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Foraging behaviour and success of Australian white ibis (*Threskiornis molucca*) in an urban environment

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Abstract The foraging behaviour and success of Australian white ibis (*Threskiornis molucca*) was investigated in a range of natural and artificial urban habitats in Queensland, Australia. Observations were made in tidal mudflat, freshwater wetland, rural grassland, urban park and landfill habitats. Australian white ibis exhibited a range of foraging behaviours, including both visual (fossicking, jabbing and pecking) and non-visual foraging behaviours (probing). The most common non-foraging behaviour was walking, followed by prey handling, pause and alert. Fighting was observed only in landfill habitats. Australian white ibis were able to capture food items in all habitats, although foraging success at landfills was more than twice as high as the other habitats. Food items captured at landfills required significantly more time to handle before swallowing. The ability of ibis to capture food items in all habitats indicates that they are effective habitat generalists.

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INTRODUCTION

The study of foraging ecology is fundamental for understanding how animals utilise different habitats. In waterbirds, investigations of foraging ecology have provided information on niche partitioning between closely related species (Frederick & Bildstein 1992), the relative quality of habitats utilized by a species (Atkinson *et al*. 2004), and the factors affecting where birds forage (Custer & Osborne 1978). The ability of individuals to feed efficiently and effectively in their foraging habitats may affect the habitat use and distribution of a species, as well as its ability to cope with habitat alteration.

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The foraging ecology of the ibises (Threskiornithidae) in natural habitats has been relatively well studied. Frederick and Bildstein (1992) described the foraging habitat and feeding behaviour of 7 sympatric species of ibis in the Venezuelan Llanos and reported that these species coexist by significant niche partitioning, with the variation in foraging habitats and differential foraging behaviour between species being sufficient to allow coexistence. Kushlan (1977; 1979) described the feeding habitat selection and foraging ecology of the American white ibis (*Eudocimus albus*) in Florida, USA, and Aguilera *et al*. (1993) reported the food habitats of both the scarlet (*E. ruber*) and American white ibis in Venezuela. In Australia, one study described the diet and general feeding habits

Table 1. Description of the 5 habitat types in which foraging behaviour observations were made.

Habitat type	Description
Tidal mudflat	Mudflats exposed at low tide in urban estuaries
Freshwater wetland	Remnant terrestrial freshwater wetlands throughout urban areas of Gold Coast
Rural grassland	Farmland or pasture in rural surrounds of Gold Coast
Urban park	Urban parkland with short manicured grass and surrounded by suburban areas
Landfill tipface	Active tipface of a waste landfill

of the straw-necked ibis (*Threskiornis spinicollis*) and the Australian white ibis (*Threskiornis molucca*) at the Macquarie Marshes in western New South Wales (Carrick 1959). However, only a few studies have investigated the foraging ecology of ibis in non-natural habitats (Meyer-Gleaves 2003; Perry 2001).

While several species of ibis are now at risk of extinction, at least 2 species of ibis have expanded their range to include urban environments (Hancock *et al*. 1992). The sacred ibis (*T. aethiopicus*) has increased its range in South Africa into urban areas where a major component of its diet is now obtained from anthropogenic food sources (Clark 1977). Feral populations of the sacred ibis in western Europe have also been recorded feeding in a variety of urban foraging sites, including meadows, ploughed fields, seashores and landfills (Clergeau & Yesou 2006). Similarly, the closely related Australian white ibis has recently become a resident in several urban areas of Australia and is now considered a bird pest in some regions (Meyer-Gleaves & Jones 2007; Murray & Shaw 2006; Ross 2004).

