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Nestling and post-fledging growth and development in an Australian passerine: Hall's Babbler *Pomatostomus halli*

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Postnatal growth and development has rarely been studied in passerines of the southern hemisphere, particularly Australian species. Developmental changes in external morphology and the growth in body mass and size of nestling and juvenile Hall's Babblers (*Pomatostomus halli*) were quantified and described. Additionally, a guide to ageing nestlings to the nearest day was developed to facilitate studies of breeding biology. Nestling growth and development in Hall's Babblers were similar to that of its closest relative, the Grey-crowned Babbler *P. temporalis*. Body mass, skeletal and feather growth, but not the sequence and timing of developmental changes in external morphology, were affected by nestling body condition. Juvenile Hall's Babblers attained adult size by four months of age, and were indistinguishable from adults by one year of age. Nestling growth rate in body mass of Hall's and Grey-crowned Babblers is lower than similarly sized northern hemisphere passerines, but the relative size at fledging is similar. This suggests nestling growth rate may, like other life-history traits, differ between passerines of the southern hemisphere and those of temperate regions of the northern hemisphere. However, since nestling growth has been poorly studied in southern hemisphere passerines, the available data are inadequate to test this hypothesis.

INTRODUCTION

All passerines exhibit an altricial mode of development, whereby neonates hatch naked, blind and helpless (Starcks and Ricklefs 1998). Nestling growth pattern and rate vary widely among species, and are an integral component of avian life-history strategies (Ricklefs 1973, 1983; Remes and Martin 2002). Ecological factors are believed to play an important role in shaping passerine life-histories (Bosque and Bosque 1995; Remes and Martin 2002). For example, nestlings of species that experience higher predation pressure grow faster and fledge at an earlier developmental stage (Remes and Martin 2002). Most data from which these conclusions are drawn come from northern hemisphere passerines (Ricklefs 1973; Remes and Martin 2002), yet there are considerable differences in life-history characteristics between northern and southern hemisphere passerines, such as clutch size, within-season reproductive effort, duration of parental care and survival (Martin 1996, 2004; Russell 2000). Postnatal growth and development of southern hemisphere passerines has rarely been studied in detail (Bosque and Bosque 1995), and represents a significant gap in our understanding of the evolution and biogeography of passerine life-history strategies.

In Australia, nestling growth and development has been well-studied in only a few passerine species (e.g. Maher 1986, 1991; Boag 1987; Rowley *et al*. 1991; Frith and Frith 2004; Russell *et al*. 2004), and most comprehensively in the Grey-crowned Babbler *Pomatostomus temporalis* (Brown 1979; Dow and Gill 1984a). Compared with passerines from temperate regions of the northern hemisphere, this species has a protracted nestling period, a slow nestling growth rate, and a below average fledging body mass relative to adult mass (Ricklefs 1968; Brown 1979; Dow and Gill 1984a). Hall's Babbler *P. halli* is the closest relative of the Grey-crowned Babbler (Edwards and Wilson 1990), but little is known of its breeding biology. Gill and Dow (1983) described changes in external morphology during the early nestling period (up to day 10) for this species, but no data on nestling growth have been collected and the development of older nestlings and fledglings has not been examined.

Knowledge of nestling age is often essential in studies of breeding biology as it influences maternal care (e.g. Moreno 1987), parental (e.g. Goodbred and Holmes 1996; Lee *et al*. 2010) and alloparental (Young 2007) food provisioning, nestling energy expenditure (McCarty 1996; Anava *et al*. 2001), and parental foraging behaviour (da Silva and Melo 2009). Determining exact nestling age requires continual monitoring of nests, but repeated disturbance is often undesirable (Ibanez-Alamo *et al*. 2012). Alternatively, the age of nestlings can be estimated from body mass, size and/or external morphology (Jongsomjit *et al*. 2007). The age of nestling Grey-crowned Babblers, for instance, can be estimated to the nearest day using body mass (Dow and Gill 1984b). The aims of this study were to quantify and describe nestling growth and development, develop a guide to ageing nestlings, and document post-fledging growth and development in Hall's Babblers.

METHODS

Study site and population

The breeding biology of Hall's Babbler was studied at Bowra Sanctuary, near Cunnamulla in south-western Queensland (27°58.8'S, 145°32.8'E) in 2006–2009. Hall's Babblers live in stable kin-structured breeding units comprised of a mated pair, up to four unpaired adults and juveniles (Portelli 2012). Between 25 and 31 breeding units were monitored regularly each year. All adults, juveniles, fledglings and older nestlings in breeding units were banded with an individually numbered stainless steel band (supplied by the Australian Bird and Bat Banding Scheme) and a unique combination of three Darvic colour-bands. Adults and juveniles were caught using standard four-shelf mist nets (12 m or 18 m long, mesh size 31 mm or 38 mm) and sex was determined through genetic methods (Portelli 2014).

Nestling growth and development

Ten nests were selected to examine nestling growth and development. At least half of nest attempts on the study site failed due to predation (Portelli 2012), so the ten nests were enclosed by wire in an attempt to protect nestlings from predators; however, this failed and the eggs in six nests were depredated. The growth and development of eight nestlings from the remaining four nests, were recorded daily. Two broods were from the same breeding unit: one nestling hatched on 21 July 2007 (brood A), and two nestlings hatched on 10 and 11 November 2007 (brood B). The third brood (C) comprised two nestlings that hatched on 26 and 27 July 2007. The final brood (D) comprised three nestlings that hatched on 21 August 2007, but they were depredated when three (n = 1) and seven (n = 2) days old.

Nestlings were measured daily at about the same time of day (1300 ± 1 hr), beginning on the day of hatching (day 0). Body mass was measured to the nearest 0.5 gram with a 60 grams Pesola spring scale. Tarsus length (proximal end of the tarsometatarsus to the leading edge of the folded digits), exposed culmen length (tip of the upper mandible to the edge of the skin covering the rhamphotheca) and total head and bill length ('head-bill length'; tip of the bill to the occipital condyle) were measured with dial callipers to the nearest 0.1 mm. Flattened wing and tail lengths were measured to the nearest millimetre using stainless steel rules; a butted rule was used for wing length.

Logistic growth curves for body mass and tarsus length were fitted for each nestling from broods A–C using DataFit version 9 (Oakdale Engineering www.curvefitting.com), which took the form $Y = A/(1 + e^{-K(t-i)})$, where A = asymptote, K = growth rate, t = age in days, and i = age when maximum growth rate occurs. Logistic growth curves provided the best fit for these traits in Grey-crowned Babbler nestlings (Dow and Gill 1984a) and other similar studies (Ricklefs 1968; Remes and Martin 2002). ANOVA was performed for each fitted curve to determine whether the fit explained significantly more variance in the data than a null model; the coefficient of determination (r^2) is reported as a measure of the proportion of the variance explained by the fitted curve. Linear regressions were fitted for culmen, head-bill, wing and tail lengths for each nestling from broods A–C using SPSS® version 21. Growth was non-linear for head-bill and wing lengths, so data were truncated at the age when growth rate ceased to be linear prior to fitting regression models.

The day when nestlings were absent from the nest was treated as the day of fledging. To determine relative size at fledging, measurements of nestlings on the day before fledging were converted to proportions of body size of adults (body mass and culmen, head-bill and tarsus lengths) or full-grown juveniles (wing and tail lengths). Juvenile wing and tail lengths were used as these were significantly shorter than in adults. Additionally, the ratio of the asymptote of the logistic growth curve to adult size for body mass and tarsus length (R, *sensu* Ricklefs 1968) was calculated. Data for adult (Portelli 2014) and juvenile (this study) male and female babblers were obtained from the same population. For each nestling, mean measurements of adults or juveniles of the same sex were used for comparisons.

Each nestling was photographed daily to record developmental changes in external morphology, minimising the time spent handling nestlings. The commencement of three stages of feather development in different tracts was recorded: 1) the appearance of follicles beneath the skin, 2) emergence of feather pins from the skin, and 3) eruption of feathers from their sheaths. The day when the following developmental milestones were reached was also recorded: eyelids split, eyes opened, and maxilla and mandible tips met. Lastly, the general appearance of the plumage was described daily once feathers erupted from their sheaths.

Nestling age estimation

Three methods to estimate nestling age were derived from the nestlings of known age that were measured daily. These included developmental changes in external morphology, and growth patterns of morphological traits. The third method was derived by fitting linear regressions with age as the response variable to pooled data for the eight nestlings for initial tarsus growth – which was approximately linear – and tail growth. Because these methods were derived from only eight nestlings, the representativeness of this small sample was assessed using a larger sample of 22 additional nestlings (ten broods from eight breeding units). These were first measured and photographed within ten days of hatching (see Gill and Dow 1983) and again 6–12 days later. Each time a nestling was examined its age was predicted from the age-specific developmental changes in external morphology and growth curves derived from the nestlings measured daily. Photographs of nestlings were randomly ordered and the author was blind to the identity of the nestling when predicting age. Predicted ages from growth curves produced a range in days for each trait, so a single day that was the most consistent among traits was chosen. Additionally, age was predicted using the linear equation for the relationship between tail length and age for nine of the 22 nestlings that were photographed and measured twice once their tail had begun to grow. To investigate consistency among the three ageing methods the predicted ages from each method were compared for each capture. To assess whether the three ageing methods accurately predicted changes in morphology and growth rate, the number of days between first and last captures (Δ days) was compared with the difference in predicted ages between captures (Δ age).

Post-fledging growth

Thirteen male and 11 female Hall's Babblers that had been measured as nestlings were recaptured post-fledging. These individuals were recaptured 1–6 times post-fledging (n = 97 captures), up until the age of 49 days to 2.6 years (mean 1.2 years; age was based on estimated age when measured and photographed as a nestling). Body mass was recorded for all but two recaptures and the other morphological traits described above were re-measured for 79–83 recaptures. Logistic growth curves were fitted to pooled data for males and females separately as described above.

Seventeen males and 19 females were captured within their first year after they had completed growth of remiges and rectrices and before they commenced the post-juvenile primary moult. This sample of juveniles included some juveniles banded as nestlings and others banded post-fledging. Wing and tail lengths were compared to those of adults using Mann-Whitney U-tests (adult data were not normally distributed). Additionally, eight males and five females banded as nestlings were recaptured after they had completed post-juvenile primary moult and were in second basic plumage (*sensu* Howell *et al*. 2003; estimated ages 0.8–1.1 years). Wing and tail lengths were compared to those of juvenile and adult plumages.

RESULTS

Nestling growth

The single nestling in brood A fledged 19 days post-hatching. The two nestlings in brood C fledged on the same day at 18 and 19 days post-hatching. Nest lining material (mainly sheep wool) had been pulled out through the nest entrance and strewn on the sides of the nest. This is usually an indication of nest predation (Portelli 2012) so it is possible disturbance by a predator hastened fledging. The two nestlings in brood B had poor body condition and died on the same day, 17 and 18 days post-hatching. This was probably due to exposure to unusually heavy rainfall as both nestlings were saturated when found dead. Malnourishment is an unlikely cause of death for the older nestling because its body mass and size on the previous day was similar to healthy nestlings of the same age (Fig. 1). Growth patterns were consistent among nestlings from broods A, C and D and, with the exception of body mass, the older nestling from brood B (Fig. 1). The growth of the younger nestling from brood B was clearly stunted (Fig. 1). Logistic growth curves explained a significant proportion of the variance in body mass and tarsus length growth for each nestling (Table 1). Body mass gain was sigmoidal, exhibiting little increase during the final week; growth rates (K) were 0.377–0.392 (Table 1). Maximum rate of gain in body mass for the three nestlings from broods A and C was approximately 2.5 g day-1. Tarsus growth was similarly sigmoidal, reaching an asymptote at approximately 13–14 days post-hatching. Tarsus growth rate was slower ($K = 0.268$–0.286) than body mass, but reached an asymptote earlier (Table 1); growth rate of the older nestling in poor body condition fell within the range of values for the three healthy nestlings. Culmen growth was linear throughout the nestling period in the three healthy nestlings (Table 2), but slowed after day 9 and 11 in the youngest and oldest nestlings that had poor body condition respectively (Fig. 1). Head-bill and wing growth was initially linear but slowed after day 11–14 and 13–14 respectively (younger nestling in poor body condition excluded; Table 2, Fig. 1). Tail growth was strongly linear throughout the nestling period in all nestlings (Table 2, Fig. 1).

