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Breeding of the Australian White Ibis *Threskiornis molucca* in the urban environment

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The Australian White Ibis *Threskiornis molucca* has increased dramatically in the urban environment since the 1970s and requires management. Currently information on its breeding, a prerequisite for appropriate management, is scarce. We studied the reproduction of Australian White Ibises at two urban sites in the wider Sydney area over an entire year. In comparison to non-urban ibises, urban ibises had a longer breeding period, smaller egg volumes and clutch sizes, but a larger range in clutch sizes. The growth rate of ibis chicks is also described. Urban ibises also had a lower hatching success, but a higher mean number of fledglings/clutch and a higher reproductive success.

INTRODUCTION

The Australian White Ibis *Threskiornis molucca* has since the 1970s expanded into coastal areas of Australia (Smith and Munro 2010). At the same time it has dramatically declined in its traditional range in inland Australia (Porter *et al.* 2006). Today this ibis causes considerable problems for environmental managers as it forms large colonies in many coastal cities, where it can cause economic, social and ecological problems (Smith and Munro 2010). Specifically, it may carry and transmit diseases potentially dangerous to humans and lifestock, destroy vegetation, foul waterbodies, compete with other native fauna, collide with aircraft when near airports, scavenge food from bins and landfills and harass people (see Martin *et al.* 2007; Corben and Munro 2008).

Many agencies are currently trying to manage urban ibises predominantly by limiting their breeding success (which is thought to be high) by destroying nests, eggs and chicks (Smith 2009). This is often resource intensive and difficult (Martin *et al.* 2007), and may be ineffective, since detailed information on the reproductive biology of urban ibises is lacking (Smith 2009). Today only one detailed study on the reproductive biology of ibises exists, which focuses on birds from non-urban areas (Lowe 1984). While this study does not explain the current breeding success, it may serve as a reference to evaluate changes in the breeding biology between urban and non-urban ibises. In addition, some small-scale studies exist from urban environments (see Smith 2009). However, these studies are of limited value, since they have concentrated on only a few nests at a single site, and have not covered the whole breeding period. In view of this we have studied the breeding biology of ibises from two large colonies in the wider Sydney region over a whole year, so that baselines for future management become available. We also compared our data to those reported for non-urban ibises and describe the growth of ibis chicks.

METHODS

Study animals and sites

The Australian White Ibis (ibis hereafter) is native to Australia and traditionally breeds colonially in inland wetlands (Marchant and Higgins 1990). Today it also breeds in large numbers in urban environments and feeds on landfills (Smith 2009; Snape 2011). Three eggs are normally laid, which are incubated for 20-23 days (Lowe 1984; Beilharz 1988). After three weeks chicks leave the nest, but depend on their parents for another three weeks (Marchant and Higgins 1990).

Ibises were studied at two sites in the wider Sydney area: (a) a sand island (0.10–0.50 ha depending on tidal levels) in Brisbane Waters at Woy Woy (WW) (33°30'S, 151°20'E) (80 km north of Sydney); and (b) an island (0.45 ha) at Lake Gillawarna (LG), Bankstown (33°55'S, 150°58'E). Despite a drought in the Sydney region during our study, with below average rainfall (816mm) and above average temperature (24.3°C) (BOM 2006), the islands were always surrounded by water. Both sites were close to landfills, where ibises foraged (Smith *et al.* 2010).

Data collection and analysis

Both colonies were visited once weekly between 1 April 2005 and 1 April 2006. During each visit, all new nests and eggs were individually marked. The nests and their content were monitored during subsequent visits. We also recorded whether nests had disappeared or were reused for new clutches after the first clutch was raised or lost.

We identified the breeding duration for each site from the first to the last nest recorded with eggs and/or hatchlings. We also determined the incubation period of eggs, and the time it took chicks to hatch and fledge. Egg lengths and widths were measured to the nearest 0.1 millimetre and egg weights to the nearest 0.5 gram. The means ± s.e. and ranges of each parameter were calculated for each site so that comparisons between sites and results of other studies could be made. Egg volumes (V = K x length x width^2, where the constant K = 0.507; Hoyt 1979) were also determined to allow for comparisons with published data and between sites. The mean clutch sizes (number of eggs per clutch and nest) ± s.e. and their ranges were calculated for both sites and compared to each other. The overall frequency (%) of each clutch size (1 to 5 eggs) was also calculated for each site, which revealed the most common (modal) clutch size.

The frequencies of clutches (%) that produced zero, one, two, three and four hatchling(s) and fledgling(s) were calculated for each site. Then the mean ± s.e. and range of the number of (1) hatchlings and (2) fledglings produced per clutch, and (3) fledglings produced per nest were calculated for both sites and compared to each other. Also, the hatching success (% eggs that hatched), fledging success (% hatchlings that fledged) and reproductive success (% eggs that hatched and fledged) were calculated from the total number of eggs, hatchlings and fledglings for each site.

Homogeneity of variance and distribution normality were determined by the Levene's and Kolmogorov-Smirnov tests, respectively. All statistical comparisons between parameters were conducted using an independent-sample t-test (two-tailed) (SPSS, version 14.0, Chicago, USA) and assessed at the P = 0.05 significance level.

During site visits, 131 and 102 ibis chicks at WW and LG, respectively, were weighed with Pesola scales and a range of morphometric parameters (i.e. head-bill, bill, wing, tarsus and tail length) was measured with Vernier calipers, rulers and a tape measure. Australian Bird and Bat Banding Scheme (ABBBS) bands were used to re-identify individuals. To gain a surrogate for growth limits of ibises, 26 adult ibises were caught between 17 Jan and 24 Mar 2006 at Centennial Park, Sydney (33°54'S, 151°14'E) and their body weight and other morphological parameters (see above) were measured. These birds were banded to prevent recapturing and re-measuring the same birds. From the above measurements on young and old birds we calculated means and standard deviations (s.d.) for each parameter for birds of different age groups. We used the Quasi-Newton method for estimating the constants of the sigmoid-regressions $y = a\frac{\exp(b(x+c))-1}{\exp(b(x+c))+1}+d$ to describe the increases in weight and other morphological parameters of chicks over time (days), as this model fitted the data best (highest R^2 values). For the mean adult weight and morphological parameters, we also calculated their 95 percent confidence intervals. All adult parameters had a normal distribution (P < 0.05; Kolmogorov-Smirnov tests), except head-bill and bill (P > 0.05), which had a bimodal distribution.

RESULTS

Ibises bred between May 2005 and March 2006 (10.5 mo) at WW and July 2005 and January 2006 (7 mo) at LG. The total number of nests and clutches differed between sites (see below). Some nests were re-used, and thus held multiple clutches. We recorded 661 nests (with 887 clutches) at WW; and 216 nests (with 337 clutches) at LG (Fig. 1). WW had significantly less clutches per nest (1.34 clutches ± 0.03 s.e.; range: 1–5; mode: 1 (73.5%)) than LG (1.56 ± 0.06; range: 1–5; mode: 1 (60.6%)) (t_{875} = -3.614, P < 0.01, t-test). Active nest numbers varied for both sites throughout the breeding season (Fig. 1). While nest numbers at WW increased from May to August, they did not rise at LG until July. Nest numbers peaked at both sites between August and October. Nest numbers at LG decreased from November and reached zero in late January, while at WW they decreased from January reaching zero by late March. Eggs were laid two days apart and hatched asynchronously approximately three weeks after laying. About three weeks after hatching, young ibises fledged.

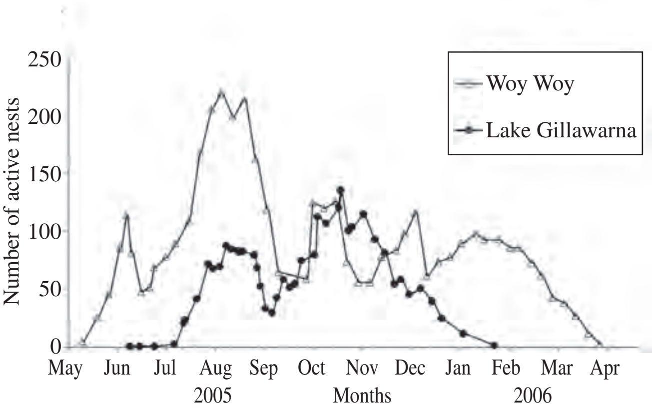


Figure 1. *Number of active nests of ibises at WW and LG between May 2005 and April 2006.*

Mean egg sizes and weights, clutch sizes and breeding success of ibises are presented in Table 1. While egg volumes and weights were significantly higher at WW than LG, mean clutch sizes did not vary between sites (Table 1). Clutch sizes ranged from one to five egg(s), but clutches with three eggs dominated (WW: 50%; LG: 53%), followed by two egg (WW: 26%; LG: 25%) and one-egg clutches (15% for both sites). Few clutches had four and five eggs (7 and 1% for both sites, respectively).

The percentage of clutches that failed to produce hatchlings was higher at WW (53%) than LG (40%). WW also produced less clutches with two and three hatchlings (20 and 11%) than LG (27 and 20%, respectively). Clutches with one and four hatchling(s) occurred at a similar level at WW (15 and 1%) and LG (12 and 1%, respectively). WW had a significantly lower mean number of hatchlings/clutch and hatching success than LG (Table 1). More clutches failed to produce any fledglings at WW (65%) than at LG (49%). While clutches with one fledgling were as frequent at WW (13%) as at LG (14%), clutches with two and three fledglings were less frequent at WW (16 and 6%) than at LG (24 and 13%, respectively). Neither site had clutches that produced four or more fledglings. The mean number of

TABLE 1

Mean ± s.e. and range are presented for egg sizes (mm), weights (g), clutch sizes, number of hatchlings and fledglings per clutch ± s.e. and overall hatching, fledging and reproductive success (%) at WW and LG (* denotes significant difference between sites).

Parameters	Woy Woy	Lake Gillawarna	Independent-Sample T-test
Sample size (egg parameters)	275	262	
Egg length (mm)	63.8 ± 0.2 (53.5–79.9)	63.6 ± 0.2 (55.1–77.5)	$t_{535} = -0.8$, P = 0.417
Egg width (mm)	43.4 ± 0.1 (32.9–47.8)	43.0 ± 0.1 (37.7–49.5)	$t_{535} = -2.7$, P = 0.007*
Egg volume (mm3)	61.3 ± 0.4 (21.6–80.2)	60.0 ± 0.5 (39.7–87.0)	$t_{535} = -2.1$, P = 0.037*
Egg weight (g)	65.0 ± 0.4 (43.0–90.0)	63.3 ± 0.5 (50.0–94.0)	$t_{535} = -2.6$, P = 0.009*
Sample size (other reproductive parameters)	851	337	
Mean clutch size	2.53 ± 0.03 (1–5)	2.52 ± 0.04 (1–5)	$t_{1186} = -0.4$, P = 0.684
Mean number of hatchlings per clutch	0.97 ± 0.04 (0–3)	1.29 ± 0.01 (0–4)	$t_{1186} = -4.4$, P < 0.001*
Hatching success (%)	38	51	
Mean number of fledglings per clutch	0.63 ± 0.03 (0–3)	1.02 ± 0.01 (0–3)	$t_{1186} = -5.9$, P < 0.001*
Fledging success (%)	65	79	
Mean number of fledgling per nest ±	0.81 ± 0.04 (0–8)	1.59 ± 0.10 (0–7)	$t_{303} = -7.0$, P < 0.001*
Reproductive success (%)	25	40	

TABLE 2

Estimates of the constants ± errors from the Quasi-Newton method for the sigmoid-regression lines for body weight and head-bill, bill, wing, tarsus and tail length of young Australian White Ibis between the day of hatching and up to 44 days of age.

Equation for calculating the sigmoid-regression lines:

$$y = a\frac{\exp(b(x+c))-1}{\exp(b(x+c))+1}+d$$

(a indicates the lateral position of the curve (i.e. the values where the inflection points lie), b and c determine Ymax (i.e. asymptote) of the equation, d indicates the specific growth rate).

Parameters	a	b	c	d
Weight	761.73 ± 48.75	0.18 ± 0.02	-11.28 ± 0.60	614.81 ± 31.58
Head-bill	69.73 ± 6.90	0.10 ± 0.01	-9.04 ± 1.33	71.49 ± 4.43
Bill	53.04 ± 5.37	0.10 ± 0.01	-11.57 ± 1.18	46.49 ± 2.82
Wing	163.40 ± 7.14	0.13 ± 0.01	-17.07 ± 0.38	151.33 ± 3.17
Tarsus	44.61 ± 3.06	0.17 ± 0.01	-9.41 ± 0.71	47.82 ± 2.22
Tail	59.76 ± 4.25	0.18 ± 0.02	-23.56 ± 0.60	65.41 ± 2.44

fledglings produced per clutch and nest, the fledgling and the reproductive success at WW were significantly lower than at LG (Table 1). However, the total number of fledglings produced at WW (*n* = 541) was much higher than at LG (*n* = 343).

