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

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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.

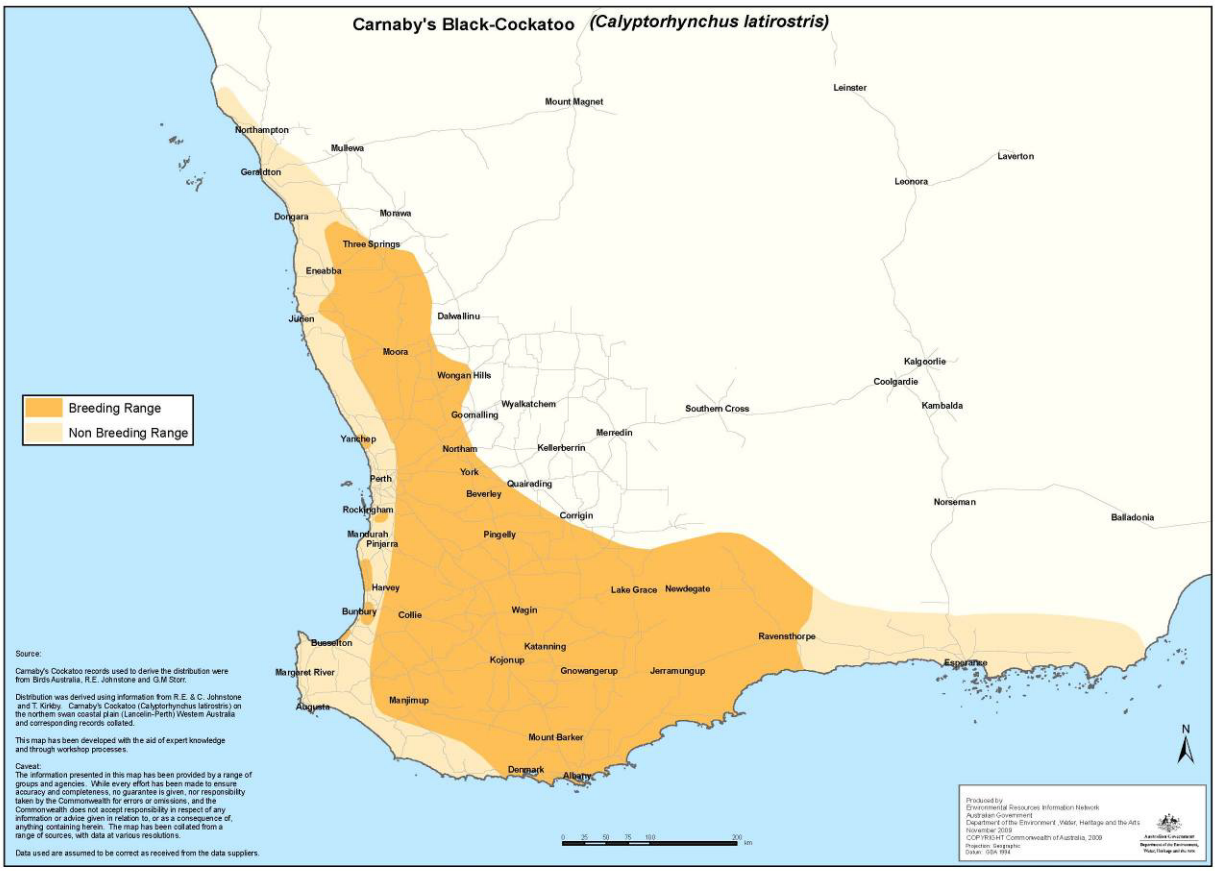
2 Introduction

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

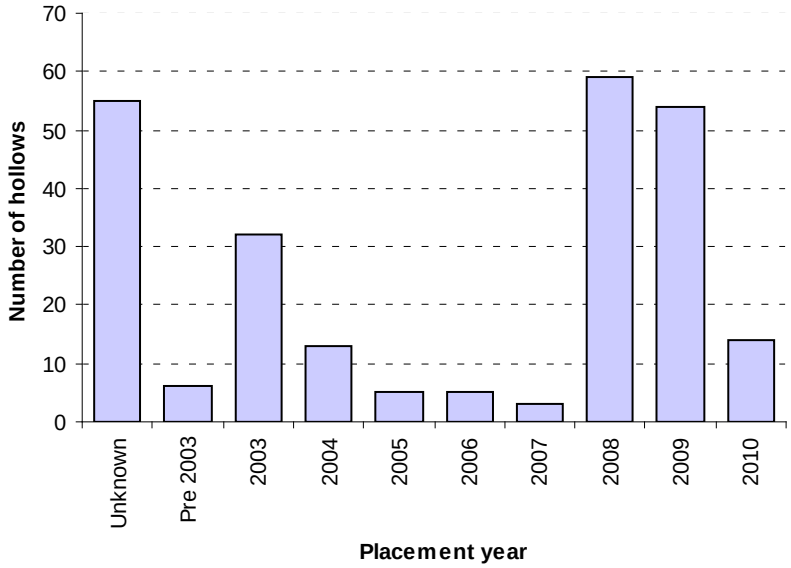
4.3.1 Timing

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.

