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Local and regional movements of the Australian White Ibis *Threskiornis molucca* in eastern Australia

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Little is known about the movements of Australian birds. Information is particularly scarce on large, aquatic birds, which are usually difficult to access and handle. Their movements are also often complex, and therefore difficult to identify. Here we present data on the local and long distance movements of the Australian White Ibis *Threskiornis molucca*, a highly mobile bird, which as many other waterbirds, continues to decline in its traditional ranges in inland Australia. At the same time it has invaded coastal urban environments, where its high abundances cause many problems and require management. Our analysis of past and present banding studies reveals that Australian White Ibis travel throughout the urban environment and visit landfills, where they forage in large numbers. They also conduct long distance movements, which lead birds from breeding sites in south-eastern Australia along the eastern coast to regions further north (Queensland and Papua New Guinea). Young birds return to their hatching site, when sexually mature. Their preferences for landfills, high mobility, complex movements and current decline in inland Australia need to be considered, when developing and implementing management strategies for Australian White Ibis and ecologically similar birds.

INTRODUCTION

In contrast to the extensive knowledge on the movements of Northern Hemisphere birds (e.g. Alerstam 1990; Berthold 2001) little is known about their Southern Hemisphere counterparts (Griffioen and Clarke 2002). In Australia, for example, where many bird species are mobile (Chan 2001; Griffioen and Clarke 2002), only the movements of some intracontinentally migrating passerines (e.g. Munro 2003; Funnell and Munro 2007) and shore- and seabirds (Waterman *et al.* 2003; Minton *et al.* 2006; Geering *et al.* 2007) have been described in detail. The movements of birds from other taxa often remain poorly understood (Kingsford and Norman 2002). This is especially the case for large and/or aquatic birds, whose movements can also be complex (Kingsford and Norman 2002).

The Australian White Ibis *Threskiornis molucca* is a large aquatic bird, whose movements have been studied to some extent. The results of these studies suggest that this bird (a) is sedentary as well as mobile (Corben 2003; Corben and Munro 2008), (b) conducts long distance northward movements from its southern Australian breeding areas (Carrick 1962; Purchase 1976), (c) performs eastwards movements from the Australian inland towards the coast, (d) conducts movements, which may differ temporally between first year and adult birds (Thomas 2007), and (e) travels on a local scale between its roosting and foraging sites (e.g. landfills (Murray 2005)). Unfortunately, all of the above studies are either based on small sample sizes (Carrick 1962; Murray 2005), and/or cover only short time scales (Corben and Munro 2008), which do not represent solid datasets for concluding about their movements.

With the recent range expansions and increase of the Australian White Ibis from their traditional inland range (Murray and Shaw 2006; Corben and Munro 2008) into urban environments understanding their movements has gained importance. The Ibis began to invade the Australian east coast approximately 30 years ago (Morris 1983; Ross 2004) and today occurs and breeds in large numbers in all major coastal cities (Smith 2009), where their presence conflicts with human interests (see Corben and Munro 2008). The public and many agencies with Ibis problems often demand a rigorous reduction in their numbers (Martin *et al.* 2007). While such measures seem appropriate for other ibis species, which have become exotic invaders (e.g. Sacred Ibis *T. aethiopicus* in Europe (Yésou and Clergeau 2005; Clergeau and Yésou 2006a) and Florida, USA (Herring and Gawlik 2008)), this may not be justified for the Australian White Ibis. This species has probably extended its breeding range coastward (Bekle 1982; Morris 1983; Ross 2004) due to water shortages caused by drought and irrigation (Corben and Munro 2006, 2008) in its traditional inland wetland breeding areas (Carrick 1962; Cowling and Lowe 1981), where it is currently in decline (Porter *et al.* 2006). While its expansion has many ecological, social and economic consequences (Mack *et al.* 2000; Corben 2003; Ross 2004), which require solutions, urban managers need to be cautious, until more knowledge on basic biological parameters of this poorly understood bird is gained (Smith 2009). In particular, we need a better understanding of the birds' movements, so that we can determine effects on local and regional populations (see Corben and Munro 2006, 2008; Thomas 2007) and numbers that can be safely removed without harming the long-term survival of the species.

