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Aging nestling Carnaby's cockatoo, *Calyptorhynchus latirostris*, and estimating the timing and length of the breeding season

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Abstract

It is important to know the age of nestling birds for many ecological and behavioural studies. Various methods have been developed for individual species; most are based on measurements of growth in wings, tarsi or heads/bills, or observations of changes in size, plumage and behaviour over time. However, techniques for aging nestlings have not been established for most avian species. This paper sets out two methods to age nestling Carnaby's cockatoo, *Calyptorhynchus latirostris*, an endangered species endemic to southwestern Australia. One method is based on the physical changes in size and plumage during the 10 to 11 weeks of the nestling period, and the other on the relationship between the length of the nestling's folded left wing and its age developed from data obtained from nestlings of known age. The estimated age of nestlings may be used to extrapolate egg-laying, hatching and fledging dates by taking the 29 days of incubation and the 76 days of the nestling period into account. The method of estimating nestling age based on length of folded left wing provides a more accurate estimate of nestling age than observations of changes in nestling size and plumage. However in situations where it is not possible to handle nestlings, the observation method should provide a reasonable basis for calculating the commencement and end of the breeding season, the length of egg-laying and nestling periods; important population parameters specified for monitoring under the species' recovery plan.

Keywords

Carnaby's Cockatoo, *Calyptorhynchus latirostris*, aging nestlings, relationship between wing length and age, sexing nestlings

Introduction

Knowing the age of nestlings is important for many ecological studies, including those investigating population dynamics, life histories, behaviour, longevity, conservation planning and management (Boal 1994, Wails et al. 2014). Aging data are also important for planning the timing of visits to breeding areas to maximise the numbers of nestlings banded/ringed for the minimum number of visits (Saunders and Ingram 1998), thus minimising the disturbance to breeding populations. Methods for estimating the ages of nestlings have been developed for some avian species, especially raptors (Steenhof and Newton 2007, Penak et al. 2013). Methods for aging have been based on measurements (Petersen and Thompson 1977, Bortolotti 1984, Poole 1989, Gosler et al. 1998, Pande et al. 2011, Penteriani et al. 2004, Penak et al. 2013, Wails et al. 2014) and observations of changes in plumage and size (Boal 1994, Gossett and Makela 2007, Becker and Weisberg 2013).

There are two species of black cockatoo with white tail bands in southwestern Australia; Carnaby's cockatoo, *Calyptorhynchus latirostris* and Baudin's cockatoo *C. baudinii* (Saunders 1974, 1979a). Carnaby's cockatoo has the widest distribution of the two species, occurring in the area of the southwest receiving more than 300 mm of annual average rainfall (Saunders 1974). As a result of changes in land use associated with clearing of native vegetation for the establishment of broadscale agriculture and urban development, Carnaby's cockatoo has undergone a major contraction of its range, and decrease in its total population (Saunders 1990). Baudin's cockatoo occurs in the forested southwest and is also believed to have declined in numbers (Department of Environment and Conservation 2008). Both species are listed as endangered under the Australian Federal Government's *Environment Protection and Biodiversity Conservation Act* 1999, listed as "Fauna that is rare or likely to become extinct" in Schedule 1 of the Western Australian *Wildlife Conservation Specially Protected Fauna Notice 2013* under the *Wildlife Conservation Act 1950*, and listed as endangered under IUCN Red List category and criteria (IUCN 2014). Both are subject of recovery plans: Cale (2003) and Department of Environment and Conservation (2012) for Carnaby's cockatoo and Department of Environment and Conservation (2008) for Baudin's cockatoo. Carnaby's cockatoo has been the subject of extensive research (Saunders et al. 2013 and references therein) while there is little published research relating to the ecology of Baudin's cockatoo.

Carnaby's cockatoo's recovery plan specifies the need for regular monitoring to provide information on breeding populations, and any changes in breeding parameters over time (Action 14.3, Department of Environment and Conservation 2012). Two of those breeding parameters are the commencement and length of the breeding season. Commencement and length of the breeding season may be established by frequent visits to breeding populations to establish when egg-laying commences and when the last nestlings for the season leave their nest hollows. The need for frequent visits is time consuming, logistically expensive and is unlikely to be undertaken (Wails et al. 2014), especially on species such as Carnaby's cockatoo whose egg-laying period may extend over several months. This information may also be generated by estimating the age of nestlings from one or more visits each breeding season and extrapolating back for laying and hatching dates and forward for fledging dates (Boal 1994, Petersen and Thompson 1977, Penteriani et al. 2004).