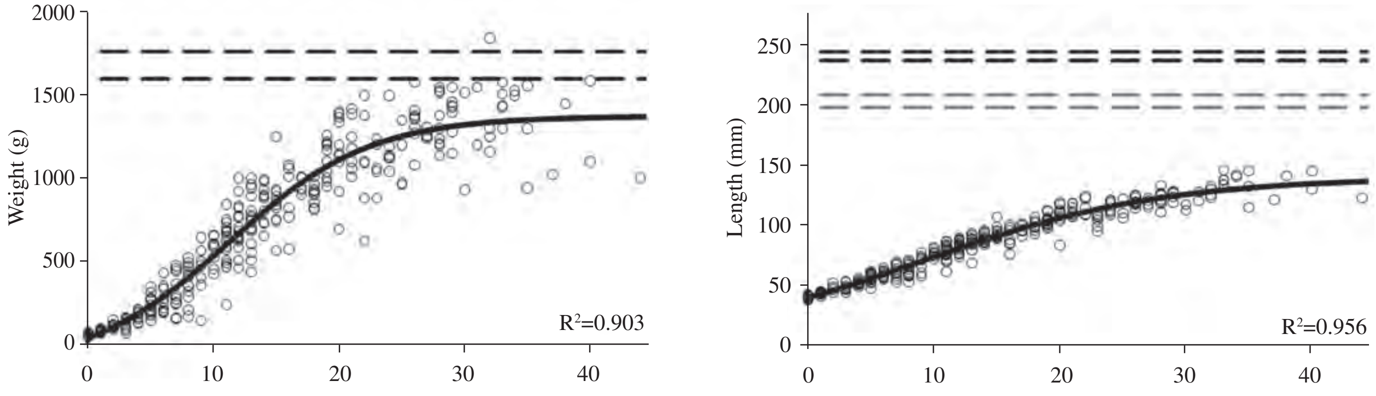
On average, freshly hatched chicks (< one hour old) weighed 54 ± 13 grams. They had a head-bill length of 42 ± 2 millimetres, a bill length of 20 ± 2 millimetres, a wing length of 22 ± 2 millimetres, a tarsus length of 16 ± 3 millimetres and a tail length of 9 ± 2 millimetres (*n* = 8) (Fig. 2a-f). The downy young began growing feathers approximately one week after hatching. They took approximately 21 days to approach adult weight and tarsus length (Fig. 2a,e). Shortly before fledging, chicks weighed 993 ± 221 g, and they had a head-bill length of 109 ± 4 millimetres, a bill length of 68 ± 4 millimetres, a wing length of 194 ± 18 millimetres, a tarsus length of 85 ± 8 millimetres and a tail length of 55 ± 6 millimetres (*n* = 11) (Fig. 2a-f). Their wings and tails may require over 45 days to reach adult length (Fig. 2d,f). Head-bill and bill length did not reach adult length within the first 45 days of life, and require additional time to reach adult size (Fig. 2b,c). Adult ibises weighed 1685 ± 216 grams and had a head-bill length of 242 ± 7 millimetres (male) and 204 ± 5 millimetres (female), a bill length of 193 ± 6 millimetres (male) and 158 ± 11 millimetres (female), a wing length of 374 ± 19 millimetres, a tarsus length of 100 ± 7 millimetres, and a tail length of 135 ± 11 millimetres (*n* = 26) (Fig. 2a-f). All equations for the sigmoid-regressions (see Table 2 for constants ± errors) of the chicks' weight and growth increases had an $R^2 > 0.9$ (Fig. 2a-f), which indicates a strong pattern (Sokal and Rohlf 1995).

DISCUSSION

Urban ibises bred during the whole year (except April) and breeding was most pronounced between June and February (Fig. 1). While the main breeding period coincides with that of non-urban ibises, its duration appears longer in the urban environment (Lowe 1984). In their traditional environment high

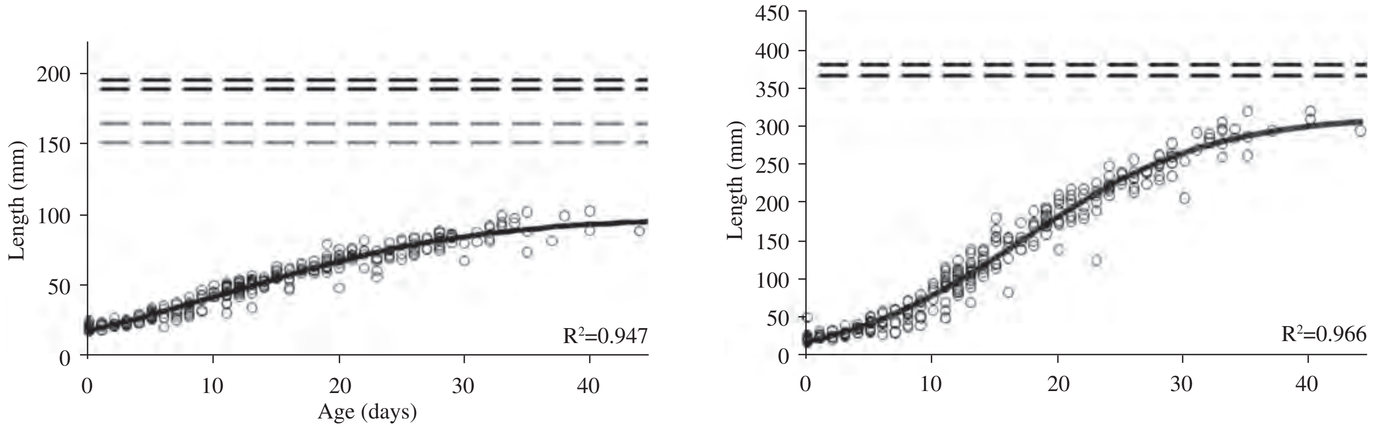
2(a) Weight

2(b) Head-bill



2(c) Bill

2(d) Wing



2(e) Tarsus

2(f) Tail

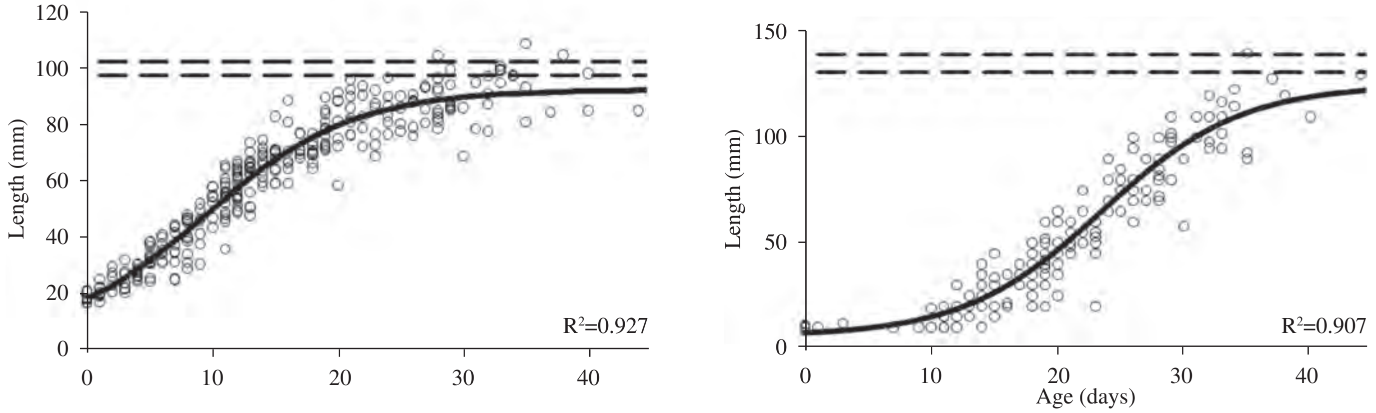


Figure 2. *Body weight (a) and length of (b) head-bill, (c) bill, (d) wing, (e) tarsus and (f) tail of young Australian White Ibis between the day of hatching and up to 44 days of age (n = 233 chicks). Sigmoid-regression lines indicate the increase of each parameter over time (day) with the R2 values located in the bottom right hand corner of each graph. The dashed lines in each graph represent the upper and lower 95% confidence interval of each parameter for adult ibises (n = 26). For (b) head-bill and (c) bill, adult males (n = 15): black dashed lines, and adult females (n = 11): grey dashed lines.*

water levels usually initiate breeding, which restrict breeding to times of heavy rain and flooding (Kingsford and Johnson 1998). In the urban environment ibises often breed on islands in park ponds (Smith 2009), where water levels fluctuate little and usually remain high. This may, in conjunction with sufficient food from landfills, induce breeding the whole year round. As in non-urban colonies (Lowe 1984), eggs hatched three weeks after laying and young fledged roughly three weeks later.

Mean egg volumes were similar between sites (Table 1) and to those of other urban colonies (59.6 and 63.4 mm^3; Murray and Shaw 2006; Thomas 2007), but were smaller than those from non-urban colonies (mean range = 64.7–65.2 mm^3; Lowe 1984). Differences were particularly pronounced in the eggs' lengths, with eggs from our and other urban colonies (63.6 and 64.3 mm; Murray and Shaw 2006; Thomas 2007) being much shorter than those from non-urban colonies (66.3–67.1 mm; Lowe 1984). It is not known why eggs in urban environments are smaller. Extensive feeding on landfills (Smith 2009) could be one reason. Smaller egg sizes have also been reported for Silver Gulls *Larus novaehollandiae* that fed at landfills instead of natural environments (Auman 2008). Sydney's ibises also carry toxicants (Burger and Gochfeld 1999), which can cause behavioural abnormalities and mortality (Edge 2008). Whether this has also contributed to small egg sizes and the severe leg deformities of some chicks (Smith 2009) is not known and needs to be addressed in further research.

Three-egg clutches were most common in this and all studies on urban (Kentish 1999; Corben and Munro 2006; Murray and Shaw 2006; Thomas 2007) and non-urban ibises (Lowe 1984). Five-egg clutches were rare, but occurred in both colonies as well as Winter Swamp (Kentish 1999) and Healesville, Victoria (Lowe 1984). These and even larger clutches may be due to some ibises inflating clutch sizes by transferring eggs between nests (Smith 2009), which has also been recorded for the American White Ibis *Eudocimus albus* (Frederick and Shields 1986). Generally, mean clutch sizes at both colonies were similar to each other and also corresponded to those from previous studies on these (Corben and Munro 2006; Thomas 2007) and other urban colonies (Movieworld, Queensland: 2.46 eggs ± 0.71 s.e. (Murray and Shaw 2006)); Winter Swamp, Victoria: 2.25 ± 0.05 (Kentish 1999)), but were considerably smaller than those at non-urban colonies (mean range: 2.65–3.21 eggs) (except for Heifer Swamp, Victoria; Lowe 1984). It is unknown why urban ibises have smaller clutch sizes. This may be, as with egg size, associated with an inadequate diet, but could also be linked to the birds' age (young birds often produce smaller clutches) (Martin 1987), different climatic conditions in coastal Australia (Klomp 1970) and other factors specific to urban birds and their environment (e.g. inbreeding depression, high pollution levels).

We found large differences in the number of clutches that failed to hatch young between sites. Also the mean number of hatchlings per clutch and hatching success differed, which suggests that urban colonies differ in their reproductive output. Possible reasons for eggs failing to hatch may include desertion by adults, egg infertility, unfavourable weather, predation and/or high toxin levels in eggs (Thomas 2007; Edge 2008). At WW nests were occasionally destroyed during king tides and storms and eggs were taken by Australian Ravens *Corvus coronoides*. To which extent this has influenced hatching success was not investigated. Monitoring of nests and eggs during incubation is needed to identify the reasons for hatching failure.

The mean number of hatchlings per clutch at our colonies (Table 1) was similar to that at other urban colonies (means = 0.7 and 1.2 hatchlings; Murray and Shaw 2006; Thomas 2007). The same was true for the overall hatching success at our and other urban colonies (mean = 38 and 48%; Murray and Shaw 2006; Thomas 2007). However, all urban colonies had a lower hatching success than that of non-urban colonies (55–60%: Lowe 1984). Unfortunately, Lowe (1984) did not calculate the mean number of hatchlings per clutch to allow direct comparison between his results to ours. Nevertheless, it appears that urban sites produce fewer hatchlings than non-urban sites. This coincides with studies on urban Herring and Ring-billed Gulls *L. argentatus* and *L. delawarensis*. Birds that feed from landfills hatch less young than birds that feed from natural environments (Belant *et al.* 1998).

