Corella, 2011, 35(2): 41-48

Diet and breeding of White-bellied Sea-Eagles *Haliaeetus leucogaster* in subtropical river habitats in the Northern Territory, Australia

Laurie Corbett[1,2,3] and Tony Hertog[1]

[1]CSIRO Tropical Ecosystems Research Centre, Darwin, Northern Territory 0800, Australia
[2]Present address: P.O. Box 27, Metung, Victoria 3904, Australia
[3]Corresponding author. Email: lkcorbett@bigpond.com

Received: 1 October 2009

Diet and breeding of White-bellied Sea-Eagles *Haliaeetus leucogaster* were studied at two sites in the subtropical Northern Territory of Australia over seven years: at Mary River (20 territories), characterised by a permanently high water level; and the Alligator Rivers at Kapalga (20 territories), characterised by high wet-season and low dry-season water levels. Overall diet comprised aquatic reptiles (45%), fish (28%), birds (24%) and mammals (3%). Relatively more fish and snakes were taken at Mary River and relatively more turtles and birds at Kapalga. Nests were significantly closer at Mary River (mean 0.9 km apart) than at Kapalga (mean 6.5 km apart). Most eggs were laid from May to August and most nestlings were fledged from August to October. Significantly more Sea-Eagle pairs successfully bred annually at Mary River (mean 7.7 pairs) than at Kapalga (mean 4.1 pairs), and significantly more young were fledged annually at Mary River (mean 9.3) than at Kapalga (mean 4.6). Mortality included eggs that failed to hatch, facultative fratricide in downy nestlings, and death of nestlings from avian pox, fratricide and accidents. Downy nestling mortality was significantly greater at Kapalga (mean 3.3/year) than at Mary River (mean 1.1/year). Sea-Eagle breeding habitats in the Northern Territory are under increasing threat from urban and tourism developments. This threat needs to be addressed through a process of management plans and public awareness programs about the ecological role of White-bellied Sea-Eagles.

INTRODUCTION

The White-bellied Sea-Eagle *Haliaeetus leucogaster* has a wide distribution from India and Sri Lanka east to South China, and south to New Guinea, the Bismarck Archipelago and Australia (Brown and Amadon 1968). This species, the second-largest Australian raptor, frequents mainly seacoasts, tidal rivers and offshore islands around the entire Australian coastline, and also occurs considerable distances inland along freshwater rivers, lakes and swamps (Cupper and Cupper 1981; Olsen 1995).

White-bellied Sea-Eagle numbers have declined in the densely settled and habitat modified regions of southeastern Australia, mainly due to loss or alteration of their feeding and breeding habitats (Bilney and Emison 1983; Dennis and Lashmar 1966; Clunie 2004; Shephard *et al.* 2005a). By contrast, the species is common in the coastal floodplains of the Northern Territory (Crawford 1972). This long-term study examines diet and breeding in two contrasting habitats, one (Mary River) with relatively constant food availability and the other (Alligator Rivers) with seasonally fluctuating food availability.

The results of this study will be vital for wildlife managers to help protect Sea-Eagle breeding habitats and foraging grounds, and also for developers when planning coastal residential and industrial infrastructures in northern Australia.

METHODS

Study sites

Mary River and Kapalga are on the coastal floodplains about 90 and 170 kilometres east of Darwin, respectively. The major habitats are rivers, billabongs, black soil floodplains, open forest/woodlands (*Eucalyptus* and other spp.) and dense paperbark forest (*Melaleuca* spp.) (Figures 1 and 2).

The Kapalga study site, within Kakadu National Park, is bounded by coordinates 12°19'S, 132°15'E and 12°44'S, 131°29'E and includes about 35 kilometres of each of the South Alligator and West Alligator Rivers (Figure 1). Most White-bellied Sea-Eagle nests associated with the relatively larger South Alligator floodplain were located up to five kilometres from the river in the ecotone between the upland forest and black soil floodplain, whereas the West Alligator River nests were within 0.5 kilometres of the river itself.

The Mary River study site comprised two approximately parallel stretches of river, within the rectangle bounded by coordinates 12°38'S, 131°38'E and 12°44'S, 131°40'E, together totalling 21 kilometres of river-line (Figure 2). Most nests were at the water's edge and all were within 0.5 kilometres of the river.

The climate at both sites is hot all year and similar to Jabiru, the nearest weather station about 50 kilometres east of Kapalga. At Jabiru, all months have a mean daily maximum temperature range of 31–38°C and mean daily minimum temperatures range from 18°C in July to 25°C from October to March. The median annual rainfall is 1 287 millimetres and markedly seasonal, with 93 percent of the rain falling between November and March. There are frequent, hot and extensive wildfires that burn in most habitats within the region between June and November.

