PHOENIX
ENVIRONMENTAL SCIENCES

Black cockatoo breeding activity census 2021-22 for Muchea North

Great Northern Highway, Muchea to Wubin Upgrade Stage 2 Project

Prepared for Main Roads WA

June 2022

Final

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Prepared for Main Roads WA

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1 INTRODUCTION

Phoenix Environmental Sciences Pty Ltd (Phoenix) was commissioned by Main Roads WA, to undertake a Carnaby's Cockatoo breeding activity census over the 2021-22 breeding season within and surrounding the disturbance footprint for the Muchea North Upgrade project area (Figure 1). This report presents the results of the census.

1.1 BACKGROUND

Main Roads has recently upgraded the Great Northern Highway (GNH) between Straight Line Kilometre (SLK) 38.60 and 51.40, referred to as Muchea North Upgrade (Muchea North in this report). The Muchea North proposal was referred under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) on 1 March 2016 (EPBC 2016/7656), assessed as a controlled action and granted conditional approval in August 2018 (DotEE 2018).

Muchea North resulted in the loss of 13 Carnaby's Black Cockatoo nesting hollows. To mitigate and offset the loss of these, Main Roads was required to install 39 artificial nest boxes (Figure 1). In accordance with EPBC 2016/7656 Conditions 4f(i) and (ii) each artificial nesting hollow installed must:

- (i): be inspected at least twice a year by a suitably qualified person during the peak breeding season to record any evidence of use by the Carnaby's Black Cockatoo and to identify any maintenance requirements.
- (ii): be monitored and maintained in accordance with relevant artificial hollow guidance for the life of the approval, with maintenance actions, if required, undertaken outside of the breeding season and before the commencement of the next breeding season.

The monitoring program also required monitoring of previously recorded natural hollows suitable for Carnaby's Cockatoo (Figure 1). Monitoring of artificial and natural hollows is required to be monitored in accordance with How to Monitor and Maintain Artificial Hollows for Carnaby's Cockatoo (DPaW 2015).

Detailed black cockatoo habitat assessments conducted as part of the baseline assessments for the Muchea North (Phoenix 2015, 2017a) recorded all potential breeding trees of species known to support black cockatoo breeding and identifed suitable nesting hollows and hollows with evidence of use.

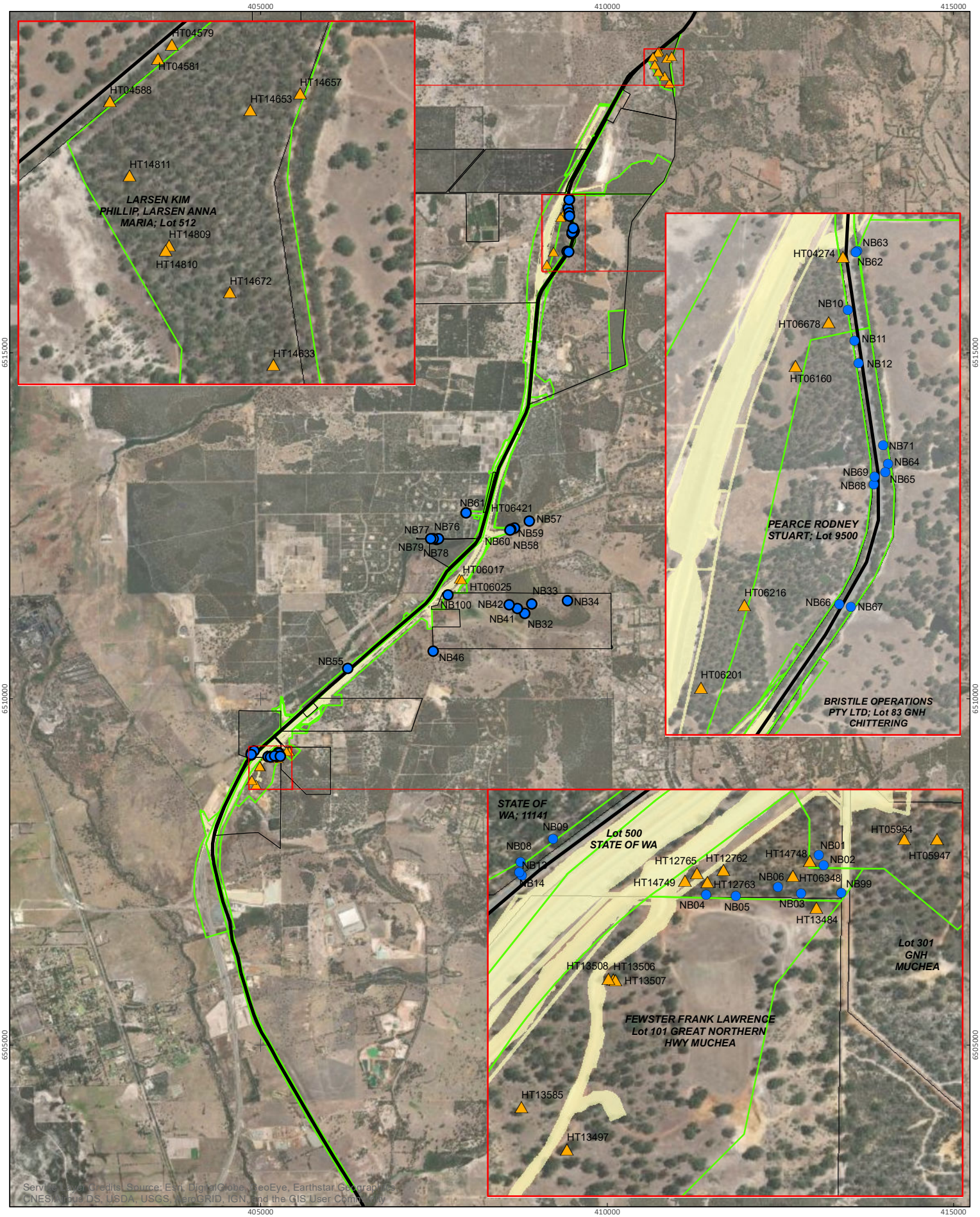
A native vegetation clearing permit (NVCP) for Muchea North (Permit no. 7563/2) has been approved by the WA Department of Water and Environmental Regulation (DWER) under the *Environmental Protection Act 1986* (EP Act).

To support Condition 4c of EPBC 2016/7656, Main Roads commissioned Phoenix to undertake monitoring of confirmed and suitable nesting hollows recorded within the EPBC Act Approval Boundary and wider baseline survey area (Phoenix 2015, 2017a) (the study area; Figure 1). A series of monitoring events have taken place to support this condition (Table 1). The initial baseline monitoring program was conducted in the 2017-18 breeding season (August 2017 – February 2018) and assessed hollow usage of suitable nesting hollows and hollows with evidence of use within the study area (Phoenix 2018). A second year of monitoring for hollow usage within the study area in the 2018-19 breeding season was undertaken by Phoenix from August 2018 to February 2019 (Phoenix 2019). The artificial nesting hollows were installed during the 2018-2019 breeding season, therefore the results of these first two surveys collectively represent the pre-impact breeding density.

Impact monitoring was subsequently conducted in the 2019-2020 breeding season (Phoenix 2020) and the 2020-2021 season (Phoenix 2021). This report incorporates the results of the 2021-2022 monitoring season into the nesting hollow usage dataset for Muchea North.

