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The feeding behaviour and diet of the Black-necked Stork *Ephippiorhynchus asiaticus australis* in northern New South Wales

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Field studies were carried out over a two and three-quarter year period (2003–2005) to study the feeding behaviour and diet of free-flying Black-necked Storks *Ephippiorhynchus asiaticus australis* (adults, immatures and juveniles) and the food fed to nestlings in New South Wales. Storks walked or stood in water searching visually, or walked in water constantly probing into water or reeds. The majority of time was spent hunting (70%) and most prey captures (68.4%) involved visual scanning rather than probing. Foraging occurred mostly in the early mornings and late afternoons with Storks loafing during the middle of the day, conforming to the behaviour of tropical storks. Storks fed on a variety of vertebrate and invertebrate prey caught in water, usually between 50–300 millimetres deep. Long-finned Eels *Anguilla reinhardtii* contributed the most to biomass due to their large size. The most frequently caught prey comprised small unidentified animals, probably insects and molluscs. The stomach contents of nine Storks from the Australian Museum comprised mostly insects and other small invertebrates.

INTRODUCTION

Storks are typical 'wading' birds that characteristically feed while walking about in shallow water. The long legs, necks and bills are adaptations for this mode of feeding (Hancock *et al*. 1992). The Black-necked Stork *Ephippiorhynchus asiaticus australis* conforms to this pattern but its specific feeding behaviour and diet are poorly understood. Detailed knowledge of these aspects of the biology of the species is important for the management of the species, particularly in New South Wales, where it is listed as *endangered*.

The feeding behaviour and diet of the Black-necked Stork has only recently been studied in detail in Australia (Dorfman *et al.* 2001) and India (Maheswaran and Rahmani 2002). The Australian study, mainly in the Northern Territory, highlighted the importance of habitat variability to hunting success and noted a high level of intraspecific and interspecific aggression during foraging. The Indian study compared visual and tactile methods of foraging and found that the majority of prey was caught by the latter method. Search effort was related to water level changes and Storks were more successful at hunting in the early hours of the day. The diet recorded in these two studies comprised only fish, although the Australian study referred to reports of other types of prey having been caught.

Prior to these studies the feeding behaviour and diet were known from only anecdotal information and casual observations. Marchant and Higgins (1990, p. 1066) stated with respect to food, "Little known but largely aquatic with a variety of fish, crustaceans and some insects as well as snakes recorded".

A two and three-quarter year study of the feeding behaviour and diet of the species was conducted as part of a larger study on the ecology, conservation and management of the species in New South Wales.

The aim of this study was to quantify feeding behaviour of the species (foraging techniques, water depth, time of day, foraging success, handling of food and interaction with other birds) and their diet (species hunted and captured, and the size and weight of prey).

METHODS

Black-necked Storks were observed opportunistically while foraging or loafing at 33 wetlands in northern New South Wales (30 in the Clarence Valley, two in the Richmond Valley and one in the Macleay Valley) covering all months during the period 25 April 2003 to 31 December 2005. These wetlands were mostly open water bodies situated in grazing land. Foraging observations were carried out opportunistically as it was impossible to predict where a particular stork would feed on a particular day. Hayward *et al*. (2009) defined loafing as a general state of immobility that involves behaviours such as sleeping, sitting, standing, resting, preening and defecating. Observations were made using one or two spotting scopes (x25 and x32), and commenced when a foraging Stork was encountered and ceased when the bird stopped foraging, disappeared from view or when the observer departed. These periods of observed foraging (average 26 minutes) are referred to as 'bouts'. Twenty-eight birds (12 adult females, 13 adult males and 3 juveniles) were watched for 42 hours, covering 97 separate feeding bouts. Short periods of inactivity often occurred during a bout, but it was only considered to be a new bout if greater than 10 minutes had elapsed since any foraging activity. These short breaks were often when the bird preened and were not considered loafing as birds usually walked from the water to loaf. Foraging activity was noted on a pro forma to the nearest minute. Details recorded were the date, location, time, weather conditions, water depth, foraging technique and prey items. Eleven foraging techniques were identified by Dorfman *et al.* (2001) or from preliminary

Table 1

Black-necked Stork foraging techniques.