The mean number of fledglings per clutch and nest, and fledging success and overall reproductive success differed between our colonies. This highlights again that reproductive parameters between colonies can differ and management baselines need to be derived from detailed studies of several colonies. The mean fledging success (WW: 65; LG: 79%) and mean number of fledglings per clutch at our colonies (Table 1) was generally higher than that at another urban (mean = 60%; Murray and Shaw 2006) and non-urban colonies (mean range = 0.34–0.76 fledglings; Lowe 1984). Since Murray and Shaw (2006) did not provide the mean number of fledglings per clutch and Lowe (1984) did not present fledging success, direct comparisons are not possible. The reproductive success at both sites and another urban colony (mean: 29%; Murray and Shaw 2006) was higher than that at non-urban colonies (mean range = 18–26%; Lowe 1984), which suggests that urban ibises have at least a similar, if not even a higher, reproductive output than non-urban birds. This may be mainly due to more hatchlings surviving to the fledging stage. Other species that feed from landfills and have increased their fledging success include the White Stork *Ciconia ciconia* (Massemin-challet *et al.* 2006) and several gulls (Belant *et al.* 1998).

This study is the first to describe the growth of ibises from hatchlings to adult size (Fig. 2a-f). All morphological parameters of chicks are likely to reach or approach adult size ranges at 45 days of age, except bill and head-bill length (Fig. 2b-c). This coincides with findings from Carrick (1962), which suggest that young birds need three months to reach the head-bill length of adults. This is similar to the American White Ibis, where young birds need approximately 72 days for their bill to reach 90 percent of its adult size (Kushlan 1977). Since the head-bill of the birds took the longest time to grow (Fig. 2b), it probably is the best indicator of age during the first two months after hatching, and before it reaches female length.

During our study, it became increasingly difficult to capture older chicks as many of them were able to fly. This decreased the sample size of older chicks, but probably also biased our results towards chicks that were weak fliers. Most chicks captured at an age of 28 days and older had protruding keel bones, which can indicate malnourishment (Gregory and Robin 1998). This hindered flight and allowed for easy capture. Many of these chicks died in the following weeks, which suggests that weaker chicks were sampled during this stage.

In summary, we discovered large differences in the breeding success of ibises between our colonies and other urban (Murray and Shaw 2006) and non-urban colonies (Lowe 1984), which need to be considered when managing this species. While overall reproductive success appears higher in urban environments, reproductive productivity cannot alone predict a population's status and its changes. Reliable predictions are only possible when mortality rates are known (Gotelli 2001). Unfortunately, mortality data for ibises are limited. Banding records suggest a lifespan of up to 26 years (ABBBS, Canberra) and mortality rates of 37 percent for first year and 24 percent for two to nine year old birds (Lowe 1984). Since these mortality rates are based on records from non-urban ibises studied between 1956 and 1968 (Lowe 1984), they may differ to those of urban ibises today and therefore may not provide reliable baselines for predicting the behavior of urban ibis populations. Further research needs to focus on the mortality rates of both urban and non-urban ibises. In addition, studies on the large-scale movements of ibises are needed. It has been suggested that at least some ibises travel to the urban environment for breeding from inland Australia (Thomas 2007; Corben and Munro 2008; Smith and Munro 2011), where breeding is difficult due to drought, river regulation and declining wetlands (Smith 2009). If this is the case, urban managers need to be cautious. They need to be aware that management may not only affect urban resident ibises, but also birds that originate from areas where this protected native species is declining (Corben and Munro 2008).

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Prey deliveries at eight nests of the Southern Boobook *Ninox novaeseelandiae* in Canberra

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In raptors, males are said to deliver most of the prey items during the breeding season. In this study we compared male versus female prey deliveries at eight nests of Southern Boobook *Ninox novaeseelandiae* in Canberra. We observed the incubation period on 103 nights, nestling /fledging period on 143 nights, for a total of 246 nights. Females hunted through the incubation period. Prey deliveries for males and females combined averaged 8.90 items per hour during the nestling period and 11.04 per hour during the fledging period, in the first hour or two after dusk. In the first half of the nestling period (weeks 1–3) females delivered significantly more prey items per hour than males did (3.44/hour compared to 1.60/hour). Females hunted near the nest and delivered more invertebrates than did males. In the second half of the nestling period, (weeks 4–6), there was no significant difference in the number of prey deliveries between males (5.11 items/hr) and females (5.84 items/hr). For the total nestling period, (weeks 1–6), females made 5.01 deliveries per hour, significantly higher than male deliveries at 3.90 per hour. There was no significant difference in the number of prey deliveries to fledged young by males (5.29/hr) and females (5.75/hr). Both males and females delivered vertebrate prey. These data do not fit the 'normal' pattern of male/female behaviour found in most raptor studies.

INTRODUCTION

Owls, like other birds of prey, capture most prey with their talons and deliver this prey to nidicolous young. Newton (1979) described three overlapping periods of female behaviour typical for breeding raptors with nestlings: (1) females do not hunt during almost continuous brooding or shading before the young have developed their own thermoregulation, (2) presence near the nest for feeding and defending the largely helpless young, and (3) attendance with flexible periods of time spent distant from older nestlings or fledged broods. Attendance patterns during the third period vary greatly, and Newton suggested that this variation depends largely on the hunting success of the male. Females seemed to leave broods only when the males' hunting efforts were insufficient and chicks required additional food.

Australian owl species are mostly nocturnal, so it is difficult to observe feeding rates to nestlings and fledglings. There are few data for prey deliveries to nests of any Australian species. Todd (2006) observed a pair of breeding Masked Owls *Tyto novaehollandiae* during the second half of the nestling period. Both male and female delivered vertebrate prey, the male 0.80 prey items per hour, the female 0.40 prey items per hour. At a nest of Barking Owls *Ninox connivens* (Barnes *et al.* 2005), the female delivered insects to the chicks (five in 30 min. in week 1, four in 10 min. in week 3) at dusk while awaiting the male's deliveries of vertebrate prey. For Southern Boobooks, Higgins (1999) stated that males bring most food to females and young early in the nestling period while females feed this food to the young. However, there was anecdotal evidence in Higgins (1999) that female Southern Boobooks hunted in the early nestling period, though these observations were of unmarked birds.

There are few data for nocturnal owls elsewhere. The Spotted Owl *Strix occidentalis* in western North America (Gutierrez *et al.* 1995) is otherwise well-studied and males deliver all prey during the incubation and early brooding periods; however, there are few quantified prey delivery data. Delaney *et al.* (1999) found that the Mexican subspecies *S. o. lucida* delivered 0.37 prey items per hour at night and 0.03 per hour during the day. The Eastern Screech Owl *Megascops asio* (also a nocturnal species), at about 167 grams for males and 194 grams for females, is about two-thirds the mass of the Southern Boobook *Ninox novaeseelandiae*, but has a similar breeding ecology and diet (Gehlbach 1994). Gehlbach (1994) studied prey deliveries to nestlings at 19 suburban nests in central Texas. Deliveries each night were about 76 per cent invertebrates and distinctly bimodal, with the major peak at dusk. Only males delivered prey, about 2.40 deliveries per hour at dusk in the early brooding period (period 1 of Newton 1979) to 5.10 deliveries per hour when nestlings were three weeks old (Gehlbach 1994). The small, insectivorous Flammulated Owl *Psilosops flammeolus* made, on average, 8.45 deliveries per hour to nests in south-central Idaho and 9.90 deliveries per hour in Colorado (Linkhart and Reynolds 1987). Prey was mainly lepidopteran and orthopteran prey, with no vertebrates. The Long-eared Owl *Asio otus*, a mammal specialist about the same mass as the Southern Boobook, often hunts nocturnally. At two nests in Utah, during the first half of the night males delivered 1.80–2.50 prey items per night while females were incubating, and 3.50–4.00 items per night during the nestling period (Delong 1982). In a study of the Long-eared Owl in Idaho, males fed branching fledglings 2.5 times as often as females did (Ulmschneider 1990).

There are also limited data for diurnal owl species. The Northern Hawk Owl *Surnia ulula* is similar in mass to the Southern Boobook but more of a mammal specialist (Duncan and Duncan 1998). In Sweden a pair fed young once per hour during daylight, but after 17:00 hours feeding decreased (Mikkola 1972). In Finland, young were fed 0.80 to 2.50 times per hour and a brood of one was fed every 30–40 minutes at night, and every 95 minutes during the day (Leinonen 1978; Simon and Simon 1980). In Manitoba, Northern Hawk Owls averaged 2.10 deliveries per hour after young had fledged (Lang *et al*. 1991).

All of these Northern Hemisphere studies reflected the division of labour between the sexes in birds of prey. All authors stated that males delivered most of the prey during the incubation and early nestling period of breeding. Only in the latter part of the nestling period did some females begin hunting for nestlings.

The Southern Boobook is the smallest of eight owl species, four *Tyto* and four *Ninox*, that breed on mainland Australia (Higgins 1999). Boobooks hunt insects and birds, mainly in the forest canopy, and some vertebrates and invertebrates from the ground, such as the House Mouse *Mus musculus* and spiders Araneae. They hunt more invertebrates on hot nights and more vertebrates on cold nights (Olsen *et al*. 2006). By biomass, breeding adults feed their young predominantly on vertebrates, mainly small mammals and birds, and by number, mainly invertebrates. In one study, breeding adults took 60.9 per cent invertebrates (n = 28), among which beetles (Coleoptera, n = 18) made up 39.1 per cent and Lepidopterans (n = 5) made up 10.9 per cent. Birds, despite making up only 30.4 per cent of the prey individuals, provided most of the dietary mass (84.3%), mainly through Common Starlings *Sturnus vulgaris* (24.4%) and juvenile Crimson Rosellas *Platycercus elegans* (32.0%) (Olsen *et al*. 2006). Similar findings were described in a study of the diet of non-breeding adults in winter (Trost *et al*. 2008).

The aim of this study was to measure the food delivery rates of male and female Southern Boobooks, during the incubation, nestling and fledgling periods of breeding. We report on 246 observation nights between 1993 and 2008 at eight nests in three territories.

STUDY AREA

The owls in this study (in Canberra, ACT) ranged over all of the 80-hectare Aranda Bushland, the north-western corner of the 600-hectare Black Mountain Reserve, the suburbs of Cook and Aranda, open grazing land to the south of Aranda Bushland and Cook, and occasionally the wooded northern flank of Mount Painter (Olsen *et al*. 2002). Except for Mount Painter and the grazing land, the area is primarily open forest and tall woodland, with dominants of Scribbly Gum *Eucalyptus rossii*, Brittle Gum *E. mannifera*, Red Stringybark *E. macrorhyncha* and Blakely's Red Gum *E. blakelyi*, with Red Box *E. polyanthemos* and Yellow Box *E. melliodora* in more open areas (NCDC 1988). The understorey has abundant tussock grasses (*Poa* spp.), with the shrub *Cassinia longifolia* dominating areas that are more open. Wildfire has been largely absent and a regime of prescription fires has created a mosaic effect on the understorey. The suburbs of Cook and Aranda have retained a significant element of eucalypt overstorey of large Brittle Gums and Yellow Box, with a mix of native and non-native understorey elements along roadsides, bushland corridors and backyards. A common tree in all areas is the Native Cherry *Exocarpos cupressiformis*, characterised by dense foliage and favoured by the owls for daytime roosts.

METHODS

Trapping, banding, and radio-telemetry

We used wire bal-cha-tri traps (Olsen and Woollard 1975) baited with a House Mouse, a noose mounted on the end of a surf-casting rod, and fishing nets on extended poles, to trap adults and fledged young. All adults were sexed (Olsen and Trost 1997), fitted with a stainless steel, numbered Australian Bird and Bat Banding Scheme band, and a plastic colour-band sealed with super-glue (n = 6 adults). Some individuals removed the plastic colour-bands, so we banded them again with coloured aluminium bands attached with two rivets. Four of the adults had back-pack style Sirtrack single-stage transmitters fitted with a string harness and weak link designed to break if the bird became entangled by its transmitter and harness (Karl and Clout 1987). Transmitters weighed 5.4 grams and harnesses 1.0 gram, making 6.4 grams on a 270-gram male (2.4% of body wt) or 340-gram female (1.9% of body wt). Batteries lasted 10–12 months.