The three healthy nestlings from broods A and C fledged when they were between two-thirds and three-quarters full-grown in most morphological measurements (Table 3). Exceptions included tarsus length, which completed growth before fledging, and culmen and tail lengths, which were the least developed upon fledging. Values were similar among nestlings, with a maximum difference of five percent (wing length 0.70–0.75). Relative size for the older of the two nestlings in poor body condition, which had attained a similar age to the other nestlings before its death, was similar (the younger nestling from brood B was excluded because its growth was clearly stunted); though values for culmen and tail lengths were slightly lower (Table 3).

Nestling development

Developmental changes in external morphology followed a distinct sequence (Table 4, Fig. 2). Almost all developmental stages of feather tracts commenced within a two-day age range. Some of this variation was attributable to measuring age in days rather than time since hatching; for example, the two siblings of brood C hatched later in the day than the single nestling of brood A (down was dry and fluffy in the latter) and consequently appeared to lag behind in development. Where the timing of developmental changes overlapped, not all nestlings followed the same sequence. Rectrices, for example, emerged from the skin either the same day, one or two days later, or one day earlier than the greater secondary coverts. Eruption of feathers from their sheaths generally followed the sequence of feather emergence. Eyelids split open and eyes opened at 4–5 and 6–9 days post-hatching respectively. The bill gradually changed from yellow to black; the transition from mostly yellow to mostly black occurred at 8–9 days. The age at which the tip of the maxilla reached the tip of the mandible was more variable at 5–11 days. The tips of the outer greater secondary coverts reached the distal ends of the sheaths of the secondaries on day 13; those of the primaries did so on day 14–15. On day 15, nestlings appeared 'fully feathered' with only sheaths of the rectrices, anterior capital tract, and interramal and submalar tracts visible. The egg tooth and some down on the sides of the crown (coronal patch) were retained throughout the nestling period. The developmental sequence and timing for the two nestlings in poor body condition did not diverge from that of the three healthy nestlings.

Nestling age estimation

A linear regression fitted to pooled data for tail growth from four nestlings (younger nestling in poor body condition excluded) yielded the following equation: age = 0.273*tail length + 6.558 ($F_{1,36} = 3072.52$; $r^2 = 0.99$; $P < 0.001$). Although tarsus growth was non-linear, growth up until about day 10 was sufficiently linear to develop a linear equation to facilitate ageing: age = 0.576*tarsus length – 3.381 ($F_{1,61} = 2943.49$; $r^2 = 0.98$; $P < 0.001$).

Predicted ages derived using the three ageing methods were in agreement for 90.9 percent of the 22 additional nestlings when they were first examined, and 54.5 percent when examined a second time. Where predicted ages disagreed ($n = 11$ cases), the maximum difference between predicted ages was one (91.7%) or two (8.3%) days. The number of days between first and last capture (Δ days) did not differ from the difference in

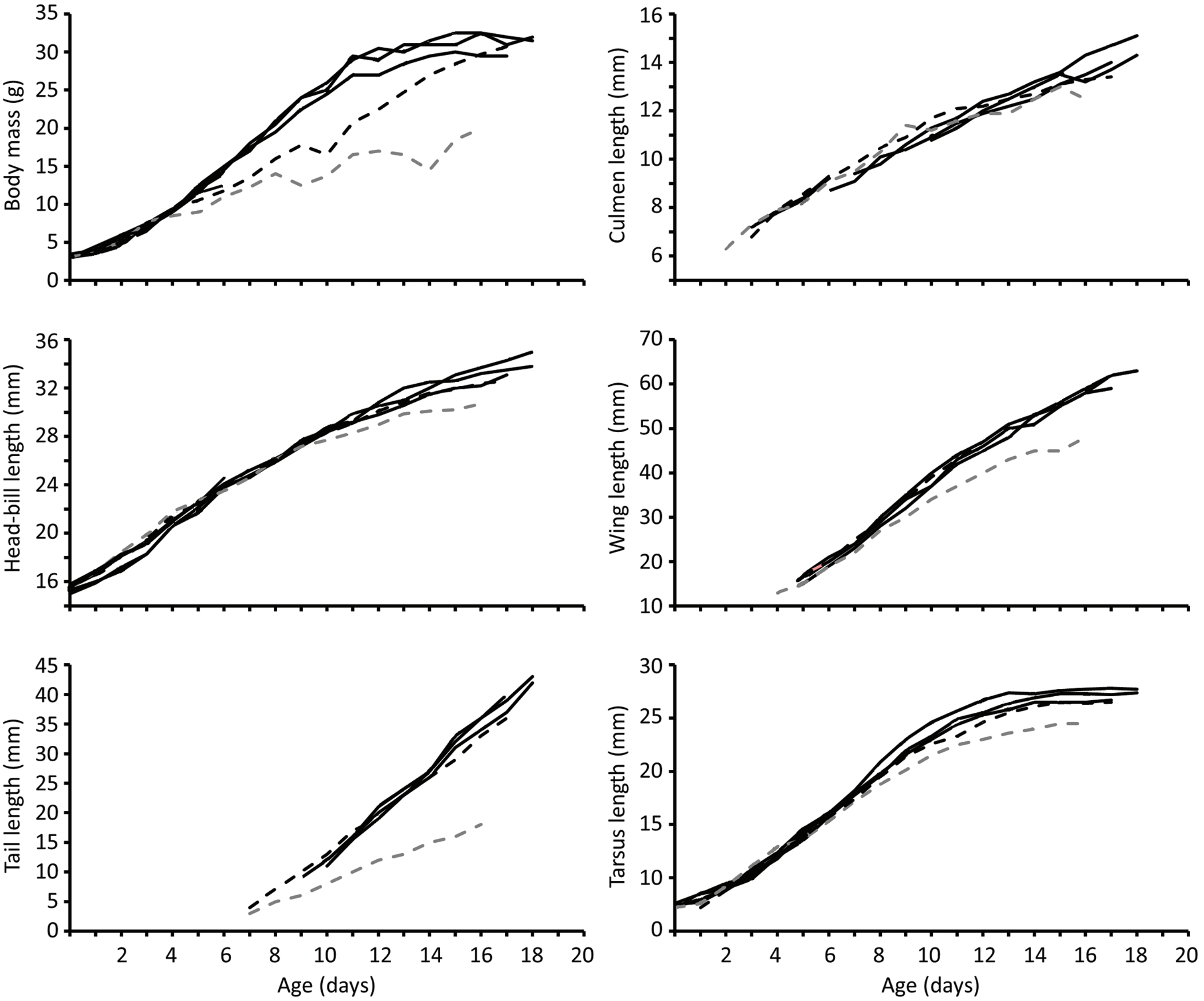

Figure 1. *Growth of Hall's Babbler nestlings. Individuals measured daily are shown by solid (six healthy nestlings, broods A, C and D) or dashed (two nestlings in poor body condition from brood B) lines.*

Table 1

Parameters of logistic growth curves fitted to body mass and tarsus growth of four Hall's Babbler nestlings. Growth curves take the form $Y = A/(1 + e^{-K(t-i)})$ where Y = body mass or tarsus length, A = asymptotic size, K = growth rate, t = age in days, i = age when maximum growth rate is reached. n indicates the number of consecutive days each nestling was measured. Results of ANOVA for each fitted logistic curve are reported; $r^2 \geq 0.99$ for all fitted curves.

Brood	Nestling (sex)	*n*	Body mass					Tarsus				
			A	***K***	***i***	***F***	***P***	***A***	***K***	***i***	***F***	***P***
A	1 (♀)	19	32.8	0.377	6.5	2175.18	<0.001	29.2	0.286	4.8	1018.20	<0.001
B*	1 (♀)	17	-	-	-	-	-	28.0	0.274	3.9	4212.08	<0.001
C	1 (♂)	19	32.9	0.392	6.5	2582.00	<0.001	29.0	0.268	5.1	1134.98	<0.001
C	2 (♀)	18	30.6	0.379	6.3	4877.98	<0.001	28.4	0.268	4.9	1439.41	<0.001
Mean			32.1	0.385	6.4			28.7	0.274	4.7		

* logistic growth curve inappropriate for data on body mass gain for this nestling, which was in poor body condition

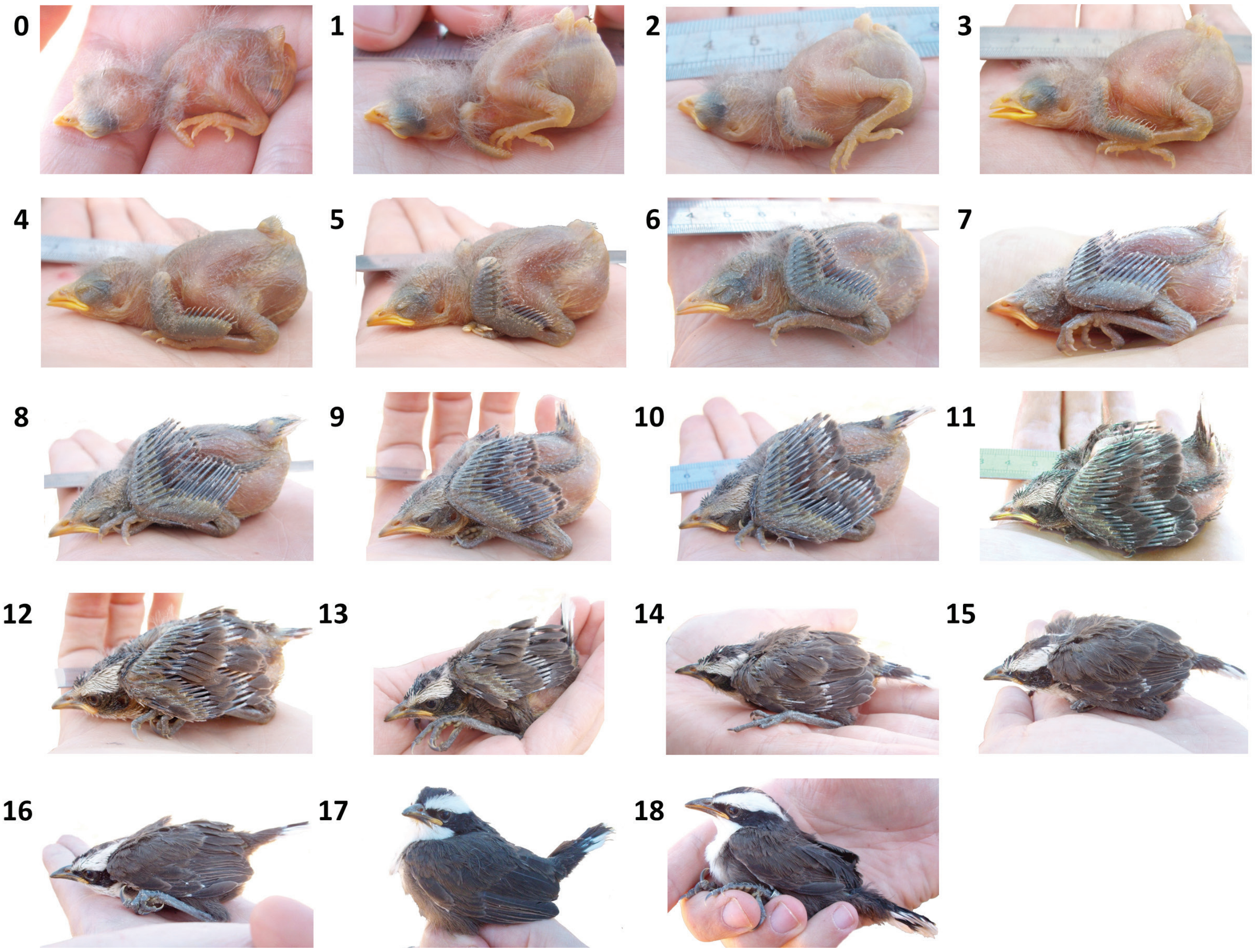

Figure 2. *Daily development of the single Hall's Babbler nestling from brood A. The number of days since hatching is shown next to the top left of each image.*

Table 2

Linear growth of culmen, head-bill, wing and tail length of four Hall's Babbler nestlings from broods A–C (the younger nestling in very poor body condition from brood B was excluded). Mean slope and intercept were derived from regressions fitted to each nestling individually ($r^2 \geq 0.95$ and $P < 0.001$ in all cases).