Activity	Acronym	References
walking in water with visual search	WVS	This study
standing still and scanning water (visual search)	SVS	Maheswaran and Rahmani (2002)
walking in water constantly probing water or vegetation (tactile search)	WP	Maheswaran and Rahmani (2002)
walking in water with visual search, alternating with intermittent probing (visual and tactile)	WSP	This study
actively running down prey in water (visual)	RDP	Dorfman et al. (2001)
probing into water while rotating at a fixed point (tactile)	PR	This study
standing still and probing water/vegetation (tactile)	SP	This study
sitting on haunches in water and probing (tactile)	HP	This study
sorting through vegetation removed from water (visual)	VRW	Dorfman et al. (2001)
walking in water, probing and shaking bill (tactile)	WPS	This study
kleptoparasitism – stealing food from other birds in water (visual)	K	Dorfman et al. (2001)

work for this project (Table 1). Techniques were considered tactile when regular contact was made by the Stork's bill with water or vegetation and visual when this contact did not occur.

Prey items were identified, where possible, from my previous experience with the taxa or by consulting relevant field guides and texts. Loafing birds were observed and their behaviour noted on pro formas in a similar manner to foraging birds.

The depth of water in which foraging occurred was approximately measured by noting the level of inundation of the Storks' legs with three categories, 0–50 millimetres equates to the birds' lower leg joint at the base of the tarsometatarsus, 51–300 millimetres the length of the tarsometatarsus; and greater than 300 millimetres above the junction of the tarsometatarsus and tibiotarsus.

Ten recently caught Long-finned Eels *Anguilla reinhardtii* were measured and weighed to calculate the relationship between length and weight and to use this to estimate the weight of eels captured and eaten by Storks. The length of eels was measured by holding them straight against a metre rule. To see if the length of wriggling eels seen from a distance was underestimated an assistant held live eels 20 metres away from me and I estimated their total length against a 300 millimetres ruler, approximately the length of a Stork's bill. In all cases I underestimated the length by about 100 millimetres.

In addition to the above, the stomach contents of nine Storks received by the Australian Museum from the New South Wales north coast during the study period were collected and analysed by Tony Rose. Prey items were identified to species, where possible, or at least to the family level. These storks were found dead or injured mainly following collision with powerlines (5 birds). Three were found exhausted or weak and one was injured by a barbed-wire fence (Appendix 1; Clancy 2010).

To allow the time of day of foraging to be compared to the time of day of loafing, observations were made on birds at rest (loafing) and details entered onto a pro forma. A bird was determined to be loafing if it was standing or sitting away from water for more than five minutes. These feeding and loafing data were supplemented with previous records of the author and other local ecologists. Eastern Standard Time was used throughout. Nocturnal observations were not attempted during this study, however, a few Storks were observed still foraging after sunset.

RESULTS

Foraging Techniques

A typical foraging bout by a Black-necked Stork involved the bird walking in shallow water with head lowered, scanning the water (WVS), interspersed with periods of standing still and visually searching the water (SVS) and periods of constant and regular probing of the water and vegetation with its bill (tactile searching)(WP), sometimes interspersed with bill shaking (WPS) or occasionally walking with intermittent probing (WSP) or standing still and probing (SP), sitting on haunches and probing (HP) or rotating at a fixed point while probing (PR). When a prey item is observed a distance away or attempts to make its escape the Stork actively runs after it (RDP)(Photograph 1). Rarely, vegetation is collected and taken to the bank to be searched for food (VRW). Kleptoparasitism (K), was not observed during the study, although interspecific interactions were observed. Capture was affected by snapping the bill closed on the prey.

