Improving population estimates of Glossy Black-Cockatoos (*Calyptorhynchus lathami*) using photo-identification

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Abstract

Site-based population estimates of the threatened Glossy Black-Cockatoo ('GBC'; *Calyptorhynchus lathami*) are often calculated based on age and sex details from transect counts. However, these estimates do not distinguish individual birds, which may result in over- or under-estimation of the population. Two methods were used to estimate GBC populations in Mugii Murum-ban State Conservation Area, New South Wales: (1) the traditional transect method, and (2) a photographic method, which used plumage patterns (primarily the yellow facial feathers of females) and other supporting features to discriminate between foraging GBC family units. The second method has been used previously on Kangaroo Island, South Australia. A catalogue with a matrix of discriminating features was established based on the photographic method; this resulted in a higher population estimate than the transect method in two seasons (winter and spring), as well as providing an annual population estimate, and information on breeding dynamics and local movement of individual family units between foraging habitat. Recommendations for the application of the photographic method are provided. The method provides benefits at both the local scale (with more accurate site population estimates and information on population dynamics) and, with widespread adoption and national cataloguing, valuable knowledge on regional movement patterns and distribution.

Introduction

The Glossy Black-Cockatoo ('GBC'; *Calyptorhynchus lathami*) is listed as near threatened under International Union for Conservation of Nature (IUCN) criteria (Garnett et al. 2010). The predominant threat to the species is the loss of foraging or breeding habitat (through clearing, fire or other disturbances), which is exacerbated by their dependence on

Allocasuarina trees for food (Forshaw and Cooper 2002). As a result of their conservation status, both site-based and national methods have been developed for surveying GBC populations. These methods typically include searches within known foraging habitat (e.g. Glossy Black Conservancy 2010; DSITIA 2014). During these surveys, each bird encountered is tallied and visually assessed for sex (based on the presence of yellow facial plumage) and approximate age (tail, body and covert plumage). This method does not enable the identification of individual birds. This is problematic for estimating population size and changes over time, as it is not possible to count all birds in all locations at a single time, nor apply mark–recapture approaches (e.g. Jolly–Seber models; Jolly 1965; Seber 1965). Bird banding does allow for the identification of individuals, and hence the tracking of single birds or family units over time (population dynamics), as well as knowledge of movement patterns, site-fidelity and behaviour. However, trapping increases stress levels in birds (Romero and Romero 2002), and as well as being particularly difficult to capture, cockatoos have a tendency to damage or remove their leg-bands with their strong bills (Higgins 1999; Carlos Senar et al. 2012).

An alternative to the invasive methods of trapping and marking wild animals is to use natural features and patterns to distinguish individuals. This has been used successfully in many taxa, including invertebrates, fish, amphibians, reptiles, terrestrial mammals and cetaceans (e.g. see reviews in Emery and Wydoski 1987; Hammond et al. 1990; Würsig and Jefferson 1990; Silvy et al. 2005). Such natural markings include patterns of fur or whisker spots in lions, bobcats, polar bears (Pennycuick and Rudnai 1970; Heilbrun et al. 2003; Anderson et al. 2007), nose scars in otters (Gilkinson et al. 2007), spots or stripes in amphibians (Bradfield 2004), scale patterns in lizards (Sacchi et al. 2010), dorsal-fin shape and notches in cetaceans (Guzman et al. 2015) and skin-wrinkle patterns in rhinoceros (Patton and Campbell 2011). Bird plumage has also been used in species that have unique patterns, including ospreys (Pandion haliaetus; Bretagnolle et al. 1994), booted eagles (Hieraaetus pennatus; Jiménez-Franco et al. 2013), hawks (Janes 1984) and buzzards (Krüger 2002). Female GBCs have yellow facial-feather patterns that are unique to individuals and asymmetrical on each side of the head (Higgins 1999).