Australian white ibis forage on both natural and artificial food sources and in a variety of habitats (Marchant & Higgins 1990). Natural foraging sites include marine environments such as tidal mudflats and mangrove swamps, terrestrial freshwater wetlands and rural grasslands (Marchant & Higgins 1990). In natural areas, Australian white ibis feed mainly on terrestrial and aquatic invertebrates such as crustaceans and aquatic insects (Barker & Vestjens 1989; Carrick 1959; Marchant & Higgins 1990). In urban areas, ibis forage at waste landfills, abattoirs, zoos, urban parks and sewage treatment plants (Marchant & Higgins 1990). Data on the diet of ibis in urban areas is limited, although it is known to include a wide range of both natural and anthropogenic food items (Meyer-Gleaves 2003).

Few studies have compared differences in the foraging behaviours across the range of habitats occupied by Australian white ibis (Meyer-Gleaves 2003; Perry 2001), and no studies have investigated the relative quality of these habitats in relation to foraging opportunities. In this study the foraging success of ibis in a range of natural and artificial habitats were assessed to better understand the exploitation of urban habitats by this species. Additionally, the foraging behaviours and techniques of ibis were investigated with a view to increasing knowledge of the feeding ecology of this species.

METHODS

Data were collected between Aug and Oct 2005 on the Gold Coast, south-east Queensland, Australia (28°2′S, 153°25′E). The behaviour and success of Australian white ibis in 5 different natural and human-modified habitat types was sampled using 2 minute focal observations of foraging individuals (Altmann 1974). The habitat types were: (1) tidal mudflat, (2) freshwater wetland, (3) rural grassland, (4) urban park, and (5) landfill tipface (see Table 1). Sampling was undertaken during periods of prevailing fine weather and observation bouts were distributed randomly throughout the day.

During each observation bout, the focal bird was recorded using a video camera (Sony Digital Handycam) from a distance of 10-60 m. This did not appear to cause any visible interference to the bird. Recordings were replayed in slow-motion (approximately 1 frame per second) and transcribed directly into a database, with foraging behaviours timed to the nearest second. The replay was slowed, paused or repeated if required. Foraging behaviours were categorized based on definitions by Kushlan (1977), Kelly *et al*. (2003) and Meyer-Gleaves (2003; Table 2). Foraging success was calculated as the number of successful captures per 2-minute observation bout. Successful captures were readily identified by a distinctive backward jerk of the head and visible swallowing motions (Frederick & Bildstein 1992; Kushlan 1977). No classification of food items was made as it was not possible to identify food items from the video footage.

A one-way analysis of variance (ANOVA) using Tukey's HSD post-hoc test was used to analyze the difference in foraging success and handling time among the 5 habitat types. The assumptions of ANOVA were met as the data were randomly sampled and drawn independently from each habitat type, were normally distributed (evaluated using a normal quantile-quantile plot), and had equal variance among groups. Tukey's HSD post-hoc test was deemed suitable because the sample sizes in each group were equal, and it is a simple and reliable multiple comparison test (Quinn & Keough 2002). Statistical analyses were performed using SPSS version 11 (SPSS Inc. 2001).

Table 2. Definitions of behaviours recorded during 2-minute focal observations of foraging Australian white ibis. Adapted from Kushlan (1977), Kelly *et al.* (2003) and Meyer-Gleaves (2003). 'Fossick' is a newly described behaviour for this study.

Behaviour type	Behaviour	Description
Foraging	Fossick	Uses bill to search unsystematically on surface for food; includes walking
	Jab	Penetrates substrate up to half of length of bill
	Peck	Uses tip of bill to peck at the surface (no penetration)
	Probe	Penetrates substrate greater than half of length of bill
Non-foraging	Drink	Drinks water, usually with bill parallel to water surface
	Fight	Confrontation with another ibis
	Handling	Handling prey once captured but before swallowing
	Lookup	Alert, non-feeding posture with head held high
	Pause	Pause from foraging activity, but does not hold head high
	Preen	Attending to feathers
	Walk	Greater than 1 step per second with no foraging