Table 1 Summary of black cockatoo monitoring activity

Year	Activity
2014-2016 Various times	Habitat assessment including recording all potential breeding trees and suitability for nesting.
2017-2018 August to January	Baseline assessment: Assessment of nest hollows for evidence of breeding.
2018-2019 August to February	Baseline assessment: Assessment of nest hollows for evidence of breeding. *Road works commenced and artificial nesting hollows were installed during this breeding season.*
2019-2020 August to January	Assessment of both natural nest hollows and artificial neststing hollows for evidence of breeding
2020-2021 August to February	Assessment of both natural nest hollows and artificial neststing hollows for evidence of breeding
2021-2022 August to February	Assessment of both natural nest hollows and artificial neststing hollows for evidence of breeding



Main Roads WA
Great Northern Highway, M2W Upgrade Project

Project No	1415
Date	18-Mar-22
Drawn by	AJ
Map author	AJ

0 1 2
Kilometers

1:70,000 (at A4) GDA 1994 MGA Zone 50

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- Study area
- Disturbance footprint
- Road
- Artificial nesting hollow
- Natural nesting hollow

Figure 1

Study area and sampling sites

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1.2 SCOPE OF WORK

The scope of work was as follows:

- Six rounds of monitoring of artificial and natural nest hollows to be undertaken between August 2021 and February 2022.
- During inspections of artificial and natural hollows, record evidence of use by Carnaby's Cockatoos at each artificial and natural hollow in accordance with (DPaW 2015).
- During inspections, identify any artificial nest box maintenance needs in accordance with (DPaW 2015) and whether natural hollows remain suitable for use by Carnaby's Black Cockatoo.
- Provide a report that summarises all records required by Conditions 4f(i) and (ii) of EPBC 2016/7656 for all artificial and natural hollows inspected. The draft report shall be provided to Main Roads in electronic PDF and Word version copy format.

2 CENSUS METHODOLOGY (DPAW 2015)(DPAW 2015)

Methods were consistent with the approach undertaken in previous monitoring events for Muchea North (Phoenix (2018, 2019, 2020, 2021)).

Prior to the surveys, site locations (artificial and natural nest hollows) were loaded onto field tablets. Data was collected electronically using a customised data collection template and included:

- site code
- signs of use – birds prospecting hollows, fresh chewings, birds perching, birds entering/existing hollows, birds flushed from hollows, gender of observed birds, chick calls, eggs observed (inc. status if possible – incubated or abandoned), chick/s observed, chick/s fledged
- other indicators, e.g. gender mix of flocks, evidence of nesting at base of trees
- condition of hollow, current suitability for use (natural hollows), maintenance requirements (artificial hollows).

The knocking and scraping method was conducted at the base of trees for all monitored hollows during the first half of the monitoring period when birds are typically prospecting fo suitable hollows and femsles are incubating eggs. Pole camera inspections were carried out at each hollow towards the latter half of the survey so as to not disturb females incubating eggs during the first half of the monitoring period. The pole camera is used to check to see if eggs or chicks are in nest hollows and their condition (ie. abandoned eggs, dead or alive chicks). Some hollows could not be accessed by pole camera due to the hollow being too high, blocked by branches, the hollow entrance at an unsuitable angle to allow a clear picture, or the hollow being located close to powerlines. These hollows rely on visual observations of parent birds activity.

Other observational methods were also employed, i.e. listening for nest activity, flock and individual bird behaviour.

Consistent with previous methodology, the following activities were recorded:

- evidence of nesting activity was noted where fresh chewing is around the hollow entrance and/or birds are seen prospecting hollows

- a confirmed breeding event was noted where eggs are seen in hollow and/or other clear evidence observed that a chick is present (i.e. female seen at hollow entrance when during brooding eggs, and/or parents seen preparing to feed chick in the hollow).

Maintenance checks of artificial hollows assessed the following:

- condition of chewing posts
- condition of attachment points
- condition of hollow bases
- stability of tree or pole used to mount the artificial hollow.

As per previous monitoring surveys, site visits were undertaken every 4-5 weeks between August 2021 and February 2022: 27 August, 8 October, 13 November, 21 December 27 January, and 21 February.

The baseline surveys for Muchea North identified a total of 57 trees in the study area containing suitable nesting hollows for black cockatoos, of which 25 had evidence of nesting activity (Table 2).

In the initial survey (2017-18 season), 36 of these were monitored as the remaining 21 were unable to be assessed due to access constraints.

In the 2018-19 season, a total of 83 hollows were monitored; 47 natural nesting hollows and 36 newly installed artifical nesting hollows were monitored (Table 2). This included two new natural hollows added to the census in the current season (HT6330 ang HT13585) and 14 trees with natural nesting hollows that were not accessible in the 2017-18 season. A further five natural nesting hollows were not monitored due to two trees no longer being accessible, and three tree hollows no longer being suitable (ie. Trer or hollow collapse).

In the 2019-2020 season, 73 hollows were monitored, of which 33 were natural nesting hollows and 40 were artifical nesting hollows (Table 2). Prior to that survey, 13 trees which contained suitable nesting hollows were removed as part of the GNH road upgrades (HT05911, HT05923, HT06020, HT06046, HT06261, HT06278, HT6330, HT06655, HT08752, HT08753, HT08754, HT13533, HT13534 and HT13535), 12 of these were monitored in the previous two monitoring programs and one was not accessible. These 13 trees were offset by the installation of the 39 artificial nesting hollows of which all were able to be monitored in the 2019-2020 season. An additional artificial nesting hollow (NB100) was included in the survey which was erected to replace HT04059. Four natural nesting hollows from the baseline dataset that had not been monitored in the previous two years were able to be surveyed in the 2019-2020 season because landowner access had been granted. Four trees with natural nesting hollows were not surveyed in the 2019-2020 season because the tree or hollow was no longer considered suitable.

In the 2020-2021 survey and the current 2021-2022 survey, 71 hollows were monitored. These were the same trees and artificial nesting hollows from the 2019-2020 season however two of the 73 trees from the 2019-2020 season were not able to be surveyed due to the hollow becoming unsuitable (HT12761) or the tree had been removed (HT13533) (Table 2).

Table 2 Monitored hollows

			Baseline		Monitoring season 1	Monitoring season 2	Monitoring season 3
HT ID*	**Baseline records (pre-2017)**	**Species**	**2017-18**	**2018-19**	**2019-20**	**2020-21**	**2021-22**
HT04059	Evidence of nesting activity, artificial hollow	*Eucalyptus wandoo*	Yes	Yes	No (tree cleared)	n/a	n/a
HT04274	Suitable, no evidence of breeding	*Eucalyptus wandoo*	Yes	Yes	Yes	Yes	Yes
HT04579 (NB)	Suitable, *artificial hollow*, no evidence of breeding	*Eucalyptus wandoo*	Yes	Yes	Yes	Yes	Yes
HT04581 (NB)	Suitable, *artificial hollow*, no evidence of breeding	*Eucalyptus wandoo*	Yes	Yes	Yes	Yes	Yes
HT04588 (NB)	Suitable, *artificial hollow*, no evidence of breeding	*Eucalyptus accedens*	Yes	Yes	Yes	Yes	Yes
HT05911	Suitable, artificial hollow, no evidence of breeding	*Eucalyptus accedens*	No access	No access	No (tree cleared)	n/a	n/a
HT05923	Suitable, no evidence of breeding	*Eucalyptus wandoo*	Yes	Yes	No (tree cleared)	n/a	n/a
HT05938	Suitable, no evidence of breeding	*Eucalyptus wandoo*	Yes	No	No (not suitable – hollow has cracked or degraded)	n/a	n/a
HT05947	Suitable, no evidence of breeding	*Eucalyptus wandoo*	Yes	No	Yes	Yes	Yes
HT05954	Evidence of nesting activity	*Eucalyptus wandoo*	Yes	Yes	Yes	Yes	Yes
HT06017	Evidence of nesting activity	*Eucalyptus wandoo*	No access	Yes	Yes	Yes	Yes
HT06020	Suitable, no evidence of breeding	*Corymbia calophylla*	No access	Yes	No (tree cleared)	n/a	n/a
HT06025	Suitable, no evidence of breeding	*Eucalyptus wandoo*	No access	Yes	Yes	Yes	Yes
HT06046	Suitable, no evidence of breeding	*Eucalyptus wandoo*	No access	Yes	No (tree cleared)	n/a	n/a
HT06148	Suitable, no evidence of breeding	*Corymbia calophylla*	Yes	No	No (not suitable – hollow has cracked or degraded)	n/a	n/a
HT06160	Suitable, no evidence of breeding	*Eucalyptus wandoo*	Yes	Yes	Yes	Yes	Yes
HT06201	Suitable, no evidence of breeding	*Eucalyptus wandoo*	Yes	Yes	Yes	Yes	Yes
HT06216	Suitable, no evidence of breeding	*Eucalyptus marginata*	Yes	Yes	Yes	Yes	Yes
HT06261	Suitable, no evidence of breeding	*Eucalyptus wandoo*	Yes	Yes	No (tree cleared)	n/a	n/a
HT06278	Evidence of nesting activity	*Eucalyptus wandoo*	Yes	Yes	No (tree cleared)	n/a	n/a
HT06330	Not currently suitable	*Eucalyptus wandoo*	No	Yes	Yes	No (tree cleared)	n/a