Visual methods dominated over tactile methods in both the number of bouts each was utilised and in the time expended. A majority of prey was captured (successful foraging) by visual methods compared with tactile methods and a combination of tactile and visual (Table 2). The most common foraging techniques were visual searching while walking or standing in the water, which were both employed in at least 70 per cent of foraging bouts (Fig. 1), and together amounted to over 70 per cent of time foraging (Fig. 2). Walking in water, constantly or intermittently probing, was also frequent, amounting to just over 20 per cent of foraging time. About five per cent of time was spent actively running down prey, which had typically been detected while walking and visually scanning. The other behaviours were employed infrequently, less than five per cent of total time (Fig. 2). An adult female Stork was observed standing still in water and moving her feet up and down, which may have been to flush prey.

Water Depth

Black-necked Storks foraged mostly at depths of 51–300 millimetres (48.8%). They also often foraged in water 0–50

Photograph 1. *Immature female Black-necked Stork actively running down prey – a mullet.* Photo: Alan Cibilic

Table 2

Frequencies of visual and tactile foraging methods recorded in the Black-necked Stork in New South Wales 2003–2005.

	% of time	No. of captures	% of captures
Visual	70	91	68.4
Tactile	20	23	17.3
Visual and Tactile	10	19	14.3

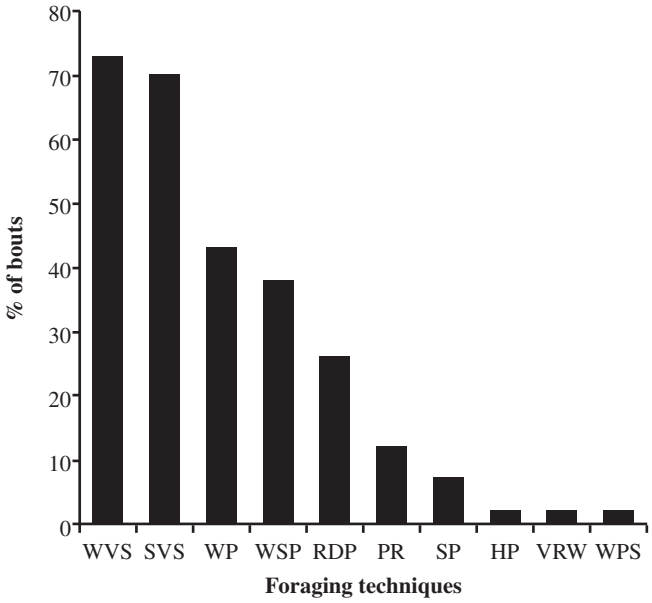


Figure 1. *Percentage of bouts in which each technique was used (n = 97 bouts). See Table 1 for abbreviations.*

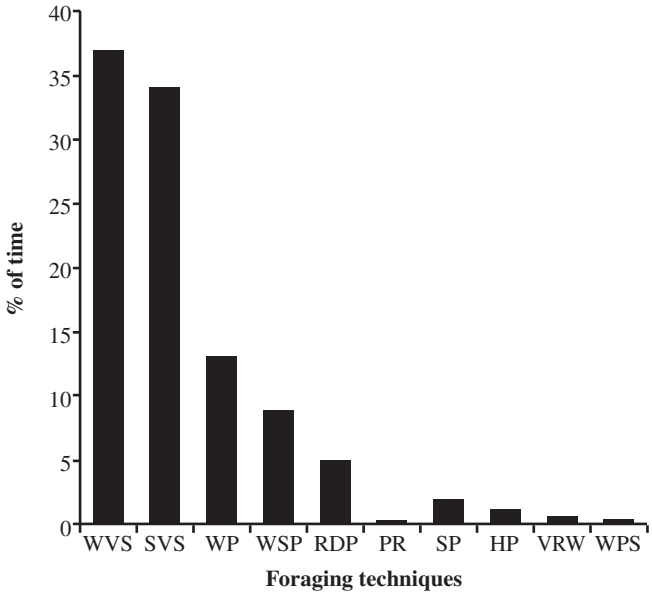


Figure 2. *Percentage of time spent on each technique (total of 1913 minutes). See Table 1 for abbreviations.*

millimetres deep (42.2%) and less frequently in water greater than 300 millimetres deep (9%) (Figure 3). Foraging was not observed away from water.