In this paper we describe two methods of aging Carnaby's cockatoo nestlings when the hatching dates are not known. One of the methods for aging is based on changes in the physical appearance of nestlings over the nestling period, and the other by comparing the length of a nestling's folded left wing against a growth curve constructed from measurements of nestlings of known age. We also report on the possibility of using the same techniques on the closely related, but poorly researched Baudin's cockatoo.

Methods

Study areas and data collected from nestlings: Two breeding populations of Carnaby's cockatoo were studied in detail from 1970–1976; one at Coomallo Creek in the northern wheatbelt of Western Australia and the other at Manmanning in the central wheatbelt (Saunders 1982). Both areas are described by Saunders (1982) and Saunders and Ingram (1998). Manmanning was visited at weekly intervals during the breeding seasons of 1970–1976, and the length of the nestlings' folded left wings (mm) were measured once during each visit from the time the nestlings were large enough to handle safely (at least 13 days old), until just before they fledged (after 10 weeks from hatching).

The folded left wing was measured with a stainless steel ruler marked in mm with a right-angled steel butt (or stop) at the zero end. The bird's left wing was folded and the carpal joint held against the butt end with the primary feathers flattened along the ruler with the length taken at the tip of the longest primary feather. This is the method described in Lowe (1989 Fig 6.5). Provided the wing is held against the butt end of the ruler and the chord flattened, the measurement is accurate and repeatable by others.

Some individual nestlings were measured up to nine times. For reasons explained by Saunders (1982), the breeding population at Manmanning was extirpated by 1977. At Coomallo Creek, visits were made each week during the breeding seasons of 1970-1974, and the folded left wings of the nestlings were measured once during each visit, but subsequently, during each breeding season the area was visited, nestlings were only measured once or twice in their nestling period. Since 1974, the Coomallo Creek population has been monitored (and nestlings measured) in 22 of the years until 2014, including each year 2009–2014.

In addition to measuring the length of the folded left wing, nestlings were weighed, the shape and colour of their cheek patches were noted and, in the breeding season of 2014 they were photographed in order to prepare descriptions of the changes in their physical appearance with age.

From 1969 to 1973 inclusive, the following measurements were also taken with vernier callipers from each nestling whenever it was handled; culmen length and width, tarsus length, length of the claw on the longest toe, and tail length (Saunders 1982).

The length of the folded left wing was found to be the easiest to measure accurately and so the other linear measurements were not recorded from 1974.

Analyses of growth data of length of folded left wing with age: As there is no difference in the lengths of the wings of adult males and females or juvenile males and females (Saunders 1974), data from both sexes of nestlings were combined for the analyses.

Analyses were undertaken to develop an inverse calibration between the length of the folded left wing (mm) and the age (days) of the nestling using data collected from Coomallo Creek (1970–1974) and Manmanning (1970–1976). The data were obtained from nestlings of known age; that is, their date of hatching was known accurately, not from extrapolation or estimation. In a sense these data were collected opportunistically; that is, we were fortunate enough to examine the hollows on the days when the nestlings hatched. The relationship between age and length of folded left wing for nestlings of known age is described by a three parameter logistic curve. Methods were then developed to use the length of the folded left wing to allow the estimation of the age of nestlings whose day of hatching was not observed; 95% confidence intervals of the estimated age were derived by inverting fitted logistic growth models.

Following Saunders's (1982) analyses of growth in length of folded left wing using methods set out by Ricklefs (1967), a three parameter logistic model was fitted to the data. This model takes the form:

$$\mathrm{FLW} = \mathit{Asym}/[1 + \exp\{(\mathit{xmid} - \mathrm{age}) / \mathit{scal}\}]$$

where "FLW" is the length of the folded left wing (mm) and "age" is the nestling's known age (days). The parameters are "*Asym*", the asymptotic length (mm), "*xmid*", the location parameter, namely the age (days) at which half the asymptotic FLW is reached, and "*scal*", a scaling parameter (days/mm) that controls the maximum steepness of the growth curve. Due to the repeated measures on individuals observed during the course of the nestling phase of growth, a non-linear mixed model was fitted to the data using R (R Core Team 2014) and the self-starting model function, SSlogis, from the package nlme (Pinheiro et al. 2014) for fitting non-linear mixed effect models.