			Baseline		Monitoring season 1	Monitoring season 2	Monitoring season 3
HT ID*	**Baseline records (pre-2017)**	**Species**	**2017-18**	**2018-19**	**2019-20**	**2020-21**	**2021-22**
HT06348	Evidence of nesting activity	*Eucalyptus wandoo*	Yes	Yes	Yes	Yes	Yes
HT06421	Evidence of nesting activity	*Corymbia calophylla*	No access	No access	No (no access)	n/a	n/a
HT06655	Suitable, no evidence of breeding	*Corymbia calophylla*	Yes	No	No (tree cleared)	n/a	n/a
HT06678	Suitable, no evidence of breeding	*Eucalyptus wandoo*	Yes	Yes	Yes	Yes	Yes
HT08752	Evidence of nesting activity	*Eucalyptus wandoo*	Yes	Yes	No (tree cleared)	n/a	n/a
HT08753	Evidence of nesting activity	*Eucalyptus wandoo*	Yes	Yes	No (tree cleared)	n/a	n/a
HT08754	Evidence of nesting activity	*Eucalyptus wandoo*	No access	Yes	No (tree cleared)	n/a	n/a
HT12761	Evidence of nesting activity	*Eucalyptus wandoo*	No	No	Yes	No (not suitable – hollow has cracked or degraded)	No (not suitable – hollow has cracked or degraded)
HT12762	Evidence of nesting activity	*Eucalyptus wandoo*	Yes	Yes	Yes	Yes	Yes
HT12763	Evidence of nesting activity (FRTBC)	*Eucalyptus wandoo*	Yes	Yes	Yes	Yes	Yes
HT12765	Evidence of nesting activity	*Eucalyptus wandoo*	Yes	Yes	Yes	Yes	Yes
HT13484	Suitable, no evidence of breeding	*Eucalyptus wandoo*	No access	Yes	Yes	Yes	Yes
HT13497	Suitable, no evidence of breeding	*Eucalyptus marginata*	No access	Yes	Yes	Yes	Yes
HT13503	Suitable, no evidence of breeding	*Eucalyptus marginata*	No access	Yes	No (not suitable – hollow has cracked or degraded)	n/a	n/a
HT13505	Suitable, no evidence of breeding	*Eucalyptus sp.*	No access	Yes	No (not suitable – hollow has cracked or degraded)	n/a	n/a
HT13506	Suitable, no evidence of breeding	*Eucalyptus wandoo*	No access	Yes	Yes	Yes	Yes
HT13507	Suitable, no evidence of breeding	*Eucalyptus wandoo*	No access	Yes	Yes	Yes	Yes
HT13508	Suitable, no evidence of breeding	*Eucalyptus wandoo*	No access	Yes	Yes	Yes	Yes
HT13511	Suitable, no evidence of breeding	*Corymbia calophylla*	No access	Yes	No (not suitable – hollow has cracked or degraded)	n/a	n/a

			Baseline		Monitoring season 1	Monitoring season 2	Monitoring season 3
HT ID*	**Baseline records (pre-2017)**	**Species**	**2017-18**	**2018-19**	**2019-20**	**2020-21**	**2021-22**
HT13523	Suitable, no evidence of breeding	*Eucalyptus wandoo*	No access	Yes	No (not suitable – hollow has cracked or degraded)	n/a	n/a
HT13533	Suitable, no evidence of breeding	*Eucalyptus wandoo*	Yes	Yes	No (tree cleared)	n/a	n/a
HT13534	Suitable, no evidence of breeding	*Eucalyptus wandoo*	Yes	Yes	No (tree cleared)	n/a	n/a
HT13535	Suitable, no evidence of breeding	*Eucalyptus wandoo*	Yes	Yes	No (tree cleared)	n/a	n/a
HT13585	Not currently suitable	*Corymbia calophylla*	No	Yes	Yes	Yes	Yes
HT14633	Suitable, no evidence of breeding	*Eucalyptus wandoo*	Yes	Yes	Yes	Yes	Yes
HT14653	Evidence of nesting activity	*Eucalyptus wandoo*	Yes	Yes	Yes	Yes	Yes
HT14657	Evidence of nesting activity	*Eucalyptus wandoo*	Yes	Yes	Yes	Yes	Yes
HT14670	Evidence of nesting activity	*Eucalyptus wandoo*	Yes	No	No (not suitable – hollow collapsed)	n/a	n/a
HT14672	Evidence of nesting activity	*Eucalyptus wandoo*	Yes	Yes	Yes	Yes	Yes
HT14748	Evidence of nesting activity	*Eucalyptus wandoo*	Yes	Yes	Yes	Yes	Yes
HT14749	Evidence of nesting activity	*Eucalyptus wandoo*	Yes	Yes	Yes	Yes	Yes
HT14805	Evidence of nesting activity	*Eucalyptus wandoo*	No access	No access	No (not suitable – hollow has cracked or degraded)	n/a	n/a
HT14806	Evidence of nesting activity	*Eucalyptus wandoo*	No access	No access	No (not suitable – hollow has cracked or degraded)	n/a	n/a
HT14807	Suitable, no evidence of breeding	*Eucalyptus wandoo*	No access	No access	No (not suitable – hollow has cracked or degraded)	n/a	n/a
HT14808	Suitable, no evidence of breeding	*Eucalyptus wandoo*	No access	No access	No (not suitable – hollow has cracked or degraded)	n/a	n/a