Between 1993 and 2008, but not always simultaneously, we located eight nests in three adjacent nesting territories – White male, Green male, Bike Path male, with differing females (Table 1) – straddling Aranda Bushland, Black Mountain Reserve and the suburb of Cook; the larger of the pair, by weight, that had a brood patch, was determined to be the female (Olsen and Trost 1997). We climbed some other nests to band and measure the young. Two of the females that were making prey deliveries before we climbed to their nest, refused to deliver after this, and these two females were excluded from the study.

Observations were conducted mainly in the first hour after the female left the nest. Lisle (observing the White pair in 1993) recorded prey deliveries for two hours after the first delivery. All prey deliveries were noted and categorised as male or female deliveries. Data were collected for nestling (defined as young being fed in the nest hollow) and fledgling periods (young fed after they had fledged and started to roost for the day outside of the nest with parents). Prey was categorised as vertebrate or invertebrate. We visited the area several nights per week at sundown and stood 10–30 metres from the nest or roost of one of the three pairs, then followed individuals after they left the roost or nest as closely as possible without disturbing them. Observation years were:

White territory	1993–94; 1998–99; 2000–01; 2003–04
Green territory	1993–94; 1998–99
Bike Path territory	2006–07; 2007–08

In 2006–2007, the Bike Path pair moved from the nest area on the night after their single juvenile fledged (Olsen 2011), and we were unable to locate them; therefore, post-fledging feeding rates could not be included.

Data analysis

We calculated frequency per hour of prey deliveries per night and used chi-square analyses (Zar 1984) to test if male and female prey delivery rates differed during both the nestling and fledgling periods.

TABLE 1

Mean number of prey deliveries per hour by male and female Southern Boobooks to nestlings and fledged young, in the first hour or two after dusk (% in parentheses) at 8 nests in 3 territories. Total number of observation nights =143. Banded males are Green, White and Bike Path; figures below – 04, 03, 00, 07, 09 - are banded females in that year.

		No. of young	Nestling Period						Fledging Period		Total	
			1st half: 0–3 wks (% male/female)		2nd half: 4–6 wks (% male/female)		Nestling totals (% male/female)		Fledgling totals (% male/female)		Nestling+ fledgling totals (% male/female)	
Mean total deliveries/hr (male + female)			5.05		10.9		8.9		11.04		9.69	
Year	Pair		m	f	m	f	m	f	m	f	m	f
1993–94	Green ♂	1	0.83	0.5	1.33	0	1	0.33	2.85	1.69	1.77	0.9
	04 ♀		(62)	(38)	(100)	(0)	(75)	(25)	(63)	(37)	(66)	(34)
1998–99	Green ♂	1	0.5	3.75	2.59	3.05	1.79	3	4.12	5.88	2.78	4.27
	03 ♀		(12)	(88)	(46)	(54)	(37)	(63)	(41)	(59)	(39)	(61)
1993–94	White ♂	3	no data	no data	8.9	6.5	8.9	6.5	10.6	5.69	9.75	6.09
	Unbanded ♀				(58)	(42)	(58)	(42)	(65)	(35)	(62)	(38)
1998–99	White ♂	3	2.25	3.25	7.61	3.27	6.2	3.26	7.33	4.67	6.36	3.48
	04 ♀		(41)	(59)	(70)	(30)	(66)	(34)	(61)	(39)	(65)	(35)
2000–01	White ♂	2	3	17	1.71	6.71	1.88	8	5.04	9.12	3.85	8.68
	04 ♀		(15)	(85)	(20)	(79)	(19)	(81)	(36)	(64)	(31)	(69)
2003–04	White ♂	2	0.6	15.66	5.57	10.63	4.96	11.27	5.25	6.25	5.2	10
	00 ♀		(4)	(96)	(34)	(66)	(31)	(69)	(46)	(54)	(34)	(66)
2006–07	Bike Path	1	2.15	2.15	2.88	6.41	2.45	4.15	no data	no data	–	–
	07 ♀		(45)	(55)	(31)	(69)	(37)	(63)				
2007–08	Bike Path	2	2.48	13.66	5.49	7.14	4.9	8.31	1.29	6.83	4.8	12.77
	09 ♀		(15)	(85)	(43)	(57)	(37)	(63)	(16)	(84)	(27)	(73)
Mean Total Deliveries/hr			1.6	3.44	5.11	5.84	3.9	5.01	5.29	5.75	4.57	5.5
			(32)	(68)	(47)	(53)	(44)	(56)	(48)	(52)	(45)	(55)

No data were collected for:

a) White 1993-94 – detailed observations started in the second half of the nestling period.

b) Bike Path pair fledgling period in 2006-07 because the adults left with the juvenile immediately after it fledged, probably to avoid ongoing harassment by possums. We were unable to locate them.

RESULTS

The mean number of prey deliveries (for males and females) was 8.90 per hour during the nestling period and 11.04 per hour during the fledgling period (Table 1), for the first hour or two after dusk (a qualification that applies to all the following observations). In weeks 1–3 of the nestling period the number of food deliveries per hour was 1.60 for males and 3.44 for females. Females delivered significantly more prey items than males ($\chi^2 = 27.7$; $P < 0.0001$); males delivered 87.5 per cent of the vertebrate prey. In weeks 4–6 there was no significant difference in the number of prey deliveries between males (5.11/hr) and females (5.84/hr) ($\chi^2 = 3.8$; $P = 0.05$). Males in this period delivered 57.1 per cent of the vertebrate prey. For the total nestling period, weeks 1–6, female deliveries (5.01/hr) were significantly more than male deliveries (3.90/hr) ($\chi^2 = 16.9$; $P < 0.0001$). There was no significant difference in the number of prey deliveries to fledged young by males (5.29/hr) and females (5.75/hr) ($\chi^2 = 1.2$; $P = 0.26$).

Males delivered more vertebrates than females (Tables 2, 3 and 4). During the incubation period, females hunted on 52 of 103 nights, with all observed prey being invertebrates.

DISCUSSION

Prey delivery rates

The prey delivery values in this study, averaging 8.90 per hour in the nestling period and 11.04 per hour in the fledgling period, were higher than those recorded for other owls of similar mass. Northern Hawk Owls in Sweden fed young once per hour during daylight (Mikkola 1972), in Finland 0.80 to 2.50 times per hour (Leinonen 1978; Simon and Simon 1980), and in Manitoba, owl parents averaged 2.10 deliveries per hour at one nest after young had fledged (Lang *et al.* 1991). Long-eared Owls delivered 3.50 to 4.00 items per night during the nestling period (Delong 1982). Another mammal specialist, the Mexican Spotted Owl, delivered 2.68 items per 24-hour period during incubation, 4.10 during brooding, and 4.51 during the nestling period (Delaney *et al.* 1999), larger prey and fewer deliveries than owls in our study. Masked Owls, being mammal specialists and larger than Boobooks, also made fewer deliveries to nestlings per hour, all vertebrates (Todd 2006). Eastern Screech Owls made about 2.40 deliveries per hour in the early brooding period to about 5.10 deliveries per hour when nestlings were three weeks old (Gehlbach 1994), fewer

TABLE 2

Number of vertebrate and invertebrate prey deliveries at eight Southern Boobook breeding events, in the first hour or two after dusk. Total number of observation nights = 143. (Large vertebrates: > 75g e.g. Eastern Rosella. Small vertebrates: < 75g e.g. micro-bats, mice, small birds)

Year	Pair		Small vertebrate	Large vertebrate	Invertebrate	Vertebrate/ total	Vertebrate %
1993–94	Green	Male	3	0	52	.055	6
		Female	0	0	28	0	0
1998–99	Green	Male	0	0	58	0	0
		Female	0	0	89	0	0
1993–94	White	Male	0	0	312	0	0
		Female	0	0	195	0	0
1998–99	White	Male	0	1	127	.01	1
		Female	0	0	71	0	0
2000–01	White	Male	2	0	76	.026	3
		Female	1	1	176	.01	1
2003–04	White	Male	2	0	85	.023	2
		Female	0	0	175	0	0
2006–07	Bike Path	Male	5	0	70	.067	7
		Female	1	1	125	.016	2
2007–08	Bike Path	Male	2	1	57	.05	5
		Female	3	3	153	.038	4
TOTAL			19	7	1849	.014	1

TABLE 3

Vertebrate and invertebrate prey deliveries at eight Southern Boobook nests during incubation, nestling and fledging periods, by males and females (% in parentheses). Number of observation nights: incubation period = 103 nights; nestling/fledgling period 143 = nights; total = 246 nights.

	Incubation (%)		Nestling (%)		Fledging (%)	
	Vert.	Invert.	Vert.	Invert.	Vert.	Invert.
Male	15	93	15	421	1	372
	(14)	(86)	(3.4)	(96.6)	(0.3)	(99.7)
Female	–	–	7	576	3	397
			(1.2)	(98.8)	(0.75)	(99.25)

TABLE 4

Vertebrate prey deliveries by males and females at eight Southern Boobook territories, in the first hour or two after dusk: nestling period (weeks 1–3 vs 4–6) and fledgling period (number of observation nights = 143).

	Weeks 1–3	Weeks 4–6	Fledgling
Male	7	8	1
Female	1	6	3

than Boobooks in this study. However, the small, insectivorous Flammulated Owl had a similar delivery rate, about 8.45 deliveries per hour to nests in south-central Idaho and 9.90 deliveries per hour in Colorado (Linkhart and Reynolds 1987). In summary, the type of prey determined the number of prey deliveries. Boobooks in this study showed similar patterns to Eastern Screech Owls in Gehlbach's (1994) study, with more vertebrates delivered in cooler weather, and therefore fewer food deliveries. Insectivorous owls, such as Flammulated Owls, had relatively higher overall rates of delivery.

Male/female prey deliveries

Prey deliveries for owls in this study averaged 4.57 and 5.50 deliveries per hour, for males and females respectively, during the first hour or two after dusk over the nestling and fledgling period combined so females delivered significantly more prey than males ($\chi^2 = 4.7$; $P < 0.05$), over half the prey during the nestling (57%) and fledgling (52%) periods.

In the early nestling period female Boobooks averaged 3.44 deliveries per hour and male 1.60 deliveries per hour, the reverse of what might be expected from a reading of the literature on other owls. Over the 6 weeks of the nestling period male Boobooks delivered an average of 3.90 prey items per hour and females 5.01 items per hour. During the fledgling period the average deliveries for males and females were 5.29 and 5.75 prey items per hour respectively. These data did not fit the 'normal' pattern of male/female behaviour set out in other studies (see above). Male Boobooks did not make most of the deliveries during the first half of the nestling period (Table 1: males 32%, females 68%). In fact, we saw females hunt on many nights during the incubation period.

Female raptors need to guard the nest and young, but some female Boobooks could guard and hunt at the same time, if prey was close to the nest. Females could hunt through the incubation period and early nestling period, as these Southern Boobooks did; males hunted vertebrates away from the nest, while females hunted invertebrates close to the nest. In terms of biomass, males may bring more prey than would be evidenced from Table 3. Our observations were made during the first hour or two after dark and counts during the remainder of the night could yield different results.

Results from this study may hold broadly for Australian *Ninox* owls with 'Normal Sexual Dimorphism' (i.e. males larger than females). For example, female Rufous Owls *Ninox rufa* hunt insects around the nest, and males hunt through the night for large prey which can be as heavy as the male (Hollands 2008). On limited data, the same may apply to the Barking Owl (Barnes *et al.* 2005). Curved beaks and strong talons give raptors certain benefits: the ability to kill, carry and dismantle large prey, but also incur costs: large prey is often rarer so raptors travel further to find it, and raptors can only catch and carry one prey item at a time to the nest, even small invertebrate prey. The balance between guarding nestlings and eggs from predation, versus foraging, is met in different ways, but direction of dimorphism does not seem to be a factor. In contrast, we can find no evidence that females of non-*Ninox* owl species regularly hunt through the incubation period or in the first half of the nestling period. That is, Australian *Ninox* species with Reversed Sexual Dimorphism and with 'Normal' Sexual Dimorphism may differ from all other owls.

The nature of female guarding could also affect studies of prey delivery rates in raptors. We climbed some nests where female Boobooks were regularly delivering prey and, after this, two females stopped delivering if we were present. They saw us as potential predators and balanced nest defence against hunting (see also Olsen and Tucker 2003). Studies that examine prey deliveries at the same time researchers are visiting the nest to collect prey remains or experiment with young are likely to be biased by female guarding, and these results should be treated with caution. That females of most raptor species *do not* hunt or contribute to foraging in the incubation and brooding periods apparently increases the fitness of the brood; that is, guarding the young from predators or inclement weather increases the number of young fledged, compared with bringing more food to those nestlings (Newton 1979). Alternatively, females that avoid hunting increase their longevity, compared with females that do hunt (Newton 1979). However, it is not clear how this benefits males. These factors are likely to vary with species and circumstances.