The fixed effect of primary interest was location, "*xmid*", to compare growth rates of nestlings from Coomallo Creek with those from Manmanning. In addition to the fixed part, under the model each parameter was assumed to have a zero mean random perturbation added to it, which varied across the combination of year and nest hollow. The random effects can be thought of as having two roles: firstly as a parametrically economic way of allowing for unobserved influences on the growth; and secondly, as a way of allowing for the growth outcomes in the nestlings from the same hollow in the same year to be correlated.

The potential significance of both random and fixed effects was assessed using a log likelihood ratio test.

A total of 163 measurements of the length of the folded left wing from known aged nestlings were available for analysis, of which a number of measurements represented a single observation of one individual nestling. The data were screened to exclude data from known aged nestlings measured on less than three occasions. This resulted in a total of 147 observations from 28 individuals.

The random effects were assessed with a full model fitted where all three parameters were allowed to vary according to location of the observation and single deletion of the random effects fitted and compared to the full model.

At Coomallo Creek between 2009 and 2014, the lengths of the folded left wing were available for 17 nestlings whose hatching date was known and subsequently measured at ages ranging from 23 to 65 days. Their measurements were compared with the inverse calibration of age on length of folded left wing (table in Appendix) to assess the accuracy of the estimation of age with nestlings this century compared with those of the period 1970-1976.

Comparison of nestling age based on observations of physical appearance with age based on length of folded left wing: Both RD and DAS have extensive experience of observing and handling Carnabys cockatoo nestlings. Following the example of Boal (1994) we have prepared a series of 10 photographs to illustrate changes in size and plumage of nestlings over the 10–11 weeks of the nestling period. In November 2014, one of us (RD) provided an estimate of the age of ten nestlings at Coomallo Creek based on their appearance at the bottom of the nest hollow, the situation those not authorised to handle nestlings would be in. RD's estimate of age was then compared with the age estimated on the basis of the length of the nestling's folded left wing. The estimates of age based on length of folded left wing were made after RD's more informal, visual estimates were made.

Results

Aging nestlings based on plumage characteristics: The changes in size and plumage of nestlings from hatching until fledging, a period of between 10 and 11 weeks (Saunders 1979b), are shown in Figure 1A–J. Nestlings can be aged approximately by comparing their appearance with the nestlings illustrated in the figures. Aging on appearance is possible up to about nine weeks, but becomes more difficult from then on as they have no distinguishing physical changes as they grow larger. By the time they fledge they are nearly the same size as their parents (Saunders 1979b).

RD estimated the age of ten nestlings (subsequently aged from 18–67 days on the basis of length of folded left wing). On the basis of plumage characteristics, he underestimated nestling ages by an average of three days (range -11 to +5). His average accuracy was 90% (range 80–100%) of the age estimated on the basis of the length of the folded left wing.

Aging nestlings based on the length of the folded left wing: The three parameter logistic models fitted to the Coomallo Creek and Manmanning data have location-specific fixed effects for the asymptotic length *Asym*, but common fixed effect values assumed for the other two parameters, *xmid* and *scal*. The asymptotic length (mm) for the Coomallo Creek population is 353 (standard error 4.19) and 328 for the Manman-

