australian native
Malus domestica (Apple)	■			Low	Tree	White					○	■				Exotic to Australia
Melaleuca leuropoma	■			Medium	Medium or small shrub	Cream, purple, yellow				■	○	■				WA native
Melia azedarach (Cape Lilac or White Cedar)**	■			Low	Tree	Purple			■	■	○ ◓	■				Exotic to Australia
Mesomeleana sp.	■			Medium	Grassy or strappy						○	■				WA native
Protea repens	■			Medium	Tree or medium to small shrub	White, cream, pink		■		■	○ ◓	■				Exotic to Australia
Protea 'Pink Ice'	■			Medium	Tree or medium to small shrub	White, cream, pink		■		■	○ ◓	■				Exotic to Australia

Species	Used for			Priority for planting for Carnaby's	Growth form	Flower colour	Soil type				Sun exposure	Soil drainage				Origin
	Feeding	Nesting	Roosting				Clayey	Gravelly	Loamy	Sandy		Well drained	Poorly drained	Waterlogged	Salt affected	
Pinus canariensis (Canary Island Pine)	■			Low	Tree	Brown	■	■	■	■	○	■				Exotic to Australia
Pinus caribea (Caribbean Pine)	■			Low	Tree	Brown					○	■				Exotic to Australia
Pinus pinaster (Pinaster or Maritime Pine)**	■		■	Medium	Tree	Brown			■	■	○	■				Exotic to Australia
Pinus radiata (Radiata Pine)**	■		■	Medium	Tree	Brown			■	■	○ ◗	■				Exotic to Australia
Prunus amygdalus (Almond Tree)	■			Medium	Tree				■	■	○	■				Exotic to Australia
Raphanus raphanistrum (Wild Radish)*	■			Low	Herb	Various	■	■	■	■	○	■				Exotic to Australia
Tipuana tipu (Tipu or Rosewood Tree)**	■			Low	Tree	Yellow	■	■	■	■	○	■				Exotic to Australia
Xanthorrhoea preissii (Grass Tree)	■			Medium	Grassy or strappy	Cream		■	■	■	○	■				WA native

* Weed

** Potential weed

Appendix 2
Artificial hollows for Carnaby's black cockatoo: an investigation of the placement, use, monitoring and maintenance requirements of artificial hollows for Carnaby's black cockatoo (Groom 2010)

Department of Environment and Conservation

Our environment, our future

Project Report

Artificial hollows for Carnaby's black cockatoo

An investigation of the placement, use, monitoring and maintenance requirements of artificial hollows for Carnaby's black cockatoo

August 2010

By Christine Groom

This project was funded by State NRM funds

Table of Contents

1 Executive summary 2

2 Introduction 2

2.1 About Carnaby's black cockatoo 2

2.2 Importance of artificial hollows 2

2.3 Purpose of this study 3

2.4 Limitations of study 3

3 Methods 3

3.1 Literature search 3

3.2 Consultation 3

3.3 Survey of artificial hollows 3

3.4 Analysis of survey results 4

4 Results and Discussion 4

4.1 Literature search 4

4.2 Consultation 7

4.3 Survey of artificial hollows 9

5 Recommendations for future study or action 27

6 References 29

1 Executive summary

Artificial hollows have been built and erected for Carnaby's black cockatoo since the 1980s. A wide variety of designs have been used with varying degrees of success in different locations. This study identified the general location of 315 artificial hollows erected for black cockatoos and determined accurate coordinates for 239. From the extensive consultation, site visits and survey data collected during this study, general guidance has been collated about the design, construction and placement of artificial hollows for Carnaby's black cockatoo.

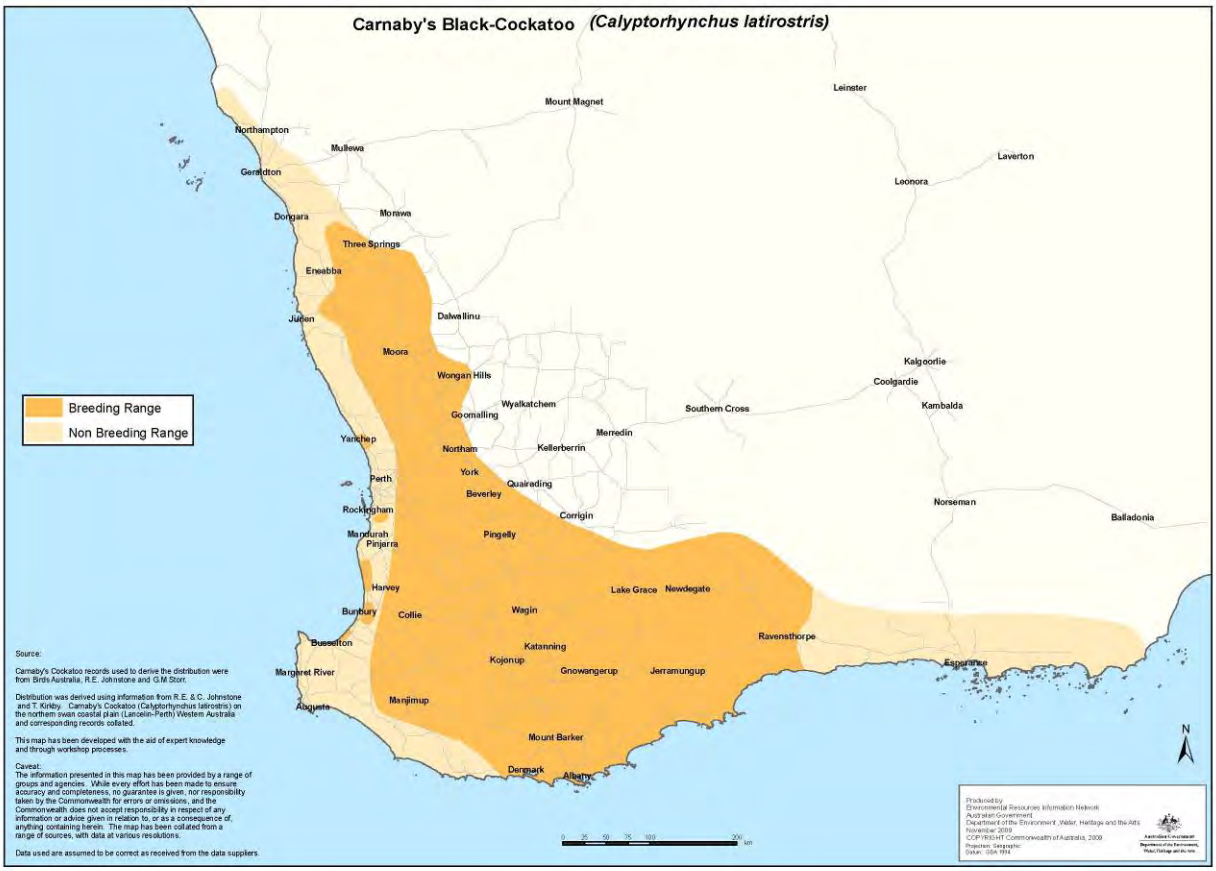
2 Introduction

2.1 About Carnaby's black cockatoo

Carnaby's black cockatoo (*Calyptorhynchus latirostris*) is endemic to south-west Western Australia. It is listed as a threatened species at state, national and international levels.

Carnaby's black cockatoo has a wide distribution as shown in Figure 1. In general, the birds breed in wheatbelt areas and move closer to coastal areas to feed during late spring and early winter.

Figure 1: Distribution map of breeding and non-breeding areas for Carnaby's black cockatoo (as at November 2009).



2.2 Importance of artificial hollows

Carnaby's black cockatoo is dependent on tree hollows for nesting. Large portions of its breeding habitat have been cleared for agriculture or impacted by logging. Remaining remnant vegetation is often degraded such that tree recruitment is hampered and will result in a lack of nesting trees in the

future. There is a shortage of available tree hollows that is likely to worsen as those hollows in current use degrade through natural processes, or if populations of nest competitors continue to increase.

The time taken for various tree species to produce hollows suitable for black cockatoos has been studied by different researchers. In jarrah and marri forest, Whitford and Williams (2002) found that trees needed to be a minimum of 130 years old to be of use to hollow dependent fauna. Nelson and Morris (1994) found that the youngest mountain ash tree used by yellow-tailed black cockatoos was estimated to be 162 years old. The time taken to recruit replacement hollows for those lost to clearing, logging or natural senescence means that there will be an significant shortage of natural hollows available to the cockatoos in some areas in the foreseeable future. Therefore, artificial hollows will be required to provide nesting opportunities until natural hollows are recruited.

2.3 Purpose of this study

This study was undertaken to:

- determine the location of existing artificial hollows
- determine which have been, or are likely to have been, used by Carnaby's black cockatoos
- investigate possible factors affecting use by Carnaby's black cockatoos.

2.4 Limitations of study

This study was limited by the availability and willingness of persons involved to provide information on the locations of artificial hollows. The precise locations for some artificial hollows identified during this study could not be determined and many more are likely to have been erected by private landholders or without record of their existence being established.

Those artificial hollows that were located, often had not been closely monitoring and so their usage by Carnaby's black cockatoo or other species could not be determined with certainty.

The Serpentine-Jarrahdale Landcare Centre holds imperfect records on a large number of artificial hollows that could not be accessed during this study.

Data that have been gathered are patchy and not all variables are available for each artificial hollow. This means that different sample sizes have been used for some analyses.

3 Methods

3.1 Literature search

A search was conducted for published and unpublished information on natural and artificial hollows for cockatoos, with a focus on the black cockatoos of Australia.

3.2 Consultation

Consultation targeted people involved in placing or constructing artificial hollows, or landholders on whose land the hollows had been erected. Consultation was closely associated with the survey of artificial hollows and was undertaken via phone or email, often followed up with meetings or on-site visits.

3.3 Survey of artificial hollows

Surveying artificial hollows began by finding out who had erected artificial hollows and where. There are many individuals and organisations involved in the placement of artificial hollows. Locating these hollows and any associated observation or monitoring data was the primary challenge of this project, and involved searching literature (both published and unpublished) and consultation. Site visits were undertaken where possible, targeting locations where artificial hollows are known to have been used by

the cockatoos.