In the current study, we aim to provide an overview of the complex movements of the Australian White Ibis, through analysing all past (records of the Australian Bird and Bat Banding Scheme (ABBBS), Environment Australia, Canberra)

and present banding records of birds (mainly juveniles) and discuss these findings in view of the current literature on their movements (see Smith 2009). We also intend to establish: (a) whether urban Australian White Ibis colonies consist of separate entities or are interlinked, (b) which distances they travel in urban environments, and (c) whether they visit landfills for foraging. This information will provide baselines for future management plans for the Australian White Ibis and most likely also the closely related Sacred Ibis, which has recently invaded Europe (Yésou and Clergeau 2005; Clergeau and Yésou 2006a) and North America (Herring and Gawlik 2008).

METHODS

Study species

The Australian White Ibis is endemic to Australia, the southern areas of Papua New Guinea and some of the surrounding islands (Marchant and Higgins 1990). It is closely related to the Sacred Ibis from Africa, and both were until recently regarded as the same species (Lowe 1984; Lowe and Richards 1991). Australian White Ibis roost and nest colonially near water bodies and on small islands (Ross 2004). Traditionally nesting occurred in the inland wetland systems (e.g. Murray-Darling river system (Carrick 1962)), but today also takes place in many coastal environments of eastern Australia (Corben and Munro 2008), where they forage predominately at landfills (Smith 2009; Smith and Munro 2010). In their natural inland habitat breeding events are correlated with sufficient waterflows into wetlands (Kingsford and Johnson 1998; Kingsford and Auld 2005). Once Australian White Ibis fledge, they can travel large distances, and some banding recoveries suggest movements from south-eastern Australia to southern Papua New Guinea (Carrick 1962; Purchase 1976). Today Australian White Ibis are very common in urban parks and on landfills, which they use as feeding sites (Ross 2004).

Study sites

We studied the Australian White Ibis (hereafter referred to as Ibis) from three urban colonies in the wider Sydney area (New South Wales (NSW), Australia) between April 2005 and April 2006. The colonies were located at: (a) Centennial Park (CP) (33º54'S, 151°14'E), an urban park (360 ha) in eastern Sydney; (b) Lake Gillawarna (LG), Bankstown (33°55'S, 150°58'E), an artificial wetland in western Sydney; and (c) a sand island near Pelican Island in the Hawkesbury River estuary at Brisbane Waters, near the town of Woy Woy (WW) (33°30'S, 151°20'E), approximately 80 km NNE of Sydney's centre). All colonies were confined to small islands (CP: 0.04 ha; LG (two islands): 0.45 and 0.03 ha; WW: 0.10–0.50 ha (depending on tidal levels)), which were surrounded by water throughout the entire breeding period. All sites were close (less than 25 km) to landfills (depositories for domestic waste), where Ibis regularly forage (Smith 2009).

Data collection

Local movements

To determine local movements of Ibis (5–100 km from each banding site) 830 birds were banded on their right tarsus, using numbered bands from the ABBBS, between 25 May 2005 and 5 April 2006. All birds were banded as nestlings or recent fledglings (CP: 14; LG: 322; and WW: 456 birds), except 38 birds from CP, which were banded as older juveniles or adults. Six hundred and eighty-nine of all number banded birds were also fitted with a colour band on their right tibia, which indicated the banding location. Three hundred and six of these birds also wore two additional bands on their left tarsus, which, together with the location band, enabled us to individually identify birds in the field.

Recoveries and re-sightings of birds banded during our current and previous small scale banding studies in the wider Sydney area (i.e. at Kingsford Smith Airport (33º34'S, 151º6'E) and the Royal Botanic Gardens (33º52'S, 151º13'E)) between 2002 and 2004 were obtained through weekly surveys of all our banding sites between April 2005 and April 2006, and Sydney's three major landfills for household waste (Eastern Creek (33º49'S, 150º52'E), Belrose (33°43'S, 151°13'E) and Lucas Heights (34º03'S, 150º58'E)) between September 2005 and January 2006 (records of D. Mulquin, University of Technology, Sydney (UTS)). Additional records were obtained from the general public, the ABBBS database, and further weekly surveys at LG and CP between 15 August and 15 October 2006, LG and WW between 3 March and 10 August 2007, and WW on 31 December 2007 and between 6 May and 24 June 2008 (records of V. Kubur, J. Roberts and C. Thomas, UTS). All local movements were mapped using ArcGIS (version 9.3) (see Fig. 1).