In this paper, we compared the traditional transect-survey method with the alternative approach of distinguishing individuals by natural markings. This method was used on the Kangaroo Island subspecies (*Calyptorhynchus lathami halmaturinus*) to individually identify GBCs by plumage and bill markings in research on breeding and behavioural ecology (Pepper 1996; Garnett et al. 1999). The permanent bonds between pairs of females and males (Arnett and Pepper 1997; Forshaw and Cooper 2002) alongside the ability to individually discriminate females reduces the need to identify males, although bill and unusual feather markings can be used to some extent. Additionally, as GBCs are relatively tolerant to quiet observation from the ground during foraging (Joseph 1984), they experience only limited disturbance or stress.

Methods

Study area

Fieldwork was conducted on Mt Airly in Mugii Murum-ban State Conservation Area in the western Blue Mountains, New South Wales, Australia (33°6′10″S, 150°1′40″E; Fig. 1). The Mt Airly sandstone mesa is ~700 ha in size and dominated by four broad vegetation types, with dense stands of black she-oak (Allocasuarina littoralis) found interspersed within the dry-eucalypt forests on the plateau and upper-talus slopes. Five stands were examined in winter (17–24 August 2014) and spring (12 October–1 November 2014). A further five stands within the conservation area (total 3650 ha) were also visited during both seasons; however, as no GBCs were observed and little evidence of foraging activity was present, these data were omitted from further discussion. Stands (where Allocasuarina were dominant) were between 2.1 and 7.3 ha in size, separated by 0.2–2 km and often positioned on different elevation shelves (up to 200 m).

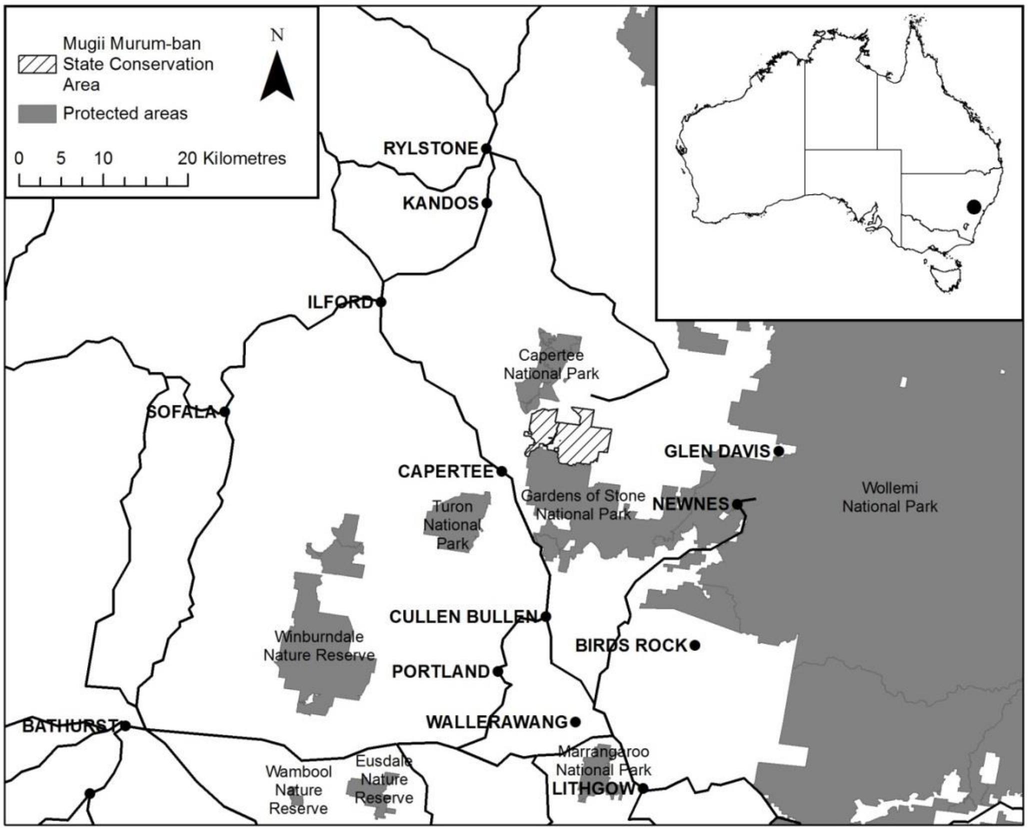

Fig. 1. Location of Mugii Murum-ban State Conservation Area, New South Wales.

