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Aspects of breeding ecology and diet of the Brahminy Kite *Haliastur indus* over two breeding seasons in Darwin, Northern Territory

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Abstract. The breeding ecology and diet of the Brahminy Kite *Haliastur indus* was studied in urban Darwin, Northern Territory, in 2015 (*n* = 10 territories) and 2016 (*n* = 13 territories). Laying was estimated to have occurred from *c*. 15 June to 3 October, with juveniles fledging during August to December. African Mahogany *Khaya senegalensis* was the most common nest-tree (12 of 14 nest-trees). A breeding success rate of 17 from 21 active nests (81%) was recorded across the two breeding seasons. Nest dispersion was 25 nests/100 km^2 in 2015, and 31.3 nests/100 km^2 in 2016. A total of 394 prey items was recorded, comprising 243 reptiles (61.7%), 34 birds (8.6%), 34 crustaceans (8.6%), 27 fish (6.9%), 22 amphibians (5.6%), 19 mammals (4.8%) and 15 insects (3.8%). The Northern Water Dragon *Lophognathus temporalis* was the most common prey item, being recorded on 233 occasions.

Introduction

The Brahminy Kite *Haliastur indus* occurs across south-eastern Asia, from India to the Solomon Islands, and in Australia it occurs across the northern coast from Shark Bay in the west to the Hunter River in the east (Debus 2012). It is common near beaches, mangroves, large estuaries and coastal towns.

The Brahminy Kite is one of the least studied raptors in Australia (Rourke & Debus 2016). Studies on its breeding behaviour and breeding cycle have occurred in New South Wales (Lutter *et al.* 2006; Rourke & Debus 2016; Wooding in press), and also in India (Sivakumar & Jayabalan 2004) and Malaysia (Indrayanto *et al.* 2011). Other studies have investigated spacing of nests (Khaleghizadeh & Anuar 2014) and breeding response to habitat clearing in Malaysia (Khaleghizadeh *et al.* 2016), and feeding behaviour in Indonesia (Iqbal *et al*. 2009).

This study investigated breeding ecology, diet and nest dispersion of the Brahminy Kite in an urban environment in northern Australia. This is the first quantitative study on this species in Australia and provides a more detailed account of diet than has previously been documented.

Study area and methods

Fieldwork was conducted from August 2015 to January 2017 in the city of Darwin, Northern Territory (12°23′S, 130°51′E). Darwin experiences a tropical savannah climate with distinct wet and dry seasons. The wet season occurs from October to April, and brings significant monsoonal rains and occasionally cyclones. In contrast, negligible rainfall occurs during the dry season (May–September) (Bureau of Meteorology 2017).

The Darwin coastline is characterised by beaches with large intertidal zones, mangroves, mudflats and small estuaries. The urban environment has houses with well-watered landscaped gardens interspersed with numerous council parks, school ovals and sports ovals fringed by large trees. The most common large tree in the city is the exotic African Mahogany *Khaya senegalensis*, which was planted throughout the city following Cyclone Tracey in 1974 (Straight 2008).

I used knowledge of the Darwin area to search for Brahminy Kite nests and territories. Several nests had already been located during a systematic survey of the urban Darwin environment for Brown Goshawk *Accipiter fasciatus* nests (Riddell 2015). In instances where previously active Brahminy Kite nests had become inactive, or the nest-tree had been cut down, a search of the surrounding area was conducted. A systematic survey of the entire Darwin area was not undertaken, and it is likely that some nests within the study area were not detected.

Active Brahminy Kite nests were monitored on a weekly to fortnightly basis during the breeding season (August–December 2015 and June–December 2016) when possible. Juvenile birds were photographed to estimate their age and to establish the timing of breeding events. Descriptions of the development of nestling plumage by Marchant & Higgins (1993) and a photograph of a 10-day-old chick in Hollands (2003) were referenced to estimate the age of chicks in the nest. Time of laying was estimated based on records of the first incubation date and the date of first chick activity in the nest, the estimated age of chicks photographed in the nest, and applying an incubation period of *c*. 35 days (Marchant & Higgins 1993; Rourke & Debus 2016).

Prey items were recorded by searching for remains below the nest- and feeding trees, and by observing birds clutching or eating prey, or transferring prey from adults to juveniles. One successful prey capture was observed. Lizard remains were common below nests, and their tails were counted to accurately estimate numbers of these prey items.