Site visits involved inspecting the hollow from the ground and making a series of observations and measurements. GPS coordinates were taken for each artificial hollow and observations made of its construction, placement and condition. An estimate of the height of the hollow was made with the aid of a clinometer and tape measure. Photographs were also taken as a visual reference and to aid relocation of artificial hollows in the future.

During site visits, landholders were asked about the use of the hollow, any maintenance that had been undertaken and the proximity of any known breeding in natural hollows.

In some instances, information was available on the dimensions of hollows recorded before, or during, installation.

Datasheets completed during sites visits have since been filed by site, together with relevant email correspondence and any reports or articles.

3.4 Analysis of survey results

Data collated from surveying artificial hollows is stored in an Excel™ spreadsheet. It contains a large number of data fields including those related to identifying each hollow, site and placement information, construction details, monitoring observations and contact information.

Locations of successful and unsuccessful artificial hollows were plotted using ArcGIS to view the spatial distribution and look for patterns. Records of breeding activity, consisting mainly of known natural hollows used for breeding, were added to determine the level of correlation between successful artificial hollows and natural breeding records. Breeding records were collated from the Threatened and Priority Fauna Database, banding records, natural nests targeted for selecting captive breeding birds during 1996 – 1998, Birds Australia records, Hugh Finn's records for Boddington Gold mine, Ron Johnstone's records for Lake Clifton, and observations of natural hollows made while surveying artificial hollows.

4 Results and Discussion

4.1 Literature search

A literature search was conducted to identify studies on the breeding of black cockatoos using both natural and artificial hollows. The literature search helped locate many of the hollows, identified characteristics of natural hollows important to breeding success and gathered valuable monitoring information.

4.1.1 Characteristics of natural hollows

It was considered appropriate to research the nesting needs of Carnaby's black cockatoos using natural hollows. The results of studying natural hollows could then be used to infer the reasons for success or failure of artificial hollows.

Firstly, the characteristics of what makes an attractive natural hollow were investigated. Hollows must be large enough to accommodate an adult cockatoo. The dimensions of museum specimens have been measured by Saunders *et al*. (1982) and Abbott and Whitford (2002) as shown in Table 1. The entrance to hollows must have a minimum diameter of at least 100mm to be suitable for use by Carnaby's black cockatoos.

Table 1: Measurements of museum specimens of Carnaby's black cockatoo (average in brackets).

Diameter at shoulders (cm)	**Adult body weight (g)**	**Reference**
9.5-11.5 (10.3)	560-790 (646)	Saunders *et al*. (1982)
11.5-13.0	520-790	Abbot and Whitford (2002)

To check that the size of the bird is a good indication of the minimum size of hollow occupied, the measurements of known natural nesting hollows were investigated. A wide variety of sizes of natural hollows are used by Carnaby's black cockatoos, as demonstrated in Table 2, and the minimum dimension matches the dimensions of the specimens well.

Table 2: Dimensions of natural hollows in wandoo and salmon gum used by Carnaby's black cockatoos for nesting (Denis Saunders, unpublished data).

Tree species	Sample size	Width of entrance (cm)	Height of entrance (cm)	Depth of hollow (cm)
Wandoo	30	14-68 (29.6)	12-50 (29.1)	60-410 (185)
Salmon Gum	31	13-32 (21.9)	10-29 (20.5)	50-254 (122)

There are many other characteristics of hollows and their positions that may influence their use by the cockatoos. The literature was searched for relevant information on hollows used by Carnaby's black cockatoo and other closely related species. Information on height of hollow entrance, depth of nest floor and aspect is collated in Table 3.

Table 3: Summary of natural hollows characteristics suited to black cockatoo species.

Hollow characteristic	Species of black cockatoo	Comments or values	Reference
Height	Carnaby's	• Wide range of nest heights used. • Average height of nest hollows in an area is influenced by the dominant tree species. • Between 2 and 10m (5.38m average) in a Wandoo dominated site • Between 3 and 10+m (7.13m average) in a Salmon Gum dominated site. • No evidence that higher hollows are preferentially chosen	Saunders, 1979
Aspect	Carnaby's	• No favoured aspect. • Choice of hollow aspect does not affect nesting success.	Saunders, 1979
	Glossy and Yellow-tailed	• No favoured aspect.	Garnett *et al*. 1999; Nelson and Morris, 1994
Nest depth	Carnaby's	• Majority recorded between 0.5 and 2.0m deep and average just over 1m. • Hollow depth varies over time as debris accumulates and as heartwood decays and depresses. • Nest depth does not appear to affect nest failure	Saunders, 1979
Living or dead tree	Carnaby's	• No preference	Saunders, 1979

Secondly, factors affecting the breeding success of Carnaby's black cockatoo in natural hollows were investigated. In general, the main threat to nesting success is competition for nests from other species. Some of these nest competitors are native species (but may have become overabundant) and others are introduced e.g. feral bees.

In agricultural areas of Western Australia, numbers of galahs and corellas have increased since

clearing occurred (Barrett *et al*. 2003). Johnstone and Kirkby (2004 – 2008) have reported numerous instances of failed breeding attempts attributed to corellas or galahs. At Koobabbie Farm near Coorow, regular galah and corella control is undertaken around the main homestead. During the last six years, 13 successful attempts have been recorded for artificial hollows located close to the homestead, compared with only one successful attempt for artificial hollows located away from the homestead. Davies (2005) reported greater success with artificial hollows where corella and galah control had been undertaken (Koobabbie and Yenderdano). A site in his study (Moora townsite) that had been very successful without control was explained by the provisioning of food that enabled birds to remain close to the artificial hollows and defend them. Little corellas and galahs have also been identified as a threat to glossy black cockatoos on Kangaroo Island (Garnett *et al*. 1999).

Feral bees also compete for hollows and have been identified as a cause of nest failure (Saunders, 1979; Johnstone *et al*. 2004; 2005; 2006; 2007). Feral bees appear to be more of a problem in some areas compared to others with Cataby being identified as an example of a problem area.

For both glossy black cockatoos (*Calyptorhynchus lathmani*) and south-eastern red-tailed black cockatoos (*C. banksii graptogyne*) predation of eggs and chicks by brushtail possums has been identified as a threat to nesting success (Garnett *et al*. 1999; Jarmyn, 2000).

Natural problems such as nest floor collapse and hollow flooding have also been observed to affect nesting success (Johnstone *et al*. 2005)

Lastly, the distribution of breeding records was investigated to determine any patterns or factors relating to distribution that might influence where breeding will occur.

There is evidence to support social factors restricting breeding to sites where breeding is already occurring. Carnaby's black cockatoos are known to return to their natal area to breed. Saunders (1986) reported six females tagged in the nest as chicks returning to their natal area to breed. Breeding is also clustered such that there are areas with a relatively high density of nests. This has also been observed in glossy black cockatoos on Kangaroo Island. Garnett *et al*. (1999) found that three-quarters of the nests of glossy black cockatoos were located within one kilometre of another nest active in the same year. Garnett *et al*. (1999) also commented that the few isolated nests found in their study could be from individuals prospecting for new areas, but are more likely to be the remnants of a larger nesting group that had depleted to just a few individuals.

This indicates that if artificial hollows are to be successful, they need to be placed where the cockatoos are already known to breed. Further research is required to determine whether or not it is possible to encourage the birds to breed in areas where they currently aren't breeding.

4.1.2 Availability of natural hollows

A number of studies have been undertaken to determine the availability of natural hollows (and therefore the likely necessity for artificial hollows). Studies have focussed either on the Wheatbelt, which is affected by agriculture, or the jarrah/marri forest, which is affected by logging.

In the Wheatbelt, the availability of tree hollows for Carnaby's black cockatoos was investigated at four study sites by Saunders (1979), who found that hollows were being destroyed faster than they were being created. Saunders (1979) states that while the total number of natural hollows is probably not limiting the population (as at 1979), the behaviour of females during the breeding season may exert some limiting effect on the population. This is because during the two to three week period over which a female chooses and prepares a hollow, she will actively deter other females from the area. After this period, when she is sitting on eggs, other females may utilise nearby hollows. This has implications for how many and how close together artificial hollows should be placed at a particular site.

In the jarrah/marri forest areas, studies have focussed on improving forestry management practices. The age at which jarrah and marri trees form suitably sized hollows for hollow-dependent fauna was studied by Whitford and Williams (2002). This study identified a minimum tree age of 130 years before a tree would be useful for hollow-dependent fauna and compared this age to the minimum age of trees left as habitat after logging, which was about 171 years. However, black cockatoo species are likely to require larger hollows in older trees than many other hollow-dependent forest species. Whitford and Williams (2001) found that almost a quarter (96/400) of habitat trees retained after logging would fall within a 100-year period. This means that in the long term there is a risk that retained trees will be lost

and new recruits not available to provide hollows.

4.1.3 Artificial hollows

A general overview of the use of artificial hollows by Australian birds and bats is provided in Goldingay and Stevens (2009) and provides guidance for future research and management. Very little information has been published on artificial hollows specifically for black cockatoos.

Design information for artificial hollows for black cockatoos has been published by Pedler (1996) and Davies (2003). Additional information is contained in grey literature[1] consisting of project reports to funding bodies/companies and community newsletters (Table 4).

Table 4: Summary of grey literature on the placement of artificial hollows for Carnaby's black cockatoo.