Regional movements

To determine regional movements, we combined all long distance band recoveries (≥ 300 km) held in the ABBBS database (1955–2007) (over 10 000 birds banded, overall 789 recoveries). All long distance recoveries ($n = 64$) were from birds, which had been banded as nestlings or recent fledglings and were mapped using ArcGIS (Version 9.3) (see Fig. 2). All map templates were obtained from Geoscience Australia (2008). One band recovery from Western Australia was omitted as it represented the only recovery from this part of Australia.

In order to obtain a rough estimate of how fast Ibis can travel on a regional scale, we screened our dataset for birds that had covered large distances (above 500 km) in short times (less than four months). The average travelling speed of these birds was calculated by dividing the distance the birds had covered by the number of days the birds needed to travel this distance.

Breeding site fidelity and sexual maturity

To gain an estimate, when Ibis reach sexual maturity and whether they return to their hatching site, we screened our dataset for recoveries of birds we had banded during the 2005/2006 breeding period and resighted at the same site at a later stage. The time difference between the banding and recovery date was used to estimate the duration Ibis require for reaching sexual maturity.

RESULTS

Local movements

In total we resighted 143 banded Ibis and identified 26 pathways they travelled on a local scale. Strong movements (indicated by thick black lines in Fig. 1) occurred between two study sites (CP and LG) and the three major landfills (Belrose, Eastern Creek and Lucas Heights) (Fig. 1). Banded Ibis from CP, LG and WW were also discovered at other roosting/breeding sites and travelled between landfills (e.g. Belrose, Eastern Creek and Lucas Heights). Ninety percent of all local

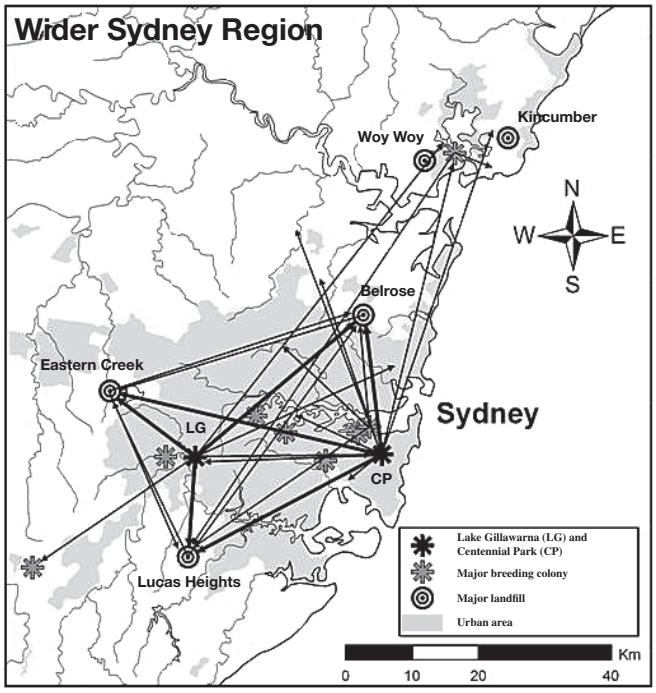

Figure 1. *Local movements (within a 100 km radius from Sydney's centre) of Australian White Ibis. Thin black lines (n = 20) represent the movement of one Ibis between two sites; thick lines (n = 6) indicate the movements of at least five different Ibis along this route. The arrowhead indicates the resighting location. The breeding colony at LG and CP are indicated by black asterices, all other major breeding colonies (≥ 100 nests between 2005 and 2007) in the wider Sydney region are represented by a grey asterisk.*

re-sightings occurred at these landfills, despite extensive surveys of roosting sites. Four individually colour banded birds visited at least two landfills, with one bird from CP visiting the Eastern Creek, Belrose and Lucas Heights landfills within three months. Two juveniles covered the longest distance by travelling from WW to the Lucas Heights landfill (~60 km SSW of WW). The movements of adults did not differ from those of juveniles; samples were therefore pooled.

Regional movements

Sixty-four recoveries (from 1955 to 2007) extended over long distances (≥ 300 km) (Fig. 2). When mapping these recoveries, north to northeastward movements dominated, which suggests that birds from Victoria (Vic.) direct their movements towards Sydney, the Gold Coast/Brisbane region and northern Queensland (Qld.) (Cape York) and southern Papua New Guinea. Two long distance recoveries (from Brisbane (27º41'S, 153º4'E) to southern Vic. (37º54'S, 144º40'E and 38º19'S, 144º43'E) (travel distance: 1380 and 1415 km) point southward (219° and 218°) and suggest that return movements take place. Eighty percent of all resightings (n = 52) were within 100 kilometres from the coast line.