Active nests were mapped using a GPS, and Google Earth software was used to assess nest dispersion and breeding density. Breeding success was defined as the fledging of at least one juvenile from a nest; it was measured as the number of young fledged per active nest.

Results

Sample size

Twenty-two Brahminy Kite breeding attempts across 13 territories were monitored in Darwin during the 2015 and 2016 breeding seasons. Nine active nests were monitored across 10 territories during the 2015 breeding season, with two breeding attempts occurring at one nest. An additional three territories were discovered for the 2016 breeding season, with 12 active nests monitored across the 13 territories.

Timing of breeding

Of the 20 Brahminy Kite breeding events for which timing could be deduced, laying was estimated to occur in June on four occasions, six times in July, seven times in August, once in September and twice in October (Table 1). Once, laying in October occurred after the initial breeding attempt failed shortly after a chick had hatched. The earliest date was estimated to be 15 June and the latest 3 October, representing a laying period of *c*.15 weeks.

Nestling period

As Brahminy Kite nests were visited weekly to fortnightly, dates of breeding events such as laying and fledging could only be estimated, with a significant degree of error (≤ 5 days). One breeding attempt was monitored more frequently (every 2–3 days) to gain a more accurate estimate of timing of breeding events. For this 2016 breeding event, date of laying was estimated as 2 July, when an adult was first observed on the nest in an incubating position, and the juvenile was observed fledging on 20 September. By applying an incubation period of 35 days, the estimated nestling period was thus 47 days.

Nest-trees

Twelve of the 14 nest-trees were African Mahogany, and the others were a Pornupan Mangrove *Sonneratia alba* and a Milkwood *Alstonia actinophylla*.

Breeding success

Young Brahminy Kites fledged from 17 of the 21 nests monitored, representing a success rate of 81%. A single juvenile fledged from each of 16 nests, two juveniles fledged from one nest, and four nesting attempts failed, representing an average of 0.86 juvenile fledged per active nest (Table 2).

Two of the failed breeding attempts occurred in newly established nest-sites after a nest-tree from the previous breeding season had been removed. A Poinciana *Delonix regia* tree, which had been used in 2014 by Brahminy Kites for successful breeding, was removed from a private backyard, and breeding was not attempted in this territory in 2015. A new nest was built in the territory in an African Mahogany in 2016, 210 m from the old nest-site, but breeding was unsuccessful. Another failure occurred in 2015 at a newly built nest 120 m from where the previous year's nest-tree had been removed. Incubation was observed only once at this nest in 2015 and failure seemed to occur early in the breeding cycle, although this nest was used successfully in 2016.

Nest dispersion

A systematic survey of the entire Darwin area was not undertaken and it is likely that some Brahminy Kite nests within the study area were not detected, thus precluding an accurate estimate of breeding density. The density for 2015 was 25 nests/100 km^2. In 2016, this increased to 31.3 nests /100 km^2 following the discovery of an additional nesting territory (overlooked in 2015) within the previous year's study area, and the expansion of the study area, accommodating an additional two nesting territories. Mean nearest-neighbour distance between active nests in 2015 was 1432 ± standard deviation 619 m (range 710–2200 m) and in 2016 it was 1224 ± 387 m (range 822–2200 m). The average distance from the coast for 12 nest-territories (excluding the nest in mangrove territory on the coast) was 1363 ± 857 m (range 230–3300 m).

Prey

A total of 394 prey items representing 22 species was recorded across the 13 Brahminy Kite nesting territories. Prey consisted of 243 reptiles, 34 birds, 34 crustaceans, 27 fish, 22 amphibians, 19 mammals and 15 insects. The most commonly recorded prey item was the Northern Water Dragon *Lophognathus temporalis*, which was recorded 233 times. Other common prey items included 21 Green Tree Frogs *Litoria caerulea*, 10 rats *Rattus* spp. and nine Bar-shouldered Doves *Geopelia humeralis*. Of the 394 prey records, 365 were recorded from prey remains

Table 1. Estimated month of laying and number of breeding events where laying could be deduced in two breeding seasons (2015 and 2016) for the Brahminy Kite in Darwin, Northern Territory. In 2015, two laying attempts occurred in one nest, and laying could not be determined at one unsuccessful nest. In 2016, the laying date could not be determined at one unsuccessful nest.