Project	**Funding body**	**Reports, newsletter articles and other references**
Moore Catchment Group's "Coast to Catchment" project	WWF Threatened Species Network, Men of the Trees and Rio Tinto Australia	Davies, 2005; Davies 2003; Davies and Loomes, 2002.
Perth to Bunbury Highway extension	GHD Australia Pty Ltd and Main Roads WA.	Johnstone *et al*. 2009, 2010
Fiona Stanley Hospital Project	Department of Health, Department of Housing and Works, Department of Environment and Conservation	Department of Health, 2010
Ewington development, Collie	Griffin Coal Mining Company	Metcalf and Cherriman, 2009; Metcalf, 2010
Cataby project area	Iluka Resources Ltd	Johnstone *et al*. 2004, 2005, 2006, 2007, 2008.
Great Northern Hwy (Muchea to Wubin)	Access Alliance, Main Roads WA	Johnstone *et al*., 2010b
BAWA Carnaby's Black Cockatoo Recovery Project	Birds Australia, Gondwana Link, Bush Heritage Australia and Greening Australia.	Howard, 2008; Scott, 2009; Stojanovic and Scott, 2009

4.2 Consultation

A wide range of people were consulted during the survey of artificial hollows for Carnaby's black cockatoos (a summary is provided in Table 5). The range of different organisations shown in the table indicates the level of interest and willingness of the community to erect artificial hollows for black cockatoos.

[1] **Grey literature** is a term used variably by the intellectual community, librarians, and medical and research professionals to refer to a body of materials that cannot be found easily through conventional channels such as publishers, "but which is frequently original and usually recent" - Debachere, M. C. (1995). "Problems in obtaining grey literature". *IFL4 Journal* **21** (2): 94–98.

Table 5: Organisations consulted whilst surveying artificial hollows for Carnaby's black cockatoo.

Type	**Organisation**
Government agencies	Department of Environment and Conservation City of Rockingham Department of Education and Training City of Nedlands
Museums	WA Museum
Universities	Curtin University Murdoch University
'Friends of' groups	Friends of Black Cockatoo Reserve
Landcare groups	Serpentine Jarrahdale Landcare Centre SERCUL
Consultants/Developers/Industry	Southern Gateway Alliance Access Alliance The Griffin Group Bamford Consulting Natural Area Consulting
Non-government cons. agencies	Kaarakin Black Cockatoo Rehabilitation Centre Birds Australia

In addition to representatives from various organisations presented in Table 5, 11 private landholders were consulted. Most of them had artificial hollows erected on their properties.

During consultation experiences with artificial hollows and gathering observations were discussed. Common topics of discussions related to:

- occupational health and safety issues
- maintenance requirements
- monitoring observations
- monitoring techniques.

Through these discussions, common themes emerged. These themes included:

- The frequency and intensity of monitoring artificial hollows being mostly opportunistic and limited by time and knowledge of what to look for.

- The type and frequency of any maintenance needed. Most hollows have been placed and left with no maintenance attempted. Examples of maintenance undertaken included, drilling holes to improve drainage, replacement of the base and replacement of chewing posts.

- Ideas were suggested about how to improve the chance of artificial hollows being successfully used by black cockatoos. Some suggestions included:
    - controlling nest competitors such as galahs and corellas
    - supplying supplementary feed to enable birds to stay close to defend their nests and discourage feeding on canola
    - playing recordings of calls and using stuffed toy cockatoos to evoke competitive behaviour in the cockatoos
    - wearing gloves during construction and placement of hollows to avoid human scent on the hollows
    - avoiding shiny materials in construction

It should be noted that many of these suggestions are supported only by anecdotal evidence.

4.3 Survey of artificial hollows

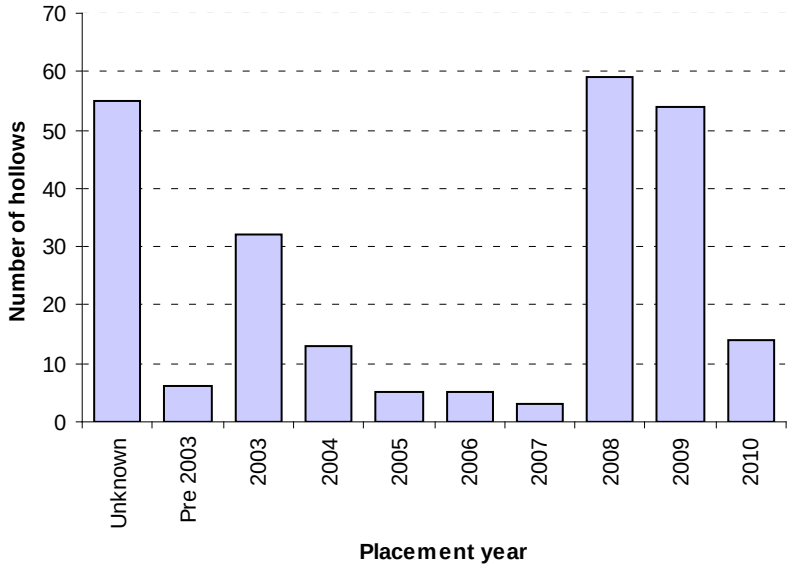
4.3.1 Timing

Artificial hollows have been erected for Carnaby's black cockatoos since the 1980s, when Wally Kerkoff built and placed artificial hollows on his property in Moora. A project undertaken in 2003 – 4 utilised Wally's artificial hollow making skills, resulting in 43 artificial hollows being erected across seven farms in the northern Wheatbelt (see Davies, 2005). In the mid-2000s, work undertaken as part of the Water Corporation and WA Museum Cockatoo Care Project resulted in artificial hollows for black cockatoos being designed and tested in water catchment areas. This design work evolved into the now popular 'Cockatube' style of artificial hollow .

There has been a large increase in the number of artificial hollows being erected for black cockatoos since 2008 (Figure 2). This is partly due to the efforts of the Serpentine-Jarrahdale Landcare Centre (who build 'Cockatubes') and the large number of artificial hollows being erected on road verges to offset potential nest trees felled during construction of highways both north and south of Perth.

Where possible, the placement date, or at least the year, was recorded for each artificial hollow surveyed. However, the placement year for a large number of artificial hollows could not be determined. Figure 2 shows the spread of when artificial hollows surveyed were established.

Figure 2: Number of artificial hollows erected over time.

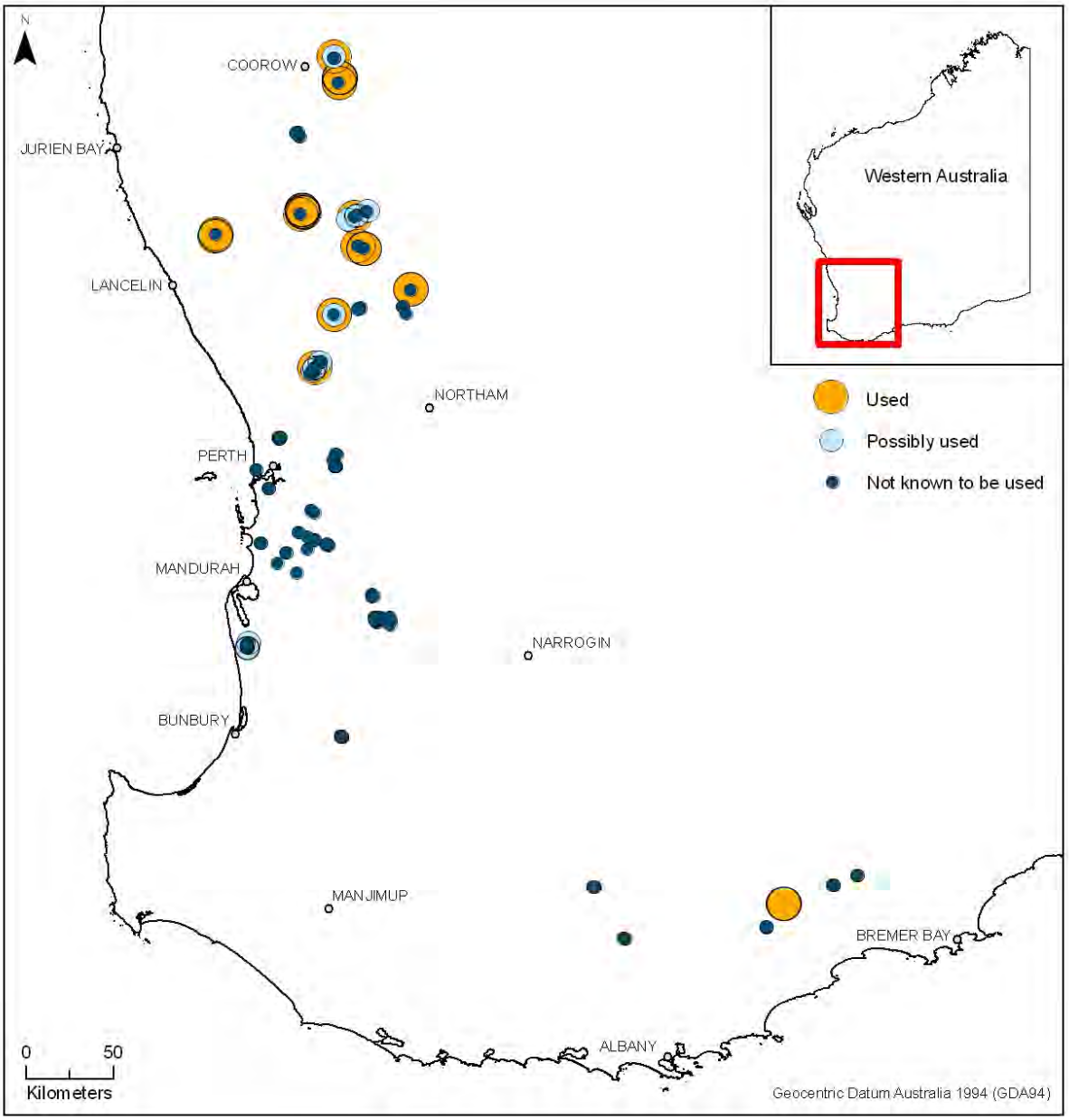


4.3.2 Distribution

During this study, 315 artificial hollows were identified as having been erected in the south-west of Western Australia for black cockatoos. Of these, accurate coordinates were recorded for 239. The artificial hollows were placed in a variety of locations from Coorow in the north to Borden in the south. They tend to be clustered in patches of remnant vegetation and/or restricted to a particular parcel of land (private property or reserve). At each location marked on Figure 3, there are, in most cases, several artificial hollows.