GBC survey methods

In each stand, a timed transect walk was conducted for 30–45 min (depending on terrain and audibility as a result of vegetation density), excluding time taken for photographing GBCs and recording details, and covered ~2 ha. The walk was conducted three times on inconsecutive days (2–13 days apart) during fine weather in both field seasons. GBCs were detected by visual searches or aural cues (distinctive cracking of cones or juvenile cries). All sites were visited on a single day in an attempt to record all birds in the area at one time and to minimise the chance of resurveying the same individual. Data collected for the two methods described below were gathered within the same transect walk on the same day.

For the traditional transect-survey count (termed 'transect count'), records of each GBC encountered included sex, age and family unit details (bonded or unbonded, with or without fledgling). A GBC population estimate was determined as the maximum number of all individuals counted on a single day and examining the age–sex combinations of individuals from each transect visited to omit potential movement of the same individuals between sites. Age (year of birth) and sex of sub-adult and adult GBCs were determined by plumage features (see Table S1 in Supplementary material available online; Glossy Black Conservancy ND; Courtney 1986).

The alternative photographic method ('photo-ID') deduced age, sex and family unit details from photographs (taken with either Nikon D7100 (Nikon, New York, NY) with Sigma 150–500 mm f/5–6.3 lens (Sigma, New York, NY) or Nikon D800E with Nikkor 600 mm f/4 lens and 1.4× converter (Nikon, New York, NY)) and field notes (as taken in the transect count method). Specifically, photographs were taken of the tail feathers (all ages and sexes), both left and right side of the face (all females, and males if yellow plumage present) and breast or covert plumage. GBCs encountered opportunistically outside scheduled transects were also photographed and added to the population count for the photo-ID method. Birds were observed for varying periods until a suitable photograph was captured, which was dependent on GBC position and 'cooperation' within the canopy. A population estimate was calculated for this method based on the total number of individuals catalogued within the family units distinguished by photographs.

Photograph analysis

Photographs were examined manually to develop a catalogue of individual females, and accompanying males and fledglings. To maximise consistency between photographs for comparison, only photos taken with the GBC at a natural resting position were used; for example, photos were omitted if birds were taking off and landing, or with feathers raised during communication or thermoregulation. When required, images were manipulated (in Adobe Photoshop CS6; Adobe Systems Inc., San Jose, CA) to rotate head position so that all individuals had their bills at 3 o'clock (right side of face) or 9 o'clock (left), or to correct minor exposure errors. Image quality was classified on a four-point scale (Q1–Q4) based on focus, position of GBC cheek relative to the camera, lighting and exposure, obstructions between bird and camera, and head size within the original photograph taken (adapted from Gilkinson et al. 2007; Table 1, with examples of Q2–Q4 in Fig. 2). In addition, a four-point individual discrimination score (D1–D4) was determined based on the distinguishing characteristics (Table 1). A matrix was created with all catalogued females, which included the image quality score, individual discrimination score, distinguishing features and supporting information (estimated age and other GBCs with the female; Table 2). Only images with Q2–Q4 and D3–D4 (or D2 if Q4) were used. Images were compared by two experienced observers (authors) independently to determine the likelihood of individuals being: (i) M1 = not a match; (ii) M2 = indeterminate; (iii) M3 = a possible match; (iv) M4 = a probable match; or (v) M5 = a positive match. A catalogue of individuals was generated, with those classed M1, M2 or M3 as new entries; notes on the possible match of M3 individuals were included and conservative population estimates would not include these as additional individuals.

Table 1. The image quality classifications and individual discrimination scores used in photographic analyses of GBC at Mt Airly in 2014. Adapted from Gilkinson et al. 2007.