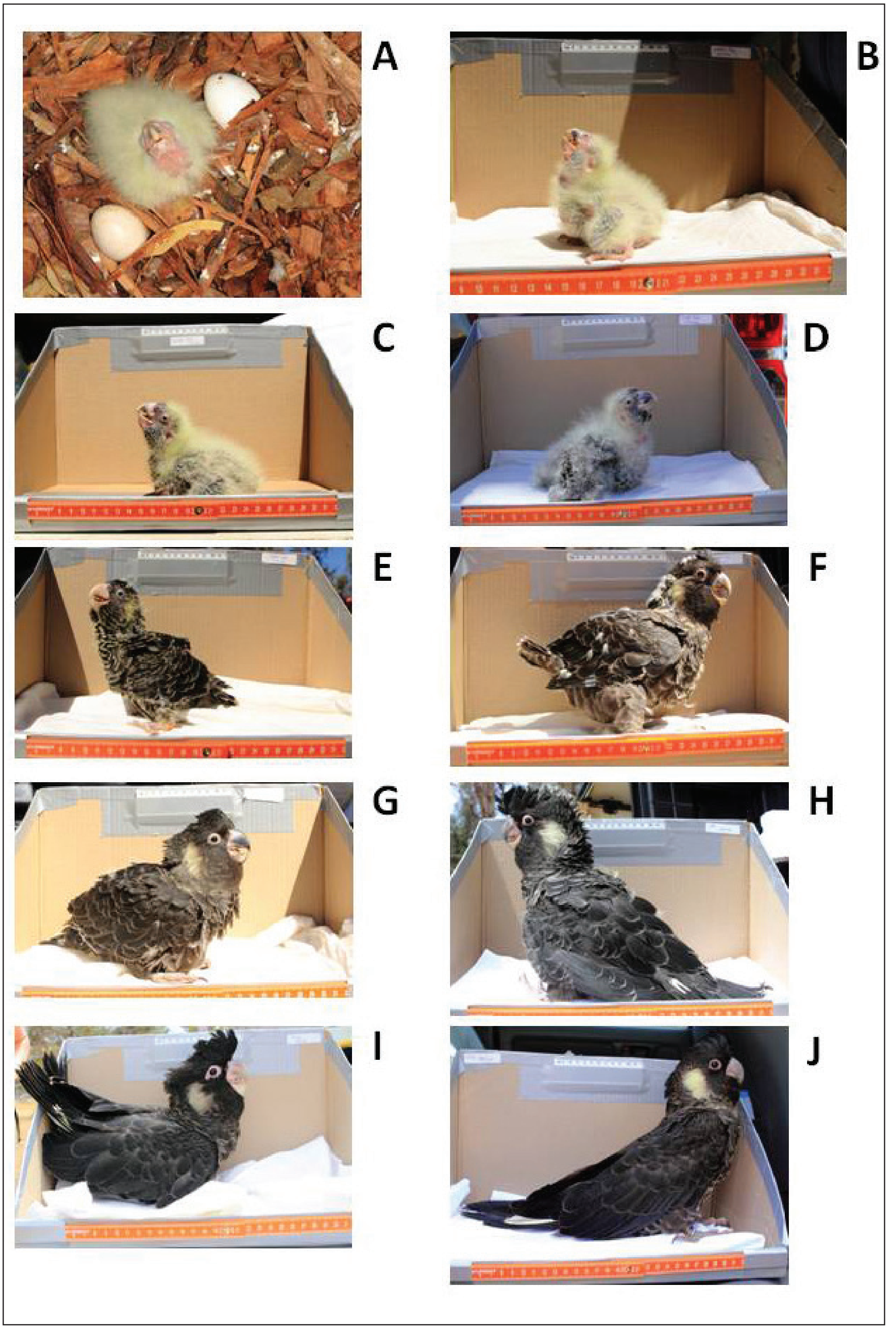
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Figure 1. A Week 1 (days 1–7, with day 1 being hatching day): On hatching, Carnaby's cockatoo nestlings are covered in pale yellow down. They are blind, can sit unaided and have a prominent egg tooth. Note the size of the nestling in relation to the width of the hatched egg which is about 34.5 mm (Saunders and Smith 1981) **B** Week 2: The nestling's eyes remain closed, it is still covered with pale yellow down with small developing dark pin feathers, the egg tooth is still present and, if touched the nestling will beg immediately. The scale in the foreground is numbered in cm **C** Week 3: The nestling's eyes begin to open, pin feathers burst through the skin on all feather tracts, giving the nestling a greyish appearance because of the feather sheaths under the down. The egg tooth starts to disappear **D** Week 4: Eyes are completely open, grey stripes become more prominent on the upper bill, down feathers are lost progressively as black feathers burst from their sheaths. The tail feathers begin to emerge and the cheek patch begins to appear **E** Week 5: The cheek patch is now clearly visible and sexing based on colour and shape of the cheek patch is possible from this age (Saunders 1979b), most down feathers are gone and black feathers with scalloping are prominent. The remnant of the egg tooth is no longer visible **F** Week 6: Tail feathers are a 2–3 cm long, down feathers continue to disappear, with body feathers almost full size and primary feathers extend almost to the tail. The small size of the cheek patch with darker suffusion and the non-circular shape indicates the nestling pictured is a male **G** Week 7: Very few down feathers, white tail band starts to emerge, bill end sharpens and crest becomes more prominent. The dusky shading and non-circular shape of the cheek patch indicate the nestling illustrated is a male **H** Week 8: White bands in tail feathers are 3–4 cm long, body feathers have a black sheen and are the same size as those of an adult, primary feathers are longer than the tail and some down feathers may be still be present. The size, clarity and more rounded shape of the cheek patch indicate the nestling illustrated is a female **I** Week 9: White bands in tail are 5–6 cm long, down feathers no longer present, nestling now resembles a small adult. It may be aggressive when handled or when an observer checks its nest hollow. The dirty colour of the cheek patch indicates the nestling illustrated is a male **J** Week 10: The size of the white bands in the tail feathers and the length of the primary feathers are close to those of adults. The nestling resembles an adult. It is capable of flight and if disturbed may fledge. The clarity of the cheek patch indicates the nestling illustrated is a female.