Trait	Slope			Intercept		
	Mean	Min.	Max.	Mean	Min.	Max.
Culmen[a]	0.47	0.41	0.52	6.32	5.89	6.96
Head-bill[b]	1.30	1.20	1.41	15.42	14.73	16.09
Wing[b]	4.35	4.26	4.40	-5.74	-6.22	-5.27
Tail	3.71	3.21	3.93	-24.77	-27.04	-18.79

[a] nestling from brood B excluded as culmen growth was non-linear

[b] data truncated before growth rate slowed at day 11–14 for head-bill length and day 13–14 for wing length

Table 3

Fledging size as a proportion of full-grown size of four Hall's Babbler nestlings. The age of nestlings on the day before fledging (broods A and C) or death (brood B) is shown in days. Values of *R* (asymptote value as a proportion of adult size; Ricklefs 1968) for body mass and tarsus are shown in parentheses.

Brood	Nestling (sex)	Age	Body mass	Tarsus	Culmen	Head-bill	Wing[a]	Tail[a]
A	1 (♀)	18	0.80 (0.83)	1.03 (1.09)	0.61	0.74	0.78	0.51
B	1 (♀)[b]	17	0.79 -	0.99 (1.04)	0.57	0.71	0.73	0.43
C	1 (♂)	18	0.78 (0.81)	0.99 (1.05)	0.59	0.73	0.76	0.51
C	2 (♀)	17	0.75 (0.77)	1.00 (1.06)	0.59	0.72	0.73	0.48
Mean			0.80 (0.80)	1.00 (1.06)	0.59	0.73	0.75	0.48

[a] calculated using mean lengths of juveniles because those of adults were significantly longer (Table 6). Adult measurements were used for the other traits.

[b] logistic growth curve inappropriate for body mass data for this nestling, which was in poor body condition

predicted ages between captures (Δ age) for 45.5, 50.0 and 44.4 percent of nestlings when age was predicted from external morphology, growth curves and the equation predicting age from tail length, respectively. Δ days was one day greater than Δ age for 50.0, 50.0 and 44.4 percent of nestlings for the three respective ageing methods, and Δ days was one day lower than Δ age for 4.5, 0.0 and 11.1 percent of nestlings for the three respective ageing methods.

Post-fledging growth and ageing

Body mass reached an asymptote when fledglings were c. 8–12 weeks old. There was considerable variation in body mass among individuals, resulting in a poor fit of the logistic growth curve compared with other traits (Table 5). Culmen and head-bill lengths approached an asymptote at about nine weeks old, and reached a peak at about 16–17 weeks old. Wing and tail lengths of the juvenile plumage were significantly shorter than those of adults (Table 6). Logistic growth curves were therefore fitted only to data collected from juveniles recaptured prior to beginning the post-juvenile primary moult. Wing and tail lengths reached maximum length at about five weeks old for both males and females. Juveniles in second basic plumage did not differ appreciably from adults in wing or tail length (Table 6), but this was not tested statistically because of an insufficient sample size.

Iris colour of nestlings and fledglings was darker than in adults, but lightened post-fledging to become reddish-brown. The rictus (gape) was bright yellow in nestlings with a conspicuous fleshy rictal flange, which remained visible for at least the first two months post-fledging. The commisure (including rictal flange) then darkened and the yellow pigmentation gradually receded to the sides, until the entire rictus was pinkish. The age when this occurred varied among individuals; most had only slight traces of yellow by 30–35 weeks old, but one individual still retained some yellow pigmentation at 40 weeks old. The bill was completely black at fledging, but gradually the lower part of the proximal two-thirds of the mandible turned light grey as in adults. The age when this occurred was highly variable: of six individuals 76–79 days old, the bill was completely black in one, becoming pale at the base only in another, partially complete in two siblings, and complete in another two siblings.

DISCUSSION

The sequence and timing of developmental changes in the external morphology of Hall's Babbler nestlings was stereotypical, even in nestlings in poor body condition. Gill and Dow (1983) found similar results for eight Hall's Babbler nestlings, except they observed remiges and rectrices erupting from their sheaths somewhat earlier: days 6–7 c.f. days 7–8 for remiges, and days 6–7 c.f. days 8–10 for rectrices. Hall's and Grey-crowned Babblers attain a 'fully-feathered' appearance, with feather sheaths visible only on the head and tail, at a similar age: c.15 days for Hall's Babbler c.f. 15–17 days for Grey-crowned Babbler (Gill and Dow 1983). Growth rate (*K*) of nestling body mass in Hall's Babblers (0.377–0.392) appeared to be slightly faster than in Grey-crowned Babblers (mean 0.349; Dow and Gill 1984a), but intraspecific variation in growth rate of some passerine species is of a similar or greater magnitude than this difference (Ricklefs 1968, 1976). The age at which growth rate of body mass peaked occurred earlier in Hall's Babblers (6.3–6.5 days) than in Grey-crowned Babblers (7.5 days; Brown 1979). Nestling body mass of both species stabilised during the last week of the nestling period, at about three-quarters the body mass of adults (Dow and Gill 1984a). Such a pattern of growth is not atypical of passerines (Ricklefs 1968). Unlike body mass, tarsus growth rate of Hall's Babblers (0.268–0.286) was similar to that of the Grey-crowned Babbler (mean 0.283; Dow and Gill 1984a).

Three methods were derived to estimate nestling age of Hall's Babblers using the sample of eight nestlings measured daily: age-specific changes in external morphology, growth

Table 4

Timing and sequence of development of feather tracts of eight Hall's Babbler nestlings from broods A–D.
The number of nestlings that commenced the developmental stage of the respective feather tract on each day is shown.
Total number of nestlings examined each day is shown in the last row.

Stage	Feather Tract	Day										
		0	1	2	3	4	5	6	7	8	9	10
Follicles visible below skin	Alar	1	7									
	Capital	1	6	1								
	Spinal	1	5	2								
	Caudal		2	6								
	Ventral		2	6								
	Femoral		1	7								
Emergence of feathers from skin	Primaries			2	6							
	Secondaries				6	2						
	Greater secondary coverts				3	4						
	Rectrices				1	2	2					
	Greater primary coverts				3	5						
	Median secondary coverts					1	3	3				
	Humeral						2	4				
	Uppertail coverts						4	1				
	Spinal						2	5				
	Capital							6				
	Ventral							6				
	Femoral							4	2			
	Throat							2	3			
	Crural								4	1		
	Median primary coverts.								3	1	1	
Eruption of feather from sheath	Primaries								3	2		
	Secondaries								3	2		
	Greater secondary coverts								2	3		
	Greater primary coverts								2	3		
	Median secondary coverts									3	2	
	Humeral									3	2	
	Uppertail coverts									3	2	
	Spinal									3	2	
	Ventral									2	3	
	Rectrices									2	2	1
	Femoral										5	
	Capital										2	3
	Crural										2	3
	Median primary coverts										1	4
	Throat											5
No. nestlings		8	8	8	8	7	7	7	5	5	5	5

Table 5

Parameters of logistic growth curves fitted to pooled data for juvenile male (*n* = 13) and female (*n* = 11) Hall's Babblers. Growth curves take the form $Y = A/(1 + e^{-K(t-i)})$ where Y = trait, A = asymptotic size, K = growth rate, t = age in days, and i = age when maximum growth rate is reached. Results of ANOVA are presented.

Trait	Sex	*A*	*n*	*K*	*i*	*F*	*df*	*P*	r^2
Body mass	♂	40.5	52	0.091	3.1	104.44	2, 48	<0.001	0.813
	♀	37.7	44	0.053	-6.9	115.05	2, 41	<0.001	0.841
Culmen	♂	25.4	42	0.048	10.1	768.96	2, 39	<0.001	0.975
	♀	23.7	36	0.043	8.4	679.79	2, 33	<0.001	0.976
Head-bill	♂	47.9	46	0.059	1.9	1863.67	2, 43	<0.001	0.989
	♀	46.0	37	0.051	-1.9	870.17	2, 34	<0.001	0.981
Wing	♂	84.1	17	0.156	11.0	387.44	2, 14	<0.001	0.982
	♀	79.5	24	0.182	10.6	1678.81	2, 21	<0.001	0.994
Tail	♂	83.0	17	0.206	17.9	773.87	2, 14	<0.001	0.991
	♀	79.9	24	0.228	16.9	924.28	2, 21	<0.001	0.989

Table 6

Wing and tail lengths (mean ± s.e.) of juvenile, second basic and adult plumages of Hall's Babbler. Results of Mann-Whitney U-tests comparing juvenile and adult plumages are presented in the last two columns; sample sizes for second basic plumage were insufficient for statistical analyses.

Trait	Sex	Juvenile[a]	Second basic[b]	Adult[c]	*U*	*P*
Wing length	♂	82.8 ± 0.51	85.8 ± 0.49	86.0 ± 0.16	152.00	<0.001
	♀	80.4 ± 0.38	84.4 ± 0.68	84.3 ± 0.21	79.50	<0.001
Tail length	♂	84.8 ± 0.70	87.1 ± 0.90	88.0 ± 0.26	299.50	<0.001
	♀	83.1 ± 0.64	84.8 ± 1.24	85.6 ± 0.20	264.00	<0.001

[a] ***n*** = 17 males; ***n*** = 19 females; [b] ***n*** = 8 males; ***n*** = 9 females; [c] ***n*** = 86 males; ***n*** = 68 females

patterns of morphological traits, and an equation predicting age from tail length. Each method predicted changes in morphology and growth to within one day for 22 additional nestlings; thus the ageing methods can be used to accurately estimate nestling age. Skeletal and feather growth and developmental sequence and timing were consistent among most Hall's Babbler nestlings. The exception was skeletal and feather growth of the younger nestling in poor body condition, but importantly, other developmental changes in external morphology of this nestling were unaffected (see images in Portelli 2012). Body mass is the most common measurement taken on nestling passerines (Jongsomjit *et al*. 2007), and has been used to estimate the age of nestling Grey-crowned Babblers to the nearest day (Dow and Gill 1984b). However, the reliability of body mass as an age estimator may vary with environmental conditions, which influences patterns of body mass gain in nestling passerines (Boag 1987; Lepczyk and Karasov 2000). This was evident in Hall's Babbler where body mass gain in the two nestlings in poor body condition deviated considerably from other nestlings. Growth rates of linear measurements of body size are generally less sensitive to environmental conditions (Lepczyk and Karasov 2000; Jongsomjit *et al*. 2007); hence they are more reliable estimators of nestling age (Murphy 1981). Skeletal and feather measurements (Fig. 1) and/or external morphology (Table 4; Fig. 2) are therefore recommended for estimating nestling age of Hall's Babbler. Tarsus and head-bill lengths are the most reliable age estimators up to 7–10 days post-hatching, while wing and tail lengths are the best estimators from 5–7 days post-hatching onward. The age of fledglings can be estimated using the equation predicting age from tail length, since tail feathers grows linearly up until growth ceases at approximately five weeks of age. However, this method is only suitable for healthy fledglings as demonstrated by the stunted growth of the younger nestling in poor body condition.

Juvenile growth and development of passerines has rarely been studied in great detail. The age when juvenile Hall's Babblers reached asymptotic body mass varied, but was generally at 2–3 months old. Immediately before fledging, wing length was about three-quarters complete and tail length was about half-grown, but both completed growth at about five weeks post-fledging. Wing and tail lengths of juveniles were significantly shorter, by 3–5 percent, than those of adults. Juveniles attained their second basic plumage at 10–11 months old, at which time wing and tail lengths were similar to those of adults. Similarly, wing and tail lengths of juvenile Grey-crowned Babblers (7–19 weeks old; $n = 6$ males, $n = 5$ females) are 4–6 percent shorter than adults (C. Blackmore unpubl. data). Culmen and head-bill lengths were the last traits to reach adult size, at c.16–17 weeks old. The most conspicuous characteristic of juvenile Hall's Babblers was the bright yellow rictus and rictal flange, which remained visible in the field for at least two months post-fledging. This pigmentation disappeared by eight months old, later than the 4–6 months reported for White-browed Babbler (Cale 1999), but earlier than the c.12 months for Grey-crowned Babbler (Brown 1979). Iris colour in Grey-crowned Babblers gradually changes over three to four years from dark brown in juveniles to pale yellow in adults (Counsilman and King 1977). In contrast, iris colour in juvenile Hall's Babblers only differed from adults during the nestling period, and began to lighten soon after fledging. This is also the case in Chestnut-crowned Babblers (pers. obs.). The juvenile plumage of Hall's Babbler lacks any conspicuous differences to subsequent plumages (pers. obs.), unlike Grey-crowned and Chestnut-crowned Babblers (Counsilman and King 1977; Higgins and Peter 2002). Some juveniles had pale brown edges at the tip of the larger alula feathers that contrasted with a darker shaft streak, which was not seen in adults, but these feathers are typically moulted in the post-juvenile moult. Consequently, juveniles are indistinguishable from adults before they reach one year old; though some juveniles retain their innermost 1–2 primaries through their post-juvenile moult, which has not been observed in adults.