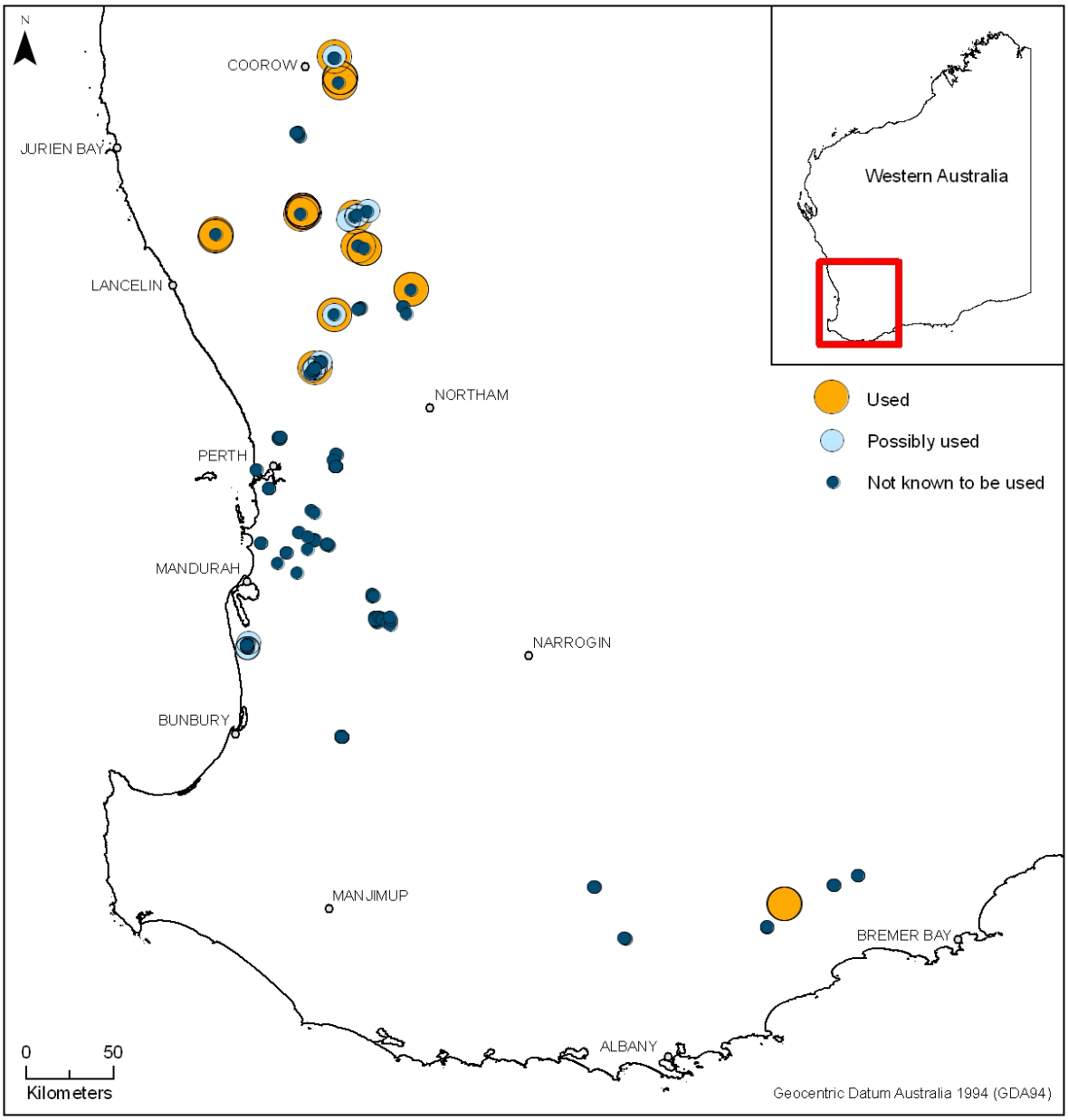


4.3.2 Distribution

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.

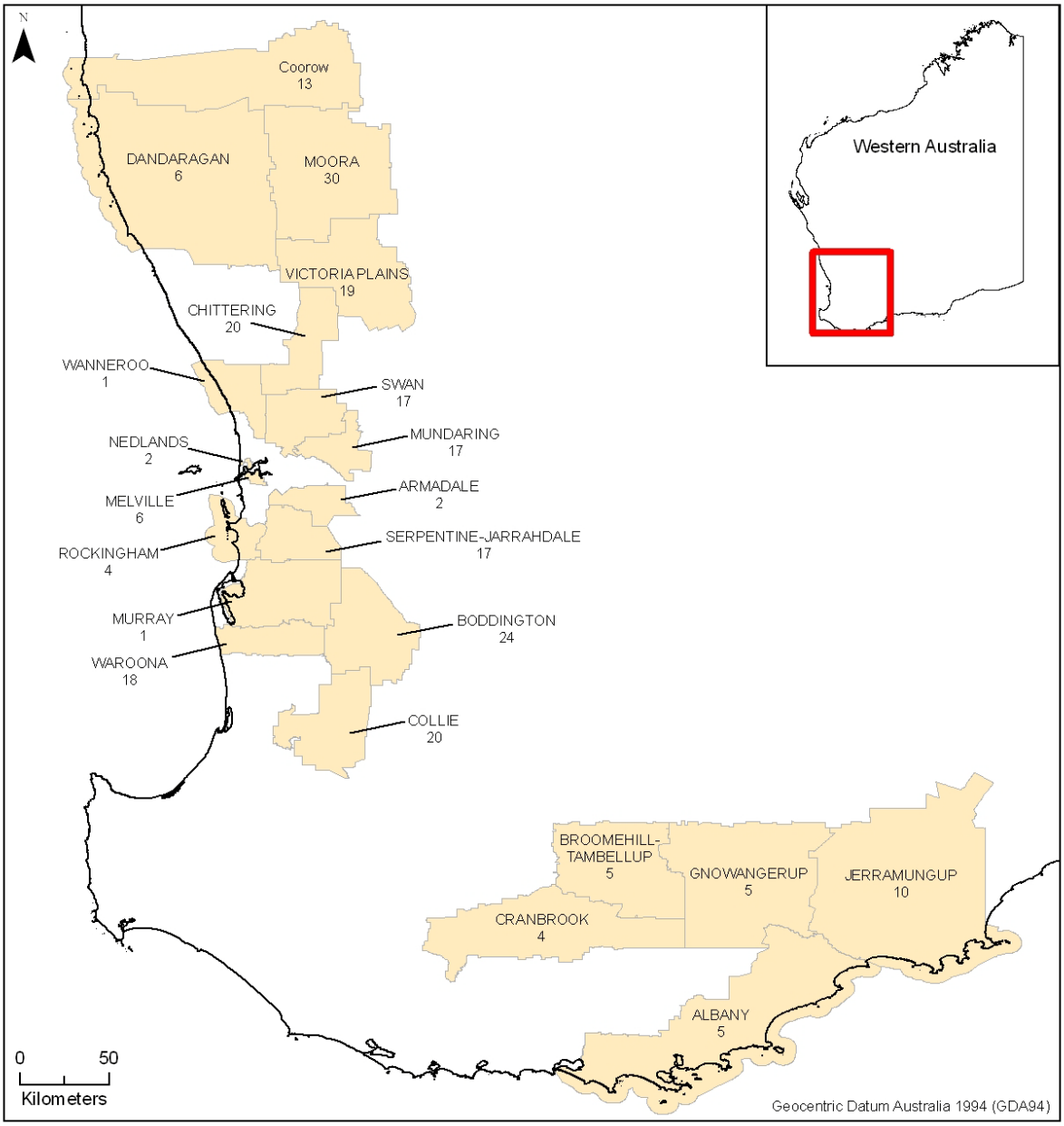
Artificial hollows that have been used by the cockatoos have predominantly been located in the northern agricultural areas, with a site near Borden and south of Mandurah being exceptions. No artificial hollows built for black cockatoos and placed in jarrah/marri forest areas were identified as being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