ning population (standard error 6.63). The other two parameters have values of 42.2 (standard error 0.62) (*xmid* in days) and 13.1 (standard error 0.22) (*scal* in days/mm). The two regression lines are shown on Figure 2 together with 95% confidence limits. There is increasing separation of the two regression lines as the ages of the nestlings increase, with nestlings from Manmanning having shorter folded left wing lengths for a given age compared with nestlings from Coomallo Creek.

These models have been used in an inverse way to estimate a nestling's age for a particular length of folded left wing as well as to provide confidence intervals around this estimate. As the regression lines approach the asymptote, the ability to estimate an upper confidence interval for nestling age is lost, as is implied by the model. The inverse calibration is given in the Appendix, together with the confidence intervals for the estimated age of nestlings given particular measurements of the length (mm) of folded left wings for nestlings in the Coomallo Creek and Manmanning populations.

The lengths of the folded left wings of the 17 nestlings of known age at Coomallo Creek 2009–2014 were compared with the data in the Appendix. These nestlings ranged in age from 27–67 days when measured. The ages of 12 (70.6%) of these were as estimated by the data for Coomallo Creek in the Appendix, or +/- 2 days of the estimate. The remainder were within the 95% confidence intervals, indicating that

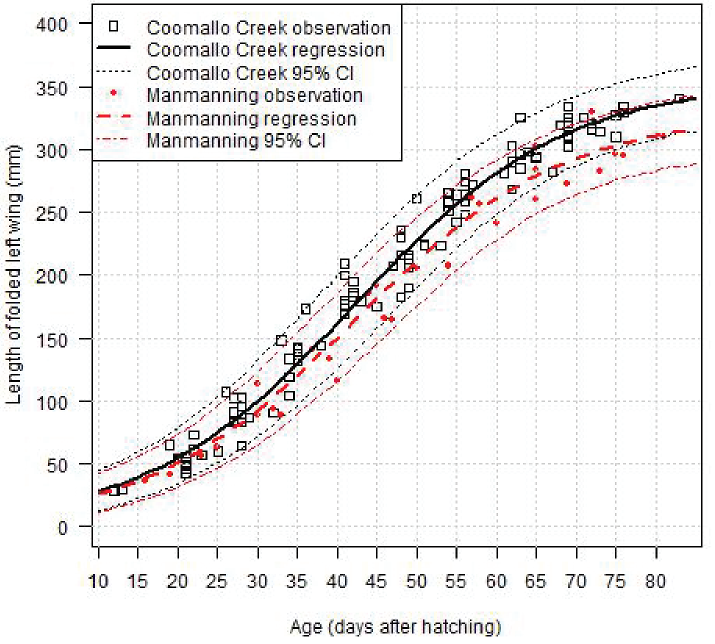

Figure 2. Fitted regressions and 95% confidence intervals for the relationship between length of folded left wing (mm) as a function of age (days) since hatching for nestlings of known age from populations of Carnaby's cockatoo at Coomallo Creek (1970–1974) and Manmanning (1970–1976).