Diurnal Pattern of Foraging and Loafing

Storks foraged more in the morning, before 0900 hrs, and afternoon, after 1500 hrs, and tended to loaf mostly during the middle part of the day (Fig. 4).

Diet

Storks were observed eating fish, amphibians, reptiles and birds, as well unidentified small animals (Table 3). Fish, reptiles and five invertebrate orders (Coleoptera - beetles, Orthoptera – grasshoppers, Hemiptera - bugs, Decapoda - crayfish and Gastropoda - snails) were found in stomachs (Appendix 1). Storks caught 46 large vertebrates in 42 hours of observation or 1.1 animals per hour.

The majority of prey could not be identified and were probably insects, tadpoles or other small vertebrates. Most of the identifiable prey were fish or frogs. Most of the fish were Long-finned Eels, though mullet (probably Sea Mullet *Mugil cephalus* or possibly Freshwater Mullet *Trachystoma petardi*) and Australian Bass *Percalates novemaculeatus* were also identified.

Only one reptile (Eastern Long-necked Tortoise *Chelodina longicollis*), weighing approximately 400 grams, and one bird (Australasian Grebe *Tachybaptus novaehollandiae*) weighing between 100 and 230 grams (Marchant and Higgins 1990) were recorded. The tortoise was broken into sections before being consumed while the grebe was swallowed whole after being bashed on the ground. The Long-finned Eel comprised the greatest biomass due to its large size. The size of eels observed being eaten ranged from 170 millimetres to 500 millimetres, although some would have been bigger (Fig. 5). One eel, estimated to be 600 millimetres long, was caught by an adult Stork but escaped when it was dropped. There was a close correlation between length