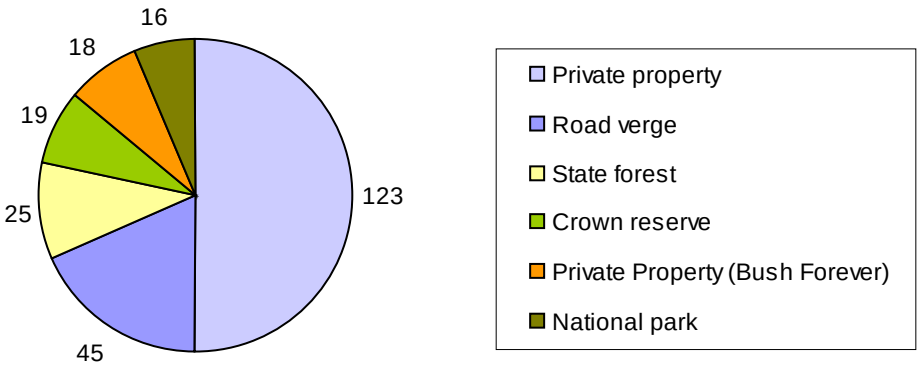
Figure 4: Distribution of artificial hollows by Local Government Authority. The numbers indicate the number of artificial hollows placed in that Shire.



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.