In our study, males sometimes arrived with prey, called to the absent female, went into the hollow, failed to find her, then went looking for the female instead of giving the prey to nestlings. We interpreted this as the male 'showing' the female that he was providing, that he had large prey for his time away, even if the prey only 'appeared' large, like a moth. This behaviour may encourage females to prolong their stay during that breeding season and return the following year after dispersing during the non-breeding season (Olsen 2011).

Another reason for the large proportion of female hunting (Table 1) could be food shortage, and the need to supplement the male's provisioning (Newton 1979). However, because the sex-bias in prey delivery was evident across all pairs over a number of years it seems more plausible that the ratios of male/female hunting we saw in Boobooks were typical of the species and not closely linked to food shortage.

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Diets of White-bellied Sea-Eagles *Haliaeetus leucogaster* and Whistling Kites *Haliastur sphenurus* breeding near Canberra, 2003–2008

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During 2003–2008, in and near the Australian Capital Territory, the diet of breeding White-bellied Sea-Eagles *Haliaeetus leucogaster* consisted of 8 per cent mammals (1% macropod, 1% hare), 42 per cent birds (33% waterbirds), 9 per cent turtles and 40 per cent fish by number (*n* = 78 items from four nests). Breeding Whistling Kites *Haliastur sphenurus* took 45 per cent mammals (26% rabbit), 43 per cent birds (13% waterbirds), 4 per cent lizards and 7 per cent fish (*n* = 136 items from three nests). By biomass, Sea-Eagles took 52 per cent fish; Whistling Kites took 64 per cent mammals, mostly rabbits, with little dietary overlap (Pianka Index 0.12). Despite the almost fivefold difference in these raptor species' respective body mass, the Geometric Mean Prey Weight found for Sea-Eagles was 995 grams, and for Whistling Kites 606 grams (the latter skewed by the high incidence of mammal carrion). Dietary diversity (species richness and evenness: Shannon Index) was higher (3.24) for the Whistling Kite than for the White-bellied Sea-Eagle (2.68).

Eight water bodies in or near the ACT, rated for human disturbance (relative levels of boating, water-skiing, public vehicle access, walking and stock grazing), were surveyed for breeding Sea-Eagles and Whistling Kites during 2002–2010. Low Disturbance areas contained no breeding Whistling Kites or Sea-Eagles, although solitary Sea-Eagles were often present. Medium Disturbance areas contained breeding Sea-Eagles and Whistling Kites; High Disturbance areas contained breeding Whistling Kites, but no breeding Sea-Eagles. Low prey availability, and possible interspecific conflict with Wedge-tailed Eagles *Aquila audax*, may limit Sea-Eagle breeding in Low Disturbance areas.

INTRODUCTION

The diets of the White-bellied Sea-Eagle *Haliaeetus leucogaster* and Wedge-tailed Eagle *Aquila audax*, breeding in contiguous territories over the same period near Canberra, Australian Capital Territory (ACT), were contrasted by Olsen *et al.* (2006a). That study compared the Geometric Mean Prey Weight (GMPW), standardised food niche breadth and Pianka Index (dietary overlap) for the two eagle species, and found that Sea-Eagles prey predominantly on fish, birds and aquatic reptiles. Subsequent studies, conducted in northern inland New South Wales (Debus 2008) and the Northern Territory (Corbett and Hertog 2011, 2012), obtained similar results, and affirm the Sea-Eagle's apparent prey specialisation across a range of freshwater habitats. (We note that, *contra* Corbett and Hertog (2011), prior dietary studies on the Sea-Eagle have been mostly at freshwater locations, not 'mostly marine'.) Similarly, Fuentes *et al.* (2005) quantified the breeding diet of the Whistling Kite *Haliastur sphenurus* at two nests near Canberra in August–September 2003 and calculated the GMPW, but there are few other published studies of the Whistling Kite's breeding-season diet (Debus 1983; Baker-Gabb 1984a,b; Marchant and Higgins 1993; Aumann 2001).

Although the White-bellied Sea-Eagle and Whistling Kite are taxonomically close, both take aquatic prey and scavenge (Marchant and Higgins 1993), their diets have not been compared quantitatively for the same region and time period. Female Sea-Eagles weigh approximately 3.8 kilograms, males approximately 3.2 kilograms (Olsen *et al.* 2006a); female Whistling Kites weigh approximately 907 grams, males approximately 632 grams (Debus 1998), so differences in the size of prey taken could be expected.

This study compares the diet of the two species, in territories in or adjoining the ACT, using new data collected from October 2003 to November 2008, i.e. after those collected for the respective species in 2002–04 and previously reported on (Fuentes *et al.* 2005; Olsen *et al.* 2006a). As breeding White-bellied Sea-Eagles are considered to be adversely affected by human disturbance (e.g. Dennis *et al.* 2011a,b), during 2002–2010 we determined where the two species were breeding on the main water bodies or stretches of river in the study area, and ranked the locations as experiencing high, medium, or low levels of human disturbance.

METHODS

The study area, habitats and field methods were as previously described for related studies around Canberra in the ACT (Fuentes *et al.* 2005, 2007; Olsen *et al.* 2006a,b, 2008, 2010a). Collections of prey remains and pellets from occupied nests and nearby roosts were as follows.

White-bellied Sea-Eagle: seven collections from four nest sites in three territories (six nest-years) August 2004–November 2008, mostly in the breeding season (August–December); one of these collections (in 2004) was made from a collapsed nest.

Whistling Kite: 17 collections over three sites (seven nest-years) October 2003–February 2007, in the breeding season (October–February), with one collection in July.

Methods for identifying prey items, calculating the minimum number of prey individuals, correction factors and their adjusted biomasses, and statistically treating the data, are described elsewhere (Fuentes *et al.* 2005; Olsen *et al.* 2006a, 2010a). The sources of prey weights were as for other papers in this series (Fuentes *et al.* 2005, 2007; Olsen *et al.* 2004, 2006a,b, 2008, 2010a). All the aforementioned study area and methods papers are available from the Institute for Applied Ecology website (www.canberra.edu.au/centres/iae) and the Global Raptor Information Network (www.globalraptors.org).

During 2002–2010, eight water bodies in the study area were surveyed for Sea-Eagle and Whistling Kite breeding activity, and each was ranked in a disturbance category (the following surface areas of reservoirs apply when at capacity). Low Disturbance (no boating, no water-skiing, no public vehicle access other than at the dam wall, little walking, some stock grazing) was assigned to Corin Dam (283 ha), Cotter Dam (47 ha), Bendora Dam (80 ha) and Lower Molonglo River; Medium Disturbance (water-skiing, fishing from motor boats, public vehicle access at several points along the water's edge, stock grazing, some walking) was assigned to Burrinjuck Dam (5500 ha), Googong Dam (680 ha) and Murrumbidgee River west of the ACT; and High Disturbance (considerable walking, considerable vehicle access, unrestricted recreational fishing from the shore) was assigned to an urban lake in Canberra city (Lake Burley Griffin, 66 ha). Many of these water bodies contain populations of introduced European Carp *Cyprinus carpio*, exceptions being Corin, Cotter, Bendora and Googong reservoirs, although these lakes contain native fish and are stocked with introduced trout (M. Lintermans pers. comm.). Except for annual variation in rainfall and hence water levels, other conditions at these water bodies were consistent during the study.

RESULTS

Diet

In pellets and prey remains collected during 2003–08, White-bellied Sea-Eagles took, by number, 8 per cent mammal prey, 42 per cent birds (33% waterbirds), 9 per cent reptiles (all aquatic, i.e. turtles) and 40 per cent fish; 1 per cent consisted of macropod and 1 per cent lagomorph (hare, but no rabbits). Whistling Kites took, by number, 45 per cent mammal prey (26% rabbits, 2% juvenile rabbits), 43 per cent birds (13% waterbirds), four per cent reptiles (all terrestrial) and seven per cent fish (Table 1; see Appendix 1 for scientific names).

By biomass, Sea-Eagles took 52 per cent fish and Whistling Kites took 64 per cent mammals, mostly rabbit (Table 1; Appendix 1), so there was little overlap in diet between the two raptors. This difference was reflected in the low Pianka Index (overlap) of 0.12. The GMPW for Sea-Eagles was 995 grams and for Whistling Kites 606 grams, indicating further niche separation. However, these values did not reflect the difference in mass between the two raptors (Sea-Eagles are close to five times heavier than Whistling Kites, ~3500 g versus ~770 g, when males and females are averaged together).

TABLE 1

Summary table of dietary parameters of White-bellied Sea-Eagles (WBSE) and Whistling Kites (WK) breeding sympatrically in the ACT, 2003–2008 (see Appendix 1 for itemised prey items).

	% *n*		% biomass	
	WBSE (*n* = 78)	WK (*n* = 136)	WBSE	WK
Mammals	8	45	19.5	63.9
Rabbit: adult	0	24	0	38.5
juvenile	0	2	0	1.6
Birds	42	43	23.4	28.4
Reptiles	9	4	4.8	3.1
Fish	40	7	52.1	4.6
Invertebrates	1	<1	0.23	<0.01
GMPW	995.2	605.5		
Shannon Index	2.68	3.24		
Overlap (Pianka Index)	0.12			

Dietary diversity (species richness and evenness), as measured by the Shannon Index, was higher for the Whistling Kite (3.24) than for the White-bellied Sea-Eagle (2.68). Typically, the value of the Shannon Index ranges from 1.5 (low species richness and evenness) to 3.5 (high species evenness and richness) (Marti *et al.* 2007), as reflected in Table 1 and Appendix 1. Sea-Eagles took approximately 28 species while Whistling Kites took approximately 40. For Sea-Eagles, three species predominated by number in the diet: 19 per cent Golden Perch, 18 per cent European Carp and approximately 9 per cent Eastern Snake-necked Turtle. Although Whistling Kites took approximately 25 per cent European Rabbit, the other 39 species in their diet were found in much smaller percentages, hence greater evenness in the Shannon Index.

Disturbance

Results for breeding attempts by White-bellied Sea-Eagles and Whistling Kites on water bodies checked during 2002–2010 were as follows:

Low Disturbance: no breeding Whistling Kites or Sea-Eagles, although solitary Sea-Eagles were present each year.

Medium Disturbance: breeding Sea-Eagles and Whistling Kites each year.

High Disturbance: breeding Whistling Kites each year, but no breeding Sea-Eagles, and only occasional solitary Sea-Eagles (Table 2).

However, there was one failed Sea-Eagle breeding attempt at a Low Disturbance area (the Molonglo/Murrumbidgee junction) in 1995, in a long-established nest normally used by Wedge-tailed Eagles (Debus 2005). Furthermore, all of the Low Disturbance lakes were probably too small (<300 ha) to support sufficient prey for breeding Sea-Eagles, and all of these lacked carp, an abundant introduced species that has inflated

TABLE 2

Breeding by White-bellied Sea-Eagles (WBSE) and Whistling Kites (WK) on water bodies in and near the ACT during 2002–2010, according to human disturbance level: Y = yes, N = no.

Disturbance rating	WBSE	WK
Low (*n* = 4[a])	N[b]	Y
Medium (*n* = 3[c])	Y	Y
High (*n* = 1)	N	Y

[a] Rivers and small (47–283 ha) reservoirs

[b] Solitary eagles only, excepting a failed breeding attempt in 1995

[c] Large reservoirs (680–5500 ha)

the food supply of Sea-Eagles elsewhere in the Murray-Darling Basin (e.g. Marchant and Higgins 1993; Olsen *et al.* 2006a).

DISCUSSION

Diet

Dietary proportions, by number and species, were similar to those found previously for White-bellied Sea-Eagles and Whistling Kites in the same area (see Fuentes *et al.* 2005; Olsen *et al.* 2006a). This study added nine new prey species for the Sea-Eagle in the ACT region, and trebled the previous ACT sample size for the Whistling Kite, adding 22 new food species for the latter in the region. As reported by Olsen *et al.* (2006a), and confirmed in this study, White-bellied Sea-Eagles in the ACT specialise on fish, aquatic reptiles and birds, and take few mammals (i.e. lagomorphs). Similar results were reported from freshwater sites in other regions (Debus 2008; Corbett and Hertog 2011, 2012), and appear to confirm a likely misinterpretation in earlier studies, where rabbit remains may have been incorrectly attributed to Sea-Eagles using vacant Wedge-tailed Eagle nests (Debus 2005).