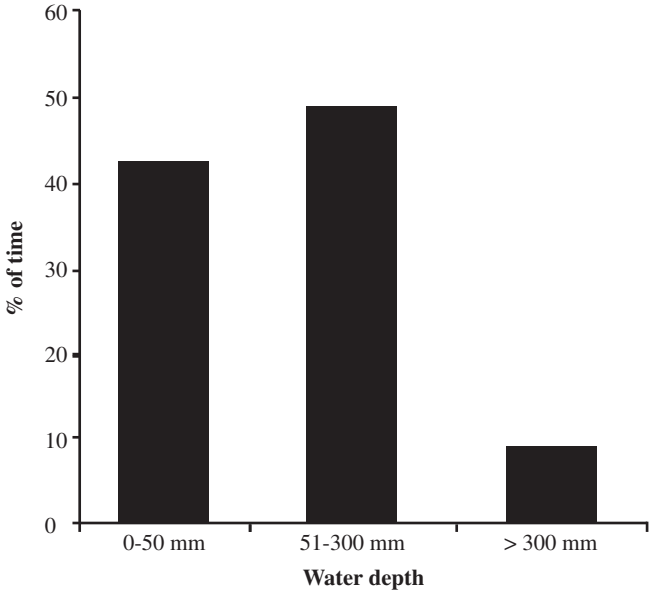


Figure 3. *Percentage of time spent foraging at different water depths.*

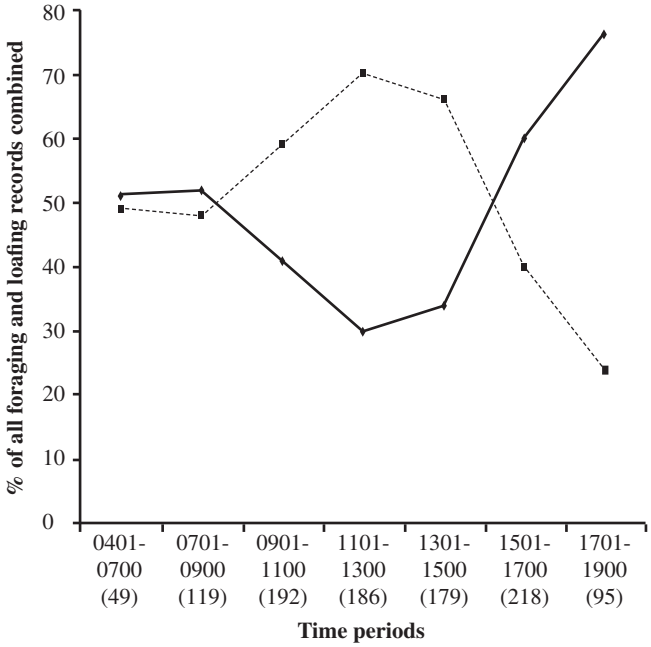


Figure 4. *Percentage of observations of either foraging or loafing records per time period (total records n = 1038, individual sample sizes in parentheses). A record is an observation of a stork foraging or loafing within the respective time period. (= foraging, ----- = loafing)*

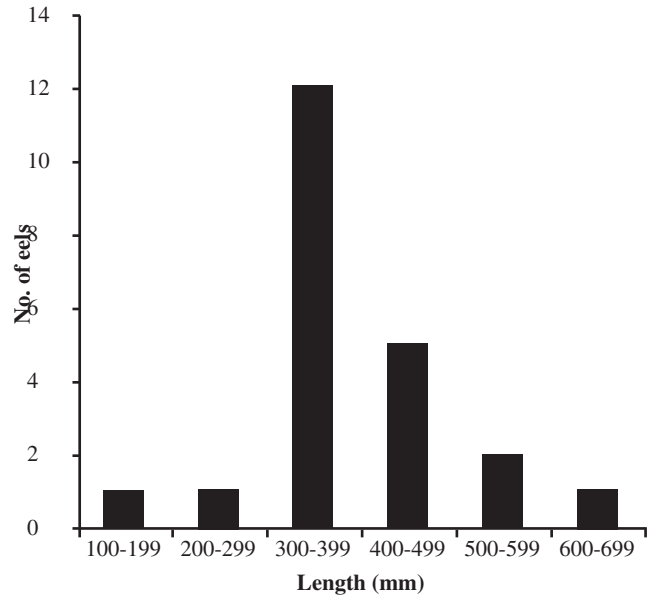


Figure 5. *Estimated lengths of eels caught by Black-necked Storks.*

Table 3

Prey observed during feeding bouts. Total successful bouts = 47

Prey type	No. of individuals
Fish	
Anguilla reinhardtii	21
Mugil or *Trachystoma*	3
Percalates novemaculeatus	2
Unidentified fish	1
Bird	
Tachybaptus novaehollandiae	1
Reptile	
Chelodina longicollis	1
Amphibian	
Unidentified frog	17
Others	
Unidentified animal	90
Total	136

and wet weight of ten captive Long-finned Eels, which ranged from 450 millimetres to 600 millimetres (Weight = -960 + 2.62 length, r^2 = 92.3%, F = 9.81, p = 0.000). This would mean that the eels caught by Storks, which were 450 and 500 millimetres long, would have weighed between 220 and 350 grams (up to 612 g if the 600 mm long eel that escaped is included). Due to observer error in the field the estimated lengths and weights of eels caught by Storks was probably too low, with weights being from about 480 to 600 grams.