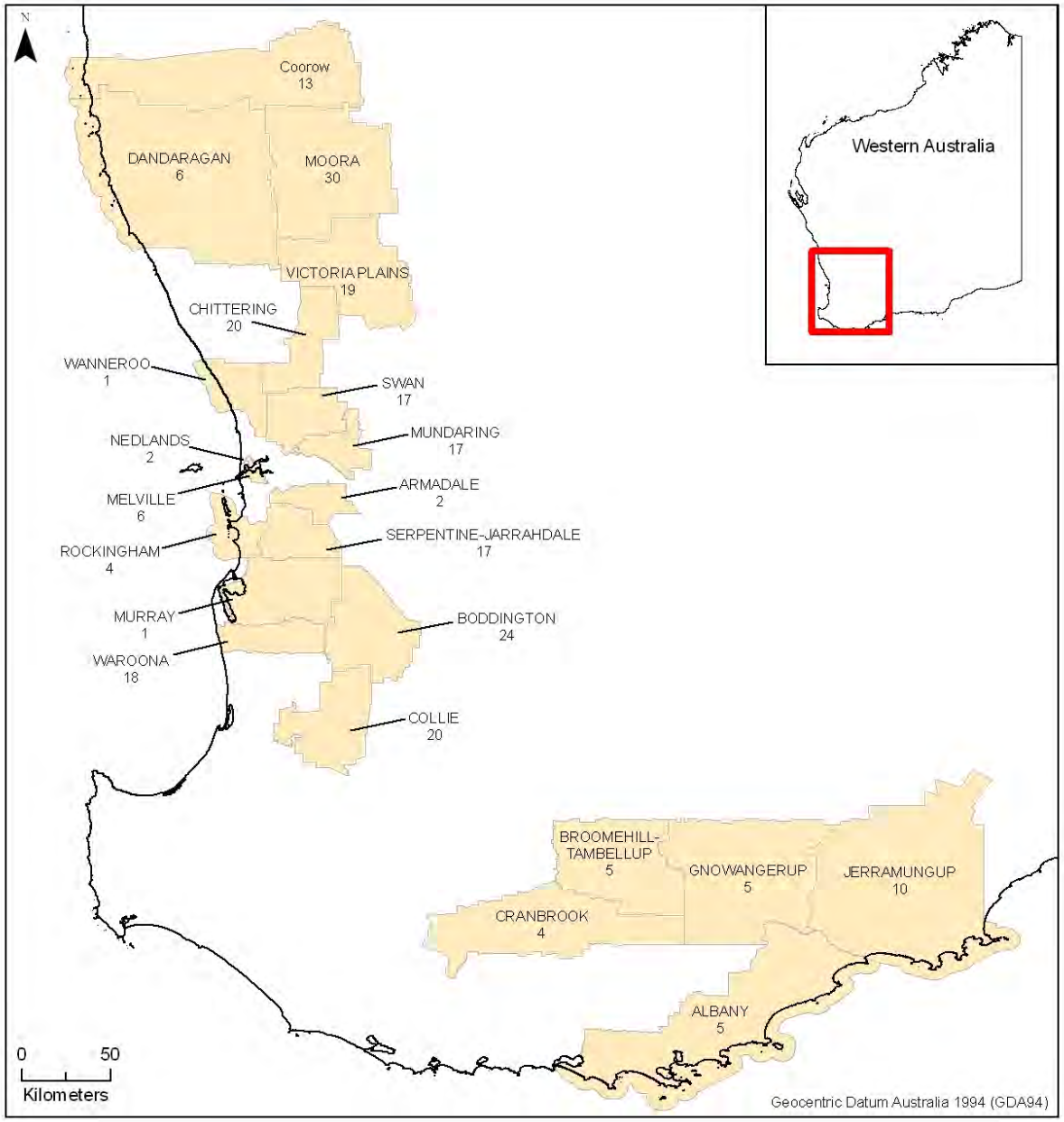
Artificial hollows that have been used by the cockatoos have predominantly been located in the northern agricultural areas, with a site near Borden and south of Mandurah being exceptions. No artificial hollows built for black cockatoos and placed in jarrah/marri forest areas were identified as being used by black cockatoos during the study.

Figure 3: Distribution of artificial hollows for black cockatoos and their use by Carnaby's black cockatoo.



To give an idea of the distribution of numbers of artificial hollows, Figure 4 shows the number of hollows erected by Local Government Authority (LGA). Artificial hollows have been placed in a total of 22 LGAs.

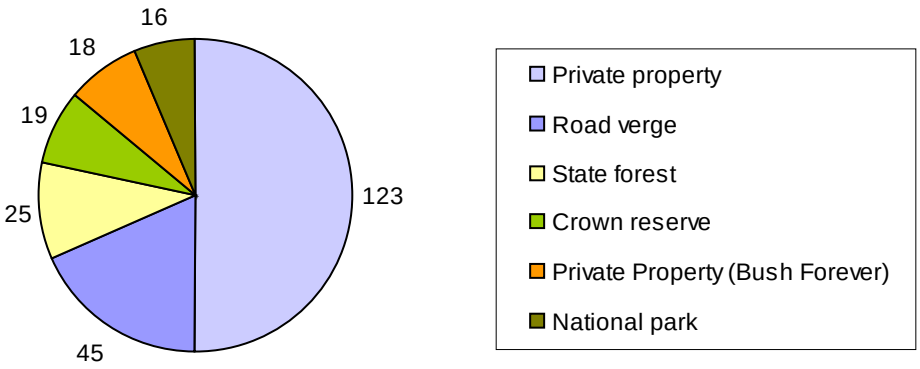
Figure 4: Distribution of artificial hollows by Local Government Authority. The numbers indicate the number of artificial hollows placed in that Shire.



Artificial hollows have been placed on a variety of land tenures (Figure 5). Half have been placed on private property. The next largest portion has been placed on road verges (18 per cent). Given the visibility and accessibility of the hollows to the public and potential for interference or poaching of chicks, this is of concern. The majority of artificial hollows on road verges have been placed to offset nesting or potential nesting trees felled during road upgrading.

A small portion of artificial hollows erected as a result of upgrades to both the Great Northern Hwy and the Perth-Bunbury Hwy have been used, or possibly, used by Carnaby's black cockatoos. Similar motivation has been behind artificial hollows being placed at mine sites at Collie and Boddington. However, no artificial hollows are known to have been used by Carnaby's black cockatoos at these sites.

Figure 5: Land tenure of locations where artificial hollows have been placed. Labels indicate the number of artificial hollows that occur on that tenure.



There is a strong correlation between the close proximity of records of Carnaby's black cockatoos breeding in natural hollows and their use of artificial hollows (Figure 6, 7 and 8). Of the 57 artificial hollows known to be used or possibly used, 71 per cent were located within one kilometre of breeding records in natural hollows and 55 per cent were observed less than 100m from breeding records in natural hollows. It is likely that a lack of knowledge of natural hollows will explain the occurrence of some breeding in artificial hollows further than one kilometre from known breeding in natural hollows.

Artificial hollows placed in the metropolitan area and nearby hills areas have been unsuccessful (Figure 7). There is a corresponding lack of recent natural breeding records from these areas. In comparison, greatest success has been observed in the northern Wheatbelt (Figure 6) where a large number of natural breeding records have been recorded in close proximity to artificial hollows.

The same pattern continues in southern areas (Figure 8) with artificial hollows placed in existing breeding areas being utilised with others not. There is an exception that can be explained by a fire destroying the site in 2006, after which nesting has not been recorded despite birds returning.

The presence of known breeding should be a key consideration when selecting sites for artificial hollows.

Figure 6: Northern distribution of Carnaby's black cockatoo breeding records (a combination of known and probable nesting sites as well as observations of breeding behaviour) and artificial hollows.