			Baseline		Monitoring season 1	Monitoring season 2	Monitoring season 3
HT ID*	**Baseline records (pre-2017)**	**Species**	**2017-18**	**2018-19**	**2019-20**	**2020-21**	**2021-22**
HT14809	Evidence of nesting activity	*Eucalyptus wandoo*	Yes	Yes	Yes	Yes	Yes
HT14810	Evidence of nesting activity	*Eucalyptus wandoo*	Yes	Yes	Yes	Yes	Yes
HT14811	Evidence of nesting activity	*Eucalyptus wandoo*	Yes	Yes	Yes	Yes	Yes
NB01	n/a	n/a	n/a	Yes	Yes	Yes	Yes
NB02	n/a	n/a	n/a	Yes	Yes	Yes	Yes
NB03	n/a	n/a	n/a	Yes	Yes	Yes	Yes
NB04	n/a	n/a	n/a	Yes	Yes	Yes	Yes
NB05	n/a	n/a	n/a	Yes	Yes	Yes	Yes
NB06	n/a	n/a	n/a	Yes	Yes	Yes	Yes
NB08	n/a	n/a	n/a	Yes	Yes	Yes	Yes
NB09	n/a	n/a	n/a	Yes	Yes	Yes	Yes
NB10	n/a	n/a	n/a	Yes	Yes	Yes	Yes
NB11	n/a	n/a	n/a	Yes	Yes	Yes	Yes
NB12	n/a	n/a	n/a	Yes	Yes	Yes	Yes
NB13	n/a	n/a	n/a	Yes	Yes	Yes	Yes
NB14	n/a	n/a	n/a	Yes	Yes	Yes	Yes
NB32	n/a	n/a	n/a	Yes	Yes	Yes	Yes
NB33	n/a	n/a	n/a	Yes	Yes	Yes	Yes
NB34	n/a	n/a	n/a	n/a	Yes	Yes	Yes
NB41	n/a	n/a	n/a	n/a	Yes	Yes	Yes
NB42	n/a	n/a	n/a	n/a	Yes	Yes	Yes
NB46	n/a	n/a	n/a	Yes	Yes	Yes	Yes
NB55	n/a	n/a	n/a	Yes	Yes	Yes	Yes
NB57	n/a	n/a	n/a	Yes	Yes	Yes	Yes
NB58	n/a	n/a	n/a	Yes	Yes	Yes	Yes
NB59	n/a	n/a	n/a	Yes	Yes	Yes	Yes
NB60	n/a	n/a	n/a	Yes	Yes	Yes	Yes
NB61	n/a	n/a	n/a	Yes	Yes	Yes	Yes
NB62	n/a	n/a	n/a	Yes	Yes	Yes	Yes
NB63	n/a	n/a	n/a	Yes	Yes	Yes	Yes
NB64	n/a	n/a	n/a	Yes	Yes	Yes	Yes
NB65	n/a	n/a	n/a	Yes	Yes	Yes	Yes
NB66	n/a	n/a	n/a	Yes	Yes	Yes	Yes
NB67	n/a	n/a	n/a	Yes	Yes	Yes	Yes
NB68	n/a	n/a	n/a	Yes	Yes	Yes	Yes
NB69	n/a	n/a	n/a	Yes	Yes	Yes	Yes

			Baseline		Monitoring season 1	Monitoring season 2	Monitoring season 3
HT ID*	**Baseline records (pre-2017)**	**Species**	**2017-18**	**2018-19**	**2019-20**	**2020-21**	**2021-22**
NB71	n/a	n/a	n/a	Yes	Yes	Yes	Yes
NB76	n/a	n/a	n/a	Yes	Yes	Yes	Yes
NB77	n/a	n/a	n/a	Yes	Yes	Yes	Yes
NB78	n/a	n/a	n/a	Yes	Yes	Yes	Yes
NB79	n/a	n/a	n/a	Yes	Yes	Yes	Yes
NB99	n/a	n/a	n/a	Yes	Yes	Yes	Yes
NB100	HT04059 was cleared and this nest box was installed to replace it in 2019	n/a	n/a	n/a	Yes	Yes	Yes

* HT = habitat tree (natural); NB = nest box (artificial); HT (NB) = this tree had an artificial nest box installed prior to the baseline records (pre-2017) and has been counted as a natural habitat tree for the pre- and post- baseline analysis.

3 RESULTS

3.1 CENSUS RESULTS 2021-22 BREEDING SEASON

A total of 27 natural or artificial hollows recorded evidence of nesting activity or a confirmed breeding event during the 2021-22 breeding season. Confirmed breeding events were recorded in 21 artificial nesting hollows during the 2021-2022 monitoring season (Table 3; Figure 2). No confirmed breeding events were recorded in natural nesting hollows.

Of the confirmed breeding events:

- Thirteen were presumed to have resulted in successful fledging of a chick (NB01, NB02 NB06, NB08, NB32, NB33, NB34, NB41 NB46, NB61, NB62, NB68 and NB76).
- Eight nests resulted in unsuccessful breeding attempts:
    - four nests recorded dead chicks (NB04, NB10, NB71 and NB99)
    - three nests recorded broken or abandoned eggs (NB03, NB13, NB63)
    - one nest had a presumed predation where a downy chick was observed in the nest and the following visit was gone (NB69).

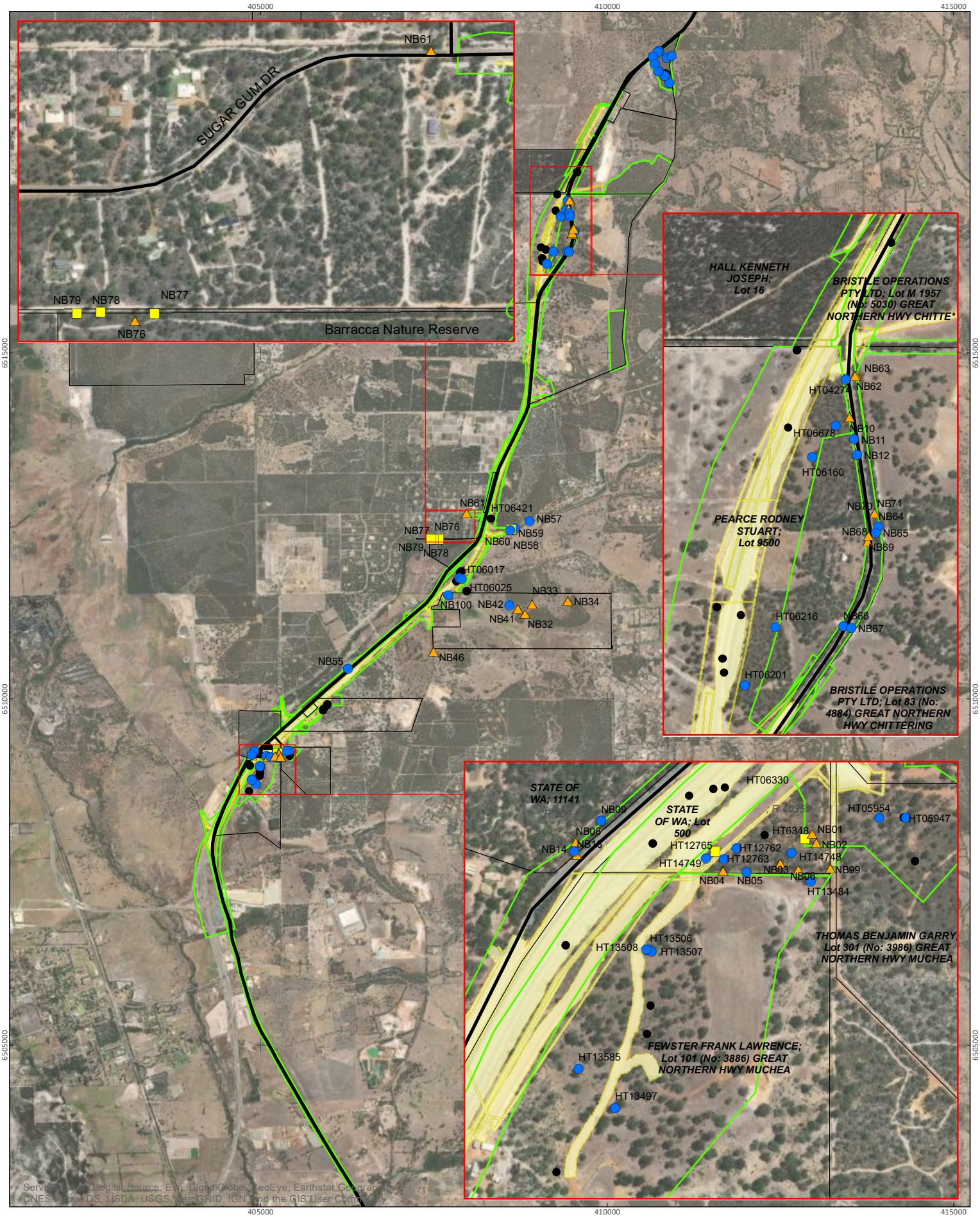
Evidence of nesting activity was observed in four artificial nesting hollows and two natural nesting hollows (Table 3; Figure 2). Of these, two were instances where females were flushed from an artificial nesting hollow, but a later inspection saw no chicks or eggs and the bird was likely to be prospecting. The remaining four hollows with evidence were observations of prospecting birds or recent chewing around the hollow or on the post.