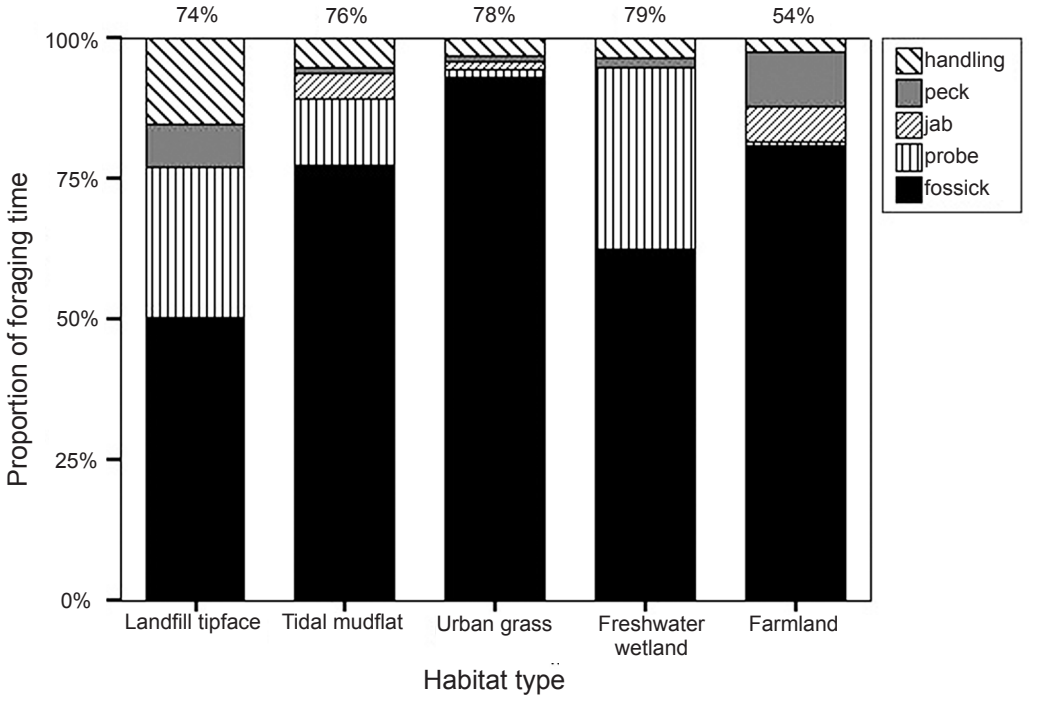

Fig. 1. Proportion of time spent by Australian white ibis in each foraging behaviour (n = 5 observation bouts in each habitat). The mean proportion of each observation bout spent in foraging behaviours is located at the top of each bar.

RESULTS

Twenty-five focal observations of foraging ibis were made with 5 observations per habitat type. A total of 825 behavioural records of 9 different behaviours were made with a mean number of 30.5 behaviour records per observation. Australian white ibis exhibited a range of foraging methods which included taking prey from the surface and from