Previously, Olsen *et al.* (2006a) found that Sea-Eagles in the ACT took 54 per cent fish by biomass, and a GMPW of 887 grams was similar to that (995 g) found in this study. For Whistling Kites, Fuentes *et al.* (2005) reported 57 per cent mammal prey (mostly rabbit) by biomass, which is similar to that reported here (64%, Table 1), but the GMPW of 606 grams found in the present study is higher than that (227 g) found by Fuentes *et al*. (2005), and most likely attributable to the larger sample size in this study. Also, comparative GMPW for the Sea-Eagle and Whistling Kite found in this study does not reflect the fivefold difference in body mass for the two raptors, probably because Whistling Kites relied so heavily on large carrion animals.

Although White-bellied Sea-Eagles and Whistling Kites are taxonomically close, and both are aquatic or marine foragers (the Whistling Kite less strictly so), little overlap in diet was found. In terms of dietary proportions by frequency and biomass, dietary overlap and GMPW, the findings of this study reflect the niche separation found in studies of the White-bellied Sea-Eagle and the similarly sized Wedge-tailed Eagle breeding in sympatry in the ACT (Olsen *et al.* 2006a, 2010a). Therefore, the main ecological difference between the two raptors in this study may rest in the Whistling Kite's much greater reliance on scavenging and the capture of some terrestrial prey, findings that require further investigation.

The lamb and many other mammal prey items from White-bellied Sea-Eagle sites may have been taken as carrion, although some may have been captured (see discussion by Olsen *et al.* 2006a). Among the reptile prey items, turtles were taken by Sea-Eagles but not Whistling Kites, and terrestrial lizards were taken by Whistling Kites but not Sea-Eagles. Fish were taken by both species, probably from the water surface, pirated from other birds, or as carrion. Most of the mammal items found at Whistling Kite nests were probably taken as carrion, although some of the smaller mammals, such as rats, may have been captured. Most of the mammals, some bird species and the terrestrial reptile prey items collected from Whistling Kite and Sea-Eagles nests are commonly observed as road-kill in the ACT region (JO and DJ pers. obs.), which may be a main dietary source of these species. Similarly, many of the larger waterbirds may have been scavenged by Whistling Kites, although they may have captured some of the smaller species, whereas White-bellied Sea-Eagles were likely to have captured the larger waterbirds (Marchant and Higgins 1993; Debus 2008).

The Whistling Kite's GMPW of 606 grams is greater than found for the similar-sized Little Eagle *Hieraaetus morphnoides* in the same region (349 g: Olsen *et al*. 2010a), probably because Whistling Kites ate more adult rabbits as carrion. Both these raptor species had all but disappeared as breeders in the ACT by 2011 (J. Olsen unpubl. data), possibly related to their reliance on rabbits and the rabbit control measures used in the region (Olsen *et al.* 2010b). Such measures have increased in the ACT with increasing rabbit numbers, and Whistling Kites could have taken rabbits poisoned by Pindone (Olsen *et al*. in prep.).

Disturbance

Except for one abortive breeding attempt at the Molonglo-Murrumbidgee river junction (Debus 2005), water bodies relatively free from human disturbance, such as Bendora Dam, Corin Dam and the lower Molonglo River, supported no breeding White-bellied Sea-Eagles. Sea-Eagles may need large water bodies with abundant fish, aquatic birds, turtles and other reptiles, and surface-feeding fish such as carp and redfin, in order to breed (Olsen *et al*. 2006a; Debus 2008; Corbett and Hertog 2011, 2012; Appendix 1, this study). Although no carp are known to occur in Googoong Dam, Sea-Eagles there brought in two carp, possibly taken from local farm dams (Olsen *et al*. 2006a). (*Contra* Corbett and Hertog (2011), Sea-Eagles have never been recorded breeding in the ACT, other than the failed event discussed by Debus (2005); the quoted doubling of breeding density on a 'Canberra lake' refers to a lake outside the ACT, in adjoining NSW.)

The larger and more powerful Wedge-tailed Eagle may inhibit White-bellied Sea-Eagle nest-site selection, interfere with foraging in certain areas, or take over Sea-Eagle nest sites (Olsen *et al*. 2006a; Debus 2005, 2008; Dennis *et al.* 2011b; Hodge and Hodge 2011). In South Australia, studies of White-bellied Sea-Eagles found nest productivity adversely affected by human disturbance (Dennis *et al*. 2011b), and that state's mainland Sea-Eagle population is in decline (Dennis *et al*. 2011a). Conversely, numbers of breeding Wedge-tailed Eagles remain high in some regions (Dennis 2006). In future studies, it will be important to assess the influences of interspecific conflict and competition (for space, nest sites and prey), prey availability and human disturbance (direct and indirect, e.g. habitat modification), and their interactions, as factors affecting White-bellied Sea-Eagle populations in Australia. Furthermore, long-term climatic change needs to be considered as a factor in changing Sea-Eagle populations (Shephard *et al.* 2005).

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APPENDIX 1

Diets of White-bellied Sea-Eagles (WBSE) and Whistling Kites (WK) breeding sympatrically in the ACT, 2003–2008. *New prey species in the ACT for the respective raptor species.

Species	Mass (kg)	*n*		% *n*		Adj. biomass (kg)		% biomass	
		WBSE	WK	WBSE	WK	WBSE	WK	WBSE	WK
Common Ringtail Possum *Pseudocheirus peregrinus*	0.9		1*		<1		0.6		0.97
juv.	0.7	1			1.3	0.47		0.6	
Common Brushtail Possum *Trichosurus vulpecula*	2.875		5		3.7		3.7		6
juv.	1.3	1*			1.3	0.87		1.1	
Eastern Grey Kangaroo *Macropus giganteus*	35		1*		<1		0.74		1.2
juv.	17.2	1*		1.3		3.8		4.81	
Swamp Wallaby *Wallabia bicolor*	2.5		1*		<1		0.74		1.2
juv.									
Black Rat *Rattus rattus*	0.28		6		4.4		1.39		2.26
juv.	0.14		1		<1		0.12		0.19
Rabbit *Oryctolagus cuniculus*	1.5		32		23.5		23.7		38.5
juv.	0.5		3		2.2		1		1.62
Hare *Lepus capensis*	4	1	3	1.3	2.2	2.68	2.22	3.39	3.6
juv.	2		1		<1		0.74		1.2
Lamb *Ovis aries*	15	1*	2	1.3	1.5	3.8	1.48	4.81	2.4
Cow *Bos taurus* bone (sawn human discard)	?		1*		<1				
Fox *Vulpes vulpes*	9	1	3*	1.3	2.2	3.8	2.2	4.81	3.57
cub	3		1		<1		0.74		1.2
TOTAL MAMMALS		**6**	**61**	**7.7**	**44.9**	**15.42**	**39.4**	**19.5**	**63.9**
Black Swan *Cygnus atratus*	5.685		1*		<1		0.74		1.2
Australian Wood Duck *Chenonetta jubata*	0.808	10	2	12.8	1.5	6.46	1.29	8.19	2.1
Australasian Shoveler *Anas rhynchotis*	0.65	1		1.3		0.52		0.66	
Grey Teal *Anas gracilis*	0.504	2	1*	2.6	<1	0.81	0.4	1.02	0.65
Pacific Black Duck *Anas superciliosa*	1.036	6		7.7		4.97		6.3	
Duck sp.	0.75		2		1.5		1.2		1.95
Australasian Grebe *Tachybaptus novaehollandiae*	0.165	1		1.3		0.15		0.18	
Hoary-headed Grebe *Poliocephalus poliocephalus*	0.24		2		1.5		0.42		0.69
juv.	0.2		1		<1		0.18		0.29
Great Crested Grebe *Podiceps cristatus*	1.1	1		1.3		0.88		1.11	
Rock Dove *Columba livia*	0.308		9		6.6		2.22		3.6
Crested Pigeon *Ocyphaps lophotes*	0.205	1*	1*	1.3	<1	0.18	0.18	0.23	0.29
Little Black Cormorant *Phalacrocorax sulcirostris*	0.819	2*	2*	2.6	1.5	1.31	1.31	1.66	2.13
Cormorant sp.	0.732		1		<1		0.59		0.95
Cattle Egret *Ardea ibis*	0.363		2*		1.5		0.58		0.94
Buff-banded Rail *Gallirallus philippensis*	0.18		1		<1		0.16		0.26
Eurasian Coot *Fulica atra*	0.545	2	2*	2.6	1.5	0.87	0.87	1.1	1.42
Whiskered Tern *Chlidonias hybrida*	0.084		1*		1		0.07		0.12
Galah *Eolophus roseicapillus*	0.335	1	5	1.3	3.7	0.27	1.34	0.34	2.17
Sulphur-crested Cockatoo *Cacatua galerita*	0.804		3		2.2		1.93		3.13
Crimson Rosella *Platycercus elegans*	0.135	1*	3*	1.3	2.2	0.12	0.36	0.15	0.58
Eastern Rosella *Platycercus eximius*	0.106	1*	1*	1.3	<1	0.09	0.09	0.12	0.15
Laughing Kookaburra *Dacelo novaeguineae*	0.345	1	3*	1.3	2.2	0.28	0.83	0.35	1.34
Red Wattlebird *Anthochaera carunculata*	0.108		1*		<1		0.1		0.15
Australian Magpie *Cracticus tibicen*	0.329	1*	6	1.3	4.4	0.26	1.58	0.33	2.56
Pied Currawong *Strepera graculina*	0.27	1		1.3		0.24		0.3	
Raven *Corvus* sp.	0.593		1*		<1		0.47		0.77
Magpie-lark *Grallina cyanoleuca*	0.09		3*		2.2		0.24		0.39
Common Starling *Sturnus vulgaris*	0.075		2*		1.5		0.13		0.21
Bird	0.075		3		2.2		0.2		0.32
TOTAL BIRDS		**33**	**59**	**42.3**	**43.4**	**18.45**	**17.5**	**23.4**	**28.4**

APPENDIX 1 (Cont.)

Species	Mass (kg)	*n*		% *n*		Adj. biomass (kg)		% biomass	
		WBSE	WK	WBSE	WK	WBSE	WK	WBSE	WK
Common Bluetongue *Tiliqua scincoides*	0.4		6		4.4		1.92		3.12
Eastern Snake-necked Turtle *Chelodina longicollis*	0.677	7		9		3.79		4.8	
TOTAL REPTILES		**7**	**6**	**9**	**4.4**	**3.79**	**1.92**	**4.8**	**3.12**
Golden Perch *Macquaria ambigua*	1	15		19.2		12		15.2	
Goldfish *Carassius auratus*	0.33		1*		<1		0.26		0.42
European Carp *Cyprinus carpio*	2.5	14		17.9		28		35.5	
small	0.4		2*		1.5		0.53		0.9
Redfin *Perca fluviatilis*	0.3		4		2.9		1.06		1.72
Fish sp.	0.7	2		2.6		1.12		1.42	
small	0.55		2		1.5		0.88		1.43
TOTAL FISH		**31**	**9**	**39.7**	**6.6**	**41.12**	**2.84**	**52.1**	**4.61**
Crayfish	0.2	1		1.3		0.18		0.23	
Locust	0.002		1*		<1		<0.1		<0.1
TOTAL INVERTEBRATES		**1**	**1**	**1.3**	**<1**	**0.18**	**<0.1**	**0.23**	**<0.1**
TOTAL		**78**	**136**	**100**	**100**	**79**	**61.6**	**100**	**100**

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SEABIRD ISLANDS

No. 254

Looking Glass Isle, Broughton Group, New South Wales

Location: 32°37'S, 152°19'E. Located approximately 15 kilometres north-east of the entrance to Port Stephens, New South Wales (NSW). It is part of the Broughton Group, situated approximately 250 metres south of Broughton Island.

Status: Crown land.

Other Names: South Reef.

Description: Looking Glass Isle is a dome-shaped island measuring 325 metres by 175 metres; its longest axis aligned north–south. The island is approximately four hectares, half of which is vegetated. It is composed principally of Carboniferous volcanic rhyolite with heavily eroded basalt dykes forming two tunnels, or 'looking-glass' holes, running through the island. Land bridges connect the three parts of the island. The southern part rises to 69 metres, and the steep slopes to the north and south dominate the rocky shoreline.