Month	*2015*	*2016*	*Total*
June	2	2	4
July	3	3	6
August	3	4	7
September	0	1	1
October	1	1	2

Table 2. Results of breeding attempts of Brahminy Kites in Darwin, Northern Territory, in two breeding seasons (2015 and 2016). In 2015, the nest where two laying attempts occurred is recorded as a success following the initial failed attempt.

Result of breeding attempt	*2015*	*2016*	*Total*
No. failed nests	2	2	4
No. nests where one juvenile fledged	6	10	16
No. nests where two juveniles fledged	1	0	1
No. fledglings/successful nest	1.14	1	1.06
No. fledglings/active nest	0.89	0.83	0.86

Figure 1. A prey transfer of a Northern Water Dragon from an adult (left) to a juvenile (right) Brahminy Kite, September 2015. Photo: William Riddell

found on the ground under the nest- and roost-trees, and 29 were recorded from adult Brahminy Kites clutching prey or feeding a juvenile (Figure 1) and one successful prey capture was observed. Prey categories are listed in Table 3, and prey items are in Appendix 1. Meat from urban refuse is another dietary component, with bones from barbeque meats commonly sighted near nests, and one adult was observed clutching and feeding upon a chicken drumstick, but these food items are not recorded as prey in Appendix 1.

Seasonal influences on diet were noted, with records of 10 of the 19 Green Tree Frogs occurring from late October to January, during the frog's breeding season when individuals become much more conspicuous following rainfall (see Anstis 2013). Passerine nestlings were also recorded as prey, including one bird embryo.

Table 3. Number and percentage of prey items recorded across two breeding seasons (2015 and 2016) for the Brahminy Kite, Darwin, Northern Territory.

Prey category	*2015*		*2016*		*Total*	
	No.	*%*	*No.*	*%*	*No.*	*%*
Reptiles	154	63.1	89	59.3	243	61.7
Birds	21	8.6	13	8.6	34	8.6
Crustaceans	21	8.6	13	8.7	34	8.6
Fish	17	7.0	10	6.7	27	6.9
Amphibians	11	4.5	11	7.3	22	5.6
Mammals	15	6.1	4	2.7	19	4.8
Insects	5	2.0	10	6.7	15	3.8
Total	**244**		**150**		**394**	

The low proportion of live prey records (29) relative to prey remains found near nests (365), makes it difficult to determine the extent to which Brahminy Kites rely on carrion compared with capturing live prey. Apart from the 17 Northern Water Dragons recorded as live prey, there were also 10 fish, one unidentified snake and one Green Tree Frog. Several prey items were probably carrion, e.g. Common Brushtail Possum *Trichosurus vulpecula* and Brown Goshawk. Other larger bird species, such as the Red-winged Parrot *Aprosmictus erythropterus* and Pheasant Coucal *Centropus phasianinus*, might also have been carrion, or sick or injured birds.

A fresh kill was observed when a Brahminy Kite was seen snatching a Northern Water Dragon from a tree-branch. On another occasion, a Kite appeared to use a still-hunting technique more commonly associated with goshawks *Accipiter* spp., with the Kite dropping from a low height in a mangrove tree onto a small unidentified prey item on a mudflat. Brahminy Kites were observed feeding on the wing, including two instances when an individual was feeding on a particularly large (>300 g) item (Figure 2), behaviour that has also been documented in Indonesia (Iqbal *et al.* 2009).

Discussion

Timing of breeding

The breeding season of the Brahminy Kite in Darwin occurs from June to December, extending from the dry season to the wet season. The incubation period (June–November) and nestling period (August–December) recorded in the present study are slightly earlier than in New South Wales, where incubation began in August (Rourke & Debus 2016) and July (Lutter *et al*. 2006), and fledging occurred by

Figure 2. Brahminy Kite feeding on fish on the wing, October 2016. Photo: William Riddell

November (Rourke & Debus 2016). Eggs were laid from June to October in the present study, which differs from the April–June period cited by Marchant & Higgins (1993) for the Northern Territory.