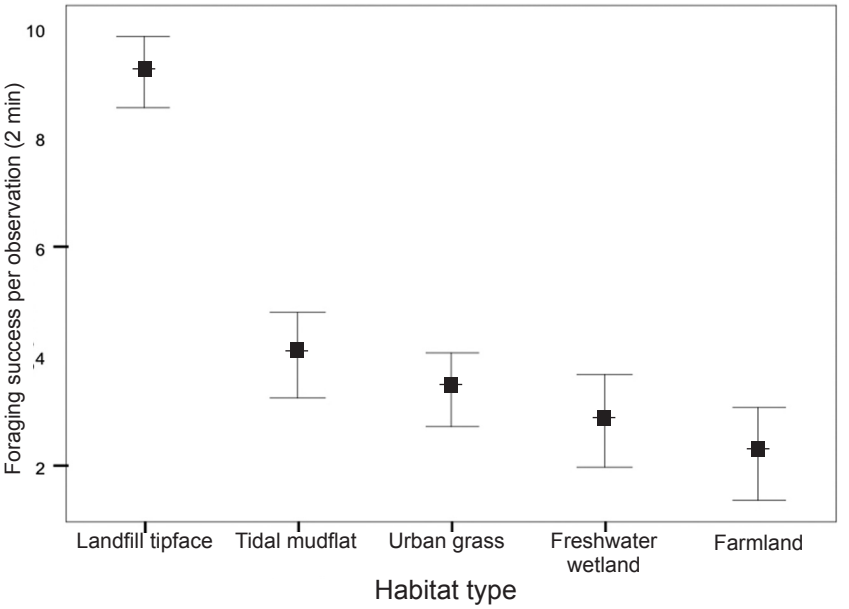

Fig. 2. Number of successful foraging attempts (mean ± s.e.) per 2 minute observation bout of Australian white ibis foraging in 5 habitat types. (n = 5 observation bouts in each habitat).

within the substrate. The most common foraging method was fossicking, a behaviour in which ibis searched unsystematically over the surface for prey items. Probing and pecking were other commonly observed feeding actions (Fig. 1).

The most common non-foraging behaviour was walking, followed by prey handling, pause and alert. The only incidences of fighting between individuals occurred in the landfill habitat, where ibis were observed in confrontations on 4 occasions. There was no significant difference in time spent in alert behaviours (pause and lookup) between habitats ($F = 13.2$, d.f. = 4, n.s.).

Number of prey items obtained ranged from 0 to 5.5 per minute. There was a significant difference in foraging success between habitat types with the number of items ingested in landfill tipface habitat being significantly higher than all other habitats ($F = 13.2$ d.f. = 4, $P < 0.05$). However, there were no significant differences in foraging success among the remaining 4 habitats (Figure 2).

DISCUSSION

In natural environments, ibis are considered tactile, non-visual foragers (Hancock *et al*. 1992; Kushlan 1979). For example, while feeding in mudflats and wetlands the basic feeding technique of the American white ibis was probing into the water or soil with the bill held agape at the tip (Kushlan 1979). Predators that hunt by sight can search and handle prey, and can cover more area than predators hunting by touch alone (Kushlan 1979; Stephens & Krebs 1986). In this study, Australian white ibis exhibited a wide range of foraging techniques, which included both visual (fossicking and pecking) and non-visual foraging behaviours (jabbing and probing). This flexibility of foraging behaviours allows Australian white ibis to obtain a broad range of food items in a wide range of habitats.

Food of Australian white ibis includes natural prey items such as fish, frogs and terrestrial and marine invertebrates (Carrick 1959; Marchant & Higgins 1990), and non-natural food items such as human food waste and carrion (Marchant & Higgins 1990). In this study it was not possible to identify food items of Australian white ibis and therefore, the actual food items preyed upon in urban habitats remains relatively unknown. Studies into the diet of other urban exploiting species have reported that artificial food items are a primary food source for some species, yet comprise an unimportant food source for others (Duhem *et al*. 2005; Lefebvre & Giraldeau 1983; Marzluff *et al*. 2001; Pierotti & Annett 2001). However, the relative quality of edible refuse compared to natural prey items is unknown, and the effects of feeding on garbage are not well understood (Belant *et al*. 1993; 1998; Duhem *et al*. 2005; Tortosa *et al*. 2002; Yorio 2002).

The type of habitat in which ibis were recorded foraging influenced foraging success. Australian white ibis recorded while foraging at waste landfills were more than twice as successful at obtaining food items than in any other habitat. However, foraging at waste landfills presents considerable hazards for a long-legged waterbird, including the possibility of leg injury in the unstable substrate and the risks associated with the presence of heavy machinery

(Belant *et al*. 1993; Burger 1981; Coulson *et al*. 1987). Furthermore, the only incidences of fighting occurred at landfills, which is likely to be due to the higher densities of ibis observed in this habitat (N. Murray, *pers. obs*.). Despite the variety of risks and higher incidences of intra-specific aggression, abundant food resources render landfills attractive foraging sites for Australian white ibis. The ability of Australian white ibis to capture food items in all habitats sampled in this study indicate that they are effective habitat generalists, which facilitates their ability to form large urban populations.

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