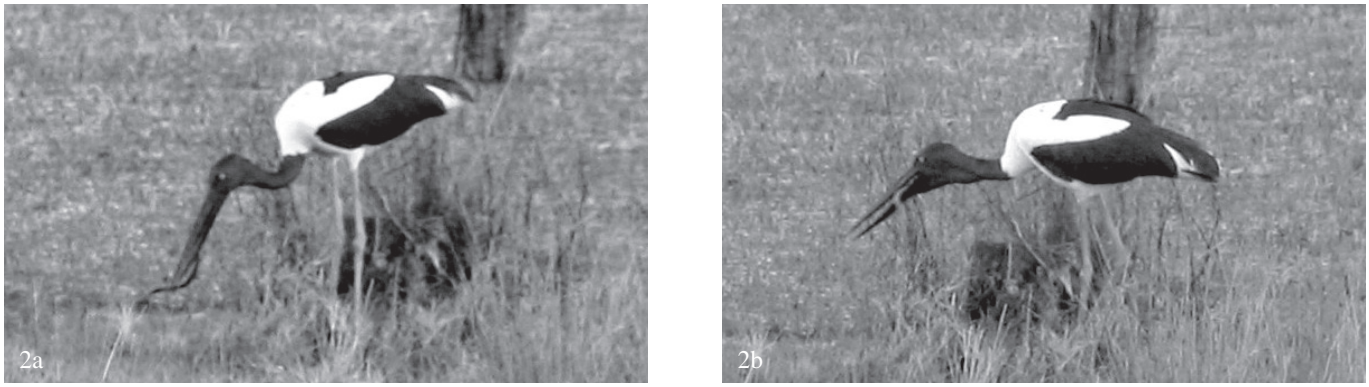
The stomach contents of nine dead Storks comprised fish (eels, gudgeon, other fish), crayfish, crickets and grasshoppers, beetles, water bugs, a snail, monocot herbage, cattle dung, pebbles and a piece of plastic (Appendix 1). The insects were mostly 10 to 60 millimetres in length (Goode 1980). The gudgeon may have been fed to the Stork, which had injured itself on a powerline, while it was in care. The other stomach contents are believed to have been eaten by Storks in the wild. Details of where the Storks were collected and the cause of death are shown in Table 4.

Invertebrates constituted the greatest number of prey in both foraging observations and stomach contents although the percentage was greater in stomach contents (91.6%) than in

Table 4

Location, biological characteristics and assumed cases of death of Black-necked Stork specimens lodged with the Australian Museum.

Specimen	Location	Age	Sex	Cause of death	Weight (g)	Other details
1	Wellingrove Road	I	F	found exhausted	2600	thin
2	Shannon Brook	A	M	found in paddock		left leg broken
3	Horseshoe Creek	I	F	powerline	4850	
4	Casino area	J	F	?starvation	3100	very thin
5	Tullymorgan	A	F	powerline	3650	
6	Tullymorgan	A	M	powerline	5200	
7	Woodford Island	J	F	barbed-wire fence	4750	
8	The Whiteman	I	F	powerline		broken 'shoulder'
9	Coraki	A	M	powerline		partly scavenged



Photograph 2a and 2b. *Adult female Black-necked Stork handling (a) and swallowing (b) eel at Brothersons Swamp, Coutts Crossing.*
Photos: Maree Davis

observations (66%). A greater percentage of vertebrates (34%) was observed being eaten than was found in stomach contents (8.4%).

Reports were also received of Storks catching and eating an Eastern Water Dragon *Physignathus lesueurii* (Russell Jago pers. comm.), a Red-bellied Black Snake *Pseudechis porphyriacus* (June Harris pers. comm.), a Flathead *Platycephalus* sp. (Reid Waters pers. comm.), and a Yellowfin Bream *Acanthopagrus australis* (Ron Hills pers. comm.).

Prey Handling

When small prey items were caught they were picked up with the tip of the bill and thrown to the back of the mouth with a jerk of the head and neck, and swallowed. Larger items, such as eels (Photograph 2a, b), fish and the one bird, were picked up in the bill, worked to the base of the bill and chewed. Large prey were then often placed on the ground or in shallow water and repeatedly speared with the closed bill. This was interspersed with crushing the food in the bill after which it was swallowed. Eels, birds and tortoises were observed being swallowed whole, minus small pieces that may have fallen off during the tenderising process, although large fish were usually broken into pieces before being consumed, as was one tortoise during the survey.