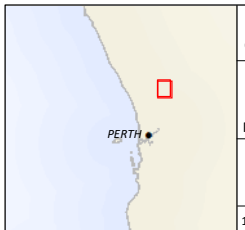
Table 3 Evidence of breeding records by Phoenix during the 2021-22 census

HT ID	Inspection date						Result
	27/08/2021	08/10/2021	13/11/2021	21/12/2021	27/01/2022	21/02/2022	
HT12765	Carnaby next to hollow						Evidence of nesting activity
HT14748	Pair of Carnaby's near hollow	Duck eggs	Duck eggs	Duck eggs			Evidence of nesting activity
NB01			Carnaby and chick in nest	Chick in nest	Chick fledged		Confirmed breeding event: assumed successful fledge
NB02	Carnaby flushed	Carnaby flushed		Pair at nest feeding chick			Confirmed breeding event: assumed successful fledge
NB03		Carnaby flushed	Broken egg				Confirmed breeding event: unsuccessful fledge
NB04		Carnaby flushed	Pin feathered chick	Large chick in nest	Remains of dead chick		Confirmed breeding event: unsuccessful fledge
NB06			Pin feathered chick in nest	Large chick in nest	Chick fledged		Confirmed breeding event: assumed successful fledge
NB08		Carnaby flushed	Carnaby flushed	Large chick in nest	Chick fledged		Confirmed breeding event: assumed successful fledge
NB10		Carnaby flushed	Two eggs. One broken and one possibly deserted	Dead chick			Confirmed breeding event: unsuccessful fledge
NB13		Heavily chewed post	Deserted egg				Confirmed breeding event: unsuccessful fledge
NB32			Downy chick in nest	Chick in nest	Large, feathered chick	Chick fledged	Confirmed breeding event: assumed successful fledge

HT ID	Inspection date						Result
	27/08/2021	08/10/2021	13/11/2021	21/12/2021	27/01/2022	21/02/2022	
NB33		Carnaby flushed	Carnaby flushed	Pair at nest feeding chick	Chick fledged		Confirmed breeding event: assumed successful fledge
NB34		Galah flushed	Downy chick in nest	Chick in nest	Chick fledged		Confirmed breeding event: assumed successful fledge
NB41		Carnaby flushed	Feathered chick	Nest empty possibly fledged			Confirmed breeding event: assumed successful fledge
NB46			Carnaby on nest	Pin feathered chick	Large, feathered chick	Chick fledged	Confirmed breeding event: assumed successful fledge
NB59		Pair at nest					Evidence of nesting activity
NB61				Chick in nest	Chick fledged		Confirmed breeding event: assumed successful fledge
NB62		Carnaby flushed	Downy chick in nest	Large, feathered chick	Chick fledged		Confirmed breeding event: assumed successful fledge
NB63				One predated egg and one deserted			Confirmed breeding event: unsuccessful fledge
NB68			Large, feathered chick	Large, feathered chick	Chick fledged		Confirmed breeding event: assumed successful fledge
NB69			Downy chick in nest	Broken eggs in nest			Confirmed breeding event: unsuccessful fledge predated?
NB71		Carnaby flushed and two eggs in nest	Dead chick				Confirmed breeding event: unsuccessful fledge
NB76		Carnaby flushed	Pin feathered chick	Nest empty possibly fledged			Confirmed breeding event: assumed successful fledge
NB77		Carnaby flushed					Evidence of nesting activity
NB78		Carnaby flushed					Evidence of nesting activity

HT ID	Inspection date						Result
	27/08/2021	08/10/2021	13/11/2021	21/12/2021	27/01/2022	21/02/2022	
NB79		Post heavily chewed	Dead bird (unknown)				Evidence of nesting activity
NB99			Carnaby flushed	Chick in nest	Remains of dead chick		Confirmed breeding event: unsuccessful fledge





Main Roads WA
Great Northern Highway, M2W Upgrade Project

Project No	1415
Date	27-Apr-22
Drawn by	AJ
Map author	AJ

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Kilometers

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Study area
Disturbance footprint
Road

Results

- Confirmed breeding event
- Evidence of nesting activity
- No evidence of breeding
- Not surveyed (no access/no longer suitable, cleared)

Figure 2

Monitoring results for 2021-22 breeding season

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Figure 3 Female perched a nest box NB08 (November 2021)

Figure 4 Chick in nest box (NB04) (November 2021)

3.2 COMPARISON BETWEEN BREEDING SEASONS

The number of hollows which had confirmed Carnaby's Cockatoo breeding events in the 2021-22 breeding season is significantly higher than both the pre-impact average and the previous year's (2020-2021) post-impact survey. Overall, the number of confirmed breeding events in 2021-2022 (21) was more than four times that of the pre-impact average of five (Table 4).

The rate of unsuccessful breeding events is standard across the monitoring project so far, with the first two post-impact monitoring seasons displaying a 75% successful breeding rate and the current season having a 62% successful breeding rate. This is consistent with historic data from a survey undertaken at Coomallo Creek (100 km north of the study area near Jurien Bay) between 1970 and 1976 where the breeding success rate from 482 nests was 64.7%(Saunders 1982). Breeding success rate is thought to be highly dependent on food availability (DAWE 2022).

Most significantly, the results of the monitoring program clearly show a trend towards increased usage of the artificial nesting hollows installed under the Muchea North offset. The nest boxes were installed during the 2018-2019 breeding season, so there were few records of use of these during that season, with only one confirmed breeding event and two records of evidence of nesting activity (Table 4). This increased in the 2019-2020 breeding season to three confirmed breeding events and 11 records of nesting activity in the artificial nesting hollows. In 2020-2021, the number of confirmed breeding events in the artificial nesting hollows increased to 12, with the majority assumed to have had a successful outcome i.e., a chick hatched and fledged (Table 4). In 2021-2022 it increased further again to 21, all of which were in the artificial nesting hollows (Table 4).

In contrast, the number of confirmed breeding events in natural nest hollows declined from three in the 2019-2020 season to one in the 2020-2021 season and to none in the current breeding season. The results suggest the birds are preferentially choosing the artificial hollows over the natural hollows.

The number of nest hollows, both artificial and natural, with evidence of nesting has decreased over the last three monitoring seasons; however, variability was also noted in surveys conducted in the pre-impact years, and the post-impact average is not notably higher than the pre-impact average. Although, the total number of nesting hollows is 25% higher in the post-impact average, this equates to a general decline. The number of natural breeding hollows with evidence of nesting was comparatively high in the first two pre-impact surveys (pre-2017-2018 and 2017-2018 breeding season), with 24 and 14 natural hollows recording evidence of nesting respectively. This reduced to three, four, six and two in subsequent years. The number of artificial nesting hollows with evidence of nesting also reduced in the post-impact breeding seasons; however, this coincided with the increased number of confirmed breeding events suggesting higher overall confirmed breeding rates are occurring in the artificial nesting boxes.

Of the 21 nesting hollows which recorded a confirmed breeding event in the current breeding season, 10 also had a confirmed breeding activity in the previous (2020-21) season and three had a successful breeding event in the 2019-2020 season.