The period September to December, when Brahminy Kite chicks are in the nest and starting to fledge, is known as the monsoonal 'build-up' in northern Australia, when temperatures and humidity increase and the first rains of the wet season occur sporadically. The process by which conditions for breeding by birds of prey become favourable involve the first rains stimulating the growth of rain-starved vegetation, causing an increase in insect activity and abundance that promotes the breeding of raptor prey such as passerine birds and agamid lizards (Riddell 2015). Rainfall has been identified as a timing mechanism by facilitating increased food supply for raptors (Hustler & Howells 1990); however, in the present study, laying in June–October was in a period of nil to minimal rainfall in Darwin (Bureau of Meteorology 2016).

The attainment of breeding condition during the dry period when prey would be scarcer may be possible, however, because of the irrigated water supply in urban Darwin, where most of the Brahminy Kite nests in this study occur. The year-round water supply provided by irrigated gardens could ensure sufficient prey for birds to reach breeding condition during a dry period. It has been identified as a reason for the greater size and abundance of the Northern Water Dragon (Iglesias *et al.* 2012), an important prey item for Brahminy Kites breeding in urban Darwin.

Previous studies on the breeding ecology of the Brown Goshawk in Darwin have recorded a similar breeding period (August–January: Riddell 2015). The earlier onset of Brahminy Kite breeding (June) compared with the Brown Goshawk (August) is typical in tropical regions with distinct wet and dry seasons, where larger birds of prey tend to begin breeding before smaller ones (Newton 1979).

The latest breeding attempt of the Brahminy Kite in the present study involved laying in October and a fledgling by 20 December. This was the second breeding attempt by this pair after the first attempt failed at the chick stage. The heavy monsoonal rains of late December and January likely determine the latest laying dates, because of the increased risk to nestlings during this period.

Nestling period

The Brahminy Kite nestling period of 47 days at one nest in the present study is less than the records of 50 days (Wooding in press) and 52 days (Rourke & Debus 2016) in central and northern coastal New South Wales, and more than the 43–45 days for eight nests in inland southern India (Sivakumar & Jayabalan 2004).

Nest-trees

Twelve of 14 nest-trees were African Mahogany trees. The large size, shade and multiple branching of these trees make them ideal for nesting raptors (Riddell 2013, 2015). These exotic trees were first been planted in Darwin in the late 1950s, with planting increasing to aid reforestation after Cyclone Tracy in 1974 (Straight 2008). However, they are increasingly seen as a hazard, with falling branches resulting in two human fatalities over the past 10 years (McDonald 2014), and several have been cut down. One large African Mahogany removed from a school contained a Brahminy Kite nest where one juvenile had successfully fledged in 2014. A new Kite nest was built subsequently 120 m from the old nest-site in a smaller African Mahogany.

The Pornupan Mangrove occurs in the seaward margins of coastal estuarine habitats (Brock 2001). This tree species was used in both the 2015 and 2016 breeding seasons, with a new nest built within the same tree for the 2016 breeding season. This was the only nest recorded in mangroves in the present study, although other nests might occur in this habitat in and around Darwin. The importance of mangroves for nesting of this species requires evaluation.

The Milkwood nest-tree was in a narrow strip of woodland adjacent to a suburban area built on reclaimed land where mangrove forest previously occurred.

Breeding success

To date, no quantitative population studies have been undertaken on the Brahminy Kite in Australia. Marchant & Higgins (1993) cited 50% breeding success in Queensland, where three of six nests produced fledglings. Two studies in New South Wales (Lutter *et al.* 2006; Rourke & Debus 2016) and one in Malaysia (Indrayanto *et al.* 2011) have documented the breeding cycle, but in these three studies (all of single nests) only one successful fledgling was recorded.

Seventeen of the 21 Brahminy Kite nests (81%) monitored in the present study represents a high success rate compared with the very limited studies on the species in Australia. However, this result is potentially misleading, as successful breeding was defined as a juvenile bird being able to leave the nest, but not necessarily gain independence from the adults. On one occasion, a juvenile that had fledged was found dead near the nest-tree 2 weeks later, although this breeding attempt was recorded as successful. Juveniles at two other nests likely died within weeks of fledging, as adult Kites could be observed sharing food close to the nest but with no juvenile in sight at a time when the juvenile would still be dependent. The longest period during which a juvenile was observed in the vicinity of a nest after fledging was 80 days.