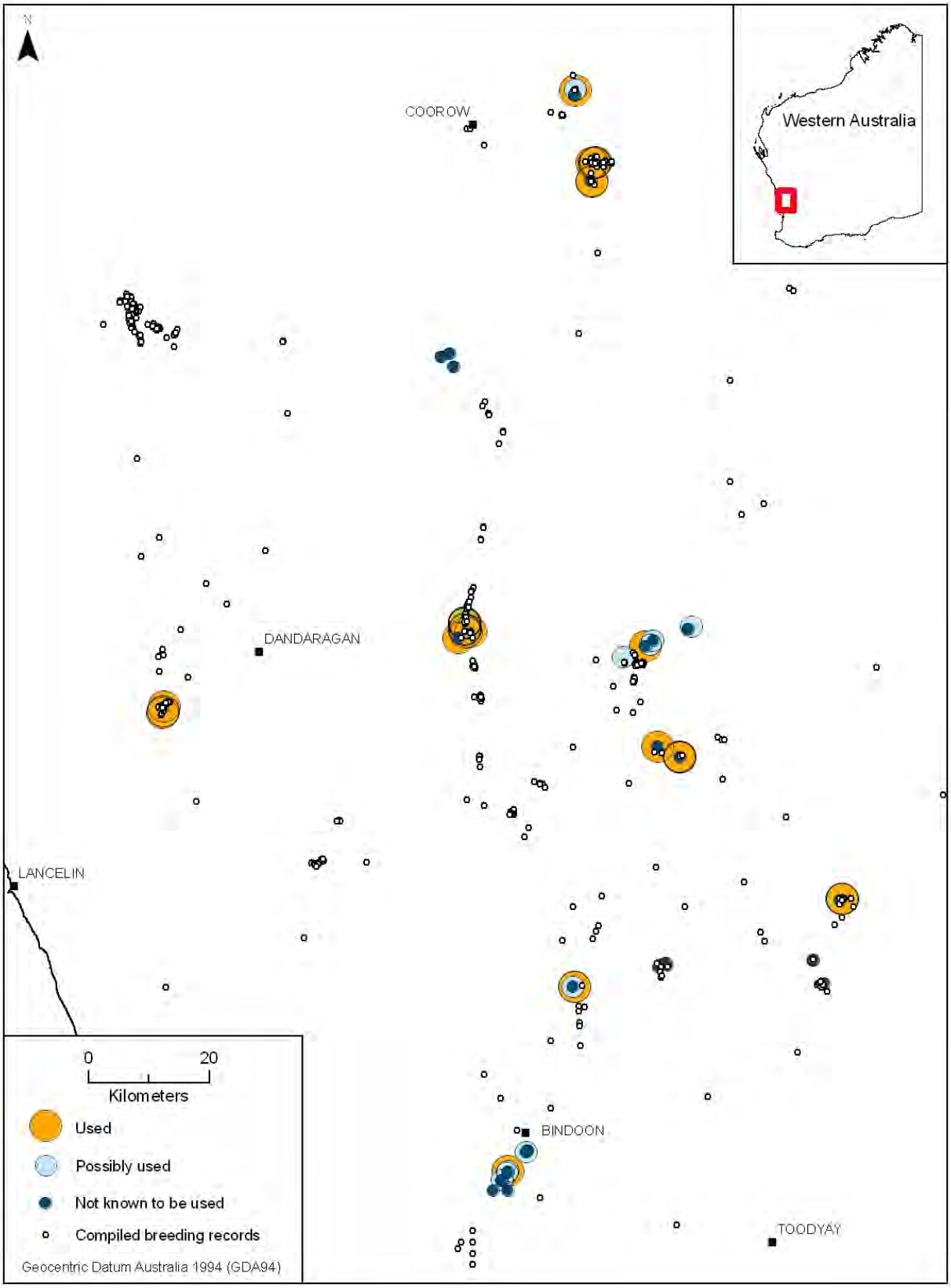


Figure 7: Central distribution of Carnaby's black cockatoo breeding records (a combination of known and probable nesting sites as well as observations of breeding behaviour) and artificial hollows.

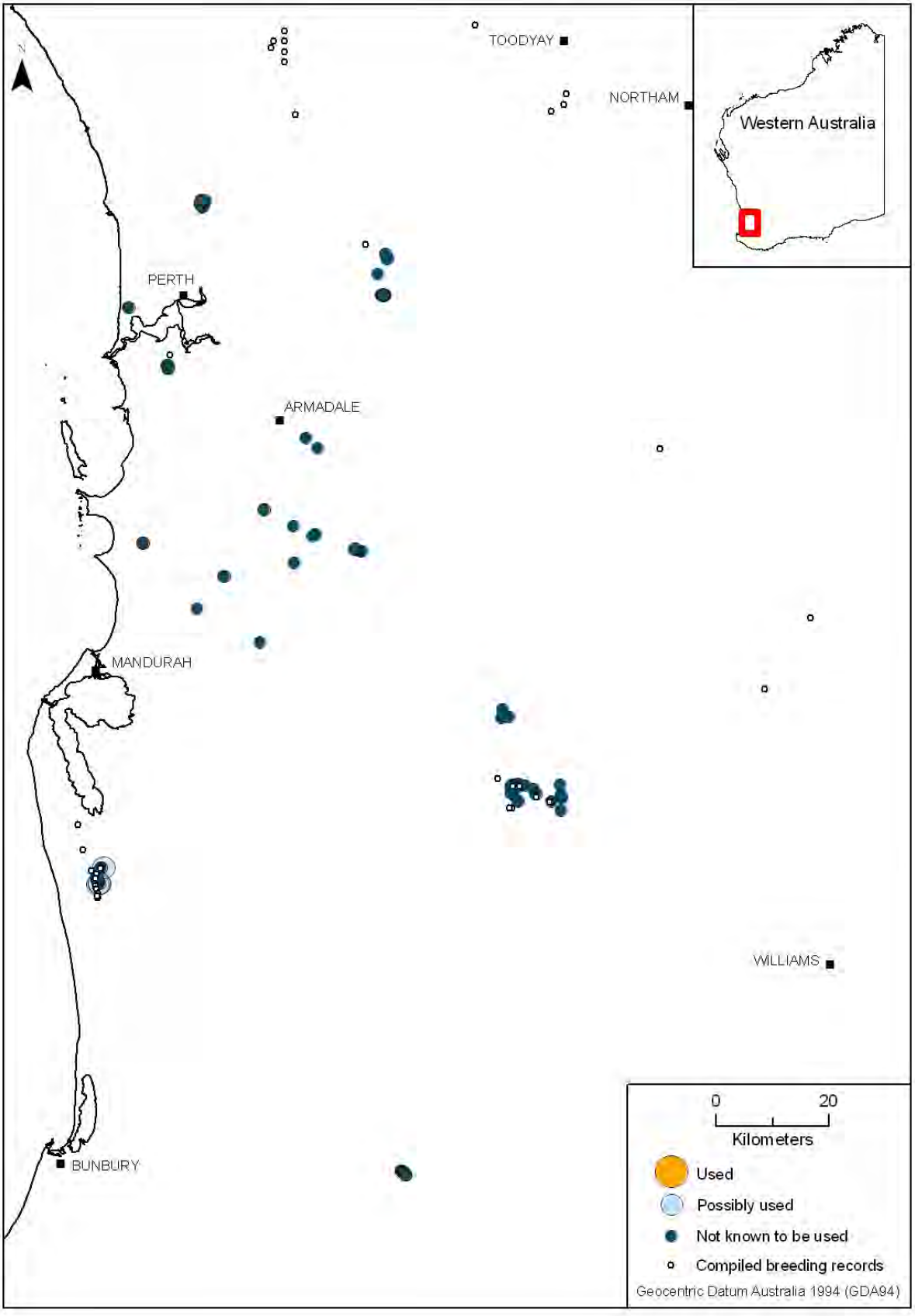
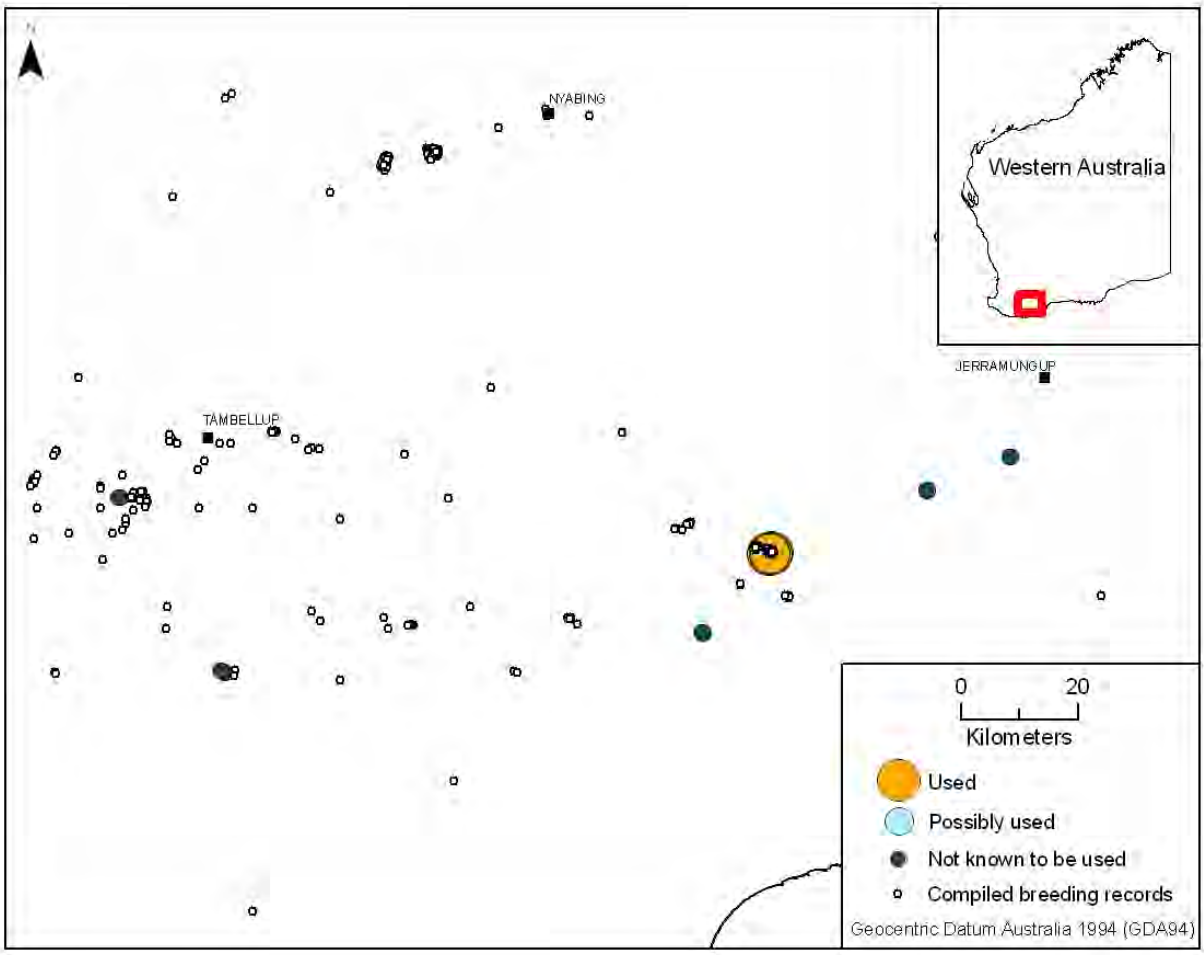


Figure 8: Southern distribution of Carnaby's black cockatoo breeding records (a combination of known and probable nesting sites as well as observations of breeding behaviour) and artificial hollows.



4.3.3 Designs

A wide variety of artificial hollow designs have been erected for use by Carnaby's black cockatoos. It is difficult to draw conclusions about the most effective designs because of the small sample sizes and many factors involved (Table 6).

Table 6: Features of artificial hollows used (or possibly used) by Carnaby's black cockatoo.

Feature	Type	Number
Design	Kerkoff	30
	Cockatube	22
	Other	5
Body material	Tree hollow	30
	Black plastic	25
	Wooden boards	2
Top material	Wooden boards	6
	Metal	24
	None (ie top entry)	27

Feature	Type	Number
Base material	Metal	19
	Plough disc	10
	Metal mesh	2
	Black plastic	5
	Not known	21
Host	Metal pole	26
	Tree	30
	Chimney	1
Entry location	Top	27
	Side	30

There are three common general designs. These are:

1. "Cockatube": made from black plastic tubing recycled from mining.