Vegetation on the northern and central sections is predominantly dense stands of Spiny-headed Mat-rush *Lomandra longifolia*, with stunted thickets of Red Olive-berry *Elaeodendron australe* along the ridgeline. The exotic Bitou Bush *Chrysanthemoides monilifera* also occurs along this ridgeline and as a large stand (~ 0.1 ha) on the edge of the southern dyke. On the southern section, around the summit, the fire-damaged vegetation is comprised of stunted rainforest-derived species, with Tuckeroo *Cupaniopsis anacardioides* dominant. Other species, including exotics (*) are:

Carpobrotus glaucescens, Tetragonia tetragonioides, Marsdenia rostrata, Enchylaena tomentose, Sarcocornia quinqueflora, Philotheca hispidula, Crassula sieberiana, Geitonoplesium cymosum, Commelina cyanea, Plectranthus graveolens, Isolepis nodosa, Leucopogon parviflorus, Monotoca elliptica, Acacia longifolia var. *sophorae, Scaevola calendulacea, Leptospermum polygalifolium, Oxalis perennans, Sporobolus virginicus, Dianella caerulea, Cyperus tetraphyllus, Correa alba* var. *alba*, *Cakile maritime, *Sonchus oleraceus and *Opuntia stricta var. stricta.

Landing: Onto rocks on the north-western end depending on prevailing conditions. Access to the central section is straightforward, but reaching the southern section and summit requires a steep scramble up a narrow, exposed land bridge.

Ornithological History: The only ornithological visit appears to be during a 1972 survey of Broughton Island by Lane and others[1] when Looking Glass Isle was climbed to determine whether it was used as a breeding site by cormorants; a negative result on that occasion. Callaghan visited for one hour on 3 September 2011 to search for signs of penguin activity and to document vegetation. The authors visited for two hours on 18 December 2011 to survey nesting seabirds.

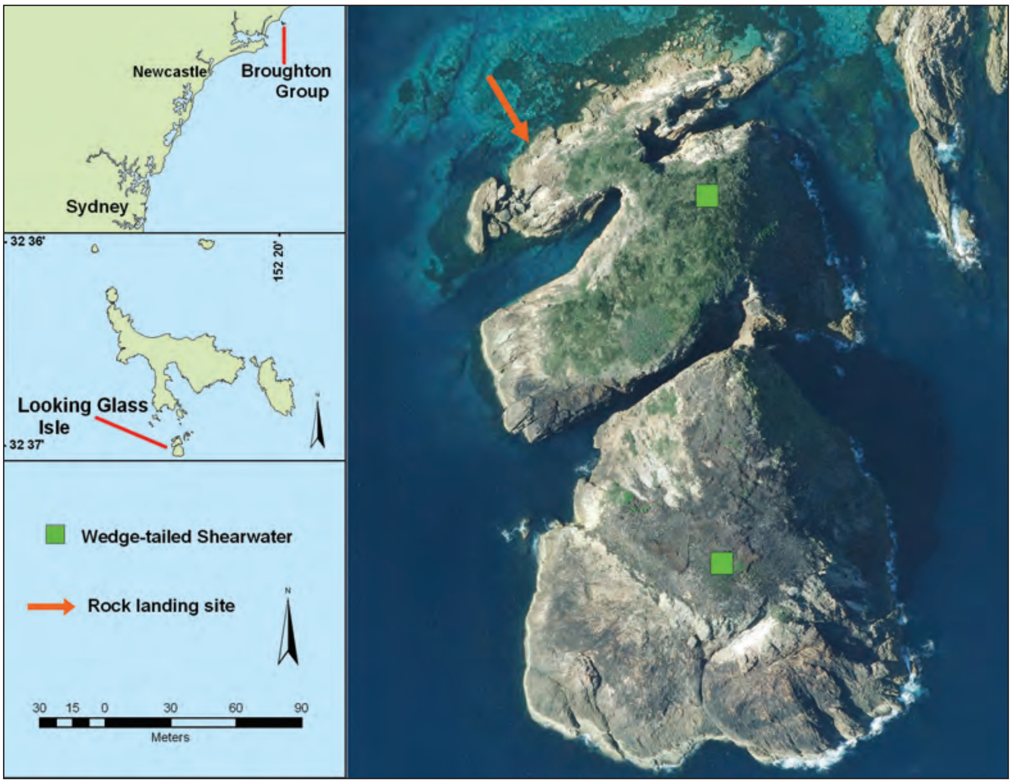

Figure 1. *Looking Glass Isle, Broughton Group, New South Wales*

Figure 2. *Looking Glass Isle from the north, as viewed from Broughton Island.*

Breeding Seabirds and Status

Ardenna pacifica Wedge-tailed Shearwater—Suitable nesting habitat is scarce due to very dense Mat-rush vegetation on the northern and central parts of the island and few other areas with soil of sufficient depth for burrowing. Four personnel searching for 1.5 hours found two breeding birds. A group of seven burrows on the southern slope of the island contained a single incubating bird. A second incubating bird was found within Mat-rush on the central section of the island. We estimate that less than 10 pairs breed on the island.

Factors Affecting Status

A fire, ignited by lightning, burnt out 0.7 hectares of the summit and southern slope of Looking Glass Isle on 20 December 2009; an area that included the larger of the two known breeding sites for Wedge-tailed Shearwater. The fire occurred during the incubation period[2], possibly resulting in the injury or death of some individuals. Fire can have significant impacts on burrow-nesting seabirds, with the loss of incubating adults leading to nest failure[3,4]. No significant erosion was observed, and the fire-damaged canopy species – Tuckeroo – was re-sprouting from rootstock as well as regrowing from seedlings.

Black Rats *Rattus rattus* were eradicated from the Broughton Group in 2009[5]. White-faced Storm-petrels *Pelagodroma marina* breed elsewhere in the Group[6,7] and the removal of rats may lead to this species expanding its range to nest in the shallow soils that occur around the ridgelines of Looking Glass Isle.

As with all islands in the Broughton Group, predation of shearwaters by White-bellied Sea-eagle *Haliaeetus leucogaster* and Swamp Harrier *Circus approximans* was evident, with the remains of Wedge-tailed Shearwaters found near the summit.

Bitou Bush was not recorded within the Broughton Group during the early 1970s[1] but is now widespread, and stands on Looking Glass Isle will require ongoing management if the species is to be contained. Prickly Pear *Opuntia stricta*, although not prevalent, is present and could expand into the area recently disturbed by fire.

Other Seabirds Recorded

No other seabirds were recorded. Lane[1] recorded Great Cormorant *Phalacrocorax carbo*, Little Black Cormorant *P. sulcirostris* and Little Pied Cormorant *Microcarbo melanoleucos* roosting on the island in 1959, 1972 and 1973, but recent signs of occupation were absent.

Figure 3. *Looking Glass Isle, from the southeast. Note the burnt vegetation, photographed in December 2009, shortly after lightning strike.*

Other Vertebrates Recorded

No other vertebrates were recorded.

Banding

No banding has been undertaken on Looking Glass Isle.

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Recent surveys of Looking Glass Isle would not have been possible without the assistance and support of the Hunter Region of the National Parks and Wildlife Service (NPWS). The Broughton Island Conservation Society (BICSI) provided accommodation on Broughton Island. Eleazar O’Connor from NatureFiji-MareqetiViti assisted in the December survey. Jeff Pettifer (BICSI) kindly provided boat transportation and Andrew Hampstead (NPWS) assisted with landings.

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Corella, 2012, 37(1): 21-22

SEABIRD ISLANDS No. 21/1

Inner Rock, Broughton Group, New South Wales

Location: 32°36'S, 152°18'E. Located approximately 16 kilometres north-east of the entrance to Port Stephens, New South Wales (NSW). It is part of the Broughton Group, situated approximately 600 metres north-west of Broughton Island.

Status: Together with nearby North Rock, forms Stormpetrel Nature Reserve, gazetted in 1976 for the conservation of seabird nesting habitat. It is part of the Myall Coast Reserves administered by NSW National Parks and Wildlife Service, Office of Environment and Heritage.

Description: Inner Rock is a teardrop-shaped island of 0.9 hectares, with an elevated (10 m) vegetated area of 0.3 hectares. The island is composed of Carboniferous volcanic rhyolite; the rocky shoreline and cliffs on the southern and eastern side make access difficult. Vegetation, rooted in shallow soils, is dominated by Spiny-headed Mat-rush *Lomandra longifolia* with low stands of Coastal Wattle *Acacia longifolia* ssp. *sophorae* and Tree Broom Heath *Monotoca elliptica*. Other species not mentioned by Lane[1] and including exotic (*) species are:

Hydrocotyle peduncularis, Doodia aspera, Histiopteris incis, Crassula sieberiana, Westringia fruticosa, Duboisia myoporoides, Peperomia leptostachya, Poa poiformis var. *poiformis, Sporobolus virginicus, *Chrysanthemoides monilifera, *Phytolacca octandra, *Andropogon virginicus* and **Solanum nigrum.*

Landing: A difficult landing onto sloping rocks on the north-west shore or onto a south-west rock stack abutting the island, depending on prevailing conditions.

Ornithological History: Lane[1] summarised two previous visits up to 1973, which recorded breeding populations of Wedge-tailed Shearwater *Ardenna pacifica* and White-faced Storm-petrel *Pelagodroma marina*. Carlile and others visited the island overnight on 2–3 October and 21–22 December 2010 to survey penguins and other seabirds. The authors visited briefly on 18 December 2011 to confirm that storm-petrels were breeding.

Breeding Seabirds and Status

Pelagodroma marina White-faced Storm-petrels—Previously recorded nesting in burrows located amongst Mat-rush[1]. The only burrows seen during the October 2010 survey were on the south-east edge of the island where soil was particularly shallow. Fresh excavations were noted, and a few individuals seen over-flying the island at night. In December 2010, a total of 100 burrow entrances were counted, but no evidence of breeding was detected. In December 2011, five downy chicks were extracted from accessible burrows, confirming that breeding occurs here. Assuming a mean occupancy rate of 63 percent[2], we estimate the total population for Inner Rock to be approximately 63 pairs, significantly less than Lane's 1973 estimate of 500 pairs[1]. How Lane obtained his estimate is not recorded, but his description of their location on the island in 1973[1] suggests their former widespread distribution may have contracted.

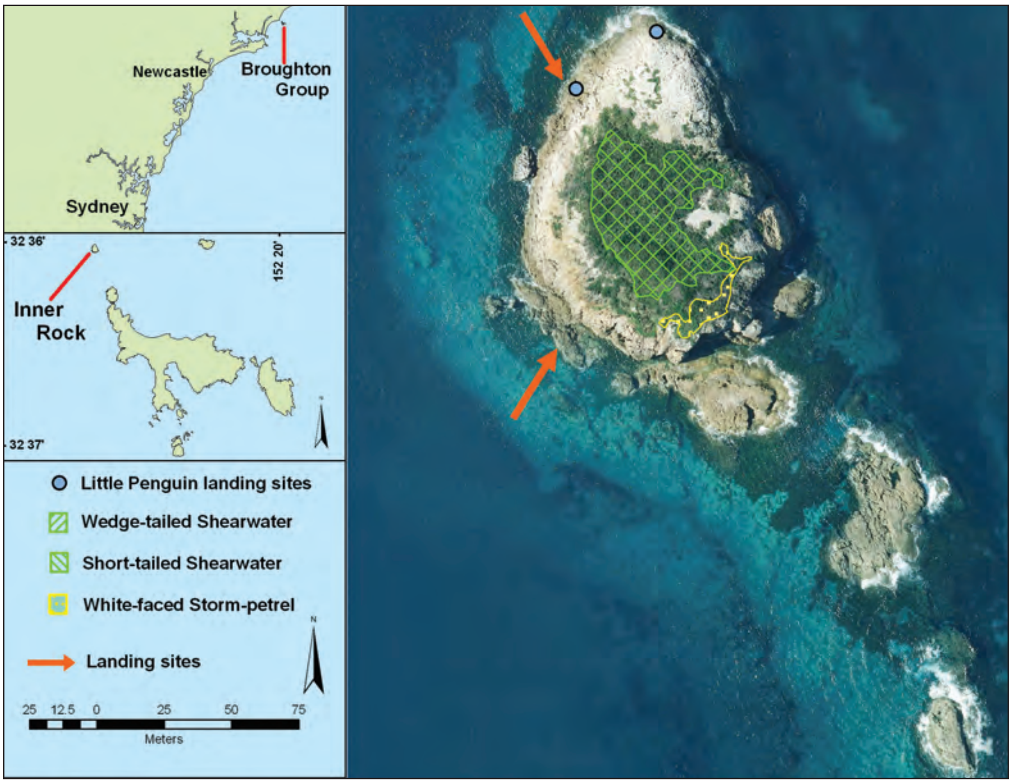

Figure 1. *Inner Rock, Broughton Group, New South Wales*

Ardenna pacifica Wedge-tailed Shearwater—Nests across most (0.18 ha) of the vegetated part of the island, either in short burrows among thick vegetation or in excavations under clumps of Mat-rush, as soil is shallow. The boundaries of the colony were mapped using a GPS and geographic information system (GIS). Population size was estimated by sampling burrows within a series of four random transects (each 20 m x 4 m). The area surveyed was approximately 18 percent of the area of the colony. At the time of the survey, adult birds were incubating eggs. All burrows within each transect were counted and searched; if occupied, the occupant was extracted and identified. In total, the transects contained 54 burrows, of which 17 were occupied; an occupancy rate of 31 percent. Of those birds present, 71 percent were Wedge-tailed Shearwaters. We estimate the total number (± s.e.) of shearwater burrows on the island to be 304 ± 34, and the population of Wedge-tailed Shearwaters to be 68 ± 34. This is similar to the estimate of 100 pairs made by Lane in 1973[1].