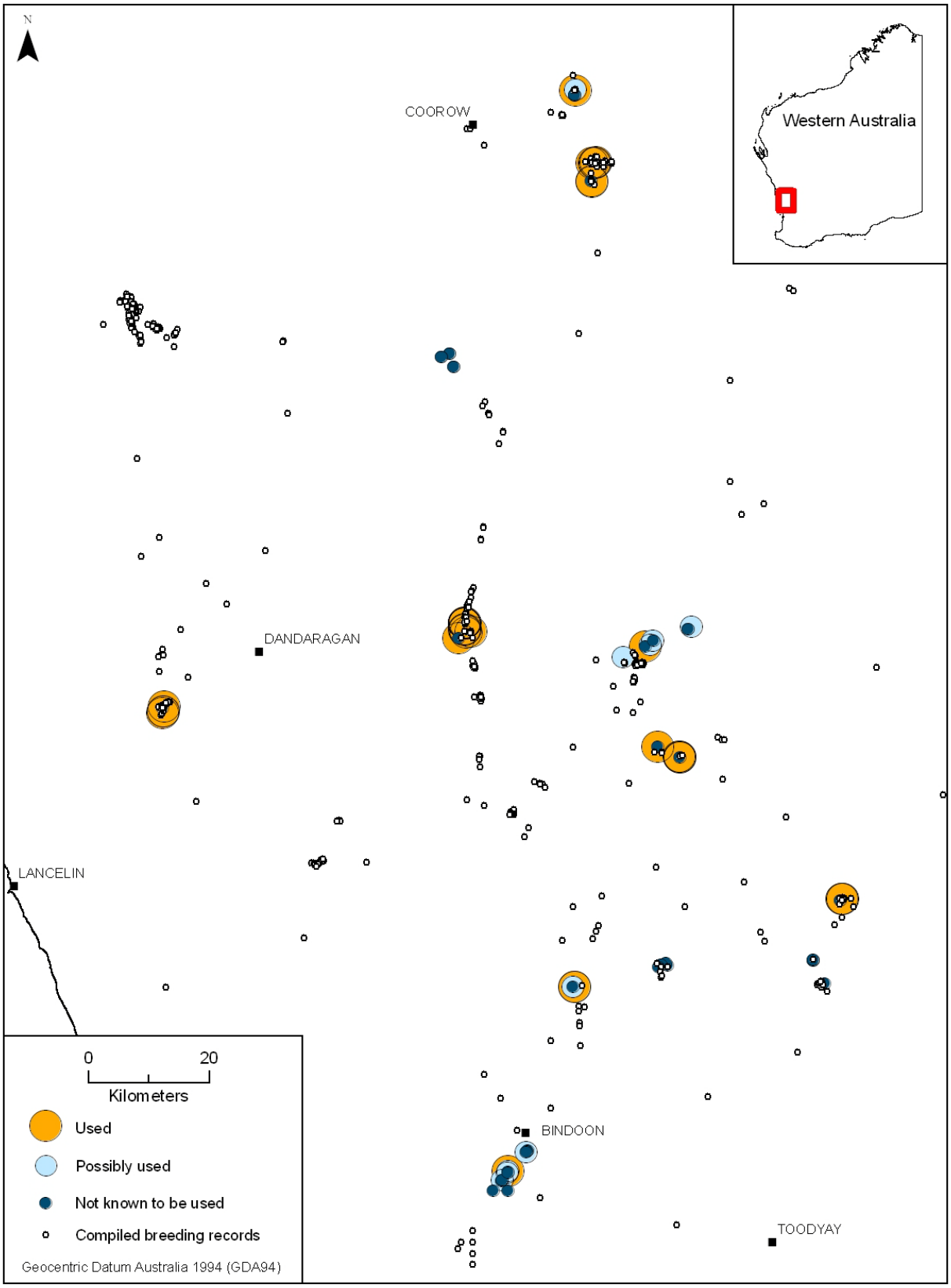


Figure 7: Central distribution of Carnaby's black cockatoo breeding records (a combination of known and probable nesting sites as well as observations of breeding behaviour) and artificial hollows.