Ibis can cover large distances in short times. One bird was recovered at Nanango, Qld. (26°40'S, 152°0'E), on 14 April 1961, 87 days after it had been banded (by P.A. Disher) as a nestling at Kow Swamp, Vic. (35º56'S, 144º18'E) on 17 January 1961. Assuming that the bird left on the day of banding and arrived on the date it was recovered, this bird had travelled

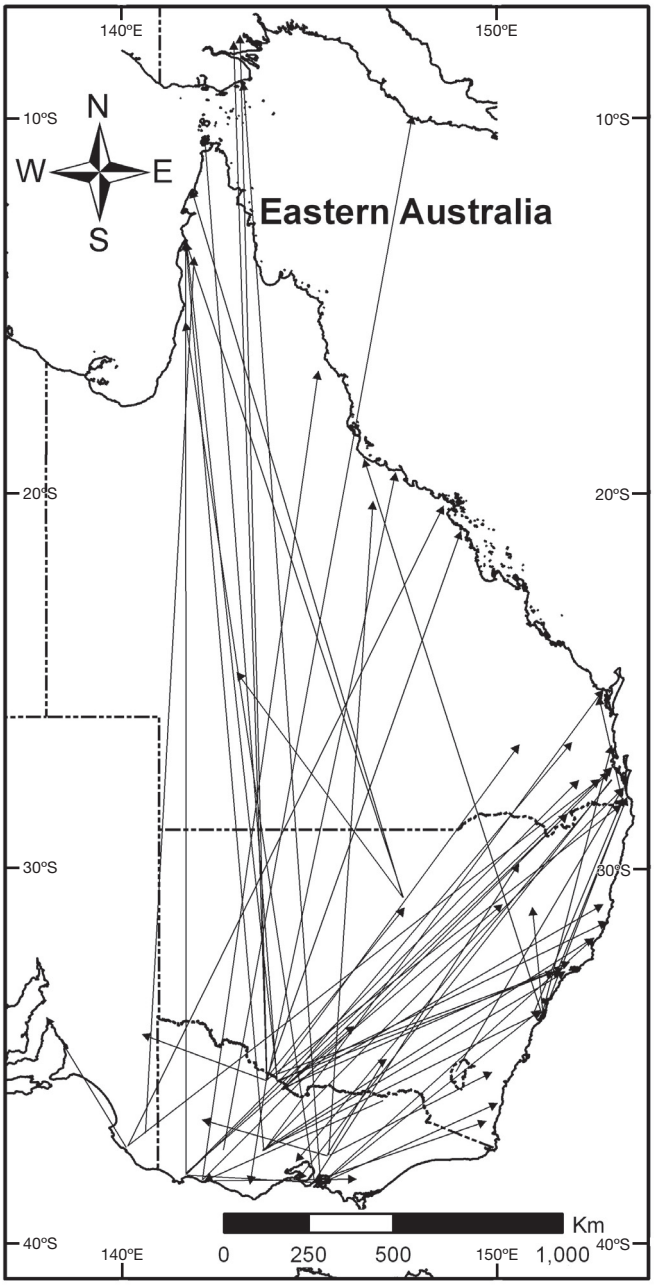

Figure 2. *Regional movements (≥ 300 km) of Ibis (n = 65) along eastern Australia. All lines originate at the banding places of Australian White Ibis and end with an arrowhead at the recovery sites of the birds.*

at least 1262 kilometres with an average travel speed of 14.51 kilometres per day. Another bird, banded as a nestling at LG on 6 January 2004, was recovered at Currumbin, Qld. (28º12'S, 153º24'E) on 22 April 2004, exactly 107 days later. Here the bird had flown a total distance of at least 675 kilometres in 107 days at an average speed of 6.31 kilometres per day. Since both birds were banded as nestlings and may not have fledged until two to three weeks after banding, the birds had probably covered these distances in a far shorter time.