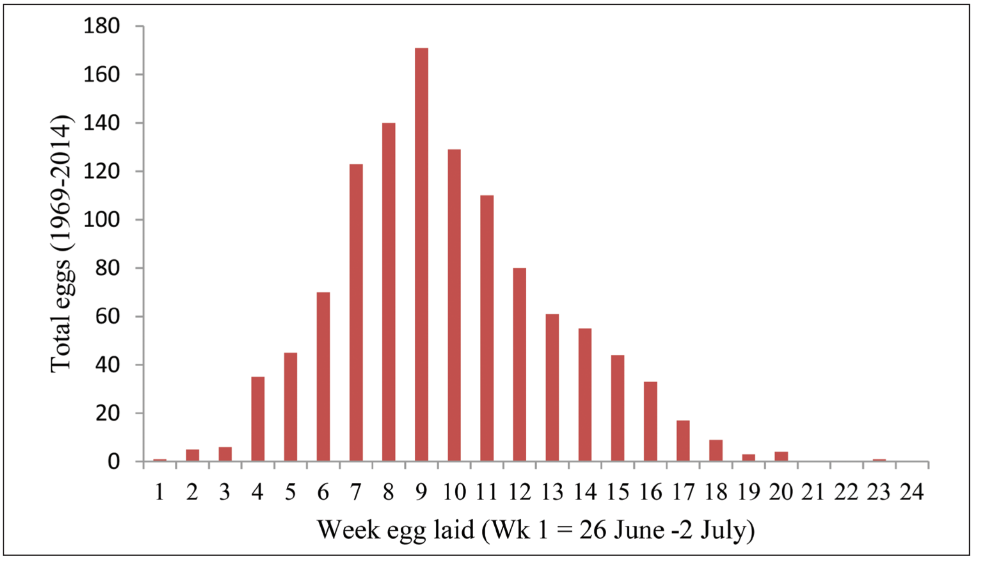

Figure 3. Mean number of eggs laid per week for the 28 years data were available from 1969–2014 (total eggs = 1143). Survey in second week of September (week 11) ensures that all early breeding attempts will be recorded (except those that have failed with no evidence left) and survey in the second week in November (week 20) allows all but 3.1% of breeding attempts to be recorded with some chance of establishing nestling age.

the table based on nestling data from the 1970s is accurate for estimating the age of nestlings this century from the length of its folded left wing.

Egg-laying period: Data are available on laying dates of 1143 breeding attempts at Coomallo Creek over 28 years between 1969 and 2014. These dates were extrapolated from the ages of nestlings. The mean number of eggs laid per week is shown on Figure 3. Because of the length of the egg-laying period, one survey each breeding season would not allow the length of the egg-laying period to be established; at least two visits are required. A survey in the second week of September (week 11 on Figure 3) would enable the commencement of egg-laying to be extrapolated as well as the number of breeding attempts to that time, with the exception of those that had failed before the visit and leaving no evidence of an attempt. A survey in the second week of November (week 20 on Figure 3) would have not been able to estimate the laying dates of 3.1% of the breeding attempts, as the eggs would not have hatched when the survey was being conducted.

Discussion

Under Western Australian Government regulations it is illegal to handle nestling Carnaby's cockatoo unless taking part in an authorised research project. However, not all those engaged in active research are authorised to handle nestlings, but they are authorised to make observations of the contents of active nest hollows in order to advise those authorised to actually handle and band/ring nestlings of the best time to visit particular populations to measure and band/ring nestlings (Matt Swan, WA Department of Parks and Wildlife *pers. comm.*).

In order to provide those engaged in research on the species with methods to age nestlings appropriate with their authorisations, we consider two methods for aging Carnaby's cockatoo nestlings when the hatching date is unknown; by looking at a nestling's physical appearance, or by comparing the length of the nestling's folded left wing against a growth curve for length of folded left wing and age developed from nestlings of known age. The former is not as accurate as the latter, but with experience it may be useful for gaining an approximation of the commencement and end of the breeding season without having to handle nestlings to take measurements. Aging nestlings by assessing changes in size and plumage has been used for a range of species, particularly raptors (Boal 1994, Gossett and Makela 2007, Becker and Weisberg 2013).

However, when more accurate estimations about commencement of breeding and the length of the breeding season are required, then measurements of the folded left wing of nestlings and aging them on some benchmark of length of folded left wing and age correlation is more appropriate. It has been found that wing length is the most reliable aging technique for a range of non-passerine and passerine species (Petersen and Thompson 1977, Bortolotti 1984, Poole 1989, Gosler et al. 1998, Pande et al. 2011, Penteriani et al. 2004, Penak et al. 2013, Wails et al. 2014), as it is for Carnaby's cockatoo. Hatching dates may then be extrapolated from the estimated age. Dates for egg-laying and fledging may also be extrapolated by taking the 29 days of incubation and the 76 (72–80) days of the nestling period into account (Saunders 1979b). The sample should consist of as many nestlings as possible from a breeding population to establish commencement of egg-laying and length of breeding season.