2. "Kerkoff": made from a section of natural hollow (see Davies, 2003).

3. "Pedler": made from white PVC tubing (see Pedler, 1996).

Other designs and variations have been custom built.





Of those artificial hollows recorded as being used, or possibly being used, by Carnaby's black cockatoos, 52.6 per cent were 'Kerkoff', 38.6 per cent were 'Cockatubes' and 8.8 per cent were 'Other'. No 'Pedler' artificial hollows were identified as being used during this study (except in aviaries).

From these results, it would appear that the 'Kerkoff' design is the most effective. However, there are many factors in deciding whether or not an artificial hollow will be used by the birds. The artificial hollows need to be placed in suitable locations. For example, a much higher proportion of 'Kerkoff' artificial hollows have been placed in close proximity to known breeding activity in natural hollows than any other design (i.e. 84.3 per cent) (Table 7).

Table 7: Usage of artificial hollows by Carnaby's black cockatoos and distance from known breeding records. Percentages are in brackets.

Design	**Number**	**Artificial hollows used, or possibly used, by Carnaby's**	**Artificial hollows located less than 1km from known breeding activity**
Cockatube	130	22 (16.9)	32 (24.6)
Kerkoff	51	30 (58.8)	43 (84.3)
Pedler	31	0 (0)	0 (0)
Other	34	5 (14.7)	10 (29.4)

Through surveying artificial hollows and extensive consultation, some basic guidelines for the constructions of artificial hollows may be summarised.

Walls

The walls of the artificial hollow need to be constructed from a material that is:

- durable enough to withstand exposure to elements for an extended period of time (i.e. 20+ years)
- able to simulate the thermal properties of a natural tree hollow
- not less than 300mm in internal diameter
- between 0.5 and 2.5m long.

Successful artificial hollows have been constructed from sections of salvaged natural hollow, black industrial pipe recycled from the mining industry and, in captivity, white PVC pipe. When using non-natural materials, care must be taken to ensure there are no toxic residues and that the materials are safe to ingest.

Base
The base of the artificial hollow must be:

- able to support the bird and chicks
- durable enough to last the life of the nest
- free draining
- At least 300mm in diameter
- covered with 100 – 150mm of dry, free draining material such as charcoal, hardwood woodchips or wood debris. (Do not use sawdust or fibre products that will retain moisture.)

Example materials that could be used for artificial hollow bases include heavy duty stainless steel, galvanised or treated metal (e.g. Zincalume ®), thick hardwood timber slab, or marine ply (not chipboard or MDF). The base material must be cut to fit internally, with sharp or rough edges ground away or curled inwards and fixed securely to the walls.

Entrance
The entrance of the artificial hollow:

- must have a diameter of at least 100mm (preferably 200 – 300mm)
- should preferably be top-entry to minimise use by non-target species.

A lid or cap would partly weatherproof the hollow, but is not necessary. Top-entry hollows are unattractive to nest competitors such as feral bees, galahs and corellas. Side-entry hollows have been successful in areas where feral bees are not a problem and where galahs and corellas are deterred.

Ladder
For artificial hollows made of non-natural materials, or of processed boards, it is necessary to provide a ladder to enable the birds to easily climb in and out of the hollow.

The ladder must:

- be securely mounted to the inside of the hollow
- be made from an open heavy wire mesh such as WeldMesh™ with mesh size of 30 – 50mm, or heavy chain
- not be made of a material that the birds can chew
- not be galvanized because the birds may grip or chew the ladder and ingest harmful compounds.

If using mesh for the ladder, the width will depend on the curvature of the nest walls. A minimum width of about 60 – 100mm is recommended.

Sacrificial chewing posts
For artificial hollows made of non-natural materials, or of processed boards, it is necessary to provide sacrificial chewing posts. The birds chew material to prepare a dry base on which to lay their egg(s). Without this material, the artificial hollow is unlikely to be used by a cockatoo.

Sacrificial chewing posts must:

- be made of untreated hardwood such as jarrah, marri or wandoo
- be thick enough to satisfy the birds needs between maintenance visits
- extend beyond the top of the hollow as an aid to see whether the nest is being used
- be placed on the inside of the hollow
- be attached in such a way that they are easy to replace (e.g. hook over the top of hollow or can slide in/out of a pair of U bolts fitted to the side of the hollow).

It is recommended that at least two posts are provided. Posts 70 x 50mm have been used, but require replacing at least every second breeding season when the nest is active. Birds do vary in their chewing habits and therefore the frequency at which the chewing posts require replacement will also vary.

Mountings
The artificial hollow must be mounted such that:

- the fixings used will last the duration of the nest (e.g. galvanized bracket or chain fixed with galvanized coach screws)
- it is secured by more than one anchor for security and stability
- it is positioned vertically or near vertically.

4.3.4 Placement

The height at which artificial hollows had been placed was recorded for only a small sample (94). The lowest recorded was 3m and the highest was 14.5m. While the average height of natural hollows in dominant tree species of the area is likely to be a good guide to the recommended placement height for artificial hollows, the actual height at which artificial hollows are placed is limited by equipment, accessibility and safety.

Carnaby's black cockatoos show no preference for the aspect of natural hollows (Saunders, 1979). However, it may still be beneficial to place artificial hollows facing away from prevailing weather.

Chains, bolts and screws were the most common method of attaching artificial hollows to trees. A novel placement requiring no chains or bolts involved putting the artificial hollows in the tops of large burnt out wandoo (*Eucalyptus wandoo*) trees.

The majority of artificial hollows were placed in trees (78.9 per cent). Tree species used were: yate (*E. cornuta*), marri (*Corymbia calophylla*), wandoo, tuart (*E. gomphocephala*), jarrah (*E. marginata*), powderbark (*E. accedens*), York gum (*E. loxophleba*) and maritime pine (*Pinus pinaster*). Other hosts used were metal poles, railway rails, a chimney and a metal sculpture. Landholders who had used metal poles or railway sleepers to host their artificial hollows promoted the benefits as being safety from fire and climbing predators.

4.3.5 Usage

Of the 57 artificial hollows recorded during this study as either being used or possibly being used, 14 were found to have been used within a year of placement. It is likely that this is an underestimation.

It is considered that the easiest and most effective method for deterring feral bees from using artificial hollows is to design them to have an open entry at the top. However, this is not 100 per cent effective. Four instances of feral bees occupying top-entry hollows were recorded during surveys. Two were in wooden hollows with natural hollow tops at Black Cockatoo Reserve, where they have ongoing problems with bees. The other two instances were in 'Cockatubes' erected at Murdoch University. These represnted the first time that feral bees have been recorded occupying 'Cockatubes'.

Other species found to be using artificial hollows were galahs (*Cacatua roseicapilla*), corellas (*C. pastinator*), Australian ringnecks (*Barnardius zonarius*), ducks (*Tadorna tadornoides*, *Chenonetta jubata*), owls (*Tyto novaehollandiae*) and inland red-tailed black cockatoos (*C. banksii samueli*). These species have varying degrees of concern and differ in the required action or solutions (Table 8). Some of these species compete with Carnaby's black cockatoos during the breeding season, while others do not require the hollows at the same time.

It is important to note that no artificial hollows were recorded as being used by forest red-tailed black cockatoos or Baudin's black cockatoos.

Table 8: Nest competitors for artificial hollows erected for black cockatoos.

Nest competitor	Areas observed using artificial hollows	Solutions
feral bees	Cataby, Moora, Murdoch, Mundaring	• Top entry artificial hollow design • Pest control
galahs	Coorow, Cataby, Jarrahdale, Watheroo, Murdoch, Mundaring	• Shooting and scarring • Top entry artificial hollow design • Larger hollow opening
corellas	Coorow, Piawaning	• Shooting and scarring • Top entry artificial hollow design • Larger hollow opening
Australian ringnecks	Calingiri	• Minimal competition, do nothing
ducks	Calingiri, Jarrahdale, Borden, Mundaring	• Remove old addled eggs
owls	Coorow, Collie	• Minimal competition, do nothing
inland red-tailed black cockatoos	Coorow	• Minimal competition, do nothing

Species observed inspecting or perching on artificial hollows during surveys for this project were galahs, corellas and forest red-tailed black cockatoos (*Calyptorhynchus banksii naso*) (Figures 9, 10 and 11).

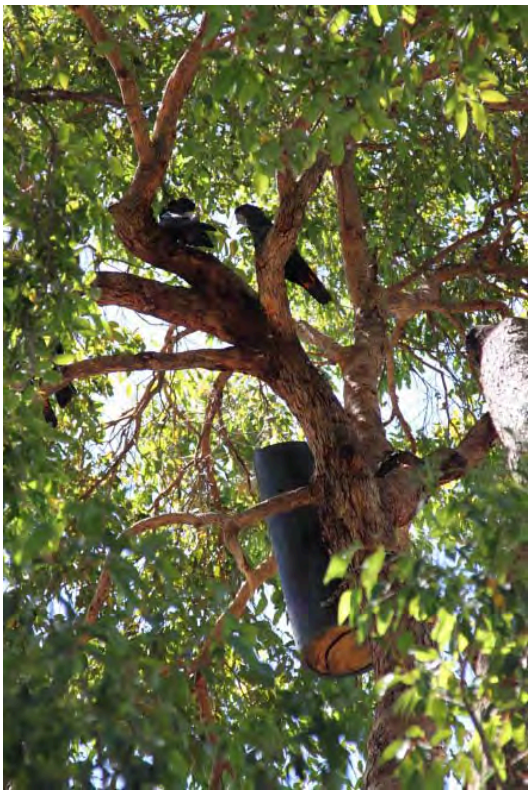


Figure 9: Forest red-tailed black cockatoos and 'Cockatube' at Jarrahdale.

Figure 10: Corellas and 'Kerkoff' designed artificial hollow at Coorow.

Figure 11: Galahs and 'Kerkoff' designed artificial hollow at Piawaning.