Life-history strategies of passerines from temperate regions of the northern hemisphere differ from passerines of temperate regions of the southern hemisphere and tropical regions (Martin 2004). These differences include a smaller clutch size, more clutches per year, longer incubation, nestling and post-fledging periods, and higher survival rates in southern hemisphere and tropical species (Yom-Tov 1987; Rowley and Russell 1991; Martin 1996, 2004). Nestling growth rate, development, and fledging size are additional fundamental components of life-history strategies in passerines, but relatively little is known about biogeographical variation in these traits. Ricklefs (1968) found mean nestling growth rates of tropical passerines were generally slower than northern temperate species, but he did not include data for southern hemisphere passerines. Some authors have attempted to examine biogeographical variation in growth rates by using nestling period duration as a proxy for growth rate (Woinarski 1985; Bosque and Bosque 1995; Martin 2004), but the former can change independently of growth rate (O'Connor 1984). Brown (1979) and Dow and Gill (1984a) concluded Grey-crowned Babblers had a slower nestling growth rate and an unusually low ratio of fledging to adult body mass than northern hemisphere passerines. However, their analyses included northern hemisphere species that varied widely in body mass (8–100g adult body mass, Brown 1979; 40–100g asymptotic nestling body mass, Dow and Gill 1984a). Ricklefs (1968) and Remes and Martin (2002) collectively published growth rates for 15 northern hemisphere passerines from eight families that are of a similar body mass to Hall's Babbler (36–48g; see Portelli 2014), and seven species from five families with a similar body mass to the Grey-crowned Babbler (68–84g; see Counsilman and King 1977). The mean nestling growth rates of these similarly sized northern hemisphere passerines were faster than both babbler species: 0.476 (range 0.358–0.598) c.f. 0.385 in Hall's Babbler, and 0.435 (range 0.302–0.546) c.f. 0.349 in the Grey-crowned Babbler (Dow and Gill 1984a). Moreover, for each babbler species, only one similarly sized northern hemisphere passerine had a slower growth rate: Black-headed Grosbeak *Pheucticus melanocephalus* (45g; 0.358), and Florida Scrub-jay *Aphelocoma coreulescens* (83g; 0.302) respectively. In contrast, the mean ratio of fledging body mass to adult body mass (*R*) was similar: 0.77 (range 0.61–1.01) c.f. 0.80 in Hall's Babbler, and 0.73 (range 0.53–1.00) c.f. 0.71 in Grey-crowned Babbler (Dow and Gill 1984a). Thus, growth rate is lower for the two babbler species, as concluded by Brown (1979) and Dow and Gill (1984a), but the mean ratio of fledging both mass to adult body mass is similar (*contra* Brown 1979; Dow and Gill 1984a). This study suggests that nestling growth rates of passerines of the southern hemisphere may, like other life-history traits, differ from those of passerines from temperate regions of the northern hemisphere. However, since nestling growth has been studied in few southern hemisphere passerines, particularly Australian species, the available data are currently inadequate to test this hypothesis.

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Do exotic birds dominate feeding at garden food stations in Melbourne in winter?

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Deliberate feeding of wild birds is common in urban Australia and supposedly has both costs and benefits for the birds and the humans that feed them. If urban domestic garden food stations are dominated by common exotic species, they may ultimately not promote, or even reduce, urban native bird species diversity. However, too few investigations have been conducted in Australia to permit a thorough evaluation of this possibility. Twelve established bird food stations in suburban gardens in Melbourne, Australia were visited in one winter by 18 bird species, five of which were exotic. Introduced Spotted Doves *Streptopelia chinensis*, Common Mynas *Sturnus tristis* and Rock Doves *Columba livia*, together with native Noisy Miners *Manorina melanocephala*, were the most prominent users of stations providing bread. Spotted Doves numerically dominated feeding at stations that provided seed, but three native species were also quite prominent feeders at some such stations. Bread and seed stations were exploited by fairly distinct bird species assemblages. On average, approximately six high-intensity inter-specific agonistic interactions per hour occurred at a food station, involving 20 species combinations overall. However, only one third of encounters were between an exotic and a native bird. Displacement of native birds from food stations by exotic birds was substantially less common than the reverse event. Thus feeding at urban garden food stations was dominated by exotic birds, but some native birds also exploited them substantially and were not disproportionately aggressively displaced from them by exotics.

INTRODUCTION

Supplementary feeding of wild birds is widespread in the Western World, particularly in cities (Robb *et al.* 2008). In Australia, an estimated 38–57 percent of households participate in garden feeding of wild birds, mainly offering bread, meat or seeds (O'Leary and Jones 2006). Stated reasons for feeding birds in urban gardens include: pleasure derived from close contact with birds; a humane concern for birds coping with the highly anthropogenically modified city environment; and, a need to counterbalance human destruction and modification of birds' natural habitats (Rollinson *et al.* 2003; Jones 2011; DuBois and Fraser 2013; Galbraith *et al*. 2014). Potentially this activity can promote wildlife conservation by raising awareness of the need to conserve native biodiversity and making the participants feel more 'connected to nature' (Sterry and Toms 2008; Galbraith *et al*. 2014).

Most people who feed wild birds believe that it benefits the birds, and there are some potentially fitness-enhancing effects for the birds. These include increased survival through periods of food limitation (e.g. Newton 1998), enhanced breeding productivity (e.g. Robb *et al*. 2008), and conservation of declining species (e.g. Chamberlain *et al*. 2005). However, there are also some likely fitness-reducing effects, including causing: over-reliance on unsuitable foods and ultimately an inability to survive on purely natural foods (Orell 1989; Stanley and Siepen 1996; South and Pruett-Jones 2000; O'Leary and Jones 2006); aggregation of wild birds at (often unhygienic) food stations that increases disease transmission (Fischer *et al*. 1997; Rollinson *et al*. 2003; Robinson *et al*. 2010; Galbraith *et al*. 2014); trophic cascades that affect the distribution and abundance of prey and predators (Robb *et al*. 2008; Galbraith e*t al*. 2015); and, lower resistance to species invasions through reducing inter-specific competition among well-fed resident species (Cannon 2010).

These likely costs and benefits of feeding wild birds in urban gardens have stimulated a lively debate on its merits and demerits. The dominant view among Australian and South African, but not New Zealand, wildlife managers, researchers and ornithological organizations is that it is harmful for the birds and should be discouraged (Rollinson *et al*. 2003; Galbraith *et al*. 2014). In contrast, in Western Europe and North America it is officially encouraged. Unfortunately the research necessary to better inform this debate has been limited in Australia and elsewhere (Jones and Reynolds 2008; Jones 2011).

The focus of the present investigation is on another very important potential problem with urban garden food stations, which has received less research attention. If these stations are dominated by common, exotic birds (Parsons 2006), they may ultimately not promote, or even reduce, the species diversity of urban native birds (Fuller *et al*. 2008; Galbraith *et al*. 2015) and generate heightened, costly aggression among them (Jones 2011; Wojczulanis-Jakubas *et al.* 2015). Our study examined whether garden food stations providing bread or seeds in winter in suburban Melbourne, Australia were dominated by common urban exotic species and whether inter- and intra-specific aggression occurred frequently and with negative consequences among wild birds visiting these stations. We predicted that exotic species would dominate feeding at these food stations because: they are the most common streetscape birds in

Melbourne (White *et al*. 2005) and correspondence between abundance in streetscapes and attendance at garden food stations has been recorded elsewhere (Cannon *et al*. 2005); and, innovative exploitation of food inadvertently and deliberately provided by humans is a key to successful urban colonization by many exotic bird species (Sol *et al*. 2011). We also predicted that aggressive interactions would be frequent at food stations in winter because natural food resources are seasonally diminished (Woinarski and Cullen 1984) and bird aggregations at point food sources typically generates aggressive interference competition, unless food is superabundant (Wojczulanis-Jakubas *et al.* 2015). It thus seemed likely that aggressive dominance of native by exotic bird species would play a role in affording the latter greater access to the food provided at garden feeders.

METHODS

Study area and food stations

The study was conducted in eastern suburban Melbourne (37.47˚S 144.58˚E) from March–July, 2012, a time of year when mean daily minimum and maximum ambient temperatures in the study area are 10.3˚C and 20.0˚C in autumn and 6.1˚C and 13.6˚C in winter. Twelve established food stations in private gardens 0.6 to 28 kilometres apart were investigated. Gardens varied in the number of trees greater than five metres in height from 0–15 (mean 4) and trees and shrubs less than five metres in height from 2–14 (mean 8). The food stations were elevated 0–197 centimetres (mean 95) above ground level and the amount of food provided daily varied from 58–700 grams. These physical attributes of stations had no influence on station use by birds and consequently are not discussed further. Stations had been operating continuously for 1–20 years and half of them provided bread and half a commercial seed mix. Seed was usually presented in a bowl, whereas bread was scattered by hand. Stations were recruited for the study by word-of-mouth and advertising on ornithological internet web sites. There were no selection criteria other than location in the eastern suburbs, agreement of the owner and obtaining equal numbers of bread and seed stations. Observations were made in the morning, starting 1.5 h after civil twilight.

Measurement of attendance, feeding and agonistic behaviour at food stations

Instantaneous sampling (Choi *et al.* 2007) at 15-second intervals over 15-minute observation periods was used to record the species visiting and feeding at food stations. Attendance and feeding were analysed separately because we reasoned initially that some species might visit the stations, but not actually feed. Birds that visited the vicinity of a station but did not stop there were not scored as 'attending'. Six observation sessions were conducted per station.

Separately, the occurrence of escalated agonistic interactions was recorded during continuous observation for 30-second periods (separated by 15-second intervals) over six or seven 30-minute observation sessions per station. An escalated interaction involved aggressive chasing and/or fighting, resulting in displacement of the 'loser' from the food station and its immediate vicinity. Focusing on escalated interactions meant that it was easy to determine that a bird that left a station did so because of the aggression of the other combatant. For each visiting species, features of its involvement in inter-specific agonistic behaviour recorded were: frequency of participating in interactions; number and identity of species with which it interacted: and, extent to which its members were displaced from the station in interactions. We also recorded each species' proportional contribution to all intra-specific aggressive behaviour observed. Scientific names of the species observed at food stations are given in Table 1 and body sizes in Table 3.

Data analysis

Attendance at food stations by a species was assessed in terms of: the number of stations which at least one species' member visited during the investigation; the percentage of all observation sessions in which at least one species' member attended any station; and, an attendance index (AI), which was the mean number of attendances by the species per 15-minute observation session per station × 100. An 'attendance' was the presence of a species' member at a station irrespective of whether it was/was not feeding. The AI thus gave an indication of the magnitude of a species' attendance at food stations, despite individuals usually not being recognisable throughout an observation session or among sessions. Similarly, feeding at food stations by a species was expressed as a feeding index (FI), which was the mean number of feeding events by the species per 15-minute observation session per station × 100. A 'feeding event' comprised a species' member feeding at a station at a particular sampling interval. Like the AI, the FI indicated the magnitude of feeding by a species at food stations, despite individuals not being recognisable. Although we calculated win: loss ratios for species' involved in inter-specific interactions at food stations, we did not subject them to significance testing because the number of separate individuals involved was unknown.

We used non-metric multidimensional scaling (NMDS) plots (Quinn and Keogh 2002) to examine visually whether the composition of the assemblages of bird species visiting food stations was influenced by the type of food offered (bread or seed). Analysis of Similarity (ANOSIM) and Similarity Percentage (SIMPER) procedures in PRIMER v. 6 (Clarke and Warwick 2001) were used to establish which species accounted for similarities within and dissimilarities between the bird species assemblages visiting bread and seed stations. Non-parametric Spearman rank correlation tests were conducted in R (R Development Core Team, 2011) to examine the relationship between attendance at food stations and involvement in agonistic interactions.