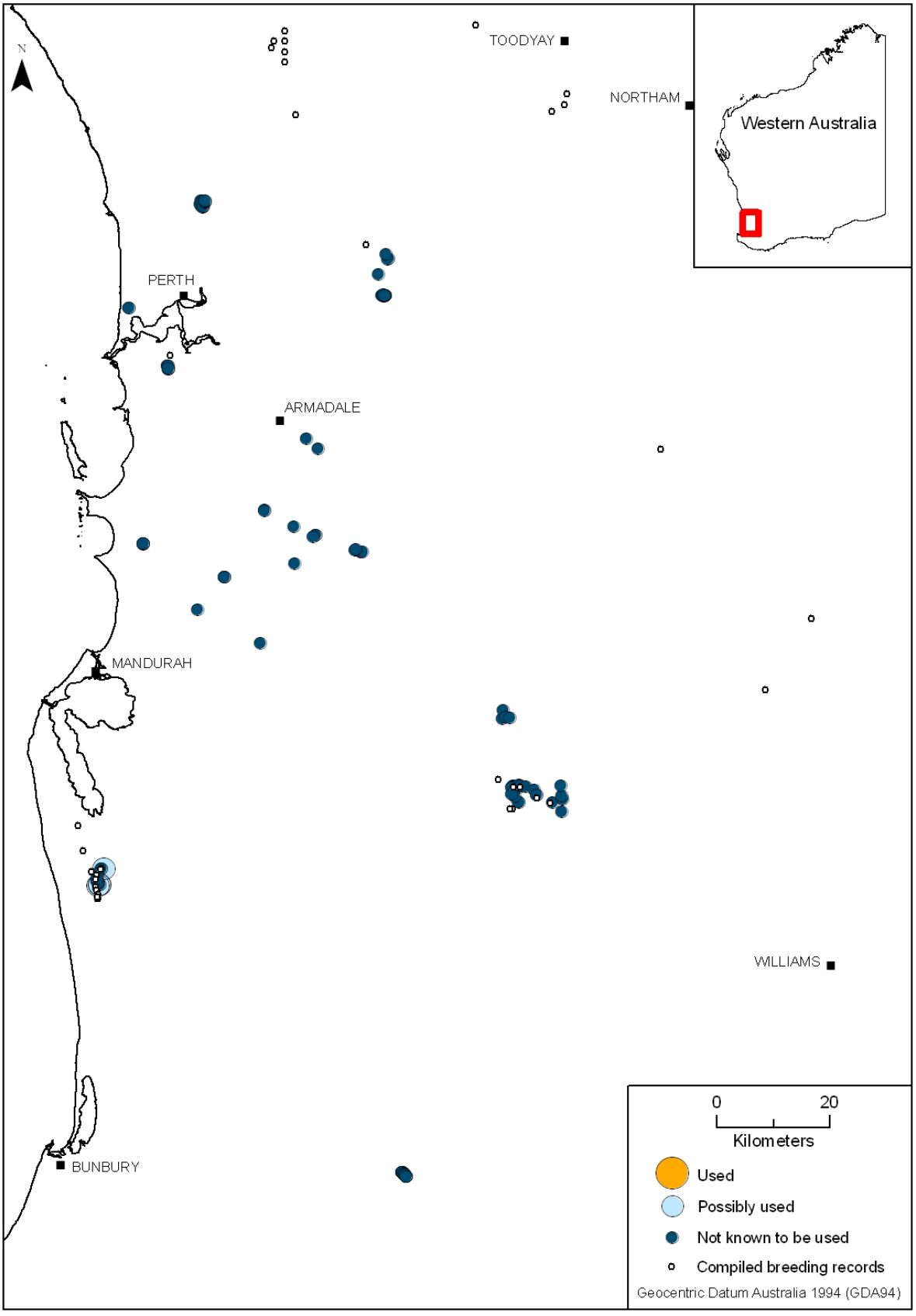
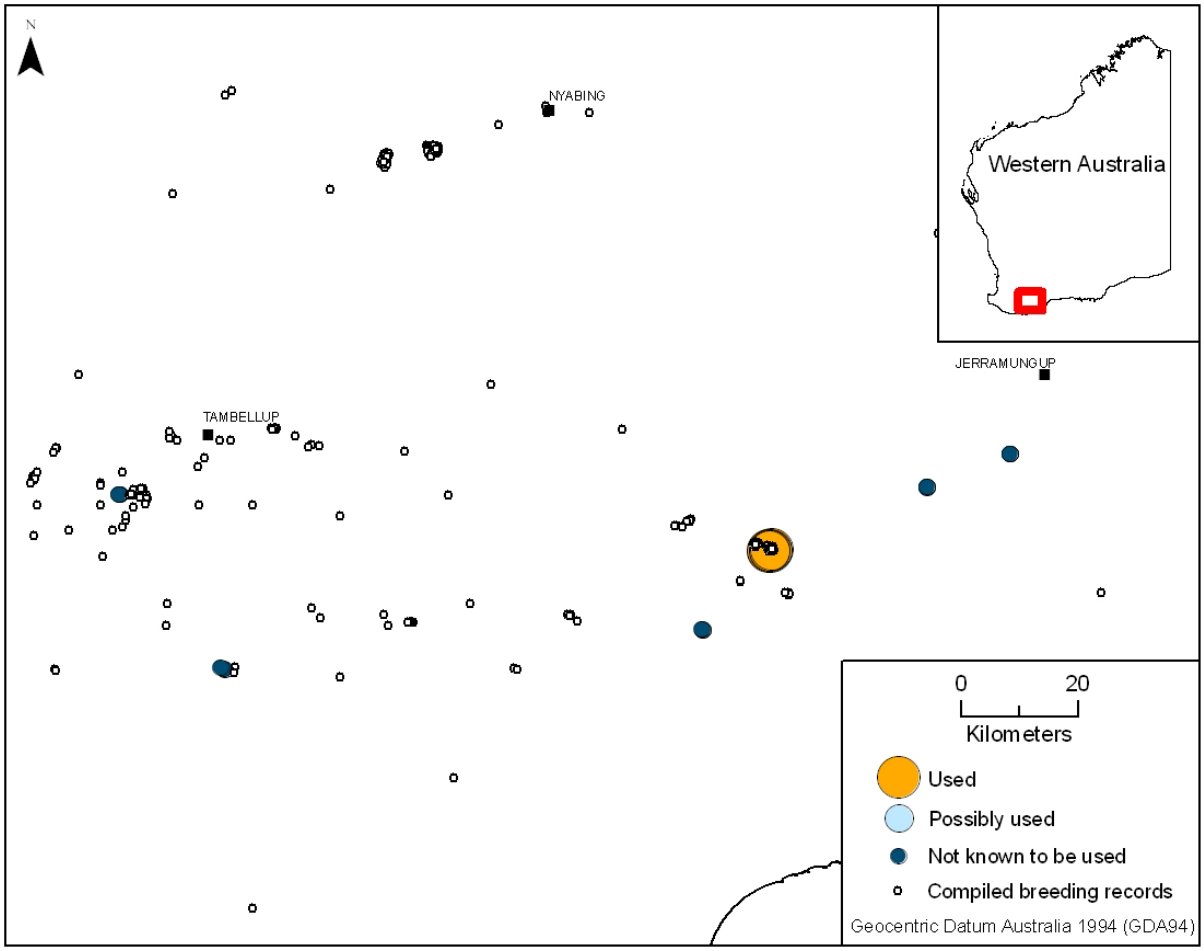