Of the 71 hollows surveyed as part of the post-impact monitoring surveys, 43 have had at least one confirmed breeding event or displayed evidence of nesting activity. Of these, 32 have recorded at least one confirmed breeding event (Figure 5).

In the three post-impact monitoring survey periods completed so far, a total of 21, 26 and 27 hollows have recorded evidence of nesting activity or a confirmed breeding event, respectively. This indicates the artificial nesting hollows are being successfully used by Carnaby's Black Cockatoo, thus meeting the completion crietria for adaptive management under condition 4d. of the EPBC 2016/7656 (DotEE 2018) which states "*adaptive management may cease when at least one artificial nesting hollow for each known nesting hollow cleared has shown evidence of use by the Carnaby's Black Cockatoo, as*

verified by the suitable qualified person, for three consecultive years; the artificial nesting hollow in use for three consecutive years need not be the same artificial nesting hollow each year".

Four distinct areas appear to be favoured for nesting in the 2021-22 season (Figure 4):

- Nesci estate – This was a location where several artificial nesting hollows were installed after it was observed that Carnaby's Cockatoos were present in higher numbers, indicating the area could be a favourable breeding area (Phoenix 2017b).
- Reserve 40350 – This location was identified in the baseline surveys as having a relatively high number of nesting trees (Phoenix 2017b). As several potential breeding trees were removed from this area, a concentration of nest boxes were installed here. This area has displayed consistent use as a breeding area.
- Road reserve adjacent to lot 9500 – this location previously had suitable hollows; therefore artificial nest boxes were installed. The prevalence of hollows with confirmed breeding events and/or evidence of breeding has increased substantially in the 2021-22 breeding season.
- Barraca Nature Reserve – Three artificial nest boxes were installed and have displayed an increase in evidence of nesting activity over the course of the post-impact monitoring surveys.

In contrast, Lot 512 in the northern part of the study area previously had a higher rate of hollows with evidence of nesting activity and/or confirmed breeding events. In the current breeding season however, none of the natural or artificial nests in this area were observed to have any evidence of nesting or confirmed breeding events.

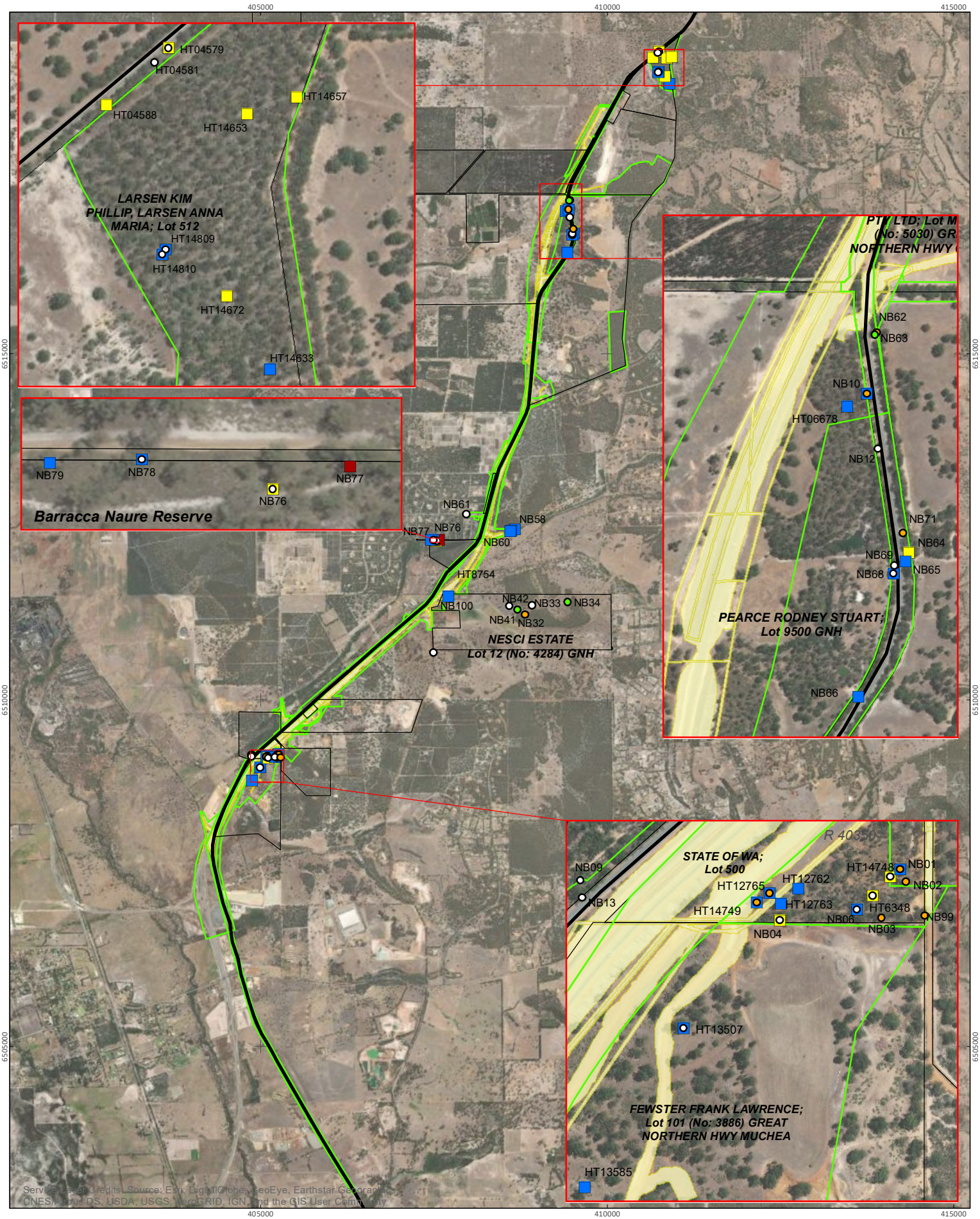
3.1 CONDITION OF ARTIFICIAL NESTING HOLLOWS

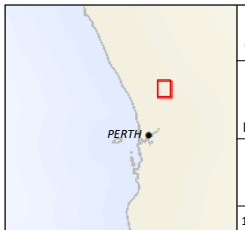
All of the artificial nesting hollows surveyed were observed to be in good condition.

Table 4 Summary of results for each breeding season

Result type	Baseline records pre-2017-18[1] Natural hollows and existing aritificial hollows	2017-18 breeding season Natural hollows and existing aritificial hollows	2018-19 breeding season All hollows (natural & existing artificial hollows/new artificial hollows)	Pre-impact average (2017-18 and 2018-19) All hollows	2019-20 breeding season All hollows (natural & existing artificial hollows/new artificial hollows)	2020-21 breeding season All hollows (natural & existing artificial hollows/new artificial hollows)	2021-22 breeding season All hollows (natural & existing artificial hollows/new artificial hollows)	Post-impact average (2019-20 to 2021-22) All hollows
Confirmed breeding event	n/a	6 (50% successful)	3 (2/1) (100% successful)	5	6 (3/3) (75% successful)	13 (1/12) (75% successful)	21 (0/21) (62% successful)	13
Evidence of nesting activity	24	14	5 (3/2)	10	15 (4/11)	13 (6/7)	6 (2/4)	11
No evidence of breeding	35	13	63 (30/33)	38	52 (25/27)	45 (24/21)	44 (29/15)	47
Total no. hollows surveyed	59	33	71 (plus 12 hollows that were removed during survey period)	53	73	71	71	71
Trees not surveyed: no longer suitable, not accessible, cleared	n/a	26	25 (24/1)	23	17 (17/0)	19 (19/0)	19 (29/0)	21

[1] Evidence of nesting activity recorded at some point. Not annual census data and cannot be compared with annual census results.