RESULTS

Attendance and feeding at food stations

Eighteen bird species visited the 12 food stations (Table 1), of which 15 (five exotic and ten native) actually fed there. The suite of bread stations was visited by 12 species, the suite of seed stations by 11 species and seven species visited both types of station. During the study, individual bird species (i.e. at least one species member) fed at up to eight stations (mean = 2.5 per species) and the number of bird species feeding at a particular station ranged from 1 to 8 (mean = 4). Native species feeding at bread stations comprised Sulphur-crested Cockatoos *Cacatua galerita*, Rainbow Lorikeets *Trichoglossus*

Table 1

Mean attendance index is the number of bird attendances per observation session per station × 100 and mean feeding index is number of feeding events per observation session per station × 100. Blank cells indicate a complete absence of attendance or feeding. * indicates exotic species.

Species	Percent sessions present (Number stations attended)		Mean attendance index		Mean feeding index	
	Bread	Seed	Bread	Seed	Bread	Seed
Rock Dove* *Columba livia*	14.3 (2)		23.8		5.1	
Spotted Dove* *Streptopelia chinensis*	28.6 (4)	45.2 (5)	8.5	137.7	5.9	82.5
Crested Pigeon *Ochyphaps lophotes*		4.8 (1)		1.2		1
Little Corella *Cacatua sanguinea*		21.4 (2)		32.1		28.1
Sulphur-crested Cockatoo *Cacatua galerita*	2.4 (1)	9.5 (3)	10.4	19.2	0.9	3.8
Rainbow Lorikeet *Trichoglossus haematodus*	2.4 (1)	7.1 (1)	1.1	8.2	0.4	14.1
Crimson Rosella *Platycercus elegans*		2.0 (2)		13.8		15.5
Laughing Kookaburra *Dacelo gigas*		2.4 (1)		0.8		
Common Blackbird* *Turdus merula*	2.4 (1)		0.7		0.1	0.5
Red Wattlebird *Anthochaera carunculatus*	21.4 (3)		3.2		2	
Noisy Miner *Manorhina melanocephala*	35.7 (3)		58.9		4.1	
Common Starling* *Sturnus vulgaris*	21.4 (3)	4.8 (1)	4.8	0.8	1.1	0.3
Common Myna* *Sturnus tristis*	50.0 (6)	11.9 (3)	24.4	2.4	5.3	0.6
Magpie-lark *Grallina cyanoleuca*	9.5 (3)	2.4 (1)	0.6	1.4	0.2	1.1
Pied Currawong *Strepera graculina*	4.8 (1)		0.8		0.3	
Pied Butcherbird *Cracticus nigrogularis*	2.4 (1)		0.1			
Australian Magpie *Cracticus tibicen*	7.1 (1)	2.4 (1)	1.3	0.2	0.1	0.1
Little Raven *Corvus mellori*		2.4 (1)		0.1		

haematodus, Magpie-larks *Grallina cyanoleuca*, Australian Magpies *Cracticus tibicen*, Red Wattlebirds *Anthochaera carunculatus*, Noisy Miners *Manorina melanocephala* and Pied Currawongs *Strepera graculina*; those feeding at seed stations included the first four of these species, plus Crimson Rosellas *Platycercus elegans*, Little Corellas *Cacatua sanguinea* and Crested Pigeons *Ochyphaps lophotes* (Table 1).

(1) Bread stations

Bread stations were visited by four predominantly nectarivorous, three granivorous, three omnivorous, two insectivorous and one carnivorous species. Feeding was predominantly by exotic Spotted Doves *Streptopelia chinensis*, Rock Doves *Columba livia* and Common Mynas *Sturnus tristis* (FIs 5.1 to 5.3) and native Noisy Miners (FI 4.1), but only the Common Myna fed at all bread stations (Table 1). At least one exotic Common Myna, Common Starling *Sturnus vulgaris* and Spotted Dove and one native Noisy Miner and Red Wattlebird visited the bread station under observation in more than 20 percent of sessions (Table 1). However, the Red Wattlebird and Common Starling were not abundant at such stations and had low AIs and FIs there. Thus overall, three exotic and one native species dominated feeding at bread stations.

(2) Seed stations

Seed stations were visited by five predominantly granivorous species, three omnivores, one nectarivore, one carnivore and one insectivore. Feeding was predominantly by exotic Spotted Doves (FI 82.5) and native Little Corellas, Crimson Rosellas and Rainbow Lorikeets (FIs 14.1 to 28.1) (Table 1). Attendance and feeding regimes of these species at seed stations varied considerably. Spotted Doves fed at five of the stations and at least one dove was present at a seed station in 45 percent of observation sessions. One or more Little Corellas visited the seed station under observation in 21 percent of sessions, but this species only fed at two seed stations during the investigation (Table 1). Overall, Crimson Rosellas and Rainbow Lorikeets were relatively prominent consumers at seed stations, but they only fed at a few such stations and were present for only two percent and seven percent of observation sessions, respectively (Table 1). Thus exotic Spotted Doves dominated feeding at seed stations, but three native species fed at them quite substantially.

Distinctness of bird species assemblages at bread and seed stations

There was marked clustering of stations in an NMDS plot of species assemblage composition as a function of food type offered (Fig. 1 shows AI-based plot). ANOSIM confirmed this distinctness (global R = 0.507 [P =0.001] and 0.259 [P = 0.007] for presence/absence and mean abundance data, respectively). SIMPER analysis indicated that exotic Spotted Doves and Common Mynas and native Noisy Miners and Little Corellas were most responsible for the similarities in assemblage composition among stations offering each of the two food types; these species, plus the native Crimson Rosella and Rainbow Lorikeet, were most responsible for the dissimilarities in bird assemblage composition between bread and seed stations (Table 2).

Agonistic behaviour at food stations

The overall rate of occurrence of intra- plus inter-specific agonistic interactions at food stations was 3.5 ± 0.7(s. e.) (range 0–33) per 30-minute observation session.

Table 2

Percentage contributions of species to Bray-Curtis similarity within and dissimilarity between bird assemblages at bread and seed stations from SIMPER analysis. Upper row for each species is derived from species presence/absence data and lower row in parentheses from presence data scaled for species' attendance rates. Contributions < 5% were excluded.

Bird species	Percentage contributions		
	to similarity within		to dissimilarity between
	bread stations	seed stations	bread and seed stations
Spotted Dove	12.2 (35.7)	64.9 (61.5)	14.3 (31.8)
Common Myna	62.3 (47.2)	11.8	20.7
Sulphur-crested Cockatoo		7.5	
Crimson Rosella		6.6	6.5 (11.3)
Noisy Miner	11.2 (8.1)		8.9
Common Starling	5.1		6.9
Little Corella		(22.9)	7.9 (19.3)

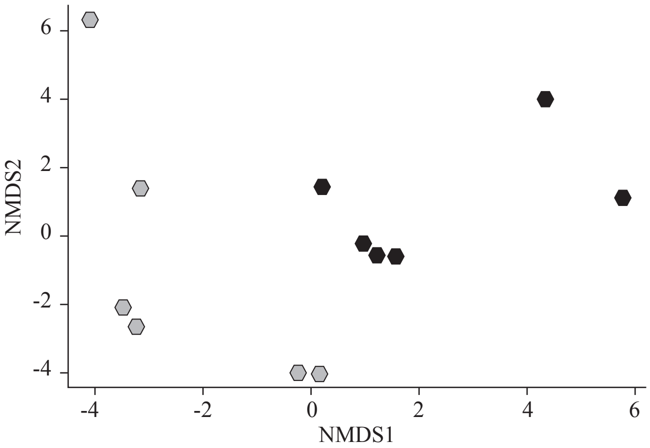

Figure 1. *NMDS plot of bird species assemblage composition at food stations as a function of food type offered at the station. Plot based on species attendance indexes. Black circles are bread stations; grey circles are seed stations.*

(1) Intra-specific interactions

At all food stations combined, 167 escalated intra-specific agonistic interactions occurred during the investigation. The overall mean number of interactions per 30-minute observation was 2.3. The highest mean number of interactions per station per session was 9.3, and 12 species (four exotic and eight native) engaged in such interactions. If we consider just species that were present at stations in more than three aggression observation sessions and visited at least two stations, the proportional contributions to the total number of intra-specific agonistic interactions observed ranged from zero percent (Magpie-lark and Australian Magpie) to 22 percent (Little Corella) (Table 3). These species' contributions were not significantly correlated with the percentage of observation sessions in which species visited the food stations (r_s = 0.045, P>0.05, N = 12). Among native species, four psittacines made the greatest proportional contributions to overall levels of intra-specific aggression and the Spotted Dove made the greatest proportional contribution by an exotic species. Little Corellas and Spotted Doves were among the most frequent visitors to food stations, but Crimson Rosellas, Rainbow Lorikeets and Sulphur-crested Cockatoos were not.

(2) Inter-specific interactions

Only 66 escalated inter-specific agonistic interactions (mean 2.8 per 30-minute observation session) occurred at all food stations combined during the study. Four exotic and nine native species (i. e. 72% of the species attending the stations) were involved in these interactions. Interactions occurred between 20 species combinations (Table 3), eight percent involving two exotic species, 34 percent an exotic and a native species and 58 percent two native species. The greatest involvement was by native Magpie-larks (41% of total encounters) and Crimson Rosellas (42%), but this was attributable to a very high number of encounters between these two species at one food station on just two days, possibly involving just a few individuals. The exotic Spotted Dove was more consistently involved at a high rate in inter-specific agonistic behaviour, participating in 27 percent of all such interactions, at five of the 11 stations where such behaviour was measured, and against seven, mostly native species. The other three exotic species that engaged in inter-specific aggression at food stations also interacted predominantly with native species, but at very low frequencies (Table 3). Considering just species that visited at least two stations, there was no correlation between the percentage of sessions in which a species attended a food station and its level of involvement in inter-specific encounters (r_s = 0.073, P>0.05, N=12).

Focusing on just those inter-specific interactions resulting in the 'loser' being at least temporarily completely displaced from a food station, three species (all native) 'won' all such interactions in which they were involved, three (two native and one exotic) 'lost' all of them and seven (four native and three exotic) experienced both 'winning' and 'losing' against a given species (Table 3B). Interestingly, two of the species that were always displaced from food stations in these highly escalated interactions were: the exotic Spotted Dove, which had high AIs and FIs (particularly at seed stations) and a high level of involvement in inter-specific agonistic interactions at food stations (Tables 1 and 3); and, the native Noisy Miner, which aggressively dominates many bird species in other contexts. If the aberrant Magpie-lark × Crimson Rosella interaction frequency is scored as 1 (see explanation above), exotic species displaced exotic and native birds from food stations equally and native species behaved similarly. The percentages of this adjusted number of interactions won by the larger (53.5%) and smaller (46.5%) combatant were similar (Binomial probability 0.109).

Table 3

Outcome of escalated inter-specific agonistic interactions at garden food stations. Data in each cell are numbers of agonistic interactions for all observation sessions at all food stations in which members of a particular species (in bold) displaced members of another species (in italics) from a station. Win: loss ratio is ratio of displacing to being displaced from food stations. Thus RD displaced RW once, NM twice and CM once (=4), and were displaced once by CM (=1). Interactions without a clear outcome are excluded. Boxed numbers on diagonal are percentages (rounded) of all intraspecific agonistic interactions contributed by the various species.

Displaced species	Displacing species RD	SD	CP	LC	SCC	RL	CR	RW	NM	CS	CM	ML	AM
RD	1										1		
SD		17	2	3	3	3	1	1			4		
CP			0										
LC				22	2								
SCC				4	10								
RL						14							
CR						1	17				1		
RW	1							7					
NM	2								7	2	1		4
CS								1		1	1		
CM	1										5		1
ML							24					0	2
AM													0
Win:Loss ratio	**4:1**	**0:17**	**2:0**	**7:2**	**5:4**	**4:0**	**25:2**	**2:1**	**0:9**	**2:2**	**8:2**	**0:26**	**7:0**

Species key (and total lengths in mm from Pizzey and Knight 2012)): RD, Rock Dove (330-340); SD, Spotted Dove (315); CP, Crested Pigeon (305-355); LC, Little Corella (355-395); SCC, Sulphur-crested Cockatoo (455-510); RL, Rainbow Lorikeet (250-320); CR, Crimson Rosella (320-370); RW, Red Wattlebird (335-360); NM, Noisy Miner (240-275); CS, Common Starling (210); CM, Common Myna (230-255); ML, Magpie-lark (260-300); AM, Australian Magpie (370-440).

