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

Andrew C. M. Smith[1], K. Heidy Kikillus[2], Geoff Ross[3] and Ursula Munro[1,4]

[1]The School of the Environment, University of Technology, Sydney, PO Box 123, Broadway 2007, Australia.
[2]School of Biological Sciences, Victoria University of Wellington, PO Box 600, Wellington 6140, New Zealand.
[3]Office of the Environment and Heritage, PO Box 1967, Hurstville 2220, Australia.
[4]Corresponding author. Email: Ursula.Munro@uts.edu.au

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 $y=a\dfrac{\exp(b(x+c))-1}{\exp(b(x+c))+1}+d$ 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.
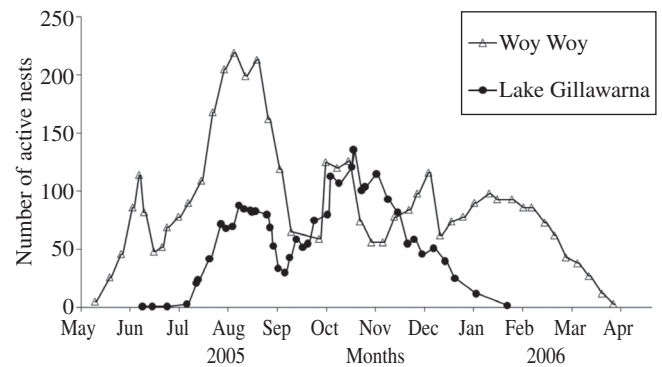
Figure 1. *Number of active nests of ibises at WW and LG between May 2005 and April 2006.*

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).
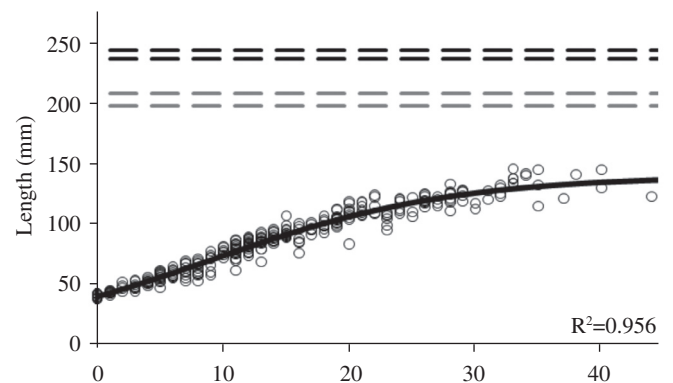
DISCUSSION