Score code	Photograph quality
Q4	Excellent quality. Photograph is in focus, GBC cheek is orthogonal to the camera, good contrast and exposure, face is wholly within shadow or in sunlight, face large in original photograph frame, no obstructions between GBC and camera.
Q3	Good quality. Has 1–2 of the following minor flaws: image very slightly out of focus, head is turned slightly from cheek orthogonal to camera, contrast or exposure needs slight post-processing adjustment, minimal obstructions or shadow/sunlight patches on face, face medium in size in original frame.
Q2	Poor quality. Has 2–3 of the flaws listed at Q3 or one of the following: image slightly out of focus, small obstruction or shadow/sunlight patches on face, contrast or exposure needs moderate adjustment, face is small within original frame.
Q1	Very poor quality. Has >2 of the flaws listed at Q2 or >3 flaws listed at Q3.
	Individual discrimination
D4	Both sides photographed. Other individualistic characteristics present: bill growth lines, bill scars (excluding superficial flakiness), feet scars or missing digits.
D3	Both sides photographed. Only facial and age-related plumage distinctive.
D2	One side photographed. Other identifying characteristics present.
D1	One side photographed. Only facial and age-related plumage distinctive.

Fig. 2. Six catalogued females (top two rows) showing different facial plumage and other discriminating features (arrows), with three recurring females from spring surveys in the third row. See Table 3 for further details on individuals and their respective matrix features. Each GBC is given a catalogue code determined by family unit number (Famn) and sex (e.g. f = female).

Table 2. Catalogue matrix for seven of the recorded females within the Mugii Murumban State Conservation area in 2014, including image quality for left and right sides of the face, individual discrimination score and features (if present), as well as other supporting information for distinguishing individuals. GBC code is determined by family unit number ('Famn') and sex (where f = female, m = male and j2014 = juvenile from the 2014 breeding season). Fam7f is omitted in the table as it was a potential match (score of M3) for Fam3f

GBC code	Quality		D Score: other permanent features	Estimated birth year: supporting plumage	Accompanying GBCs in family unit
	L	R			
Fam1f	Q4	Q4	D4: Right bill with puckered groove from nostril to tip	2012: Spots and scalloping on wing coverts and breast	Male (<2008; Fam1 m), juvenile (likely male; Fam1j2014)
Fam2f	Q3	Q4	D4: Left bill with crack above ridge at tip; right bill with two ridges above tip	2008–2010: Tail with some yellow-red rectrices; small patch of scalloping at vent	Male (<2008; Fam2 m)
Fam3f	Q2	Q1	D3: Large amount of yellow on left face and back of head (unlike all other females)	2008–2010: tail with some yellow-red rectrices	Male (<2008, Fam3 m), juvenile (likely male; Fam3j2014)
Fam4f	Q3	Q2	D3	2010–2011: From several to all yellow rectrices present; few small spots on wing coverts	Male (<2008; Fam4 m)
Fam5f	Q3	Q3	D4: On left bill, small crease half way down near anterior angle (visible in full size photo only – not in Fig. 2)	<2009: Tail with some yellow-red rectrices and thin bars	Male (<2008; Fam5 m), juvenile (likely female; Fam5j2014)
Fam6f	Q3	Q3	D4: Left upper bill with large diagonal scar above ridge at tip	2010–2011: Small patch of scalloping on breast; few small spots on wing coverts	Male (<2008; Fam6 m), juvenile (likely male; Fam6j2014)
Fam8f	Q2	Q2	D3	2012: Large spots on wing coverts; scalloping on breast; several tail rectrices all yellow	Male (<2008; Fam8 m)

Results and discussion

Differences in female GBC plumage captured using the photo-ID method, in addition to supporting features (bill scars, age etc.), allowed family units to be catalogued for determining population estimates (Fig. 2; Table 2). Although population estimates were determined primarily by distinguishing females within family units, it was possible to distinguish the male in Family 1 ('Fam1'; Fig. 3) by several yellow feathers on the lower portion of both cheeks, as yellow facial plumage is unusual (but not unheard of) in male GBCs (Higgins 1999). This male was always observed (n = 5, occurring in both August and October surveys) with the same female (Fam1f), providing further evidence that GBCs form monogamous pair bonds, and supporting the use of family units for population estimates.