Which regression line should be used; that derived from the Coomallo Creek or Manmanning data? What is apparent from Figure 2 and the table in the Appendix is the increasing separation of the two regression lines as nestlings age, with those from Manmanning having shorter folded left wings for a given age compared with nestlings from Coomallo Creek, although the difference in estimate of age is only 2.9% with the oldest birds. Saunders (1982, 1986) demonstrated that the population breeding at Manmanning was under stress, most likely related to shortages of food, particularly later in the breeding season. The Manmanning population had lower breeding success, changed breeding behaviour, and lower nestling growth rates than the population at Coomallo Creek (Saunders 1979b, 1982), which is still extant, with a breeding population similar in size to that of the early 1970s (Saunders et al. 2014). The Manmanning population had ceased breeding in the area by 1977. The facts that the breeding success of the Coomallo Creek population is similar to that of the 1970s, the breeding population is of a similar size and that growth rates for folded left wing is similar to that of the 1970s indicates that the regression line for the Coomallo Creek population should be used as the benchmark on which to age nestlings from other areas.

When is the most effective time to examine nestlings? Saunders and Ingram (1987) analysed egg-laying dates and established that two visits to breeding areas in the second week in September and the second week in November were the most likely to make sure all early and most late breeding attempts were recorded. Saunders et al. (2013) demonstrated that commencement of egg-laying in Carnaby's cockatoo is correlated with rainfall in the Austral autumn. The wetter the autumn the earlier egg-laying commences. In dry autumns, when egg-laying commences later, the second visit should be made in early December. If resources are available for only one visit a season, then the middle of October would result in recording most breeding attempts, with the caveat that some late breeding attempts may not be recorded.

Baudin's cockatoo is closely related to Carnaby's cockatoo and is of similar size and colouring (Saunders 1979a). The mean length of the folded left wing of Baudin's cockatoo is 379 mm (n = 102) compared with Carnaby's cockatoo's 364 mm (n = 293), a difference of 4.1%. Considering the lack of information on the nestling period and nestling growth of Baudin's cockatoo, the data presented for Carnaby's cockatoo should be used to age Baudin's cockatoo, until the methods described in this paper are used with data generated for Baudin's cockatoo to prepare more accurate aging methods.

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Appendix

Estimated age (days) since hatching of nestlings at Coomallo Creek and Manmanning based on the length of the folded left wing (mm) for lengths from 50 mm to 324 mm. The lower and upper 95% confidence intervals of the estimates are also given. Nestlings may be aged by taking the length of the folded left wing and looking up the predicted age for that length of folded left wing. Hatching dates can be extrapolated from that age, as can laying dates by taking the 29 days of incubation into account. Fledging dates can be extrapolated by taking the 76 days of the nestling period into account. For reasons explained in the text, the data from Coomallo Creek should be used the benchmark to age nestlings from other areas.

		Coomallo			Manmanning	
FLW (mm)	**Lower estimate**	**Predicted age**	**Upper estimate**	**Lower estimate**	**Predicted age**	**Upper estimate**
50	12	19	25	13	20	26
52	13	19	25	14	20	26
54	13	20	26	14	21	27
56	14	20	26	15	22	28
58	15	21	27	16	22	28
60	15	21	27	16	23	29
62	16	22	28	17	23	29
64	16	22	28	18	24	29
66	17	23	29	18	24	30
68	17	23	29	19	25	30
70	18	24	30	19	25	31
72	18	24	30	20	26	31
74	19	25	31	20	26	32
76	19	25	31	21	27	32
78	20	26	31	21	27	33
80	20	26	32	21	27	33
82	21	27	32	22	28	34
84	21	27	33	22	28	34
86	22	27	33	23	29	34
88	22	28	33	23	29	35
90	22	28	34	24	29	35