DISCUSSION

Bird species using the garden food stations

Thirteen of the 18 species attending the food stations were native. However, the exotic Spotted Dove was the most prominent attender and feeder at both types of station, but particularly at bread stations. Galbraith *et al.* (2015) also found that the Spotted Dove particularly benefitted from supplementary feeding on urban properties in Auckland, New Zealand. The exotic Common Myna and Rock Dove and native Crimson Rosella and Rainbow Lorikeet were also prominent visitors to, and feeders at, bread but not seed stations, although they attended a more restricted number of such stations than Spotted Doves. Native Little Corellas were prominent seed consumers, but only at a small number of stations. In contrast to the situation in Auckland, New Zealand (Galbraith *et al.* 2015), the House Sparrow (*Passer domesticus*), a common exotic urban species, did not feed at the suburban food stations, perhaps because it is more common in, although not confined to, the inner city. Overall, our prediction that exotic species would dominate feeding at the food stations was fairly true of bread, but not seed, stations.

Exotic Spotted Doves and Common Mynas are two of the most common birds in Melbourne streetscapes and native Rainbow Lorikeets (mean FI at seed stations 14.1) and Noisy Miners (mean FI at bread stations 4.1) are also amongst the more common streetscape residents (White *et al.* 2005). Correspondence between abundance in streetscapes and attendance at garden food stations has also been recorded in Great Britain (Cannon *et al.* 2005) and echoes Fuller *et al.*'s (2008) finding that garden supplementary feeding simply seems to subsidize and perpetuate the dominance of the already common city species, many of which are exotic (Daniels and Kirkpatrick 2006). However, in our study there were some exceptions to this pattern. Native Australian Magpies are very common streetscape birds throughout Melbourne (White *et al.* 2005), but did not visit food stations often. Native Crimson Rosellas (mean FI at seed stations 15.5) were prominent feeders at seed stations, but are not among the most common street birds in the city.

In contrast to what has been reported in Brisbane and Sydney (Rollinson *et al.* 2003; Parsons *et al.* 2006; Ishigame and Baxter 2007), birds visiting suburban Melbourne garden food stations were not predominantly large, aggressive, carnivorous species, such as magpies, butcherbirds, currawongs, kookaburras and corvids. The reason may be that none of the stations that we studied offered meat, whereas 32 percent of Brisbane and many Sydney stations did, and many of the Brisbane station operators deliberately targeted these large, carnivorous species and even actively discouraged other species. There was otherwise a considerable commonality in the species assemblages visiting Brisbane and Melbourne food stations, allowing for differences in species' geographic distributions. Parrots and doves featured prominently as visitors in both cities. Interestingly, Red-browed Finches (*Neochmia temporalis*), frequent visitors to Sydney gardens containing seed stations (Parsons *et al.* 2006), were absent from Melbourne food stations, despite occurring in some areas of suburban Melbourne (A. Lill, personal observation).

Distinctness of bird species assemblages at bread and seed stations

Although seven of the 18 species recorded at food stations visited both bread and seed stations, species assemblages using the two types of station were fairly distinct. The Spotted Dove, Common Myna and Little Corella were the most important species generating this distinctness. The species that fed exclusively at seed stations are naturally totally or partially granivorous, but those feeding exclusively at bread stations are more varied in their natural diets (including granivory, carnivory and omnivory). Five of the species that fed at both types of station ate more seed than bread, although only one of them (Spotted Dove) is naturally largely granivorous.

Consumption of low quality food

Most species that fed at the garden stations were consuming foods that were 'unnatural' for them to varying degrees, although some commercial seed mixtures now available may provide a reasonably balanced diet for natural granivores (Jones 2011). It might potentially be more worrying that 12 species consumed bread, four of them quite substantially. Heavy consumption of this highly processed, nutritionally unbalanced food at bird food stations is common worldwide (Chace and Walsh 2006). However, in our investigation any concern about bread consumption should be directed more towards the birds' wellbeing than the effect on native biodiversity conservation, because three of the significant bread consumers were common, urban, exotic birds.

Agonistic behaviour of birds at food stations

The mean number of intra-specific agonistic interactions at food stations per hour was only about five. The exotic Spotted Dove and four native members of the Psittaciformes had the greatest relative involvement in intra-specific agonistic encounters at food stations. However, level of attendance at stations did not strongly influence proportional involvement in such behaviour; the Spotted Dove and one of the psittacine species were among the most common visitors to stations, but the other three psittacine species were not.

The mean number of inter-specific agonistic encounters per hour was approximately six, only slightly higher than that for intra-specific interactions. Again, there was no overall association between a species' attendance level at food stations and its involvement in inter-specific agonistic interactions. Although most exotic species recorded at food stations had high AIs (Table 1), only about 33 percent of inter-specific agonistic interactions were between exotic and native birds. Introduced Spotted Doves were among the most consistent visitors to food stations and involved in more than 25 percent of all inter-specific interactions, but they were always displaced from food stations by other species in highly escalated interactions. Despite this species' long residence history in Melbourne and other eastern Australian cities (Long 1981), species' members appear to be less bold than many other co-habiting urban birds, as also indicated by their reactions to human proximity in the urban environment (Gendall *et al*. 2015). The other three exotic species involved in inter-specific agonistic interactions both 'won' and 'lost' encounters against particular exotic or native species. Overall, larger and smaller species were equally likely to displace each other from food stations (cf. Wojczulanis-Jakubas *et al*. 2015). Thus our predictions that inter-specific agonistic interactions would be frequent and that exotic birds would generally displace natives from the food stations were not really borne out (see also Sol *et al*. 2012). However, conceivably just the passive presence of some exotic species may directly and indirectly reduce feeding rates of native birds at garden food stations (Peck *et al*. 2014).

Low level of aggression by Noisy Miners visiting food stations

Highly aggressive, inter-specific territorial defence by Noisy Miners transforms diverse assemblages of insectivorous and nectarivorous birds into simpler assemblages with fewer species of mostly large, sedentary birds (Mac Nally *et al*. 2012; Maron *et al*. 2013). However, although Noisy Miners were prominent exploiters of bread (but not seed) at garden food stations in our study, they were only involved in nine escalated inter-specific agonistic interactions (14% of total), in all of which they were displaced from the food station by Australian Magpies or exotic birds. Noisy Miners are particularly effective in territorially excluding species smaller than themselves (Maron *et al*. 2013), and almost all the other species attending food stations, and most of those that displaced Noisy Miners there, were as large as, or larger than, the miners. It is likely that the Noisy Miners had aggressively excluded most species smaller than themselves from food station areas prior to the commencement of our observations.

CONCLUSIONS

Feeding at Melbourne's domestic garden food stations that provided bread in winter was dominated by exotic birds, but one exotic and three native species dominated feeding at seed stations. Therefore to a considerable extent the food stations potentially aided the survival of exotic species that are the most common streetscape birds in Melbourne, and consequently they may have had only a modest role in promoting urban native bird species diversity. However, agonistic behaviour was not very common at food stations and the dominance of feeding at stations by exotic birds was not size-related or achieved primarily through aggressive displacement of natives. This 'snapshot' study was limited to one autumn/winter in one Australian city, and extension of research to other seasons, years and cities, and to food stations providing meat, would be valuable.

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Use of ultraviolet light to help age nightjars, owlet-nightjars, frogmouths and owls

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INTRODUCTION

Ultraviolet (UV) light is widely used by researchers to help determine feather generations of most North American owls. It was originally developed for use on Barn Owls *Tyto alba*; however, it is most extensively used on Northern Saw-whet Owls *Aegolius acadicus* due to the frequency at which this species is banded (Weidensaul 2011). Its use is possible because exposing feathers that contain porphyrin pigments to UV light results in them fluorescing a spectacular, hot pink colour (Gill 2007). The pigments degrade over time as feathers are exposed to sunlight, resulting in older feathers fluorescing less brightly than newly grown feathers (Gill 2007; Weidensaul 2011). Moult stages are identifiable under incandescent light by looking at the amount of wear and fading of the feathers, although this requires significant experience on the part of the bander. The use of UV light enables inexperienced banders to easily and accurately identify moult patterns. Although moult strategies differ between species, some are predictable. Therefore, by understanding moult patterns researchers are able to accurately age these kinds of birds (Rogers *et al.* 1986).

METHODS

The methods described by Weidensaul (2011) were used by the authors to demonstrate that the exposure of flight feathers to UV light is useful in determining feather generations not only in owls, but also in nightjars, owlet-nightjars and frogmouths. These birds were caught using hand nets and mist nets in 2014 and 2015 at Bold Park and Matuwa (Lorna Glen), Western Australia. Bold Park is one of the largest bushland remnants in Perth's urban region and Matuwa is an ex-pastoral lease on the southern edge of the Little Sandy Desert. Trapped birds were banded and examined under a handheld UV light. As the described fluorescence is not visible in daylight, a portable 1.5m^3 dark room was used to examine any birds that were captured at dawn. The single Christmas Island Hawk-Owl *Ninox natalis* examined was being held in captivity due to an old injury and used as an educational aid. It was examined at night in a laboratory with the lights off. The UV source used for all examinations was a General Electric 12 inch, battery-operated light, Model number 50975, with a longwave 365nm bulb. The wavelengths providing the best results are considered to be produced by longwave black UVA lights in the range 400-315nm (Weidensaul 2011). Exposure to the UV light, particularly of the eyes, should be kept to a minimum to avoid potential damage to both researchers and subjects.

RESULTS

All individuals listed in Table 1 exhibited differing degrees of fluorescence when examined under UV light, members of some species more markedly so than others. The newly grown feathers of the Tawny Frogmouth *Podargus strigoides*, with feather moult stages ranging from two to five (as described by de Rebeira 2006), were by far the most spectacular, with the ventral side fluorescing hot pink across the entire vane. This differed from the new feathers of Spotted Nightjars *Eurostopodus argus* and Australian Owlet-nightjars *Aegotheles cristatus*, which showed more fluorescence in the shaft of the feather than in the vane. In all species examined, the white parts of the feathers fluoresced more than the darker parts. The first-year birds that were examined first under incandescent light and aged using characteristics described by de Rebeira (2006), Higgins (1999) and Rogers *et al.* (1986), had a full set of hot pink primary feathers when examined under UV light. This would be expected if they had not yet started their post-juvenile moult. The remaining birds examined had a contrasting mix of new and old primaries that, whilst sometimes hard to distinguish under incandescent light, were easily recognised under the UV light.

Australian bird banders commonly age individuals of the species listed in Table 1 as 'unknown', 'first- year' or 'older-than-first year'. Aging is often based on information available in banding guides and aids, such as "markings on forehead obscure" in Australian Owlet-nightjars, "juvenile plumage duller and looser than adults" in Tawny Frogmouths and "slight variations in plumage" in Boobooks *Ninox novaeseelandie*, all of which can be subjective (Rogers *et al.* 1986; Higgins 1999; de Rebeira 2006). It is hoped that the methods described

Table 1

The number of birds examined under UV light.

Species	Number examined
Strigiformes	
Christmas Island Hawk Owl *Ninox natalis*	1
Southern Boobook *Ninox novaeseelandie*	13
Barn Owl *Tyto alba*	6
Caprimulgiformes	
Tawny Frogmouth *Podargus strigoides*	13
Spotted Nightjar *Eurostopodus argus*	20
Australian Owlet-nightjar *Aegotheles cristatus*	21
Total	74

here will help banders to determine moult strategies and more accurately and consistently age owls, nightjars and frogmouths in Australia.

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Observation of mass road-kill of Superb Parrots *Polytelis swainsonii* feeding on spilt grain

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In August 2014, whilst driving along the Barrier Highway between Nyngan and Cobar, New South Wales, I observed large numbers of the nationally threatened Superb Parrot *Polytelis swainsonii* that had been killed on the road whilst feeding on grain spilt by trucks. Here I give an account of my observations that morning and discuss the previously underestimated threat of road-strike to the survival of the Superb Parrot.

The Superb Parrot is a nationally threatened species, listed as 'vulnerable' under the Environmental Protection and Biodiversity Conservation Act 1999, and restricted in range to inland southeast Australia (Webster 1998). Estimating population trends for the species is difficult, because it is highly mobile and dispersive, but anecdotal reports and records from targeted surveys indicate that its population remains perilously low (Webster 1998; Garnett *et al.* 2011). Although road-strike has been previously identified as a cause of Superb Parrot mortality, it has generally not been considered a major threat to the species' survival (Webster and Ahern 1992; Garnett *et al.* 2011), with habitat destruction for agriculture and reduced availability of nesting hollows generally suspected to be the key causes of its historical decline (Manning *et al.* 2006, 2013).