Breeding site fidelity and sexual maturity

Three birds, which were banded as nestlings at WW (breeding site) between 30 August and 20 September 2005,

were resighted at WW during the 2007/2008 breeding period (i.e. 27.5, 28 and 34 months after banding). All three birds were in adult breeding plumage and attended nests or were caring for young. No Ibis banded as a juvenile during the 2005/2006 breeding season was resighted during the 2006/2007 breeding period, despite extensive monitoring (records of V. Kubur and C. Thomas, UTS).

DISCUSSION

Our findings confirm that the Ibis is a highly mobile bird on a local and a regional scale (Thomas 2007; Corben and Munro 2008). Band recoveries reveal that birds travel between roosting sites and landfills, which implies that colonies are interlinked. Since resightings of banded birds (mainly juveniles) were particularly high at landfills (90% of all resightings), these birds seem to strongly depend on domestic waste from a young age onwards, and their populations are probably sustained by landfills (Thomas 2007). It is interesting that birds do not only visit the landfills closest to their roosts, but also travel to more distant landfills. We do not know why Ibis do this. Several reasons are possible. During the breeding season many Ibis and pelicans (another common bird of Sydney's landfills) (Smith 2009; Solomon 2009) frequent landfills and competition for food and space at the tip-face (point of waste deposition) is high (pers. obs.). Nearby landfills may therefore not provide sufficient food for all scavengers, so some birds (in particular juveniles) may be forced to search for and explore other sites. Food quality and quantity could also differ between landfills, and birds may favour sites with higher and/or better food availability, regardless of the travel distance involved. While the exact reasons for the birds' choices remain unknown, the use of multiple landfills and roosts has major implications for managing this species. Current management practices, which focus on the destruction of roosting and nesting sites (Martin *et al.* 2007) and, to some extent, restrict access to landfills (C. Stalker, Gosford City Council, pers. com.), need to take this into account. Managers need to consider that such management practices may force the birds to switch to alternative urban sites, which may transfer or even worsen the problem (Smith 2009). If management is desired, this needs to take place concurrently at all major breeding and foraging sites, so that birds cannot relocate to other sites.

The long distance recoveries of Ibis (Fig. 2) highlight the vast distances these birds can cover. Similar long distance movements (> 1000 km) have been reported for other Ibis species (Dowsett 1969; Hancock *et al.* 1992). Our results further strengthen previous reports of north and north-eastward movements of Ibis from south-eastern Australia (mainly Vic. and NSW) into Qld. and up to Papua New Guinea (Carrick 1962; Purchase 1976). Since banding studies usually only provide us with the location, where the birds have been originally banded, and the end point of their travels, it is often difficult to conclude about the exact route the birds are taking. This is particularly the case, when band recoveries are low and/or the species travels long distances. Until our study less than 20 long distance band recoveries had been available for Ibis (Carrick 1962; Purchase 1976), which made it difficult to speculate about the birds' pathways. In our study we obtained 64 long distance recoveries, which provided more details on the birds' movements and their potential routes. The high recovery rates of birds banded in Vic. along the lower south-eastern coast of NSW and southern Qld. (mainly within 100 km from the coast) suggest that movements generally follow the eastern coastline, which may act as a landmark (Berthold 2001). It is obvious that at least some birds travel beyond southern Qld. up to northern Qld. and as far up as Papua New Guinea (Carrick 1962; Purchase 1976; see also Draffan *et al.* 1983). While it is possible that Ibis travel directly from Vic. to northern Qld., we consider this unlikely, because resting and feeding stops for aquatic birds can be limited in the vast semi-arid outback of inland Australia. Despite the fact that the birds need to travel further, a coastal route probably offers more reliable resources.