A major environmental difference between the two study sites is the availability of open-water habitats for White-bellied Sea-Eagles to hunt prey. At Mary River the water level remains

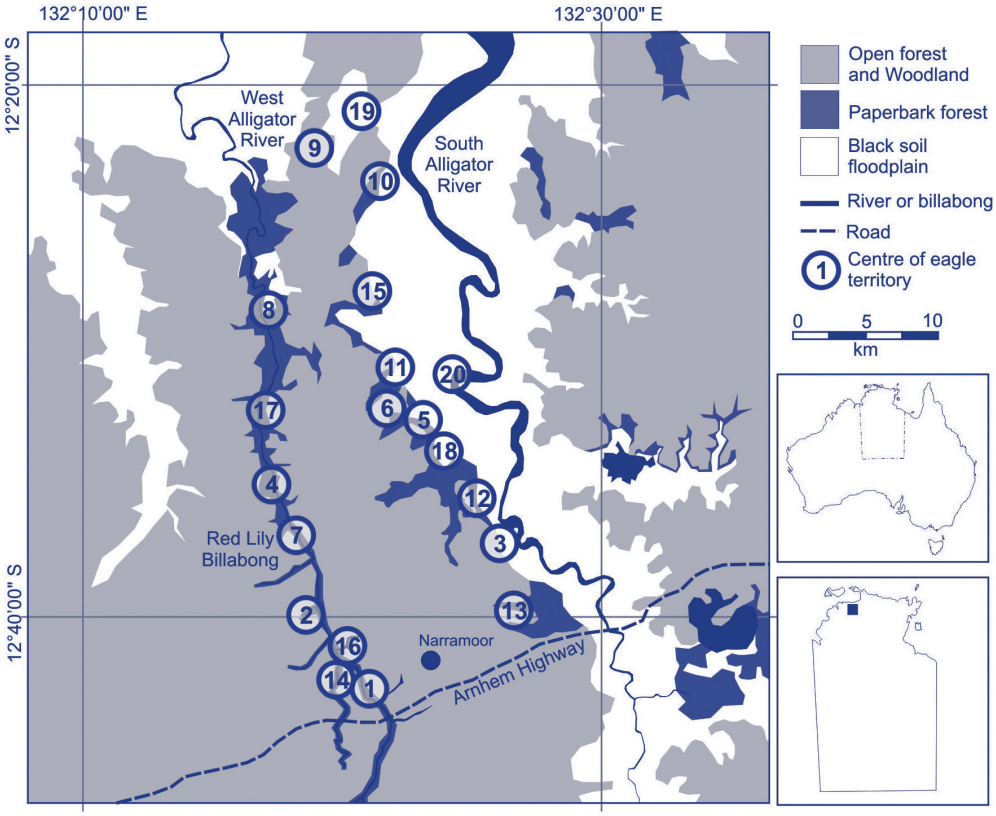

Figure 1. *Kapalga study area.*

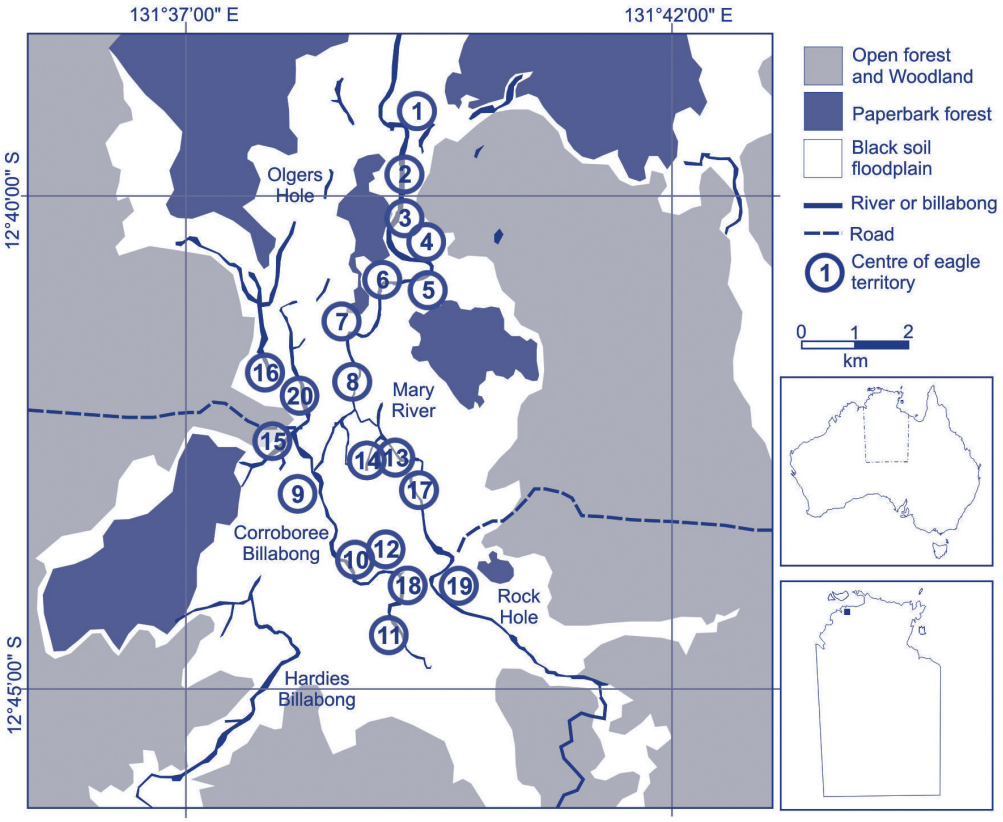

Figure 2. *Mary River study area.*

high all year, whereas the Alligator Rivers at the Kapalga site reduces to a series of isolated shallow swamps during the dry season when the Sea-Eagles breed.

Assessing diet

Comparisons of diet between Kapalga and Mary River were mainly based on prey remains which were either collected from nests, under the nest tree or from under nearby roosting/feeding trees. Other prey types were identified and individuals summed from pellets or observations of prey captured by adults. Samples were collected and labelled in the field and species later identified in a laboratory. Reptiles were identified from scales and bones (snakes) or carapace pattern and shape (turtles). Birds were identified from feathers and/or bones and mammals were identified by hair structure (medulla and cuticle scales: Corbett 1974) and/or bones and teeth.

Assessing breeding activity

In northern Australia, White-bellied Sea-Eagle egg laying is reported to occur between May and August with nestlings fledging through to October (Brown and Amadon 1968; Cupper and Cupper 1981; Marchant and Higgins 1993; Pizzey and Knight 1997). Based on this information, surveys were initially conducted in July and September each year but later adjusted to include other months according to our experience. The earlier survey of each year aimed to identify occupied territories, record breeding and non-breeding pairs, and clutch size. The second survey aimed to record nestling survival, causes of nestling mortality and overall breeding success.

Adult White-bellied Sea-Eagle pairs were assumed to hold a breeding territory if: they displayed courtship behaviour; and/or displayed aggressive behaviour to other Sea-Eagles, Wedge-tailed Eagles and crows; and/or a nest or nest-building activity was observed; and/or one member of the pair had a brood patch.