Fig. 3. In addition to female facial plumage patterns, supporting information can be obtained from accompanying GBCs in distinguishing family units. This includes unusual plumage patterns on males (e.g. yellow facial feathers, left image) compared with 'normal' male facial plumage (middle image) or the presence of accompanying juveniles (right image; Fam5 female juvenile and female adult, respectively).

The photo-ID method used in this paper calculated a higher population estimate for GBCs in each season than the traditional transect count, and allowed a yearly population estimate to be computed based on both seasons and opportunistic sightings. Specifically, the transect count recorded fewer GBCs in winter (47% less than the photo-ID method) and in spring (55% less; Table 3). A yearly estimate of 20 GBCs was possible using the photo-ID method; this was considerably higher than any individual season estimate by the transect count method. This suggests that surveys where individual females or family units are not distinguished may result in underestimation of GBC population numbers.

Table 3. Observations of GBC family units (with the number of GBCs in each family unit displayed in parentheses) and population estimates at Mugii Murum-ban State Conservation Area in 2014 during scheduled surveys and opportunistically ('Opp'). Although recorded, age of individuals is not shown for conciseness. GBC catalogue and family code is determined by family unit number ('Famn') or whether unbonded ('UB'), and sex where applicable. Population estimates were calculated based on: (1) transect count – maximum number of GBCs observed in 1 day where all sites were visited and not including GBCs observed outside these days, and (2) photo-ID method – cumulative total of individuals when family units were distinguished and catalogued, also incorporating GBCs observed opportunistically outside survey days and times

	Visit	Site 1	Site 2	Site 3	Site 4	Site 5	Max. GBCs per visit
Winter	1	Fam1 (3)	–	Fam2 (2) UB♂ (3)	–	–	8
	2	–	UB♂ (3)	Fam4 (2)	Fam1 (3)	–	8
	3	–	–	Fam2 (2) Fam5 (2) Fam4 (2)	–	–	6
	Opp	Fam3 (3)	–	Fam3 (3)	–	–	NA
Spring	1	–	–	Fam6 (3)	Fam4 (2), Fam1 (3)	–	8
	2	Fam1 (3)	Fam6 (3)	–	–	–	6
	3	UB♂ (2), Fam4 (2), Fam8 (2)	–	–	–	–	6
	Opp	Fam1 (3), Fam5 (3), Fam6 (3)	Fam6 (3)		Fam5 (3)	Fam7 (3)	NA

Population estimates	Transect count (max. GBCs observed per visit)	Photo-ID method (number of individuals within family units)
Winter	8	15[Fam1 (3), Fam2 (2), Fam3 (3), Fam4 (2), Fam5 (2) + 3 UB♂]
Spring	8	18[Fam1 (3), Fam4 (2), Fam5 (3), Fam6 (3), Fam7 (3), Fam8 (2) + 2 UB♂]
Both seasons	8	20[Fam1 (3), Fam2 (2), Fam3 or 7 (3), Fam4 (2), Fam5 (3), Fam6 (3), Fam8 (2) + 2 UB♂][A]

[A]For the population estimate for both seasons of the photo-ID method, Fam7 was omitted due to possibility of being Fam3 (match score of M3), as was 1 unbonded male, which may have formed a new family unit during the spring survey. Note, a 2014 juvenile was observed with Fam5 during spring, but not during winter.

The photo-ID method also gave what we believe (in the absence of double-blind marking experiments) to be more accurate population estimates, primarily as it was able to differentiate family units (cumulatively counting individuals) and did not rely on estimates being the maximum GBCs being observed in a single day. For example, in winter, the photo-ID method was able to determine that the eight GBCs observed during the first visit (Fam1, Fam2 and three unbonded males) were not all the same individuals as those observed in the second visit (Fam1, Fam4 and three unbonded males), despite similar ages within family units Fam2 and Fam4. Opportunistic records were also valuable for the photo-ID method, but not the transect count method, as the observations outside dedicated surveys (i.e. opportunistic) could be compared with the established catalogue to determine whether they were new individuals. In this study, the use of opportunistic records added one family unit in winter (Fam3) and two in spring (Fam5 and Fam7) to the population estimate, as well as additional recordings of site-use by particular families (e.g. Fam6 observed at Sites 2 and 3 during surveys, but also Site 1 opportunistically).