4.3.6 Monitoring

Monitoring artificial hollows is important to detect:

- usage by Carnaby's black cockatoo
- maintenance requirements (e.g. replacing chewing posts, rusty attachments, rotting timber etc)
- usage by other native species
- usage by pest or feral species (e.g. feral bees, rainbow lorikeets).

Results from monitoring can also be used to determine the success of erecting the hollows, as well as how to improve them.

Monitoring requires keen observation and naturalist skills. It is often not possible to directly observe evidence of breeding (i.e. eggs or chicks) so inferences must be made based on a variety of observations, including the birds' behaviour.

There are several methods currently used for monitoring artificial hollows. They vary in degrees of difficulty and resource requirements.

Looking for signs of use
Cobwebs covering the entrance to the hollow will indicate that the hollow has not been used recently. This would also apply to other light debris that may have fallen to partially cover the opening. Signs of recent use or interest in the hollow include evidence of chewing.

Observing parent behaviour around the nest
The behaviour of parent birds around a nest will give some indication of the age of young in the nest (Table 9).

Table 9: Observing behaviour around nests and approximate age of young

Parent behaviour	Approximate age/stage of young
Prospecting for hollow	Unborn
Male only seen out of hollow	Egg or very young chick (< 3 – 4 weeks old)
Male and female seen entering/exiting the hollow	Young have hatched (> 3 – 4 weeks old)

Observing feeding flocks
Flocks of all male birds indicate that the females are sitting on eggs. When flocks are mixed it suggests the birds either have not yet laid or that the chicks have hatched and no longer require brooding (> 3 – 4 weeks old).

Tapping
When hens are sitting on eggs they will usually respond to tapping at the base of their tree by appearing at, or flying from, the hollow's opening. This is not a guarantee of breeding activity, but an indication that it might be occurring in the hollow.

Observing insect activity around the nest
The faecal matter produced by chicks in a nest attracts insects, especially flies and ants. The type and number of these insects will help indicate the age of any chicks present. Factors such as temperature and humidity will also affect insect activity. so observations of insect activity should only be used as supporting evidence for other indications of age/usage. Blowflies around a nest usually indicate that a death has occurred.

Listening for chicks
With experience, it is possible to determine if one or two chicks are present and a broad estimate of age based on the type and loudness of noises they make.

Looking inside the nest
Looking inside the nest can be achieved by using a mirror on a pole, a telescopic pole and camera or a ladder or other climbing equipment. See Hayward and Deal (1993) for information on designing a suitable telescopic pole and camera setup. This method can produce the most detailed monitoring information for artificial hollows. However, it is also the most time-consuming and difficult to organise. Special equipment is likely to be needed depending on the height and position of artificial hollows. There are also safety issues associated with ladder or rope climbing .

4.3.7 Frequency of monitoring

Information was gathered on the frequency of monitoring and techniques used for each artificial hollow site surveyed (Table 10). Most artificial hollows have only been monitored opportunistically after placement.

Table 10: Summary of artificial hollow monitoring by site.

Site ID	Number of artificial hollows	Monitoring	Techniques used	Monitoring by
PEN	5	2008-present	Looking inside nest, taking measurements of chicks	Birds Australia, DEC
CHE	5	2008-present	Looking inside nest, taking measurements of chicks	Birds Australia, DEC
YAR	5	2008-present	Looking inside nest, taking measurements of chicks	Birds Australia, DEC
MON	4	2008-present	Looking inside nest, taking measurements of chicks	Birds Australia, DEC
WAN	5	2008-present	Looking inside nest, taking measurements of chicks	Birds Australia, DEC
THO	5	2008-present	Looking inside nest, taking measurements of chicks	Birds Australia, DEC
HEN	3	Not formally	Opportunistic observations	Landholder
SJL	2	Not formally	Opportunistic observations	Serpentine Jarrahdale Landcare Centre
ELL	1	Not formally	Opportunistic observations	Landholder
BGM	24	2008-present	Tapping, opportunistic observations	Murdoch University
PBH	18	2009-present	Looking inside nest	Ron Johnstone *et al.*
MUR	6	2009-present	Opportunistic observations	Murdoch University
BIN	17	2009-present	Looking inside nest	Ron Johnstone *et al.*
KIR	4	2009-present	Looking inside nest, opportunistic observations	Ron Johnstone *et al.*
WAL	9	2009-present	Looking inside nest	Ron Johnstone *et al.*
JAR	2	No	None	
JPS	1	Not formally	Opportunistic observations	School gardener
HOV	3	No	None	
BAL	2	No	None	
WEW	20	2008-present	Looking inside nest	Bamford Consulting
KOO	7	2003-present	Looking inside nest, taking measurements of chicks, opportunistic observations	Birds Australia volunteer, DEC
MOO	7	2004-present	Looking inside nest, taking measurements of chicks	DEC
KER	6	1980's-present	Detailed observation of parent behaviour, listening for chicks, observing insect activity around nest	Landholder
STA	2	2009-present	Opportunistic observations	Landholder
EDM	4	2004-present	Looking inside nest	Birds Australia volunteer
RAE	5	2004	Opportunistic observations	Stephen Davies *et al.*
WYN	4	2004-present	Looking inside nest	Birds Australia volunteer
YEN	7	2004	Opportunistic observations	Stephen Davies *et al.*
EHF	6	2004	Opportunistic observations	Stephen Davies *et al.*
CAR	4	2004	Opportunistic observations	Stephen Davies *et al.*
BCF	4	Not formally	Opportunistic observations	
BCR	3	Not formally	Opportunistic observations	Friends of Black Cockatoo Reserve

Site ID	Number of artificial hollows	Monitoring	Techniques used	Monitoring by
BUN	1	No	Opportunistic observations	
WUN	1	No	Opportunistic observations	
CAT	6	2004-present	Looking inside nest	Ron Johnstone *et al.*
SWA	2	No	Opportunistic observations	
COO	1	Not formally	Opportunistic observations	Landholder
TEL	18	2009-present	Looking inside nest	Natural Area Consulting
PHC	13	No	Opportunistic observations	
NDP	1	Not formally	Opportunistic observations	School
SNP	3	Not formally	Opportunistic observations	
KOR	1	Not formally	Opportunistic observations	Shire/local residents

If the goal of monitoring is to assess nesting success, it is necessary to undertake more intensive monitoring than if the goal was simply to decide whether or not hollows are being used. Undertaking additional monitoring increases the certainty of identifying nesting success and reduces assumptions. Saunders (1986) found that two visits during the nesting season overestimated nesting successes because early failed nesting attempts were missed. Apparently healthy nestlings observed late in the season and assumed to fledge, may also have subsequently died.

4.3.8 Maintenance

During survey of artificial hollows, maintenance requirements were noted.

Carnaby's black cockatoos chew material to prepare a dry base on which to lay their eggs. Evidence of chewing is an indication of possible breeding (Figure 12). Birds vary in their chewing habits, so the frequency with which posts require replacement will vary. Some will need replacing each season, while others may not need replacing for several seasons (one nest did not need the chewing post replaced in five years of use). Observations of sacrificial posts being chewed even when not used for breeding were made at Murdoch University and at the Serpentine-Jarrahdale Landcare Centre.

(a)  (b) 

(c) 

Figure 12: Evidence of Carnaby's black cockatoos chewing on sacrificial posts (a and b) and on top of hollow (c).

Problems related to the base of artificial hollows were noted in several instances during survey. Rotting wood (Figure 13), wire mesh rusting or netting becoming detached were some of the problems observed.

Figure 13: Rotted wooden base of artificial hollow.

Problems with the bases of some artificial hollows resulted from too little or too much drainage. The

netting size used on some artificial hollows appears to have been too large and the nest bedding material fell through (Figure 14). Where drainage was found to be insufficient, damp nest bedding material was removed, drainage holes drilled and dry nest bedding material replaced (John Lauri pers. comm.).

Figure 14: Artificial hollow with insufficient bedding material remaining inside the hollow.

Artificial hollows built from sections of natural hollow will decompose and crack over time. Cracks have been patched either with a filler substance or by covering with a sheet of metal (Figure 15).

Figure 15: A crack in an artificial hollow repaired using a sheet of metal.

4.3.9 Costs

Artificial hollows cost money to build, install, monitor and maintain. They are often made from donated or recycled materials, which significantly reduces costs. Artificial hollows can be purchased from a limited number of suppliers in Perth.

The Serpentine Jarrahdale Landcare Centre builds artificial hollows for black cockatoos using donated materials and black plastic pipe provided by mining companies. The average cost is $375 (as at August 2010). Hire of a cherry picker to install the artificial hollow is estimated to be around $180 per hollow.

A "Black Cockatoo tube" purchased from Natsync Environmental costs $750 (prices valid as at 1 August 2008).

Wooden hollows erected in the Shire of Mundaring cost between $195 and $220 each in 2003.

Artificial hollows erected in Coorow in 2003 each cost $225 in materials plus an estimated $330 in

labour.

4.3.10 Occupational Health and Safety

Occupational and health and safety concerns have influenced where artificial hollows have been placed. At Boddington Gold Mine there is a limit to the height to which personnel may raise elevated work platforms (EWP) (10m) and this limits the height at which artificial hollows can be placed at the site.

Accessibility for cherry pickers or EWPs also influences the choice of tree and position of artificial hollows. Some EWPs are very difficult to manoeuvre into a place where they are stable, level and safe to use.

A theory on the lack of use of artificial hollows at Boddington Gold Mine relates to the average height of used natural hollows being higher than the height of artificial hollows and, therefore, are either not found by the birds or do not appeal (Jessica Lee pers. comm.).

5 Recommendations for future study or action

5.1 Refine monitoring methodology

There's a need for better guidance on the suitability of each monitoring technique, what combination of techniques work well, and the timing and frequency of monitoring. It is important to match the aims of monitoring and available resources with suitable techniques, and to understand their limitations.

5.2 Research reasons for lack of use of artificial hollows in forest areas

It is unclear why artificial hollows have been unsuccessful for black cockatoos in forest areas. Further study is needed.