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
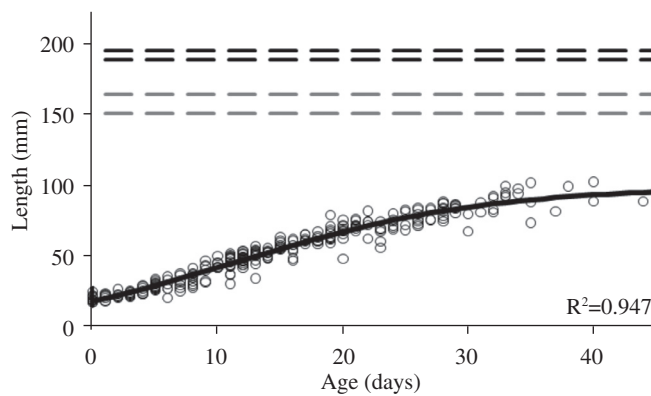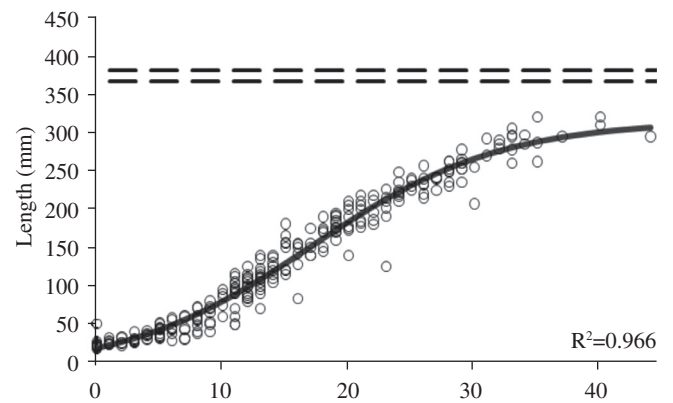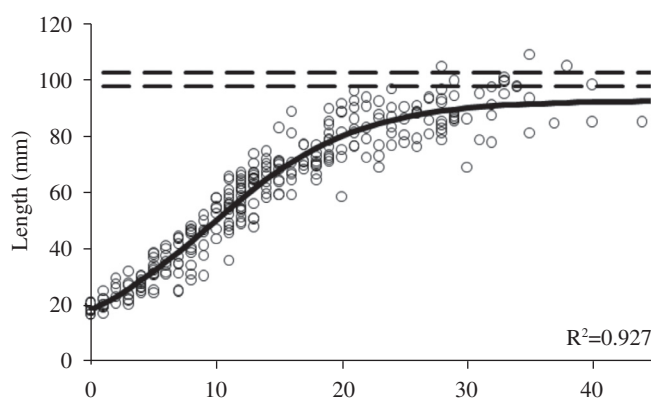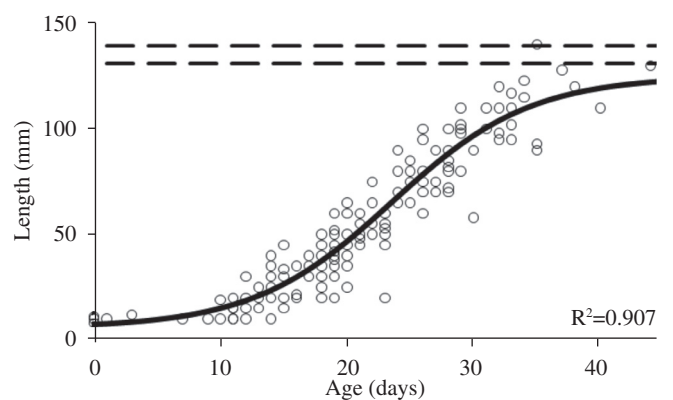
2(a) Weight
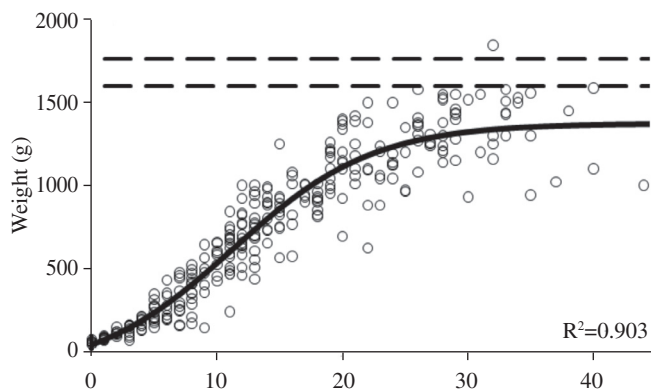
2(b) Head-bill

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).

ACKNOWLEDGEMENTS

REFERENCES

Auman, H. J. (2008). 'The effects of anthropogenic food on the body condition, biochemistry, stable isotopes and egg quality of Silver Gulls in Tasmania'. Ph.D. Thesis, University of Tasmania.

Beilharz, M. I. (1988). 'Individual variation in reproductive success in the Sacred Ibis'. Ph.D. Thesis, University of Melbourne.

Belant, J. L., Ickes, S. K. and Seamans, T. W. (1998). Importance of landfills to urban-nesting Herring and Ring-billed Gulls. *Landscape and Urban Planning* **43**: 11–19.

BOM (Bureau of Meteorology) (2006). Sydney climate summary - NSW Regional Office. http://www.bom.gov.au/announcements/media_releases/nsw/20060101.shtml Accessed 6 October 2007.

Burger, J. and Gochfeld, M. (1999). Interspecific and locational differences in heavy metal levels in four species of birds near Sydney, Australia. *Environmental Monitoring and Assessment* **58**: 105–119.

Corben, D. T. and Munro, U. (2006). Clutch size and fledgling success of the Australian White Ibis *Threskiornis molucca* in an urban environment. *Corella* **30**: 55–58.