Sea-Eagles were considered to be breeding if one of the pair was seen sitting in an incubating position on the nest, or the nest contained eggs or young. Nest contents were initially inspected by climbing to nests with the aid of a rope ladder. However, in order to minimise nest desertion by attending adults, most nests in the third and following study years were inspected using a 10-metre extension ladder and a swivel-head mirror fitted to an 8-metre extendable pole. Both the distance between the nest and nearby open water, and the distance to the next Sea-Eagle breeding territory were estimated.

During the second annual survey, the large nestlings were usually conspicuous by ground observation, so that it was unnecessary to climb to the nest. Breeding success was categorised as failed (eggs laid but no young fledged), successful (one or two young fledged) or unknown (eggs laid but fate unknown).

Statistical methods

Most data presented are summarised as mean ± standard deviation. Differences between Kapalga and Mary River samples were tested using the Wilcoxon Rank Sum Test with significance at $P \leq 0.05$.

RESULTS

Diet

A total of 779 prey items (Table 1) was recorded at nest and feeding trees, comprising reptiles (45.4%), fish (28.1%), birds (23.9%), mammals (2.6%) and invertebrates (0.1%).

The Northern Long-necked Turtle *Macrochelodina rugosa* (33.8%) and the Arafura File Snake *Acrochordus arafura* (6.0%) were the most common reptilian prey. Most turtles (73%) had shell lengths at least 15 centimetres and about half of the snakes (56%) were longer than 50 centimetres, which suggests that Sea-Eagles targeted sub-adult prey. Of seven fish species identified, catfish *Arius* spp. (12.6%) and Barramundi *Lates calcarifer* (9.4%) were most common and, based on body length, both large and small individuals were taken (49% of catfish were ≥40 cm and 53% of Barramundi were ≥50 cm). The Magpie Goose *Anseranas semipalmata* (12.3%), ducks (3.5%, five species), ibis (3.3%, two species), Little Corella *Cacatua sanguinea* (1.2%) and egrets (1.1%, three species) were the most common of 18 bird species identified. About half (54%) of the geese were juveniles and probably unable to fly. Of the six mammal species represented, flying-foxes (1.8%) were most common and included both the Black Flying-fox *Pteropus alecto* and Little Red Flying-fox *Pteropus scapulatus*. A freshwater crayfish *Cherax* sp. was the only invertebrate recorded.