In August 2014, whilst driving along the Barrier Highway between Nyngan and Cobar (31.4949° S, 145.8402° E), New South Wales (NSW), I stopped to observe a flock of approximately 40 Superb Parrots on the roadside at about 07:00 AEST. The parrots were feeding on large quantities of grain, which had been spilt along the highway by passing trucks. I observed the flock for approximately fifteen minutes, during which time approximately ten vehicles passed by. Each of these vehicles struck and killed one to four Superb Parrots. Each time a vehicle approached, the flock would take off from the roadside and one or more parrots would collide with the passing vehicle. Then the flock would immediately settle on the roadside to resume feeding on spilt grain. During the time that I observed the flock, 15 Superb Parrots were killed in vehicle collisions and several others were injured. Before I moved on, I carried two stunned parrots off the road and placed them in nearby vegetation.

On the same morning, I also observed two other, larger flocks, each of approximately 80 Superb Parrots, feeding on spilt grain on the same section of the Barrier Highway. Many dead individuals were visible on the road where these large flocks were feeding (I estimated > 30 carcasses in total), but I did not stop or count dead parrots at these sites. At the three sites where members of parrot flocks had been road-killed, the road was straight and the speed limit was 110 km/h. If the three flocks I observed that morning continued feeding on the roadside and the traffic and rate of strikes remained constant, an estimated 180 Superb Parrots per hour (90% of the parrots that I observed) would have been killed by vehicle collisions on that 130 km section of highway.

Large numbers of Superb Parrots are probably lost to road-strikes, given that the species' range is almost entirely within the cereal grain-producing belt of eastern Australia and contains approximately 3000 kilometres of major highway. Consistent with this prediction, Superb Parrot road-strikes often occur in southern NSW (D. Oliver, personal communication), with individuals that have been injured in road collisions being frequently admitted to veterinary clinics across the NSW South West Slopes (W. Cadell, personal communication).

Anecdotal reports provide further evidence that great numbers of Superb Parrots are road-killed in many parts of their range. For example, large numbers were road-killed at a Riverina feedlot before the feedlot reduced the speed limit for grain carriers (R. Webster, personal communication). Road-kill incidents involving Superb Parrots have also been reported on websites administered by the Office of Environment and Heritage (www.environment.nsw.gov.au/), ABC Rural (www.abc.net.au/news/rural/) and various bird observer groups. Such examples of Superb Parrot road-kills in NSW include at least 18 being road-killed whilst feeding on spilt grain at Cudal on 28 September 2015 (reported by Rosemary Stapleton), "dozens" road-killed near Boorowa on 31 December 2008 (reported by Sarina Locke) and "many" road-killed near Charcoal Tank in October 2011 (reported by Stuart Rae). Despite the public nature of these records, general awareness of the threat of road-strike to Superb Parrots apparently remains low.

Superb Parrots are likely to be at greatest risk of road-strikes during the annual harvest of winter cereal crops (approximately six weeks, August-January), when large quantities of grain are regularly spilt over long stretches of road (Rees, unpublished data). However, grain transport between stockpiles could also lead to grain spills that attract Superb Parrots to feed on roadsides at other times of year. The parrots use vegetated road corridors more frequently than surrounding cleared, agricultural country (Manning *et al.* 2006, 2007), so they are likely to find and feed on any grain spills on local roads and consequently are at high risk of being killed.

Recovery efforts for the Superb Parrot currently focus on habitat restoration, particularly planting favoured nesting trees, but do not address the immediate threat of road-strike to the population (Webster and Ahern 1992). Quantifying this threat to the species would require systematic investigation during the NSW winter cereal grain harvest season. However, recent observations, including the present account, indicate that urgent prevention of grain spillage on NSW roads is probably necessary to secure the Superb Parrot population. By requiring that carriers are fitted with, and use, high quality tarpaulins and comply with load restrictions, silo operators and NSW Roads and Maritime Services would both improve road safety for motorists and help conserve the Superb Parrot.

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Dry season diet of a Barking Owl *Ninox connivens peninsularis* on Adolphus Island in the north of Western Australia

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The Barking Owl *Ninox connivens* is a medium-sized hawk-owl that is associated with the open forest and woodland environments of mainland Australia (Higgins 1999). Two subspecies are recognised. The larger *N. c. connivens* (males 695 g, females 592 g) occurs in southern and eastern Australia, whilst the smaller *N. c. peninsularis* (males 501 g, females 440 g) is restricted to the north of the continent (Higgins 1999). The Barking Owl is common in the wet-dry tropics, but uncommon to rare and declining in the temperate zone (Debus 2009; Parker *et al*. 2007).

Fleay (1968) described the species as a robust and versatile owl. Dietary studies indicate that it is a non-specialist raptor, capable of killing a wide variety of mammalian, avian and invertebrate prey species, which range from its own size (or even larger) to quite tiny prey items (see Higgins 1999 for review; Debus and Rose 2003; Barnes *et al*. 2005; Debus *et al*. 2005; Stanton 2011; Corbett *et al*. 2014). The diet of the larger and better studied *N. c. connivens* varies among geographical regions. For example, in Victoria and western Queensland, the principal prey were young Rabbits *Oryctolagus cuniculus* and Long-haired Rats *Rattus villosissimus*, respectively (Higgins 1999; Debus and Rose 2003). In temperate areas elsewhere in south-eastern Australia, diets were more diverse, with small- to medium-sized birds, mid-sized arboreal marsupials, (particularly Sugar Gliders *Petaurus breviceps*) and invertebrates being the most common prey (Higgins 1999; Barnes *et al*. 2005; Debus *et al*. 2005; Stanton 2011). The diet of the smaller, tropical *N. c. peninsularis* is poorly known, although Corbett *et al*. (2014) recorded mammal (4 spp.), bird (5 spp.), reptile (1sp.), fish (1sp.) and invertebrate (3 spp.) prey being consumed on the South Alligator River floodplain at Kapalga, Northern Territory. Dusky Rats *Rattus colletti*, Magpie Geese *Anseranas semipalmata*, beetles and other insects were the most common prey items there.

Here we describe the diet of *N. c. peninsularis* from Adolphus Island in the wet-dry tropics of northern Western Australia, The Kimberley islands have impoverished mammal faunas compared with the adjacent mainland (Gibson and McKenzie 2012), but larger islands closer to the mainland, such as Adolphus, can have two to seven species of native rodents. We therefore predicted that the Barking Owl would predominantly exploit rodents on this island.

A 12-day survey was undertaken in August 2008 on Adolphus Island (4138 ha), which is situated in the southern section of Cambridge Gulf, 35 kilometres north of Wyndham. The vegetation is dominated by open eucalypt woodlands, *Acacia* shrublands, grasslands and fringing, low-lying mud flats with extensive areas of mangal (mangrove swamp forest). Standard survey techniques were used to record the island's vertebrate fauna (details in Gibson *et al*. 2015).

A single Barking Owl was observed on three occasions roosting in a cluster of fig trees *Ficus atricha* (15°06'33"S, 128°09'07"E), under which seven fresh, egested pellets were found. The pellets were analysed and their contents quantified using standard techniques described by Debus and Rose (2003). Rodent skulls recovered from the pellets were lodged with the Western Australian Museum and their identification verified. Biomass of prey species was inferred from live animals captured during the survey and from the literature. We measured abundance of ground mammals in the dominant habitat types using baited Elliott traps set for four nights on four different trap lines across two sites on the island, for a total of 1040 trap-nights (Gibson and McKenzie 2012). At each site, two trap lines were in sloping, rocky areas (an *Acacia* wooded hillside with mixed tussock *Triodia* spp. and tall grasses *Sorghum stipoideum* and a treed creek system cut into a hillside with boulders on its upper slopes) and two were in flat areas with sandy soils (a *Eucalyptus*/*Melaleuca* woodland along a drainage line and an open grassland with scattered trees).

Rodent remains were found in all pellets; they comprised the Common Rock Rat *Zyzomys argurus*, Grassland Melomys *Melomys burtoni* and Western Chestnut Mouse *Pseudomys nanus* (Table 1). Overall, these rodents comprised 87% of the dietary biomass, with arthropods and birds being of minor significance. We live-trapped these three rodents, plus the Northern Quoll *Dasyurus hallucatus*, which was not represented in the pellets. The Common Rock Rat was the most abundant rodent, with 29 individuals being captured, whilst the Grassland Melomys and Western Chestnut Mouse were relatively uncommon, with three and two captures being made, respectively. Common Rock Rats were only caught in the rocky habitats, where they were moderately abundant (7.7 individuals per 100 trap nights) in the *Acacia* woodland sites and less abundant along the rocky creek lines (3.5 individuals per 100 trap nights). The other two rodent species were found in the sandy woodland and grassland habitats.

Table 1

Diet of a Barking Owl on Adolphus Island expressed as the minimum number of individual prey items, total prey biomass (g) and % biomass of prey. Values are mean ± standard deviation.

Prey Species	**Mean mass (g)**	**Minimum no. of individuals**	**Total mass (g)**	**% Biomass of prey**	**Relative abundance of mammals (%)**
Mammals					
Western Chestnut Mouse *Pseudomys nanus*	22.2 ± 6.9	1	22.2	6.1	5.4
Common Rock Rat *Zyzomys argurus*	37.5 ± 7.8	6	225.0	62.1	78.4
Grassland Melomys *Melomys burtoni*	69.1 ± 26.2*	1	69.1	19.1	8.1
Northern Quoll *Dasyurus hallucatus*	320.0 ± 74.6	-	-	-	8.1
Other prey					
Unidentified bird	20	1	20	5.5	
Grasshopper (Acrididae)	2	5	10	2.8	
Cricket (Gryllidae)	2	3	6	1.7	
Beetle (Coleoptera)	2	3	6	1.7	
Crab (Brachyura)	4	1	4	1.1	

* mostly sub-adults

Although our sample size of seven pellets, presumably from one owl, was very small, we speculate that Barking Owls on Adolphus Island probably took rodents in proportion to their abundance as recorded by live-trapping (Table 1). The apparent habitat separation between the Common Rock Rat and other rodents also suggests that the Barking Owl obtained its prey from a variety of contrasting habitats. The carnivorous Northern Quoll is potentially a dangerous prey item for a Barking Owl, although Oakwood and Spratt (2000) suspected that one took a radio-collared quoll at Kapalga. However, such an event appears to be uncommon, as Corbett *et al*. (2014) did not detect Northern Quolls in the 94 Barking Owl pellets that they collected over a 10-year period at that site.

Birds were scarce on Adolphus Island during the dry season, as there were few plants flowering and we found no fresh water. One potential prey animal was the large arboreal gecko, *Gehyra koira koira*, which was abundant on tree trunks and vertical rock faces on the island. This gecko weighs up to 14 grams and is up to 150 millimetres long (pers. obs.). Elsewhere on the mainland, Barking Owls take roosting birds and arboreal mammals from branches of trees, but there is little evidence that they prey on nocturnal reptiles (Higgins 1999).

Our study, whilst limited by the very small number of pellets obtained, is consistent with the observation by Debus *et al*. (2005) that Barking Owls rely on available mammalian prey. The mean live-capture rate of small- to medium-sized rodents on Adolphus Island was relatively low (3.3 individuals per 100 trap-nights), but the main prey species, the Common Rock Rat, was common in patches of suitable habitat. At Kapalga, Barking Owls exploited the larger Dusky Rat (30–250 g), which was generally in relatively high numbers in this more productive tropical floodplain site (Corbett *et al*. 2014). Collectively, these studies indicate that native rodents are a major prey of the Barking Owl in northern Australia.

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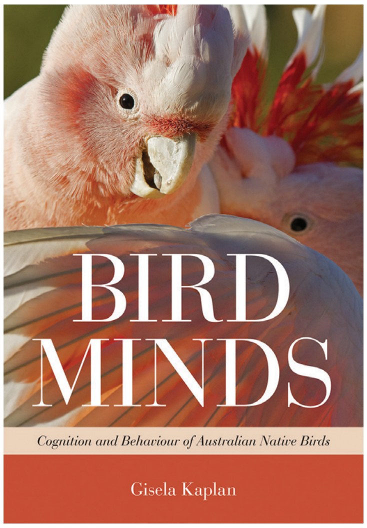
Book Review



Bird Minds: Cognition and Behaviour of Australian Native Birds

Kaplan, Gisela T. 2015. CSIRO Publishing. Paperback 280 pp, black and white photographs, illustrations and tables, two appendices. ISBN: 9781486300181. RRP $45.00.