Ardenna tenuirostris Short-tailed Shearwater—Nocturnal observations in October 2010 indicated the presence of this species on the island. In December 2010, transect sampling revealed that they nest across the island, in a mixed colony with Wedge-tailed Shearwater. Twenty-nine percent of shearwaters present were Short-tailed Shearwaters. We estimate the population (± s.e.) of Short-tailed Shearwaters to be 28 ± 6 pairs. This species was not recorded breeding on Inner Rock previously.

Eudyptula minor Little Penguin—In October 2010, no landing sites could be identified from excrement trails. However, from a nocturnal patrol of the island's perimeter between 1900 hr and 2000 hr, two birds were found coming ashore at the northern tip of the island and five birds 40 m along the shoreline to the south-west near the boat landing site. In December 2010, nine birds came ashore at the northernmost site, and three at the other site. Also, two nests, containing chicks four and six weeks old, were located in dense vegetation during transect surveys (see below). Assuming that birds landing in October were arriving to relieve their partner during incubation (1 arrival per nest), and birds landing in December were arriving to feed large nestlings (2 arrivals per nest), we estimate five pairs using each landing site; i.e. 10 pairs in total. Little Penguins have not been recorded breeding on Inner Rock previously.

Factors Affecting Status

The addition of Little Penguins and Short-tailed Shearwaters to the breeding seabirds of Inner Rock is not surprising as both species breed on West End, Broughton Island, 700 metres away[3]. The possible reduction in White-faced Storm-petrel is surprising and, if accurate, not easily explained. Shearwaters can exclude storm-petrels[2,4] from nesting sites, but there has been no apparent change in shearwater numbers on Inner Rock, nor has there been comparable reductions in storm-petrels on most other NSW islands that remain free of rodents[5,6,7].

Bitou Bush *Chrysanthemoides monilifera* and Prickly Pear *Opuntia stricta* are well established on the island and, after Mat-rush, are the most dominant plants. These invasive weeds require ongoing management if they are to be prevented from spreading across the entire island.

White-bellied Sea-eagle *Haliaeetus leucogaster* and Swamp Harrier *Circus approximans* were both observed hunting over the island and would likely take shearwaters and penguins not utilising the thick cover of vegetation during daylight.

Other Seabirds Recorded

Silver Gull *Chroicocephalus novaehollandiae.*

Other Vertebrates Recorded

Yellow-bellied Water-skink *Eulamprus heatwolei.*

Banding

First banding	–	10 December 1973.
Pelagodroma marina	–	six nestlings; no recoveries.
Ardenna pacifica	–	three adults, with one recovery at banding place 37 years after banding. Another recovery of an adult banded at-sea off Ulladulla NSW, 278 kilometres to the south two years and five months previously.

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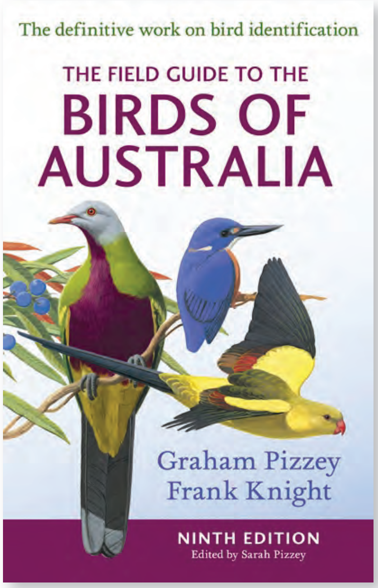
Book Review



The Field Guide to the Birds of Australia (Ninth Edition).

Graham Pizzey and Frank Knight. Edited by Sarah Pizzey. 2012. HarperCollins*Publishers* Pty Limited, Sydney, Australia. Paperback, 608 pp. ISBN 9780732291938. RRP $45.

The original *Field Guide to the Birds of Australia*, carefully crafted by highly regarded naturalist Graham Pizzey and illustrated by Roy Doyle, was published in 1980. Over the years this field guide has been regularly revised and updated, culminating in this ninth edition. Since Graham Pizzey's passing in 2001, scientific editing of the updates has been undertaken by Peter Menkhorst (editions seven and eight) and now, for the first time, by Graham's daughter, Sarah Pizzey. Illustrations are now the work of Frank Knight, one of our leading natural history illustrators.

While the ninth edition incorporates many revisions and updates it follows a similar format to earlier editions. A 'quick find guide' inside the front and back covers, to help users quickly find the relevant page to identify their bird, is now presented as a 'visual index'. To facilitate identifications, 'the quick find guide' has been reworked so that species are grouped in the environment in which they are most likely to be encountered rather than in taxonomic order. The 'Introduction to the Guide' explains the set up of the book and the format of species accounts. Whether novice or experienced birdo, it is worth taking the time to read, or at least skim, this section if you are to get the most from the field guide. There is valuable information regarding field identification of birds as well as some general tips which will be of particular value to those newer to bird watching and identification.

In this ninth edition species accounts are provided for 842 species, including 86 vagrants. Species accounts and distribution maps have been amended to take into account new information. The order of species entries has been revised to be consistent with the new taxonomic order that has evolved with the advent of DNA technology. This is a major change and time is needed to assimilate this new order. In addition, the vagrants, birds whose 'normal' range is outside Australia, are now grouped in a new section after the main body of species accounts. Thirteen new vagrants are included. Vagrants include seabirds (33 species), waterbirds (6), waders (25) and birds of bush and open country (22).

In keeping with the taxonomic changes, some 100 families of birds are now recognised in Australia and a brief introduction to each family (in their new form and order) is provided. Family introductions have been substantially amended since the previous edition. Appendices to the book include a glossary, a list of suggested further reading and references, and a list of major bird watching organisations within Australia. Unfortunately, lists of the more local birding groups, which are frequently of interest to amateur bird watchers, are not included. A separate index is provided for scientific and common names. While I prefer a single combined index – having a tendency to waste time navigating two indexes – this is a minor quibble and I can accept, if not understand, that others might prefer common names to be separated from scientific. It is reassuring to read that commonly used names have only been altered where there is a compelling reason.

In this field guide the all important illustrations show a good range of the diversity within each species – male, female, breeding, non-breeding, immature, juvenile and so on. For some species, images of perching birds are complemented by depictions of birds in flight. Illustrations are labelled simply to indicate the species (common name) and race, sex, age or breeding status as required. A number of the illustrations are enlivened by the inclusion of habitat features: foliage, logs, leaf litter and so on. To me, in a field guide, this is clutter which detracts from the job at hand – identification – but I am happy to acknowledge that this is a personal preference.

In 1980, in his foreword to the first edition of this field guide, the late Dr D. L. Serventy expressed his opinion that "The virtue of a field guide is that it contains all the information necessary, in pictures and text, to *identify* a bird. But no more." I find myself in agreement with this sentiment. In this field guide a fair amount of additional information is provided and, despite my above stated preferences and the associated extra weight and size of the book, I cannot help but be intrigued by all this extra information in one handy text.

Australian birdwatchers are spoilt by choice with four good national field guides now available. Each is good but different. If you are already a fan of the "Pizzey and Knight" field guide then this considerably updated ninth edition is well worth upgrading to. If you are now working with another guide then I would still recommend the "Pizzey and Knight" guide as it complements the other three guides. If you find that having four field guides is excessive (I do not), then look long and hard at each to decide which suits you best.

Sarah Pizzey is to be congratulated on bringing to fruition this ninth edition of what has always been a high quality field guide.

Judy Smith
Blaxland, NSW

Corella, 2013, 37(1): 24

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

Northern Mallard *Anas platyrhynchos*

2757598*. Juvenile female banded at Pipiroa, Hauraki, New Zealand (37^{0}15'S 175^{0}30'E) on 8 Jan. 2010. Recovered dead at Broken Head, south of Byron Bay, NSW (28^{0}42'S 153^{0}36'E) by S. Ivanac on 1 Nov. 2012. 2245 km WNW.

*New Zealand Banding Scheme band

Black-browed Albatross *Thalassarche melanophris*

CF40477*. Nestling banded on Kerguelen Islands, Terres Australes et Antarctiques, France (49^{0}21'S 70^{0}13'E) on 27 March 2005. Band number read in field, (breeding with one egg) at Petrel Peak, Macquarie Island, Tas. (54^{0}45'S 158^{0}46'E) by J.B. Cleeland on 7 Nov. 2012, over 7 years, 7 months after banding. 5671 km SE.

*French Banding Scheme band.

Australasian Gannet *Morus serrator*

131-65460. Nestling banded by C.G. Cooper on Lawrence Rocks State Faunal Reserve, Portland, Vic. on 23 Dec. 1988. Recovered dead between Blackfellows Caves and Black Point, SA on 28 July 2012, over 23 years 7 months after banding. 117 km WNW.

Peregrine Falcon *Falco peregrinus*

270-08398 plus Readable Band : Green ER. Nestling female banded by V.G. Hurley at Freestone Creek, Vic. on 10 Nov. 1998. Recovered stunned on Churchill Island, Vic. by T. Heywood and J. Evans. Found sitting on ground on top of Australian White Ibis, was taken to Philip Island Nature Park Wildlife Rehabilitation Centre where it was held overnight. The bird was fully recovered in the morning and was released at the site of capture, over 13 years 9 months after banding. 175 km WSW.

Kelp Gull *Larus dominicanus*

111-08648. Nestling banded by W.C. Wakefield on Green Island, D'Entrecasteaux Channel. Tas. on 27 Dec. 1990. Recovered sick or injured at Claremont, Tas, was rehabilitated and released alive with band on 4 Oct. 2012, over 21 years 9 months after banding. 46 km N.

Tooth-billed Bowerbird *Scenopoeetes dentirostris*

071-52106. Adult (1+) banded by S.G. Lane at Paluma State Forest (now National Park), Paluma, Qld. on 30 Nov. 1990. Recaptured, released alive with band near banding place by C. Panayi on 7 Dec. 2012, over 22 years after banding

(This is the oldest recorded for the species.)

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BANDING SNIPPETS

The travels of Little Tern *Sternula albifrons* ABBBS Band No: 041-36223

This Little Tern was banded as a chick at Towra Point National Park, New South Wales by Geoff Ross for the NSW NPWS Seabird Project on 18 December 1996. A single site and year cohort blue flag was placed on its left leg and an ABBBS metal band on its right leg.

On 4 January 2000 I trapped it whilst on a nest at Lake Wollumboola, Culburra, New South Wales (~110 kms south) and placed a pale blue flag over the blue flag and a red flag over the metal band (an individual colour combination). I recorded it again at Lake Wollumboola on 11 November 2000 and again on 4 November 2001.

In 2002 it headed towards warmer climes and was seen by Jill Denning at Bribie Island, Queensland (~1000 kms north) on 29 March of that year.

I then re-sighted this tern over the next seven years, back again on the south coast of New South Wales, where it moved between Shoalhaven Heads, Culburra and Lake Conjola:

2 November 2002	– Shoalhaven Heads – its sex was determined as a male from watching its courtship display
11 January 2003	– Lake Wollumboola, Culburra
9 January 2004	– Shoalhaven Heads
23 December 2007	– Lake Wollumboola, Culburra
28 December 2008	– Lake Wollumboola, Culburra (on nest)
20 December 2009	– Lake Conjola

The last recorded sighting was on 16 November 2012 at Tuross Lake by John Cornish who was able to photograph it while performing its courtship display (see below) – verifying its sex as a male.

This much-travelled Little Tern recently celebrated its sixteenth birthday.

Photo: John Cornish

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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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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.

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