White-bellied Sea-Eagles sometimes kleptoparasitise the prey of other predatory birds, including Eastern Ospreys *Pandion cristatus* (Cupper and Cupper 1981) and Australasian Gannets *Morus serrator* (Mooney 1986). We recorded a Sea-Eagle pirating a duck from a Whistling Kite *Haliaster sphenurus* and another Sea-Eagle pirating a Freshwater Long-tom *Strongylura krefftii* from a Barramundi. The Barramundi had forced the Long-tom and other fish to the surface of a billabong, which gave the Sea-Eagle the opportunity to swoop down and seize the fish in its talons.

Comparison of diet between Kapalga and Mary River

Overall, relatively more prey species were taken at Kapalga (32 species) than at Mary River (19 species) (Table 1) but the proportion of major prey types varied between the two sites (Figure 3f). Relatively more turtles and birds were taken at Kapalga than at Mary River (turtles: 55.4% vs. 7.0%; birds: 28.3% vs. 15.0%). Conversely, relatively more fish and snakes were taken at Mary River (fish: 58.4% vs. 10.7%; snakes: 16.8% vs. 3.1%). There was a similar level of mammal prey items recorded at both sites. However, none of these dietary differences were statistically significant.

There were also no significant differences in the annual occurrences of prey types (turtles, birds, fish, snakes and mammals) between the two sites (Figure 3a-e).

Nest characteristics

Paperbark *Melaleuca* sp. was the most common species of nest tree (67.6%, $n = 68$ trees) out of a total of seven species recorded across both sites. At Mary River, paperbark was used almost exclusively (97.1%) whereas Ghost Gum *Corymbia bella* (39.4%) and paperbark (36.4%) were the common species in a

TABLE 1

Occurrences of prey remains found in and under White-bellied Sea-Eagle nests, Kapalga and Mary River, 1980–86

			Kapalga		Mary River		Total	
			n	%	n	%	n	%
Reptiles	Northern Long-necked Turtle	*Macrochelodina rugosa*	253	51.3	10	3.5	263	33.8
	Northern Snapping Turtle	*Emydura dentata*	0	0.0	2	0.7	2	0.3
	Undetermined turtle species		17	3.4	8	2.8	25	3.2
	Arafura File Snake	*Acrochordus arafura*	1	0.2	46	16.1	47	6.0
	Macleay's Water Snake	*Enhydris polylepis*	1	0.2	0	0.0	1	0.1
	Blue-tongued Lizard	*Tiliqua spp.*	1	0.2	0	0.0	1	0.1
	Undetermined snake species		13	2.6	2	0.7	15	1.9
		Total reptiles	**286**	**58.0**	**68**	**23.8**	**354**	**45.4**
Fish	Catfish	*Arius spp.*	19	3.9	79	27.6	98	12.6
	Barramundi	*Lates calcarifer*	18	3.7	55	19.2	73	9.4
	Sleepy Cod	*Oxyeleotris lineolata*	0	0.0	12	4.2	12	1.5
	Freshwater Long Tom	*Strongylura krefftii*	3	0.6	4	1.4	7	0.9
	Bony Herring	*Nematalosa erebi*	2	0.4	4	1.4	6	0.8
	Diamond Mullet	*Liza alata*	3	0.6	0	0.0	3	0.4
	Saratoga	*Scleropages jardinii*	1	0.2	1	0.3	2	0.3
	Undetermined fish species		6	1.2	12	4.2	18	2.3
		Total fish	**52**	**10.5**	**167**	**58.4**	**219**	**28.1**
Birds	Magpie Goose	*Anseranas semipalmata*	80	16.2	16	5.6	96	12.3
	Plumed Whistling-Duck	*Dendrocygna eytoni*	4	0.8	1	0.3	5	0.6
	Wandering Whistling-Duck	*Dendrocygna arcuata*	0	0.0	1	0.3	1	0.1
	Radjah Shelduck	*Tadorna radjah*	4	0.8	15	5.2	19	2.4
	Pacific Black Duck	*Anas superciliosa*	1	0.2	0	0.0	1	0.1
	Hardhead	*Aythya australis*	2	0.4	0	0.0	2	0.3
	Australasian Darter	*Anhinga novaehollandiae*	1	0.2	0	0.0	1	0.1
	Eastern Great Egret	*Ardea modesta*	1	0.2	0	0.0	1	0.1
	Intermediate Egret	*Ardea intermedia*	2	0.4	0	0.0	2	0.3
	Pied Heron	*Egretta picata*	1	0.2	0	0.0	1	0.1
	Undetermined Egret/Heron species	*Egretta spp., Ardea sp.*	5	1.0	0	0.0	5	0.6
	Nankeen Night-Heron	*Nycticorax caledonicus*	1	0.2	0	0.0	1	0.1
	Glossy Ibis	*Plegadis falcinellus*	22	4.5	3	1.0	25	3.2
	Australian White Ibis	*Threskiornis molucca*	1	0.2	0	0.0	1	0.1
	Royal Spoonbill	*Platalea regia*	1	0.2	0	0.0	1	0.1
	Whistling Kite	*Haliastur sphenurus*	0	0.0	1	0.3	1	0.1
	Purple Swamphen	*Porphyrio porphyrio*	1	0.2	0	0.0	1	0.1
	Little Corella	*Cacatua sanguinea*	7	1.4	2	0.7	9	1.2
	Sulphur-crested Cockatoo	*Cacatua galerita*	1	0.2	0	0.0	1	0.1
	Red-winged Parrot	*Aprosmictus erythropterus*	1	0.2	0	0.0	1	0.1
	Undetermined bird species		7	1.4	4	1.4	11	1.4
		Total birds	**143**	**29.0**	**43**	**15.0**	**186**	**23.9**
Mammals	Flying-fox	*Pteropus spp.*	7	1.4	7	2.4	14	1.8
	Northern Brown Bandicoot	*Isoodon macrourus*	1	0.2	0	0.0	1	0.1
	Agile Wallaby	*Macropus agilis*	2	0.4	0	0.0	2	0.3
	Dusky Rat	*Rattus colletti*	1	0.2	0	0.0	1	0.1
	Feral Cat	*Felis catus*	1	0.2	0	0.0	1	0.1
	Feral Pig	*Sus scrofa*	0	0.0	1	0.3	1	0.1
		Total mammals	**12**	**2.4**	**8**	**2.8**	**20**	**2.6**
Invertebrates	Freshwater crayfish	*Cherax sp.*	0	0.0	1	0.3	1	0.1
		Total ocurrences	**493**	**100.0**	**286**	**100.0**	**779**	**100.0**