This book is an ambitious attempt to draw together a large body of research from a number of scientific disciplines, combined with a lifetime of personal experience, into a single volume book. The result lies somewhere between popular science and a scientific review, making some very complex issues accessible but not overly simplified. The breadth of topics covered is reflective of the author's own background in neurology, ornithology and wildlife care.

The first chapter sets the scene by describing the unique geological and evolutionary history of Australia that has shaped the biota we have today. What I first noticed was how much there is that we simply do not know – a common theme throughout the book. This is followed by eleven chapters describing various aspects of native birds' behaviour and ecology and the cognitive complexities required for each of these attributes. The subjects covered include foraging, tool use, nest building, play, mimicry, learning, emotions, communication and the ability to understand abstract concepts.

What is it that makes Australian birds unique and worth discussing in such depth? The first curiosity is the high number of cooperatively breeding species in Australia. It is with good reason that Australia has been dubbed the land of cooperative breeding i.e. birds that live and breed in groups. This is obviously a topic about which the author is passionate and a large part of the book is dedicated to these species. Secondly, Australian birds are relatively long-lived compared to most northern hemisphere birds. Lastly, there is good evidence that songbirds evolved in Australia before spreading across the globe. Despite all this, Kaplan points out, Australian birds are vastly underrepresented in scientific literature. For this reason, the author draws on examples from all over the world, including some from other taxa such as apes and humans, as well as drawing upon her own extensive experiences observing wild and rescued birds. Although these stories and anecdotes provide a lot of depth and interest to the book, many of them would be difficult to verify or replicate, a fact that should be taken into consideration when reading them. The author also selectively chooses references that promote her point and is often generous in the importance she gives to some studies or parts of studies that support her argument.

Behaviours are described very vividly, so that even without the drawings you can picture the birds acting them out. I am sure all of us can relate to many of the analogies drawn, such as cockatoos filling the role that monkeys occupy on other continents. Occasionally I found myself a little lost in the flow of the book, as there is a fair bit of 'jumping around', and I frequently found myself re-reading paragraphs or sentences. However, this happens less and less throughout the book as more concepts are explained. The final chapter provides a good summary of the rest of the book and goes some way towards answering the question we all want to ask – who is the 'smartest' bird of all?

This book is written for those with an interest in birds and bird behaviour, but without the means or knowhow to trawl through the huge body of pertinent scientific literature. If you enjoyed any of Kaplan's numerous earlier works (such as *Australian Magpie: Biology and Behaviour of an unusual Australian Songbird*; CSIRO Publishing 2004), you will certainly also enjoy this book.

Catherine Young

RECOVERY ROUND-UP

This section is prepared with the co-operation of the Secretary, Australian Bird and Bat Banding Schemes, Australian Nature Conservation Agency. The recoveries are only a selection of the thousands received each year; they are not a complete list and should not be analysed in full or part without prior consent of the banders concerned. Longevity and distance records refer to the ABBBS unless otherwise stated. The distance is the shortest distance in kilometres along the direct line joining the place of banding and recovery; the compass direction refers to the same direct line. (There is no implication regarding the distance flown or the route followed by the bird). Where available ABBBS age codes have been included in the banding data.

Recovery or longevity items may be submitted directly to me whereupon their merits for inclusion will be considered.

Hon. Editor

The following abbreviations appear in this issue:

AWSG - Australasian Wader Study Group.
VWSG - Victorian Wader Study Group.

Australian Pied Oystercatcher *Haematopus longirostris*

(a) 100-92431. Nestling banded by G. P. Clancy at Beswicks Beach, Empire Vale, NSW on 6 Nov. 1998. Band number read in field (bird not trapped) at Boundary Creek, South Ballina, NSW on 3 Jul. 2016, over 17 years, 7 months after banding. 10 km SSW.

(b) 100-92435. Nestling banded by G. P. Clancy south-west of Patches Beach, Ballina, NSW on 30 Nov. 1998. Band number read in field (bird not trapped) at South Ballina Beach, NSW on 3 Jul. 2016, over 17 years, 7 months after banding. 17 km NNE.

(c) 100-96111. Nestling banded by G. P. Clancy at Beswicks Beach, Empire Vale, NSW on 19 Dec. 2000. Band number read in field (bird not trapped) at Boundary Creek, South Ballina, NSW on 3 Jul. 2016, over 15 years, 6 months after banding. 10 km SSW.

Grey-tailed Tattler *Tringa brevipes*

052-71950. Adult (2) banded by AWSG on the Shores of 80 Mile Beach, WA on 1 Nov. 2001. Recaptured, released alive with band at banding place on 14 Feb. 2016, over 14 years, 4 months after banding.

Curlew Sandpiper *Calidris ferruginea*

042-29860. Immature (1) banded by VWSG at Yanerbie, SA on 17 Nov. 2013. Recaptured released alive with band at Beaches Crab Creek Road, Roebuck Bay, Broome, WA by AWSG on 20 Feb. 2016. 2034 km NW.

White-throated Treecreeper *Cormobates leucophaeus*

034-31916. Adult (1+) male banded by K. Gover at Scheyville National Park, NSW, on 13 April 2008. Recaptured, released alive with band at banding place by L. Hook on 9 August 2015, over 7 years 3 months after banding.

Superb Fairy-wren *Malurus cyaneus*

019-30149. Adult (1+) male banded by C. Young at Scheyville National Park, NSW, on 10 May 2008. Recaptured, released alive with band at banding place five times, the last occasion by J. Hardy on 9 August 2015, over 7 years 2 months after banding.

White-browed Scrubwren *Sericornis frontalis*

025-22262. Adult (1+) male banded by J. Farrell at Scheyville National Park, NSW, on 13 July 2008. Recaptured, released alive with band at banding place four times, the last occasion by D. McKay on 9 August 2015, over 7 years after banding.

Yellow Thornbill *Acanthiza nana*

019-24325. Adult (1+) banded by K. Gover at Scheyville National Park, NSW, on 10 May 2008. Recaptured, released alive with band at banding place by D. Smith on 10 April 2015, over 7 years 11 months after banding.

Lewin's Honeyeater *Meliphaga lewinii*

041-38907. Adult (2+) male banded by A. & A. Leishman at Camden Airport, NSW on 13 Aug. 2007. Recaptured, released alive with band at banding place three times, the last occasion on 20 Aug. 2016, over 9 years after banding

Golden Whistler *Pachycephala pectoralis*

(a) 034-37388. Adult (2+) banded by A. & A. Leishman at Camden Airport, NSW on 27 Aug. 2007. Recaptured, released alive with band at banding place twice, the last occasion on 16 Jul. 2016, over 8 years, 10 months after banding.

(b) 034-37389. Adult (2+) female banded by A. & A. Leishman at Camden Airport, NSW on 10 Sep. 2007. Recaptured, released alive with band at banding place four times, the last occasion on 16 Jul. 2016, over 8 years, 10 months after banding.

Eastern Yellow Robin *Eopsaltria australis*

(a) 024-94110. Adult (1+) male banded by J. Hardy at Scheyville National Park, NSW, on 12 August 2007. Recaptured, released alive with band at banding place four times, the last occasion by M. Franklin on 15 May 2016, over 8 years 9 months after banding.

(b) 024-94137. Adult (1+) female banded by J. Hardy at Scheyville National Park, NSW, on 10 May 2008. Recaptured, released alive with band at banding place four times, the last occasion by J. Webb on 12 June 2016, over 8 years 1 month after banding.

(c) 025-97621. Adult (2+) male banded by A. & A. Leishman at Camden Airport, NSW on 17 Mar. 2008. Recaptured, released alive with band at banding place on 17 Sep. 2016, over 8 years, 4 months after banding.

(d) 026-30603. Adult (1+) female banded by J. Farrell at Scheyville National Park, NSW, on 12 August 2007. Recaptured, released alive with band at banding place five times, the last occasion by J. Hardy on 11 October 2015, over 8 years 1 month after banding.

Notice to Contributors

Manuscripts relating to any form of avian research will be considered for publication. Field studies are preferred particularly where identification of individual birds, as by banding, has formed an integral part of the study. Some broad areas of research which do not necessarily require individual identification include morphometric analyses, techniques, species diversity and density studies as well as behavioural investigations. Behavioural, plumage and breeding studies can be conducted in captivity but must provide basic ornithological knowledge rather than avicultural interest.

Manuscripts are classified as either major articles (more than 1,500 words) or minor articles (500 to 1,500 words). Minor articles need no summary. Shorter notes relating to almost any aspect of ornithology are welcomed but must adhere to the aims of the Association. Species lists or sightings which are not discussed in relation to historical evidence or scientific parameters are not suitable for publication in *Corella*. Authors proposing to prepare Seabird Island items should contact the Assistant Editor,Seabird Islands, and obtain a copy of the guidelines.

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Contributors are requested to observe the following points when submitting articles and notes for publication in *Corella*.

Manuscripts:

A guide to the format required for tables, figures and manuscripts can be attained by reference to a recent edition of the journal and more specifically to the Publication Style found on the ABSA website.

Articles or notes should be sent via email to the editor as a .doc or .rtf file or typewritten and submitted in triplicate via post. Double spacing is required with typing on one side of the paper only. Margins of not less than 25 mm width at the left hand side and top, with similar or slightly smaller at the right hand side of the page are required.

All pages of the manuscript must be numbered consecutively, including those containing references, tables and captions to illustrations, the latter placed in after the text. No underlining and no abbreviations should be used within the text.

The *Style Manual for Authors,Editors and Printers* (6th edition 2002; John Wiley & Sons Australia, Ltd.) is the guide for this journal. Spelling generally follows the Macquarie Dictionary.

Nomenclature and Classifications follow:

Christidis, L. and Boles, W. E. (2008). 'Systematics and Taxonomy of Australian Birds'. (CSIRO: Collingwood, Victoria).

Proper nouns, particularly place and bird names must commence with a capital letter.

Headings are as follows: **HEADING – capitals and bold** (e.g. **RESULTS)**

Sub Heading – lower case and italics (e.g. *Ecology*)

Referencing:

References to other articles should be shown in the text – '. . . Bell and Ferrier (1985) stated that . . .'or '.... this is consistent with other studies (Jones 1983; Bell and Ferrier 1985).'– and in the Reference Section as:

Bell, H. L. and Ferrier, S. (1985). The reliability of estimates of density from transect counts. *Corella* 9: 3-13.

Jones, J. C. (1983). 'Sampling Techniques in Ornithology.'(Surrey Beatty and Sons: Chipping Norton, NSW.)

Figures (Maps and Graphs) and Tables:

The printable area of the page is 18 cm x 27 cm; double column figures/tables will be 18 cm across; single column figures/tables will be 8.5 cm across; widths between one column and double column can also be accommodated.

The captions for figures should be typed up onto a page separate from the figure.

Maps

Maps should be clear and relevant to the study and can be submitted in a variety of formats (.tif, .eps, .pcx) but the recommended one is a high resolution .jpg file (colour is acceptable). In some instances simply listing the latitude and longitude may suffice instead of a published map. Maps should only show necessary information. Excessive labelling(including names of towns, roads, rivers) will clutter the figure making it difficult to locate key place names. Photocopies of original hand drawn maps are not suitable for publication. They should be submitted only initially. When the paper is accepted for publication, the originals must be submitted so that they can be scanned into an appropriate electronic format.

Graphs

Lines should be thick and dark and any fill used should show a clear distinction between sets of data (colour fills are acceptable). Borders around the graph and the key are not necessary. The recommended format is an .xls file – this makes it very easy to adjust fills, thickness of lines etc, if necessary.

Where possible, please present the figure at final size. Figures that seem satisfactory when they are large, can present problems when they are reduced. Remember that if the figure has to be reduced for publication the figure will reduce equally in all dimensions i.e. both width and height will reduce. This can cause some problems, such as: (i) Line graphs where the lines are very close together can lose clarity. (ii) The typeface will reduce. Please ensure that the final typeface size AFTER reduction will be a minimum of 10 times Times New Roman typeface.

Tables

The recommended format is an .xls file but tables created in Word are acceptable. These should normally have a maximum size of one page but larger tables can be accommodated, if necessary.

FOR MORE DETAILED INFORMATION OR ASSISTANCE IN THE PREPARATION OF FIGURES PLEASE CONTACT THE PRODUCTION EDITOR.

CORELLA

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