Figure 8: Southern distribution of Carnaby's black cockatoo breeding records (a combination of known and probable nesting sites as well as observations of breeding behaviour) and artificial hollows.



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).

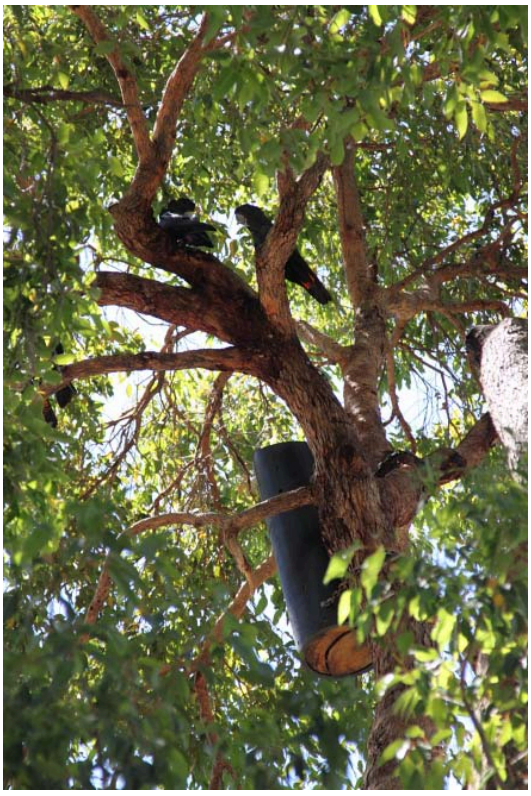


Figure 9: Forest red-tailed black cockatoos and 'Cockatube' at Jarrahdale.

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.

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