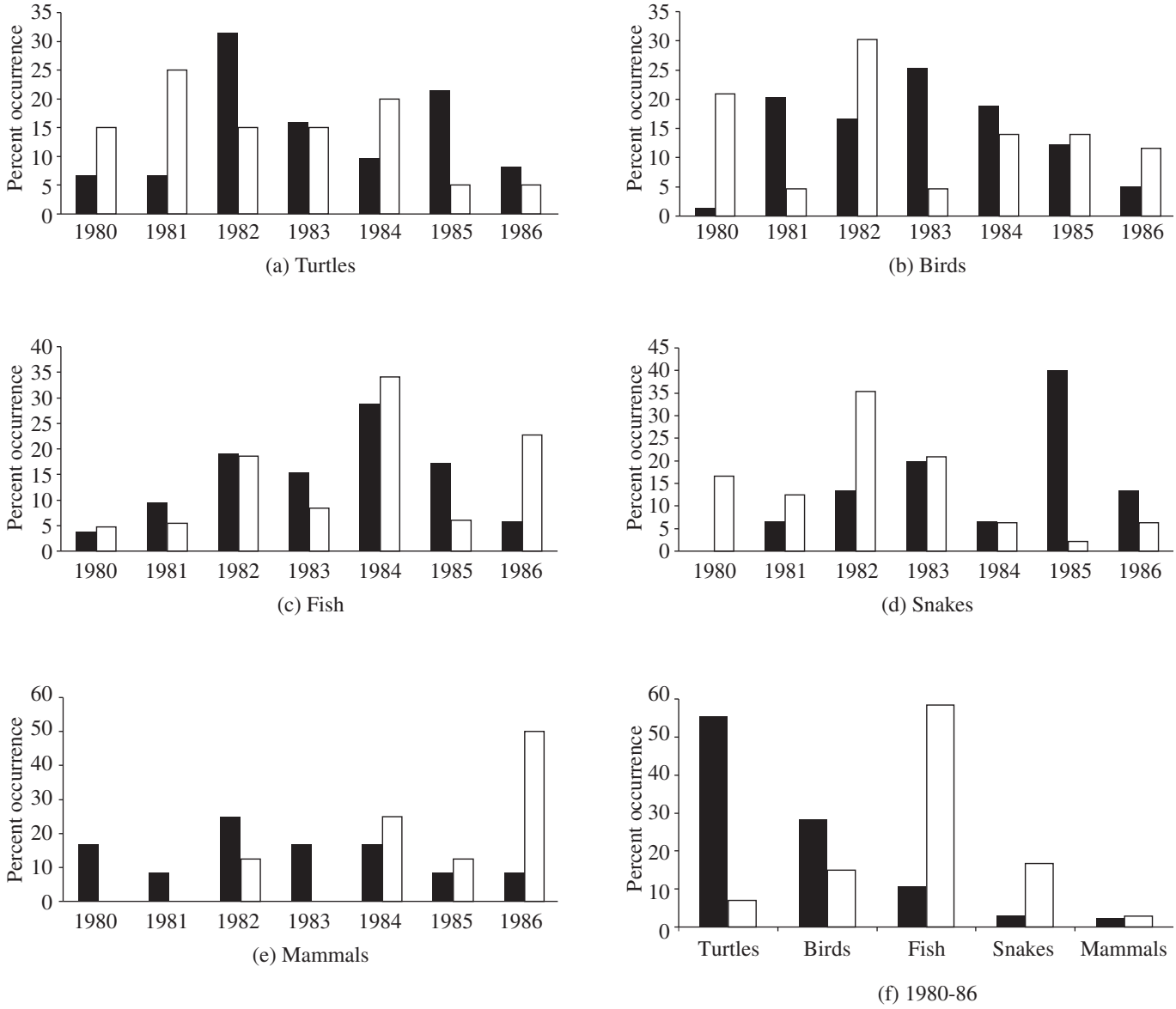

Figure 3. *Comparison of major prey items of White-bellied Sea-Eagles between Kapalga (solid bars) and Mary River (open bars) 1980–86.*

range of six species used at Kapalga. White-bellied Sea-Eagles appeared to base tree selection on the tallest tree and/or clear line of sight to adjacent territories.

The mean straight-line distance (km) to the nearest active nest was estimated from topographical maps as 6.5 ± 4.3 (n = 24) and 0.9 ± 0.4 (n = 22) for Kapalga and Mary River respectively. The distance between nests at Mary River was significantly closer than at Kapalga (U=11.0, P<0.001).

Breeding effort and success

Over the seven study years at Kapalga (Table 2), a mean of 13.0 occupied territories was recorded annually, but only a mean of 8.3 pairs attempted to breed, of which a mean of 4.1 pairs fledged young, resulting in a mean of 4.6 nestlings fledged annually. Two-egg clutches were laid in six of the seven years (mean 2.3 two-egg clutches annually), and half of those eggs converted to fledged nestlings, which also represents half of all nestlings fledged. The overall mean number of fledged young per nest at Kapalga was 0.55.

Equivalent data for Mary River (Table 2) were: a mean of 15.3 occupied territories recorded annually with a mean of 10.0 pairs attempting to breed, a mean of 7.7 pairs successfully fledging young, resulting in a mean of 9.3 nestlings fledged annually. Two-egg clutches were recorded every year (mean 3.7 annually) with 55.8 per cent of those eggs converting to fledged nestlings, representing 44.6 per cent of the total fledged nestlings from all breeding birds. The overall mean number of fledged young per nest at Mary River was 0.93.