Main Roads WA
Great Northern Highway, M2W Upgrade Project

Project No	1333
Date	27-Apr-22
Drawn by	AJ
Map author	AJ

0 1 2
Kilometers

1:70,000 (at A4) GCS WGS 1984

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Study area
Disturbance footprint
Road

Hollows with confirmed breeding events
- 1 confirmed breeding event
- 2 confirmed breeding events
- 3 confirmed breeding events

Hollows with evidence of nesting activity
- 1 year of evidence of nesting activity
- 2 years of evidence of nesting activity
- 3 years of evidence of nesting activity

* years may or may not be consecutive

Figure 5

Confirmed breeding events and evidence of nesting activity across five breeding seasons (2017-2022)

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4 CONCLUSION AND RECOMMENDATIONS

The 2021-2022 breeding season results indicate that breeding activity is occurring mainly throughout the Nesci Estate and surrounding road reserve of the Muchea North area and that it is an important breeding area for Carnaby's Cockatoo. The current breeding season was remarkably more successful than previous seasons, with a significantly higher number of confirmed breeding events recorded compared with the last breeding season and more than four times the pre-impact average. There was a clear trend towards confirmed breeding in the artificial nesting hollows.

The difference in nesting activity recorded between the breeding seasons is not unexpected as the sample size for this monitoring program is small and breeding activity can be highly variable between years; however, the increased rate of post-impact breeding observed over the past three years is promising for mitigating population decline.

The willingness of Carnabys Cockatoo to utilise the artificial nesting hollows as an alternative to natural nest hollows is evident from the 2021-2022 breeding data. Considering the artificial nesting hollows were installed during the 2018-2019 season, the uptake of many of these for breeding and several more with evidence of nesting activity in the first three years post-installation is encouraging, particularly this breeding season where there were only confirmed breeding events in artificial nesting hollows and not in natural nesting hollows.

The repeated use of the same hollows suggests that Carnaby's Cockatoo have preferred locations, either in the landscape, breeding areas or within the tree itself.

The generally consistent rate of unsuccessful breeding events across the monitoring project suggests that the shift from natural to artificial hollows has not resulted in an increase in failed breeding.

All the artificial nesting hollows were in good condition, therefore none require any maintenance.

Due to the historic large-scale clearing of trees and continuing decline of suitable trees with hollows in the area, all remaining suitable nesting hollows in the study area should be considered of high value to Carnaby's Cockatoo.

Under EPBC 2016/7656 (DotEE 2018), condition 4d states: "*Adaptive management may cease when at least one artificial nesting hollow for each known nesting hollow cleared has shown evidence of use by the Carnaby's Black Cockatoo, as verified by the suitable qualified person, for three consecutive years; the artificial nesting hollow in use for three consecutive years need not be the same artificial nesting hollow each year*". In each of the three post-impact monitoring survey periods completed so far, more than 13 hollows (the number of nesting hollows cleared) have recorded evidence of nesting activity or a confirmed breeding event. This indicates the artificial nesting hollows are being successfully used by Carnaby's Cockatoo, thus meeting the completion criteria for adaptive management.

For future monitoring of the nesting hollows, consistent methodology should be employed to that used in the 2019-2020 and 2020-2021 and 2021-2022 breeding censuses, including continuing the use of pole cameras to inspect suspected breeding events where possible.

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Appendix 1 Results for all hollows in all breeding seasons

HT ID	Result 2017-18	Result 2018-19	Result 2019-20	Result 2020-2021	Result 2021-2022
HT04059	No evidence of breeding	No evidence of breeding	Tree cleared. Further monitoring not required	n/a	n/a
HT04274	No evidence of breeding	No evidence of breeding	No evidence of breeding	No evidence of breeding	No evidence of breeding
HT04579	Confirmed breeding event - failed	No evidence of breeding	No evidence of breeding	Evidence of nesting activity	No evidence of breeding
HT04581	Confirmed breeding event - failed	No evidence of breeding	No evidence of breeding	No evidence of breeding	No evidence of breeding
HT04588	Evidence of nesting activity	No evidence of breeding	Evidence of nesting activity	No evidence of breeding	No evidence of breeding
HT05911	No access	Hollow not located	Tree cleared. Further monitoring not required	n/a	n/a
HT05923	No evidence of breeding	Tree cleared. Further monitoring not required	n/a	n/a	n/a
HT05938	No longer suitable hollow. Further monitoring not required	n/a	n/a	n/a	n/a
HT05947	No evidence of breeding	Not located	No evidence of breeding	No evidence of breeding	No evidence of breeding
HT05954	No evidence of breeding	No evidence of breeding	No evidence of breeding	No evidence of breeding	No evidence of breeding
HT06017	No access	No evidence of breeding	No evidence of breeding	No evidence of breeding	No evidence of breeding
HT06020	No access	Tree cleared. Further monitoring not required	n/a	n/a	n/a
HT06025	No access	No evidence of breeding	No evidence of breeding	No evidence of breeding	No evidence of breeding
HT06046	No access	Tree cleared. Further monitoring not required	n/a	n/a	n/a
HT06148	No longer suitable. Further monitoring not required	n/a	n/a	n/a	n/a
HT06160	No evidence of breeding	No evidence of breeding	No evidence of breeding	No evidence of breeding	No evidence of breeding
HT06201	No evidence of breeding	No evidence of breeding	No evidence of breeding	No evidence of breeding	No evidence of breeding

HT ID	Result 2017-18	Result 2018-19	Result 2019-20	Result 2020-2021	Result 2021-2022
HT06216	No evidence of breeding	No evidence of breeding	No evidence of breeding	No evidence of breeding	No evidence of breeding
HT06261	No evidence of breeding	Tree cleared. Further monitoring not required.	n/a	No evidence of breeding	n/a
HT06278	Evidence of nesting activity	Tree cleared. Further monitoring not required.	n/a	No evidence of breeding	n/a
HT06330	Not sampled	No evidence of breeding. Added to breeding census in 2018-19	No evidence of breeding	No evidence of breeding	n/a
HT06348	Evidence of nesting activity	No evidence of breeding	Confirmed breeding event - failed	Evidence of nesting activity	No evidence of breeding
HT06421	No access. Evidence of nesting activity (from a distance)	No access	n/a	n/a	n/a
HT06655	No longer suitable. Further monitoring not required	Tree cleared. Further monitoring not required	n/a	n/a	n/a
HT06678	Evidence of nesting activity (FRTBC)	No evidence of breeding	No evidence of breeding	No evidence of breeding	No evidence of breeding
HT08752	No evidence of breeding	Tree cleared. Further monitoring not required	n/a	n/a	n/a
HT08753	Evidence of nesting activity	No evidence of breeding	Tree cleared. Further monitoring not required	n/a	n/a
HT08754	No access	Confirmed breeding event	Tree cleared. Further monitoring not required	n/a	n/a
HT12761	Hollow not located	Hollow not located	No evidence of breeding	n/a	No evidence of breeding
HT12762	Evidence of nesting activity	No evidence of breeding	No evidence of breeding	No evidence of breeding	No evidence of breeding
HT12763	Evidence of nesting activity	No evidence of breeding	No evidence of breeding	No evidence of breeding	No evidence of breeding
HT12765	Confirmed breeding event - successful	No evidence of breeding	Confirmed breeding event	No evidence of breeding	Evidence of nesting activity
HT13484	No access	No evidence of breeding	No evidence of breeding	No evidence of breeding	No evidence of breeding
HT13497	No access	No evidence of breeding	No evidence of breeding	No evidence of breeding	No evidence of breeding