		Coomallo			Manmanning	
FLW (mm)	Lower estimate	Predicted age	Upper estimate	Lower estimate	Predicted age	Upper estimate
92	23	29	34	24	30	36
94	23	29	34	25	30	36
96	24	29	35	25	31	36
98	24	30	35	25	31	37
100	24	30	36	26	31	37
102	25	30	36	26	32	37
104	25	31	36	27	32	38
106	25	31	37	27	33	38
108	26	31	37	27	33	39
110	26	32	37	28	33	39
112	26	32	38	28	34	39
114	27	33	38	28	34	40
116	27	33	38	29	34	40
118	27	33	39	29	35	40
120	28	34	39	29	35	41
122	28	34	39	30	35	41
124	28	34	40	30	36	41
126	29	35	40	30	36	42
128	29	35	40	31	36	42
130	30	35	41	31	37	42
132	30	35	41	31	37	43
134	30	36	41	32	37	43
136	31	36	42	32	38	43
138	31	36	42	32	38	44
140	31	37	42	33	38	44
142	31	37	43	33	39	44
144	32	37	43	33	39	45
146	32	38	43	34	39	45
148	32	38	44	34	40	45
150	33	38	44	34	40	46
152	33	39	44	35	40	46
154	33	39	44	35	41	46
156	33	39	45	35	41	47
158	34	39	45	36	41	47
160	34	40	45	36	42	47
162	34	40	46	36	42	48
164	35	40	46	36	42	48
166	35	41	46	37	43	48
168	35	41	47	37	43	49
170	36	41	47	37	43	49
172	36	42	47	38	44	49
174	36	42	47	38	44	50
176	36	42	48	38	44	50

		Coomallo			Manmanning	
FLW (mm)	**Lower estimate**	**Predicted age**	**Upper estimate**	**Lower estimate**	**Predicted age**	**Upper estimate**
178	37	42	48	39	44	50
180	37	43	48	39	45	51
182	37	43	49	39	45	51
184	38	43	49	40	45	51
186	38	44	49	40	46	52
188	38	44	50	40	46	52
190	39	44	50	40	46	52
192	39	45	50	41	47	53
194	39	45	50	41	47	53
196	39	45	51	41	47	53
198	40	45	51	42	48	54
200	40	46	51	42	48	54
202	40	46	52	42	48	55
204	41	46	52	43	49	55
206	41	47	52	43	49	55
208	41	47	53	43	49	56
210	42	47	53	44	50	56
212	42	48	53	44	50	56
214	42	48	54	44	50	57
216	42	48	54	45	51	57
218	43	48	54	45	51	58
220	43	49	55	45	52	58
222	43	49	55	46	52	58
224	44	49	55	46	52	59
226	44	50	56	46	53	59
228	44	50	56	47	53	60
230	45	50	56	47	53	60
232	45	51	57	48	54	61
234	45	51	57	48	54	61
236	45	51	57	48	55	62
238	46	52	58	48	55	62
240	46	52	58	49	55	62
242	46	52	59	49	56	63
244	47	53	59	50	56	63
246	47	53	59	50	57	64
248	47	53	60	50	57	65
250	48	54	60	51	58	65
252	48	54	61	51	58	66
254	48	55	61	51	58	66
256	49	55	61	52	59	67
258	49	55	62	52	59	68
260	49	56	62	53	60	68
262	50	56	63	53	60	69

		Coomallo			Manmanning	
FLW (mm)	**Lower estimate**	**Predicted age**	**Upper estimate**	**Lower estimate**	**Predicted age**	**Upper estimate**
264	50	56	63	54	61	70
266	50	57	64	54	61	70
268	51	57	64	54	62	71
270	51	58	65	55	62	72
272	51	58	65	55	63	73
274	52	58	66	56	64	74
276	52	59	66	56	64	75
278	53	59	67	57	65	76
280	53	60	67	57	65	77
282	53	60	68	58	66	79
284	54	61	69	58	67	80
286	54	61	69	59	67	82
288	55	62	70	59	68	83
290	55	62	71	60	69	
292	56	63	72	60	70	
294	56	63	72	61	70	
296	56	64	73	61	71	
298	57	64	74	62	72	
300	57	65	75	62	73	
302	58	65	76	63	74	
304	58	66	77	64	75	
306	59	67	78	64	77	
308	59	67	79	65	78	
310	60	68	81	66	80	
312	60	69	82	67	81	
314	61	69	84	67	83	
316	61	70	85	68		
318	62	71		69		
320	62	72		70		
322	63	73		71		
324	63	74		72		