Statistical comparisons of these data sets indicated significantly greater values at Mary River than Kapalga in the number of successful breeding pairs (U=0.50, P<0.01) and in total number of young fledged (U=1.5, P<0.01).

TABLE 2

White-bellied Sea-Eagle breeding effort and success, Kapalga and Mary River, 1980–86

Year	Occupied Territories		Breeding pairs		Breeding pairs that fledged young		Total young fledged		2-egg clutches		Fledged young from 2-egg clutches	
	Kapalga	Mary River	Kapalga	Mary River	Kapalga	Mary River	Kapalga	Mary River	Kapalga	Mary River	Kapalga	Mary River
1980	12	10	9	8	2	7	2	8	0	3	0	3
1981	12	13	4	10	4	9	4	10	1	2	1	2
1982	13	16	8	12	4	10	6	14	4	4	5	8
1983	15	12	10	9	5	7	5	9	3	2	3	4
1984	13	18	11	11	6	8	6	9	5	6	4	5
1985	13	19	8	10	5	6	6	6	2	5	3	2
1986	13	19	8	10	3	7	3	9	1	4	0	5
Mean ± sd	13.0 ± 1.0	15.3 ± 3.6	8.3 ± 2.2	10.0 ± 1.3	4.1 ± 1.3	7.7 ± 1.4	4.6 ± 1.6	9.3 ± 2.4	2.3 ± 1.8	3.7 ± 1.5	2.3 ± 2.0	4.1 ± 2.1
Difference	U = 16.0, P = 0.293		U = 12.0, P = 0.116		U = 0.5, P = 0.002**		U = 1.5, P = 0.003**		U = 13.0, P = 0.154		U = 13.0, P = 0.174	

Mortality in eggs and nestlings

The total mortality rate for the combined Kapalga and Mary River sites was 48 per cent (the percentage of eggs that did not convert to fledged nestlings), and comprised eggs that failed to hatch (16%), death at the downy nestling stage (18%), and death at the juvenile nestling stage (14%) (Table 3).

The total mortality at Kapalga (mean 6.9 ± 3.9) was relatively greater than at Mary River (4.6 ± 3.6) over the seven study years, mainly due to the significantly greater mortality of downy nestlings ($U=7.5$, $P<0.05$; Table 3).