Since banding programs on Ibis and other large birds have mainly focused on birds which were banded in Vic. and NSW (mainly Sydney), with no equivalent programs at locations further north, our data provide strong evidence for northward movements of south-eastern populations, but less conclusive evidence of return movements. Two long distance recoveries from birds banded in Brisbane (southern Qld.) in Werribee and Portsea Beach, Vic., suggest that at least some birds travel south. It is not clear whether this is an annual event for each bird, and is strictly followed by each first year and adult birds. Since the Ibis belongs to the Ciconiiformes, which mature late (Hancock *et al.* 1992) and can show differential migration (Berthold 2001), we regard this as unlikely. Instead we believe that the movements of the adult and young may differ, which finds some indirect support in previous research. Both Thomas (2007), and Corben and Munro (2008) reported that fledgling Ibis disappear from their breeding areas and only adult birds remain. At the start of the next breeding period, the colonies consist nearly entirely of adults (whose numbers increase as breeding progresses) with either no or very few young present (Corben 2003). The above in conjunction with our banding results suggest that the young birds travel widely, but do not return to their hatching site until they have reached sexual maturity. Similar (i.e. a retarded or graded return to the breeding site; see Berthold 2001) is known from the White Stork *Ciconia ciconia*, the Osprey *Pandion haliaetus*, herons and some waders. In these species the young leave the breeding sites, and remain at their non-breeding resting places beyond their first year of life, or they travel only a fraction of their return path back to their breeding site, and spend the time until sexual maturity as a ´non-breeder´ at a suitable non-breeding site (Berthold 2001). During their absence young storks can conduct large-scale movements, which appear to differ in their scale, route and goal to those of adults (Berthold 2001). While we cannot be certain that this also applies to Ibis, a study by Thomas (2007) indicates that adult Ibis may incorporate other routes into their overall movements.

Until our study, it was not known, when Ibis reach maturity. While the closely related Sacred Ibis acquires its adult plumage at three years of age, it is uncertain whether it commences breeding at this stage or delays it until a later age (Hancock *et al.* 1992). Based on our resightings of banded birds at WW we know now that Ibis can obtain adult plumage, commence breeding and care for chicks when two-years old. These results are important for several reasons. They provide evidence of when Ibis reach sexual maturity, show that Ibis can breed at a young age, and exhibit site fidelity to their hatching site, all of which is important for the development of management plans for this and related birds. The return of the young birds to their breeding site is of particular interest. It suggests they have a bond to their hatching site and will breed, where they have been

raised successfully. Therefore it is likely that at least some Ibis will continue to exist in urban environments, and will not, as some managers believe, return to their inland wetlands, in case waterflows in inland wetlands are restored.

Besides being highly mobile, Ibis also appear to be sedentary, which seems to be especially prevalent in coastal urban environments (Corben 2003; Corben and Munro 2008; Smith 2009). As yet it is not known what causes this behaviour. Two explanations appear possible. Firstly, resource availability is high enough to allow some birds to stay on the breeding ground, which is common in many birds with flexible movement patterns (Berthold 2001; Funnell 2007). Resources are often particularly high in urban environments (Cooke *et al.* 2006), and many migratory birds from densely populated areas have either shortened their migration routes and/or become sedentary (Blanco 1996; Barbraud *et al.* 1999; Tortosa *et al.* 2002, 2003; Partecke and Gwinner 2007). It is possible that Ibis have responded in a similar fashion, and the now sedentary population has split from the mobile population. In this process some birds may have not become completely sedentary, but instead have shortened their migration routes. This may explain the high abundances in Australia's east coast cities, (e.g. Sydney and Brisbane), which all lie along the general northward route birds from further south would take (Fig. 2). Secondly, the Ibis that remain behind are distinctly different from the mobile population and originate from sedentary zoo escapees (DEC 2005). In 1973, seven pairs of Ibis escaped from Taronga Zoo, Sydney (DEC 2005). It is possible that these birds have, like the Sacred Ibis in Europe (another recent zoo escapee) (Yésou and Clergeau 2005; Clergeau and Yésou 2006b), increased in numbers and eventually produced a stable sedentary population (Corben and Munro 2008). However, while this scenario appears plausible for Sydney, it does not explain the consistent presence of Ibis in other cities (Smith 2009), where no zoo escapees have been reported. Until further investigations (e.g. genetic studies) become available the origin of the sedentary birds remains unknown.

In the case of the Ibis we have been able to show that movements can extend over vast distances, be complex, and probably vary with age. Our findings provide baselines for further studies on this and other large, aquatic birds, so that their biology becomes known and effects of habitat changes can be assessed and species protected. Since our study has also focused on the local movements of Ibis and identified them as highly mobile and dependent on landfills, our findings are also important for managing these birds and other native and exotic invaders in urban landscapes. Since habitat degradation and destruction will probably progress (Kingsford and Thomas 1995, 2004; Eby and Lunney 2002; Kingsford and Auld 2005) and may even accelerate with climate change (Finlayson *et al.* 2006), it is likely that more native species, which we legally need to protect, will be forced into urban environments. Currently we seem ill equipped to manage such species, and further studies on urban invaders are urgently needed to obtain baselines for appropriate management.

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