Intraspecific and Interspecific Aggression

Individual Black-necked Storks rarely foraged close together and no intraspecific aggression was recorded. However, interspecific aggression was observed. Foraging Storks attacked a number of waterbird species: Pacific Black Duck *Anas superciliosa*, Australian Pelican *Pelecanus conspicillatus*, White-faced Heron *Egretta novaehollandiae*, White-necked Heron *Ardea pacifica*, Eastern Great Egret *Ardea modesta*, Intermediate Egret *Ardea intermedia*, Cattle Egret *Ardea ibis*, Straw-necked Ibis *Threskiornis spinicollis,* Australian White Ibis *Threskiornis molucca*, Royal Spoonbill *Platalea regia* and Yellow-billed Spoonbill *Platalea flavipes*. Storks attacked other birds by flying over the wetland and swooping low over them, sometimes causing them to fly off. Occasionally a Stork ran or fluttered through the water towards other waterbirds. Masked Lapwings *Vanellus miles* frequently dive-bombed foraging Storks, perhaps regarding them as a potential predator of their young. Adult Black Swans *Cygnus atratus* also chased Storks away from their cygnets. White-bellied Sea-Eagles *Haliaeetus leucogaster* and Whistling Kites *Haliastur sphenurus* sometimes swooped over Storks in an attempt to scare them off food or pick up morsels that had been dropped.

Storks swooped low over a Dingo *Canis lupus dingo*, and walked, with wings spread, towards a hunting fox *Vulpes vulpes*.

One followed, in a defensive or aggressive manner, a prowling Lace Monitor *Varanus varius*, walking close to the reptile with its head and bill directed towards it. Domestic livestock (cattle and horses) approached loafing or foraging storks sometimes causing them to move.

DISCUSSION

The Black-necked Stork in New South Wales usually feeds in shallow wetlands, mostly by searching visually, while standing or walking. Less often it forages by walking and constantly probing the water or actively running down prey. Kleptoparasitism was not recorded, although some cases of apparent pirating of food were noted in earlier years (pers. obs.). This largely agrees with observations on how the species forages in the Northern Territory (Dorfman *et al.* 2001). In India, tactile foraging is much more frequent than visual foraging, with 96 per cent of food being caught by tactile foraging (Maheswaran and Rahmani 2002). This is probably because the water is shallower and more turbid in India, at least during the summer, making visual searching difficult (Maheswaran and Rahmani 2002).

Black-necked Storks in New South Wales normally foraged in water that was up to 300 millimetres deep. They usually spent less than two minutes in deeper water before moving into shallower areas of the wetland. Storks in India preferred a water depth of 300 millimetres or less, although foraging was more successful at depths of over 550 millimetres (Maheswaran and Rahmani 2002), at which the body was almost in the water. These deeper waters were fished in summer when water levels decreased rapidly and larger fish were only available in deep waters. In other seasons Storks caught smaller fish in greater abundance in shallower water (Gopinathan Maheswaran pers. comm.).

Temperate breeding stork species are active throughout the daylight, especially during breeding, whereas tropical species tend to feed mostly early and late in the day (del Hoyo *et al.* 1992). In New South Wales, Black-necked Storks mostly fed before 1100 hrs and after 1500 hrs, indicating a tropical foraging pattern. Foraging sometimes continued after dark, but could not be quantified. Nocturnal foraging has been recorded twice in the Northern Territory (Hancock *et al.* 1992; Whiting and Guinea 1999). Post-breeding Wood Storks *Mycteria americana* in South Carolina forage more at night than during the day (Bryan *et al*. 2001). Early-morning foraging by the Black-necked Stork was sometimes difficult to observe due to poor light and fog. In India, Black-necked Storks were more successful early in the day (0600–1000 hrs) (Maheswaran and Rahmani 2002).

Black-necked Storks in northern New South Wales preyed on animals ranging from small insects to large eels, birds and reptiles. Medium-sized eels (300–500 mm) contributed the greatest biomass and were the only food seen to be delivered to nestlings (Clancy 2008). Maheswaran and Rahmani (2002) estimated that one Black-necked Stork requires about 960 grams of food per day. This equates to 4 to 6 eels of the size caught during this study. Small food items, such as insects and molluscs, were probably underestimated, though a large number would be needed to feed a Stork. The high frequency of small invertebrates and lack of vertebrate prey in the stomachs of dead Storks may be due to their poor condition or young age or because they had been injured. The predominantly tropical Long-finned Eel is ubiquitous and abundant in coastal wetlands in New South Wales (Pease 2004). More information is needed on how closely the distribution and abundance of Storks and Eels coincide and what Storks eat if they forage where Eels are absent.