The causes of failure in egg hatching included parents breaking eggs, egg predation by goannas *Varanus* spp., Torresian Crows *Corvus orru* and other unidentified predators, and nest desertion due to researcher disturbance.

Twenty-seven per cent of downy nestlings that died were siblings in broods of two. Sibling rivalry and competition leading to the death of the weaker sibling was frequently observed in this study, but not all junior siblings died. This indicates that White-bellied Sea-Eagles are facultatively fratricidal (C2) (Brown and Amadon 1968; Meyburg 1974; Cupper and Cupper 1981). It is notable that all cases of downy C2 nestlings deaths were at Kapalga. Other causes of mortality (73%) in downy nestlings are unknown, but are likely to include attack or predation by Sea-Eagles from adjacent territories, crows, pythons and goannas.

Twenty-eight per cent of nestling deaths were due to avian pox. Infected birds typically had pussy lesions (about 3–4 mm diameter) around both eyes, the beak and sometimes both feet. Most infected nestlings were lethargic and some had weakened limbs, barely being able to stand or flap their wings; and despite being fed by their parents, probably all infected nestlings died. Mortality from avian pox has also been recorded in Bald Eagles *Haliaeetus leucocephalus* (Bortolotti *et al.* 1985).

Identified causes of mortality in juvenile nestlings were avian pox (28%), fratricide (12%), shooting by vandals (8%), injury caused by researchers (4%), and misadventure (4%). Other causes of mortality (44%) are unknown, but likely to include deaths from wildfire and strong wind displacing young from the nest.

Support for the notion that food quality contributes to the occurrence of fratricide (Godfray and Harvey 1986) is provided by two cases in this study. At one Kapalga territory there were two visually healthy nestlings of similar size (weights 2 800 and 2 400 g, total length 106 and 95.1 mm) when initially tagged (unpublished data); however, 17 days later the smaller nestling was found dead under the nest and both adults were feeding the other nestling. At another Kapalga territory, adjacent to a permanent billabong, there was a large size difference when the nestlings were tagged (weights 2 000 and 850 g, total length 800 and 106 mm), and also about five weeks later when both nestlings fledged. The major difference between the two territories appeared to be the greater availability and accessibility of food (turtles, fishes and waterbirds) at the billabong.

DISCUSSION

Brown and Amadon (1968) stated that 90–95 per cent of White-bellied Sea-Eagle diet throughout its range from Asia to Australia consists of fish and sea-snakes, with the remainder comprising young water birds (especially herons) some mammals including fruit bats, small crocodiles and possibly carrion. In this study, turtles, file snakes, fish (catfish and Barramundi), birds (geese and ibis) and mammals (fruit bats) were the main prey, which is similar to prey types recorded elsewhere in Australia (Cupper and Cupper 1981; Smith 1985; Marchant and Higgins 1993; Olsen 1999; Olsen *et al.* 2006; Debus 2008). That relatively more turtles and file snakes were recorded was probably because this study was centred mainly

TABLE 3

Mortality in White-bellied Sea-Eagle eggs and nestlings, Kapalga and Mary River, 1980–86

Year	Territories		Eggs laid		Eggs that failed to hatch		Downy nestling deaths		Juvenile nestling deaths		Total mortality	
	Kapalga	Mary River	Kapalga	Mary River	Kapalga	Mary River	Kapalga	Mary River	Kapalga	Mary River	Kapalga	Mary River
1980	9	8	9	11	2	1	4	0	1	2	7	3
1981	4	10	5	12	0	0	1	0	0	2	1	2
1982	8	12	12	15	2	0	2	0	2	1	6	1
1983	10	9	13	11	6	1	5	0	3	1	14	2
1984	11	11	14	17	2	3	4	1	2	5	8	9
1985	8	10	10	14	1	4	4	6	0	0	5	10
1986	8	10	8	14	1	4	3	0	3	1	7	5
Mean ± sd	8.3 ± 2.2	10.0 ± 1.3	10.1 ± 3.1	13.4 ± 2.2	2.0 ± 1.9	1.9 ± 1.8	3.3 ± 1.4	1.0 ± 2.2	1.6 ± 1.3	1.7 ± 1.6	6.9 ± 3.9	4.6 ± 3.6
Difference	U = 12.0, P = 0.116		U = 9.5, P = 0.062		U = 23.0, P = 0.896		U = 7.5, P = 0.030*		U = 23.5, P = 0.948		U = 17.0, P = 0.369	

on freshwater habitats, compared with mainly marine habitats studied elsewhere.