Potential areas of study include:

- height of artificial hollows versus natural hollows
- determining if the availability of hollows is or isn't limiting in the forest (e.g. see Abbott, 1998)
- identifying differences in the behaviour of forest black cockatoos. Black cockatoos that reside in forest areas appear to be more sedentary and less time-restricted (i.e. they don't need to migrate seasonally). This might result in the cockatoos being more choosy about their nesting sites. The cockatoos might also require a sense of competition, and hence close proximity to other used hollows, to ensure they occupy artificial hollows.

5.3 Create a registry of artificial hollow data

There are increasing numbers of artificial hollows being erected for black cockatoos. Given the threatened status of all three black cockatoo species that occur in the south-west of Western Australia, it is considered important to keep a record of the location of artificial hollows that are potential breeding sites.

The creation of a state registry of artificial hollow locations for black cockatoos is recommended. The excel spreadsheet utilised during this study is inadequate for undertaking complex analyses or storing large amounts of data. An Access™ database would be a more suitable option.

Entry into the state register should be made a condition of approval for external funding for the placement of artificial nest and it should be included in the conditions of approval for development (both State and Commonwealth levels) where artificial hollows have been suggested.

5.4 Research into a method of assessing adequacy of food availability in breeding areas

Before erecting artificial hollows it is important to asses whether or not there will be adequate food

resources in the area to support any breeding attempts.

Studies by Saunders (1977 and 1986) have indicated that the intactness and connectivity of feeding habitat surrounding breeding areas affects nestling weights and fledging rates. The ability of parent birds to fly to feeding areas is hampered in fragmented landscapes such that adequate feed may not be provided to nestlings. This results in a failed or compromised breeding attempt.

A method to assess whether sufficient food resources are accessible to the birds from a site chosen for erecting artificial hollows is needed.

5.5 Research how to extend current breeding

Further research is required to determine if it is possible to encourage Carnaby's black cockatoo to breed in areas where they currently aren't breeding. If this can be achieved, more artificial hollows may be used by the birds.

5.6 Microclimate of artificial hollows

Further testing of the microclimate of artificial hollows is needed. Temperature and humidity will be affected by the design of and materials used to build the artificial hollow. The tolerance limits of adult birds, chicks and eggs are currently unknown. McComb and Noble (1981) provided a methodology that may be applied to investigate the microclimate of natural and artificial hollows.

5.7 Chemical testing of artificial hollows

Artificial hollows built from non-natural materials should be tested to ensure that they are safe for the birds. There are three aspects that require testing.

1. The material may produce harmful emissions during heating and cooling under field conditions.

2. The material may have residual chemicals on its surfaces from past use (e.g. pipe recycled from mining).

3. The safety of ingesting the material to ensure the birds can chew it without any adverse effects.

During the survey of artificial hollows, no observation was made of Carnaby's black cockatoos chewing black plastic tubes, but beak marks were observed at the top of some used hollows (Figure 16).

Figure 16: Beak marks made by Carnaby's black cockatoo in top of 'Cockatube'.

5.8 Timing of sacrificial post replacement

Carnaby's black cockatoos use sacrificial posts in artificial hollows, where they have been fitted. However, it has not been established how essential the posts are to hollows being used or how often they need replacing.

6 References

Abbott, I. (1998). Conservation of the forest red-tailed black cockatoo, a hollow-dependent species, in the eucalypt forests of Western Australia. Forest Ecology and Management 109: 175-185.

Abbott, I. and Whitford K. (2002). Conservation of vertebrate fauna using hollows in forests of south-west Western Australia: strategic risk assessment in relation to ecology, policy, planning, and operations management. Pacific Conservation Biology 7: 240-255.

Barrett, G., Silcocks, A., Barry, S., Cunningham, R. and Poulter, R. (2003). The New Atlas of Australian Birds. Royal Ornithologists Union, Hawthorn East, Victoria.

Davies, S. (2003). Some practical steps for enhancing the status of Carnaby's black cockatoo. In Conserving Carnaby's black cockatoo, Future Directions: Proceedings from a conservation symposium. Ed. C. Gole, Birds Australia and Department of Conservation and Land Management, Perth, Western Australia.

Davies, S. (2005). Usage of artificial nest boxes by Carnaby's cockatoo. Assessment of status 2004. Report to World Wide Fund for Nature, Threatened Species Program and Men of the Trees January 2005.

Davies, S. and Loomes, D. (2002). Carnaby's cockatoo – Coast to catchment. Final report on the project. Unpublished report prepared for the Moore catchment Group, W.A.

Department of Health (2010) Investigation of potential use of nesting boxes, by Carnaby's black cockatoo, installed at the Fiona Stanley Hospital Site. Memorandum of Understanding Section 7.1. February 2010. Fiona Stanley Hospital Project.

Garnett, S.T., Pedler, L.P. and Crowley, G.M. (1999). The breeding biology of the glossy black cockatoo *Calyptorhynchus lathami* on Kangaroo Island, South Australia. Emu 99: 262-279.

Goldingay, R.L. and Stevens, J.R. (2009). Use of artificial tree hollows by Australian birds and bats. Wildlife Research 36: 81-97.

Hayward, G.D. and Deal, J.W. (1993). An optic device to inspect nest boxes from the ground. Journal of Field Ornithology 64(2): 179-187.

Howard, K. (2008). Carnaby's granted a new chance to nest. TSN News Summer 2008. p9.

Jarmyn, B. (2000). Nest predation of cockatoos in south-west Victoria: with special reference to the endangered sub-species of red-tailed black cockatoo, *Calyptorhynchus banksii graptongyne*. B.Sc. (Hons) thesis, University of Adelaide, South Australia.

Johnstone, R.E., Johnstone, C. and Kirkby, T. (2004). Report on Carnaby's Cockatoo *Calyptorhynchus latirostris* breeding season 2003-2004 within the Cataby Project Area. Prepared for Iluka Resources Limited. Unpublished report.

Johnstone, R.E., Johnstone, C. and Kirkby, T. (2005). Report on Carnaby's Cockatoo *Calyptorhynchus latirostris* nest monitoring within the Cataby Project Area breeding season 2004-2005. Prepared for Iluka Resources Limited. Unpublished report.

Johnstone, R.E., Johnstone, C. and Kirkby, T. (2006). Report on Carnaby's Cockatoo *Calyptorhynchus latirostris* nest monitoring within the Cataby Project Area breeding season 2005-2006. Prepared for

Iluka Resources Limited. Unpublished report.

Johnstone, R.E., Johnstone, C. and Kirkby, T. (2007). Report on Carnaby's Cockatoo *Calyptorhynchus latirostris* nest monitoring within the Cataby Project Area breeding season 2006-2007. Prepared for Iluka Resources Limited. Unpublished report.

Johnstone, R.E., Johnstone, C. and Kirkby, T. (2008). Report on Carnaby's Cockatoo *Calyptorhynchus latirostris* nest monitoring within the Cataby Project Area breeding season 2007-2008. Prepared for Iluka Resources Limited. Unpublished report.

Johnstone R.E., and Johnstone, C. and Kirkby, T. (2009). Perth-Bunbury Highway black cockatoo habitat tree monitoring survey. Unpublished report by Biota Environmental Sciences for Southern Gateway Alliance.

Johnstone R.E., and Johnstone, C. and Kirkby, T. (2010). Perth-Bunbury Highway black cockatoo nest monitoring 2009-10 season. Unpublished report by Biota Environmental Sciences for GHD Pty Ltd/Main Roads Western Australia.

Johnstone R.E., and Johnstone, C. and Kirkby, T. (2010b). DRAFT Carnaby's cockatoo nest box monitoring, Bindoon region 2009-2010. Unpublished report for Access Alliance/Main Roads Western Australia

McComb, W.C. and Noble, R.E. (1981). Microclimates of nest boxes and natural cavities in bottomland hardwoods. The Journal of Wildlife management 45(1): 284-289.

Metcalf, B.M. (2010). 2009 artificial nest hollow monitoring, Ewington Area. Unpublished report by Bamford Consulting Ecologists for the Griffin Coal Mining Company.

Metcalf, B.M. and Cherriman, S. (2009). Artificial nest-hollow monitoring, Ewington Area, 2008. Unpublished report by Bamford Consulting Ecologists for the Griffin Coal Mining Company.

Nelson, J.L. and Morris, B.J. (1994). Nesting requirements of the yellow-tailed black cockatoo, *Calyptorhynchus funereus*, in *Eucalyptus regnans* Forest, and implications for forest management. Wildlife Research 21: 267-278.

Pedler, L. (1996). Artificial nest hollows for black cockatoos. Eclectus 1: 13.

Saunders, D.A. (1977). The effect of agricultural clearing on the breeding success of the white-tailed black cockatoo. Emu 77: 180-184.

Saunders, D.A. (1979). The availability of tree hollows for use as nest sites by white-tailed black cockatoos. Australian Wildlife Research 6: 205-216.

Saunders, D.A. (1986). Breeding season, nesting success and nestling growth in Carnaby's cockatoo, *Calyptorhynchus funereus latirostris*, over 16 years at Coomallo Creek, and a method for assessing the viability of populations in other areas. Australian Wildlife Research 13: 261-273.

Saunders, D.A., Smith, G.T. and Rowley, I. (1982). The availability and dimensions of tree hollows that provide nest sites for cockatoos (Psittaciformes) in Western Australia. Australian Wildlife Research 9: 541-556.

Scott, R. (2009). Artificial hollow trial on the south coast. Western Australian Birds Notes 131:1-2.

Stojanovic, D and Scott, R. (2009). Carnaby's black cockatoo project.19(3): 31-33.

Whitford, K.R. and Williams, M.R. (2001). Survival of jarrah (*Eucalyptus marginata* Sm.) and marri (*Corymbia calophylla* Lindl.) habitat trees retained after logging. Forest Ecology and Management 146: 181-197.

Whitford, K.R. and Williams, M.R. (2002). Hollows in jarrah (*Eucalyptus marginata*) and marri (*Corymbia calophylla*) trees: II. Selecting trees to retain for hollow dependent fauna. Forest Ecology and Management 160: 215-232.