In the present study, five breeding attempts failed, with one pair of Brahminy Kites undertaking a successful second breeding attempt in one season. Determining causes for nesting failures is difficult as several factors can influence the breeding success of raptors (Paviour 2013). A specific reason for breeding failure cannot be positively identified for any of the failed attempts in this study. A juvenile found dead close to a nest from which it had fledged had an abrasion on the back of its head, though how this occurred could not be determined (Megan Edmonds pers. comm.). In the 13 nesting territories monitored, twelve had at least one successful breeding attempt across the 2-year monitoring period.

Disturbance of the old nest-site might have contributed to breeding failures at two nesting territories. In these instances a new nest was built after the previous year's nest-tree had been removed and the following breeding attempt was unsuccessful. Brahminy Kite nesting failure following a shift in nest-site has also been documented by Rourke & Debus (2016).

Two breeding failures in 2015 occurred relatively late in the breeding cycle, with chicks hatching in the nest but failing to fledge. Harassment by other birds of prey was observed at both the nest-sites. At one site, up to five Black Kites *Milvus migrans* were commonly observed near the nest. On one occasion, an adult Brahminy Kite left the nest during incubation to chase Black Kites from the territory. On a separate occasion, an adult Brahminy Kite roosted on a branch immediately above the nest in which a chick could be heard, and appeared to be closely guarding the nest. Five Black Kites were roosting on powerlines ~40 m away, and it is possible that harassment by Black Kites contributed to breeding failure at this nest, by direct predation or indirectly by drawing the adult Brahminy Kites' energy resources away from food provision towards nest-defence.

One Brahminy Kite nest successfully used in 2014 was occupied by Black Kites in 2015. A new Brahminy Kite nest could not be detected within this territory in 2015 or 2016. Another Brahminy Kite nest was relocated from an exotic Raintree *Albizia saman* for infrastructure development in 2015 by Northern Territory Parks and Wildlife staff to another Raintree (M. Edmonds pers. comm.). However, it was then occupied by a pair of Black Kites, and a pair of Brahminy Kites built a new nest in an African Mahogany in 2016, 200 m from the relocated nest. Territorial skirmishes between Brahminy and Black Kites were common in the area, indicating that the latter species is likely to be a competitor of the Brahminy Kite in Darwin.

Another likely competitor of the Brahminy Kite is the Brown Goshawk, which nests throughout urban Darwin (Riddell 2015). Remains of a Brown Goshawk were discovered below a Brahminy Kite feeding tree, though this prey item had probably been consumed as carrion. At the site of a second successful Brahminy Kite breeding attempt, Brown Goshawks successfully bred ~120 m from the Brahminy Kite nest. On one occasion, a Brown Goshawk was observed swooping at the Brahminy Kite nest and was chased away by both adult Brahminy Kites.

Nest density and nest dispersion

Nest density for the Brahminy Kite was estimated to be 25 nests/100 km^2 in 2015 and 31.3 nests/100 km^2 in 2016 but was probably higher as a systematic survey was not undertaken and some nests were likely overlooked. The increase in density from 2015 to 2016 likely reflects increased survey effort and the discovery of a previously overlooked territory rather than an increase in nest density.

No previous studies on nest dispersion of Brahminy Kites have been conducted in Australia. In coastal New South Wales, distances between neighbouring nests of 5 km and 2 km have been recorded (n = 3) (Lutter *et al.* 2006). Marchant & Higgins (1993) described six nesting pairs of Kites on Barrow Island, Western Australia, and 4–5 pairs on Magnetic Island, Queensland, representing a breeding density of 2.7 pairs/100 km^2 and 7.7–9.6 pairs/100 km^2, respectively. Six pairs have been observed along a 20-km stretch of the Brisbane River, Queensland, representing an average distance of ~3.3 km between pairs (Marchant & Higgins 1993). These figures represent a significantly lower nesting density than 25 and 31.3 nests/100 km^2 recorded for the present study.

In coastal Malaysia, the average distance between Brahminy Kite nests has been recorded as 1489.4 ± standard deviation 1134.5 m (n = 27) (Khaleghizadeh & Anuar 2014), which is comparable with 1432 ± 619 m (n = 9) but higher than 1224 ± 387 m (n = 12) recorded for the present study in 2015 and 2016, respectively.