Storks chased a number of waterbirds from feeding sites, mostly species that consume similar types of food. Prior to this study, White-necked Herons were twice chased by an adult male Stork that had caught an eel close to the Herons. The aggression appeared to be more related to the Stork catching food disturbed by the Herons rather than an attempt to repel them from the wetland. Eastern Great and Intermediate Egrets and Pied Herons *Egretta picata* were also attacked by Storks in the Northern Territory (Dorfman *et al.* 2001). Storks often fed close to other waterbirds without aggression. Maheswaran and Rahmani (2001) concluded that most aggressive behaviour by Black-necked Storks in India was exhibited towards Eurasian Spoonbills *Platalea leucorodia* and Woolly (White)-necked Storks *Ciconia episcopus* when food was scarce or declining. Although recorded in the Northern Territory (Dorfman *et al.* 2001), intraspecific aggression by foraging storks was not recorded in this study, probably because Storks are rare in New South Wales.

CONCLUSIONS

The Black-necked Stork relies on shallow wetlands with an abundance of small vertebrate and invertebrate animal prey. Small invertebrates (beetles, grasshoppers, crickets and crayfish), frogs and eels were predominant in the diet. Eels constituted the greatest biomass of prey items, and conservation of Storks in New South Wales may depend on maintaining good eel populations. Interspecific aggression occurs, but intraspecific aggression during foraging was not recorded. To preserve the foraging habitat of the species, shallow wetlands need to be protected from being drained or deepened. Run-off into these wetlands needs to be managed to prevent pollutants that could adversely affect prey species. Wetlands that dry prematurely due to artificial drainage works should be managed to maximise the period of inundation.

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APPENDIX 1

Stomach contents of Black-necked Stork specimens.

Food type	Specimen no.									
	1	2	3	4	5	6	7	8	9	Total
Vertebrates										
Lizard (? Bluetongue)	-	-	-	-	-	-	-	-	1	1
Eel	-	1	1	-	-	-	-	-	1	3
Fish species	-	-	-	-	-	-	1	1	-	2
Gudgeon	-	-	-	-	-	-	1	-	-	1
Sub-total	*0*	*1*	*1*	*0*	*0*	*0*	*2*	*1*	*2*	*7*
Invertebrates										
Crayfish	1	-	-	-	-	-	-	-	-	1
Mole Cricket	1	-	-	-	-	-	-	-	-	1
Black Cricket	-	-	-	1	-	-	-	-	-	1
Grasshopper	-	1	4	-	-	-	-	-	-	5
Locust	-	-	-	1	-	-	-	-	-	1
Water Beetle	2	4	-	-	-	-	-	-	-	6
Weevil	3	-	-	-	-	-	-	-	-	3
Longicorn Beetle	1	-	-	-	-	-	-	-	-	1
Carab Beetle	1	-	-	3	-	-	5	-	-	9
Scarab Beetle	2	-	-	-	-	-	-	-	-	2
Pie Dish Beetle	3	-	-	-	-	-	-	-	-	3
Dung Beetle	-	-	5	5	5	1	1	5	-	22
Other beetle	2	-	3+	-	-	-	-	3	10	18
Water Bug	2	-	-	-	-	-	-	-	-	2
Snail	-	-	-	-	-	1	-	-	-	1
Monocot plant material	-	+	+	-	-	-	+	+	+	-
Pebbles	-	-	2	-	3	-	-	-	-	-
Plastic	-	-	+	-	-	-	-	-	-	-
Cattle dung	-	-	-	+	-	+	-	-	-	-
Sub-total	*18*	*5*	*12*	*10*	*5*	*2*	*6*	*8*	*10*	*76*
Total animals	**18**	**6**	**13**	**10**	**5**	**2**	**8**	**9**	**12**	**83**