Corben, D. T. and Munro, U. (2008). The abundance and movements of the Australian White Ibis *Threskirornis molucca* in an urban environment. *Corella* **32**: 58–65.

Edge, K. (2008). Level and profiles of dioxins, dioxin-like compounds and brominated flame retardants in various tissues of Australian White Ibis (*Threskiornis molucca*) from Sydney. B.Sc.(Hons) Thesis, University of Technology, Sydney.

Frederick, P. C. and Shields, M. A. (1986). Suspected intraspecific egg dumping in the White Ibis (*Eudocimus albus*). *Wilson Bulletin* **98**: 476–478.

Gregory, N. G. and Robins, J. K. (1998). A body condition scoring system for layer hens. *New Zealand Journal of Agricultural Research* **41**: 555–559.

Gotelli, N. J. (2001). 'A primer of ecology.' 3rd edn. (Sinauer Associates: Sunderland.)

Hoyt, D. F. (1979). Practical methods of estimating volume and fresh weight of bird eggs. *Auk* **96**: 73–77.

Kentish, B. (1999). Breeding of Australian White Ibis, Straw-necked Ibis and Silver Gulls on Winter Swamp, Ballarat from 1990–1997. *Corella* **23**: 37–42.

Kingsford, R. T. and Johnson, W. (1998). Impact of water diversions on colonially-nesting waterbirds in the Macquarie Marshes of arid Australia. *Colonial Waterbirds* **21**: 159–170.

Klomp, H. (1970). The determination of clutch-size in birds, a review. *Ardea* **58**: 1–124.

Kushlan, J. A. (1977). Differential growth parts in the White Ibis. *Auk* **94**: 164–167.

Lowe, K. W. (1984). 'The feeding and breeding biology of the Sacred Ibis *Threskiornis aethiopicus* in southern Victoria'. Ph.D. Thesis, University of Melbourne.

Marchant, S. and Higgins, P. J. (1990). 'Handbook of Australian, New Zealand and Antarctic birds'. Vol. 1. (Oxford University Press: Melbourne.)

Martin, T. E. (1987). Food as a limit on breeding birds: a life-history perspective. *Annual Review of Ecology and Systematic* **18**: 453–487.

Martin, J. M., French, K. and Major, R. E. (2007). The pest status of Australian White Ibis (*Threskiornis molucca*) in urban situations and the effectiveness of egg-oil in reproductive control. *Wildlife Research* **34**: 319–324.

Massemin-challet, S., Gendner, J-P., Samtmann, S., Pichegru, L., Wulgué, A. and Le Maho, Y. (2006). The effect of migration strategy and food availability on White Stork *Ciconia ciconia* breeding success. *Ibis* **148**: 503–508.

Murray, N. and Shaw, P. (2006). Breeding biology of the Australian White Ibis *Threskiornis molucca* at an urban breeding colony, South-East Queensland. *Corella* **30**: 41–45.

Porter, J. L., Kingsford, R. T. and Hunter, S. J. (2006). Aerial surveys of wetland birds in Eastern Australia - October 2003–2005. Occasional Paper 37. DEC, NSW.

Smith, A. C. M. (2009). 'Population ecology of the Australian White Ibis, *Threskiornis molucca*, in the urban environment'. Ph.D. Thesis, University of Technology, Sydney.

Smith, A. C. M. and Munro, U. (2010). Seasonal population dynamics of the Australian White Ibis (*Threskiornis molucca*) in urban environments. *Emu* **110**: 132–136.

Smith, A. C. M. and Munro, U. (2011). Local and regional movements of the Australian White Ibis *Threskiornis molucca* in eastern Australia. *Corella* **35**: 89–94.

Snape, J. (2011). 'Abundances and feeding success of birds on landfills'. B.Sc.(Hons) Thesis, University of Technology, Sydney.

Sokal, R. R. and Rohlf, F. J. (1995). 'Biometry: The Principles and Practice of Statistics in Biological Research'. 3rd edition. (W.H. Freeman: New York.)

Thomas, C. (2007). 'Abundances, distribution, habitat requirements and the breeding biology of urban Australian White Ibis (*Threskiornis molucca*)'. B.Sc.(Hons) Thesis, University of Technology, Sydney.