The predominance of turtles, geese and ibis in the Sea-Eagle diet at Kapalga was likely due to their greater accessibility to predation by Sea-Eagles and vulnerability in the dry season when river and floodplain water levels were greatly reduced and isolated in small waterholes and billabongs. Conversely, the predominant prey of catfish, Barramundi and file snakes at Mary River probably resulted from their high abundance and accessibility in the permanent high water level there.

The Sea-Eagle breeding season (eggs laid to young fledged) in this northern Australian study was five months (June–October), which is similar to Sea-Eagles in inland northern New South Wales (Debus 2008), but much shorter than the nine-month breeding season (June–February) in southern Australia (Favaloro 1944; Bilney and Emison 1983). The mean clutch size in this study was 1.3, and 32 per cent were two-egg clutches, which is similar to data obtained elsewhere in Australia (mean clutch size 1.7, range 1–3: Marchant and Higgins 1993). The mean productivity in this study was 0.7 nestlings/nest, which is similar to Sea-Eagles in inland northern New South Wales (0.8 nestlings/nest: Debus 2008) but much lower than in southern Australia (1.1 nestlings/nest, 37 nests, 1978–81: Bilney and Emison 1983).

Nests at Mary River were located closer together and nearer permanent water than at Kapalga, and reflected the greater availability and vulnerability of prey at Mary River, and consequently the greater breeding success there. These results suggest that White-bellied Sea-Eagle density and breeding success are relatively greater in habitats with abundant and continuously available prey. This is supported by the finding that nestling mortality was greater at Kapalga because parents had to fly farther to hunting grounds, and thus expose their nestlings to predators. The results also support Olsen's (1999) suggestion that Sea-Eagle breeding density depends partly on prey availability, based on the doubling of the number of Sea-Eagles breeding at a Canberra lake after fish availability had greatly increased.

Bilney and Emison (1983) reported White-bellied Sea-Eagles to be susceptible to human disturbance, often deserting the nest, young or deterred from breeding altogether. Other types of recorded human-induced mortality are: being shot illegally (Favaloro 1944; Debus 2008); drowning in fishing nets (Favaloro 1944); and poisoning following baiting programs for vermin (Hunt and Mooney 1983). Sea-Eagles were declared vermin and bounties were paid in the Roebourne District of Western Australia between 1938 and 1970 on the basis they preyed on lambs and other stock (Serventy and Whittell 1976). Dennis and Baxter (2006) recorded that 53 per cent of 17 breeding White-bellied Sea-Eagles on Kangaroo Island were disturbed by human activities; and elsewhere in South Australia there has been a substantial decline (>40%) in the overall population range of Sea-Eagles (Dennis and Lashmar 1996; Dennis 2004). Spencer and Lynch (2005) recorded that the density of Sea-Eagles in Jervis Bay, New South Wales, was highest in undeveloped military and conservation reserves, compared to the density in urban settlements. Furthermore, Sea-Eagles were only observed perching in forest reserves interspersed between urbanised areas, despite the availability of suitable perches throughout the coastal suburbs.

White-bellied Sea-Eagle populations are declining worldwide (Shephard *et al.* 2005b). Populations have declined in southern Australia because of loss or degradation to primary breeding habitats and consequent reduced breeding success, and increased mortality due to uninformed humans. These threats were also recorded in this study, so it is likely that similar reductions in Sea-Eagle breeding success and, therefore, in

overall population number will also occur in northern Australia. In the Northern Territory, nesting habitats are under increasing threat from residential, industrial and tourism developments along the coastline and associated rivers.

Specific management models and actions are needed to ensure primary breeding refuges and foraging habitats are protected from inappropriate and ill-informed land-use developments. For example, in Scandinavia and the USA, special land-use regulations give protection to significant raptor breeding sites by the establishment of 1 500 to 3 000-metre buffer zones of undisturbed habitat surrounding nests (Newton 1979; Richardson and Miller 1997). Also, education programs that increase public awareness of the threats to White-bellied Sea-Eagles and the role they play in aquatic ecosystems should result in greater understanding that the Sea-Eagle is not a threat to livestock or recreational fishing.

ACKNOWLEDGEMENTS

Field methods involving live animals were approved annually by the Animal Ethics and Experimentation Committee, CSIRO Tropical Ecosystems Research Centre, Darwin.

We thank Mary Hertog and the Wildman River Rangers for assistance with field surveys at Mary River, and Terry Smith, John Randall and Gordon Milne (CSIRO Darwin) for field assistance at Kapalga. Lorna Melville and Geoff Guard (Northern Territory Department of Primary Industry) conducted autopsies on avian pox-infected Sea-Eagle nestlings. Gerry Van Tets (CSIRO Canberra) identified many prey remains and Adam Liedloff (CSIRO Darwin) drew the maps of the study areas. Penny Olsen, John Woinarski, Stephen Debus, Tom Aumann and Terry Dennis kindly reviewed the draft manuscript.

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