Eleven of the 13 nest territories in the present study occurred in urban habitat, with one in mangrove forest and one in a narrow strip of woodland between suburban housing and a major road that could be described as a habitat corridor.

Prey

Previous studies on Brahminy Kites in Australia have produced limited information on prey species, with recorded

prey items including fish, crustaceans (crabs), molluscs, freshwater turtles, orthopterans (grasshoppers and crickets) and small birds (Marchant & Higgins 1993; Lutter *et al.* 2006; Rourke & Debus 2016; Wooding in press). Prey items in urban Darwin have included dragon lizards and a grasshopper (Riddell 2013). A study in India recorded a diet of fish (53%), crabs (31%) and equal proportions of birds (5.5%), rats (5.5%) and frogs (5.5%) from identified prey items during the breeding period (Sivakumar & Jayabalan 2004). Results from the present study confirm that the Brahminy Kite is a generalist predator.

Reptiles constituted the majority of the diet (62%) in the present study, largely because of the predominance of Northern Water Dragons, which probably reflects prey availability rather than a preference by the Brahminy Kite to hunt lizards. Northern Water Dragons are abundant in urban Darwin (Iglesias *et al.* 2012) and are also an important dietary component of Brown Goshawks in the area (Riddell 2015).

Coastal and estuarine prey items such as crustaceans and fish were recorded in all 13 nesting territories. Of the crustaceans found below nests, two were identified to species level: Blue Swimmer Crab *Portunus pelagicus* and Mangrove Swimming Crab *Thalamita crenata*. These species are commonly found stranded on tidal flats or washed along the shore at high tide, and remains found near nests were from mature specimens, indicating that these might have been dead when collected (Adam Bourke pers. comm.).

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Appendix 1. Brahminy Kite prey items recorded in 2015 and 2016 breeding seasons, and in January 2016 and January 2017 when fledged juveniles remained in nesting territories, Darwin, Northern Territory.

	Prey species		*Number*
Reptiles	Frill-necked Lizard	*Chlamydosaurus kingii*	1
	Northern Water Dragon	*Lophognathus temporalis*	235
	Spotted Tree Monitor	*Varanus scalaris*	4
	Unidentified snakes		2
	Unidentified lizard		1
	Total reptiles		**243**
Birds	Domestic Chicken	*Gallus gallus domesticus*	1
	Bar-shouldered Dove	*Geopelia humeralis*	9
	Pied Imperial-Pigeon	*Ducula bicolor*	1
	Pheasant Coucal	*Centropus phasianinus*	1
	Brown Goshawk	*Accipiter fasciatus*	1
	Sacred Kingfisher	*Todiramphus sanctus*	1
	Red-winged Parrot	*Aprosmictus erythropterus*	1
	White-breasted Woodswallow	*Artamus leucorynchus*	1
	Magpie-lark	*Grallina cyanoleuca*	3
	Unidentified birds		15
	Total birds		**34**
Crustaceans	Blue Swimmer Crab	*Portunus pelagicus*	3
	Mangrove Swimming Crab	*Thalamita crenata*	1
	Unidentified crabs	*Neosarmatium* spp.	29
	Unidentified shrimp	Caridea	1
	Total crustaceans		**34**
Fish	Yellowtail Grunter	*Amniataba caudavittata*	1
	Starry Puffer	*Arothron stellatus*	1
	Slender Rainbow Sardine	*Dussumieria elopsoides*	2
	Oxeye Herring	*Megalops cyprinoides*	1
	Mullet	Mugillidae	1
	Hairback Herring	*Nematalosa come*	1
	Unidentified fish		20
	Total fish		**27**
Amphibians	Green Tree Frog	*Litoria caerulea*	19
	Cane Toad	*Rhinella marina*	3
	Total amphibians		**22**
Mammals	Common Brushtail Possum	*Trichosurus vulpecula*	3
	Rat	*Rattus* spp.	10
	Unidentified mammals		6
	Total mammals		**19**
Insects	Dragonfly	Anisoptera	7
	Cicada	Auchenorrhyncha	1
	Grasshopper	Orthoptera	7
	Total insects		**15**
	Total		**394**