The photo-ID method also allowed comparisons of females between field seasons, with three females recorded in both winter and spring (Fig. 2, rows 2 and 3). However, the importance of capturing both left and right cheeks, as well as supporting information (such as male aberrant plumage or bill scars), was obvious in young birds (e.g. Fam1), where adult plumage is still developing (until ~2 years of age, Higgins 1999) and patterns can change over time. The permanency of adult female facial plumage over multiple years is uncertain. Although previous studies on GBCs have followed what they consider the same individuals through consecutive moults (e.g. Pepper 1996; Garnett et al. 1999), the use of plumage identification over multiple years needs to be confirmed through banding or genetic studies (J. Pepper, pers. comm.).

There are limitations on the reliability of using natural markings to distinguish individuals, as more than one animal may have identical or similar markings. The probability of duplication is dependent on two factors: (1) pattern complexity (where more complex patterns decrease probability), and (2) population size (larger populations increase probability) (Pennycuick 1978). Equations to determine the reliability of identifications are available (e.g. Pennycuick 1978); however, this was not possible in the current study because of the low GBC numbers and minimal use of the method previously (for calculating prominence or independence of particular patterns). Considering the large number of feathers on one side of a female GBC face (several hundred in other bird species, e.g. Wetmore 1936; Brodkorb 1951), which can provide complex patterns, as well as the asymmetry of the two face-sides (thus two complex patterns) and other supporting features (age, bill scars), we propose that with good-quality photographs, the photo-ID method would have a high reliability.

Conclusions

The photo-ID method used in this study was able to catalogue and distinguish between seven individual female GBCs and provided a higher population estimate than the traditional transect count. Additionally, in this study, several birds were able to be recognised between seasons. However, until certainty relating to the permanency of plumage patterns is confirmed (e.g. by a double-marking experiment), surveys should be conducted within the same moulting period to minimise the potential for changes in plumage patterns over time. If future research finds that plumage patterns alter only marginally after moulting, regular monitoring (e.g. twice-yearly) may allow the continual discernment of individuals over a longer period, particularly in young birds when moulting is incomplete (i.e. not all feathers are replaced each year; Higgins 1999).

Currently, this method is most suitable for site-based surveys and monitoring of populations; however, with increased application, a database could be established to catalogue GBCs nationally. Additionally, the method could include citizen scientists; this has proved valuable with other taxa (Marshall and Pierce 2012; Davies et al. 2012), particularly as bird photography is popular in Australia (Low 2014). Although match comparisons were done manually in the current study by experienced observers, other research has used computer-assisted photo-identification successfully in a range of species (e.g. Sherley et al. 2010; Bolger et al. 2012); this may be applicable to GBCs. Alternatively, image-matching could also be performed by trained volunteers, although accuracy in relation to GBC comparisons is yet to be assessed. In due course, such data could result in the conduct of more formal mark–recapture surveys, which will potentially offer greater insight into certain population parameters, including survival and movement (e.g. Nichols et al. 2004) of this threatened species.

Practical recommendations arising from the current study include:

- the use high-quality digital photographic equipment (e.g. high-resolution digital SLR camera and telephoto lens) and imaging software (e.g. Adobe Photoshop or similar) to ensure accurate identifications;
- the capture of multiple photographs of both sides of individuals (especially in dappled light conditions), as well as other body parts for supporting information and ageing;
- the recording of detailed notes of observed families (time, age, location, accompanying GBCs);
- the use of a predetermined method to segregate photographs of different GBC families in the field to ensure efficiency and accuracy during post-field analysis (e.g. take a photograph of the ground between recordings of sequential family units);
- comparisons of retrices made ventrally at rest, as rectrices (inner to outer) vary considerably within the same individual (although observations of other rectrices may help with ageing);
- the visiting of sites on multiple days to account for local movement; and
- the consideration of potential behavioural or weather effects on feather arrangements (e.g. fluffed-up feathers in display or wind) and how this may change observed patterns.

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