HT ID	Result 2017-18	Result 2018-19	Result 2019-20	Result 2020-2021	Result 2021-2022
HT13503	No access	No longer suitable. Further monitoring not required	n/a	n/a	n/a
HT13505	No access	No longer suitable. Further monitoring not required	n/a	n/a	n/a
HT13506	No access	No evidence of breeding	No evidence of breeding	No evidence of breeding	No evidence of breeding
HT13507	No access	Evidence of nesting activity	No evidence of breeding	No evidence of breeding	No evidence of breeding
HT13508	No access	No evidence of breeding	No evidence of breeding	No evidence of breeding	No evidence of breeding
HT13511	No access	No longer suitable. Further monitoring not required	n/a	n/a	n/a
HT13523	No access	No longer suitable. Further monitoring not required	n/a	n/a	n/a
HT13533	No evidence of breeding	No evidence of breeding	Tree cleared. Further monitoring not required	n/a	n/a
HT13534	Evidence of nesting activity	Tree cleared. Further monitoring not required	n/a	n/a	n/a
HT13535	Evidence of nesting activity	Tree cleared. Further monitoring not required	n/a	n/a	n/a
HT13585	Not sampled	No evidence of breeding. Added to breeding census in 2018-19, chewing observed at hollow	Evidence of nesting activity	No evidence of breeding	No evidence of breeding
HT14633	Evidence of nesting activity	No evidence of breeding	No evidence of breeding	No evidence of breeding	No evidence of breeding
HT14653	Evidence of nesting activity	No evidence of breeding	No evidence of breeding	Evidence of nesting activity	No evidence of breeding
HT14657	No evidence of breeding	No evidence of breeding	Evidence of nesting activity	Evidence of nesting activity	No evidence of breeding
HT14670	Collapsed, no longer suitable. Further monitoring not required	n/a	n/a	n/a	n/a
HT14672	Evidence of nesting activity	Evidence of nesting activity	No evidence of breeding	No evidence of breeding	No evidence of breeding

HT ID	Result 2017-18	Result 2018-19	Result 2019-20	Result 2020-2021	Result 2021-2022
HT14748	Confirmed breeding event - successful	Evidence of nesting activity	No evidence of breeding	No evidence of breeding	Evidence of nesting activity
HT14749	Confirmed breeding event - successful	Confirmed breeding event	No evidence of breeding	Evidence of nesting activity	No evidence of breeding
HT14805	No access	No access	No longer suitable. Further monitoring not required	n/a	n/a
HT14806	No access	No access	No longer suitable. Further monitoring not required	n/a	n/a
HT14807	No access	No access	No longer suitable. Further monitoring not required	n/a	n/a
HT14808	No access	No access	No longer suitable. Further monitoring not required	n/a	n/a
HT14809	Evidence of nesting activity	No evidence of breeding	No evidence of breeding	Confirmed breeding event	No evidence of breeding
HT14810	Confirmed breeding event - failed	No evidence of breeding	No evidence of breeding	Evidence of nesting activity	No evidence of breeding
HT14811	No evidence of breeding	No evidence of breeding	No evidence of breeding	No evidence of breeding	No evidence of breeding
NB01	n/a	No evidence of breeding	Evidence of nesting activity	Confirmed breeding event	Confirmed breeding event
NB02	n/a	Confirmed breeding event	No evidence of breeding	No evidence of breeding	Confirmed breeding event
NB03	n/a	No evidence of breeding	No evidence of breeding	Confirmed breeding event	Confirmed breeding event
NB04	n/a	No evidence of breeding	Evidence of nesting activity	Evidence of nesting activity	Confirmed breeding event
NB05	n/a	No evidence of breeding	No evidence of breeding	No evidence of breeding	No evidence of breeding
NB06	n/a	No evidence of breeding	No evidence of breeding	Evidence of nesting activity	Confirmed breeding event
NB08	n/a	No evidence of breeding	No evidence of breeding	No evidence of breeding	Confirmed breeding event
NB09	n/a	No evidence of breeding	No evidence of breeding	No evidence of breeding	No evidence of breeding
NB10	n/a	No evidence of breeding	Evidence of nesting activity	Confirmed breeding event	Confirmed breeding event
NB11	n/a	No evidence of breeding	No evidence of breeding	No evidence of breeding	No evidence of breeding

HT ID	Result 2017-18	Result 2018-19	Result 2019-20	Result 2020-2021	Result 2021-2022
NB12	n/a	No evidence of breeding	No evidence of breeding	Confirmed breeding event	No evidence of breeding
NB13	n/a	No evidence of breeding	No evidence of breeding	No evidence of breeding	Confirmed breeding event
NB14	n/a	No evidence of breeding	No evidence of breeding	No evidence of breeding	No evidence of breeding
NB32	n/a	No evidence of breeding/no access	No evidence of breeding	Confirmed breeding event	Confirmed breeding event
NB33	n/a	No evidence of breeding/no access	No evidence of breeding	No evidence of breeding	Confirmed breeding event
NB34	n/a	n/a	Confirmed breeding event	Confirmed breeding event	Confirmed breeding event
NB41	n/a	n/a	Confirmed breeding event	Confirmed breeding event	Confirmed breeding event
NB42	n/a	n/a	No evidence of breeding	Evidence of nesting activity	No evidence of breeding
NB46	n/a	No evidence of breeding	No evidence of breeding	No evidence of breeding	Confirmed breeding event
NB55	n/a	No evidence of breeding	No evidence of breeding	No evidence of breeding	No evidence of breeding
NB57	n/a	No evidence of breeding	No evidence of breeding	No evidence of breeding	No evidence of breeding
NB58	n/a	No evidence of breeding	Evidence of nesting activity	No evidence of breeding	No evidence of breeding
NB59	n/a	No evidence of breeding	No evidence of breeding	No evidence of breeding	Evidence of nesting activity
NB60	n/a	No evidence of breeding	Evidence of nesting activity	No evidence of breeding	No evidence of breeding
NB61	n/a	No evidence of breeding	No evidence of breeding	No evidence of breeding	Confirmed breeding event
NB62	n/a	No evidence of breeding	No evidence of breeding	Confirmed breeding event	Confirmed breeding event
NB63	n/a	No evidence of breeding	Confirmed breeding event	Confirmed breeding event	Confirmed breeding event
NB64	n/a	Evidence of nesting activity	Evidence of nesting activity	Evidence of nesting activity	No evidence of breeding
NB65	n/a	No evidence of breeding	Evidence of nesting activity	No evidence of breeding	No evidence of breeding
NB66	n/a	Evidence of nesting activity	No evidence of breeding	No evidence of breeding	No evidence of breeding

HT ID	Result 2017-18	Result 2018-19	Result 2019-20	Result 2020-2021	Result 2021-2022
NB67	n/a	No evidence of breeding	No evidence of breeding	No evidence of breeding	No evidence of breeding
NB68	n/a	No evidence of breeding	Evidence of nesting activity	No evidence of breeding	Confirmed breeding event
NB69	n/a	No evidence of breeding	No evidence of breeding	No evidence of breeding	Confirmed breeding event
NB71	n/a	No evidence of breeding	No evidence of breeding	Confirmed breeding event	Confirmed breeding event
NB76	n/a	No evidence of breeding	Evidence of nesting activity	Evidence of nesting activity	Confirmed breeding event
NB77	n/a	No evidence of breeding	Evidence of nesting activity	Evidence of nesting activity	Evidence of nesting activity
NB78	n/a	No evidence of breeding	No evidence of breeding	Confirmed breeding event	Evidence of nesting activity
NB79	n/a	No evidence of breeding	No evidence of breeding	Evidence of nesting activity	Evidence of nesting activity
NB99	n/a	No evidence of breeding	No evidence of breeding	Confirmed breeding event	Confirmed breeding event
NB100	n/a	n/a	Evidence of nesting activity	No evidence of breeding	No evidence of breeding