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Diets of White-bellied Sea-Eagles *Haliaeetus leucogaster* and Whistling Kites *Haliastur sphenurus* breeding near Canberra, 2003–2008

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During 2003–2008, in and near the Australian Capital Territory, the diet of breeding White-bellied Sea-Eagles *Haliaeetus leucogaster* consisted of 8 per cent mammals (1% macropod, 1% hare), 42 per cent birds (33% waterbirds), 9 per cent turtles and 40 per cent fish by number (*n* = 78 items from four nests). Breeding Whistling Kites *Haliastur sphenurus* took 45 per cent mammals (26% rabbit), 43 per cent birds (13% waterbirds), 4 per cent lizards and 7 per cent fish (*n* = 136 items from three nests). By biomass, Sea-Eagles took 52 per cent fish; Whistling Kites took 64 per cent mammals, mostly rabbits, with little dietary overlap (Pianka Index 0.12). Despite the almost fivefold difference in these raptor species' respective body mass, the Geometric Mean Prey Weight found for Sea-Eagles was 995 grams, and for Whistling Kites 606 grams (the latter skewed by the high incidence of mammal carrion). Dietary diversity (species richness and evenness: Shannon Index) was higher (3.24) for the Whistling Kite than for the White-bellied Sea-Eagle (2.68).

Eight water bodies in or near the ACT, rated for human disturbance (relative levels of boating, water-skiing, public vehicle access, walking and stock grazing), were surveyed for breeding Sea-Eagles and Whistling Kites during 2002–2010. Low Disturbance areas contained no breeding Whistling Kites or Sea-Eagles, although solitary Sea-Eagles were often present. Medium Disturbance areas contained breeding Sea-Eagles and Whistling Kites; High Disturbance areas contained breeding Whistling Kites, but no breeding Sea-Eagles. Low prey availability, and possible interspecific conflict with Wedge-tailed Eagles *Aquila audax*, may limit Sea-Eagle breeding in Low Disturbance areas.

INTRODUCTION

The diets of the White-bellied Sea-Eagle *Haliaeetus leucogaster* and Wedge-tailed Eagle *Aquila audax*, breeding in contiguous territories over the same period near Canberra, Australian Capital Territory (ACT), were contrasted by Olsen *et al.* (2006a). That study compared the Geometric Mean Prey Weight (GMPW), standardised food niche breadth and Pianka Index (dietary overlap) for the two eagle species, and found that Sea-Eagles prey predominantly on fish, birds and aquatic reptiles. Subsequent studies, conducted in northern inland New South Wales (Debus 2008) and the Northern Territory (Corbett and Hertog 2011, 2012), obtained similar results, and affirm the Sea-Eagle's apparent prey specialisation across a range of freshwater habitats. (We note that, *contra* Corbett and Hertog (2011), prior dietary studies on the Sea-Eagle have been mostly at freshwater locations, not 'mostly marine'.) Similarly, Fuentes *et al.* (2005) quantified the breeding diet of the Whistling Kite *Haliastur sphenurus* at two nests near Canberra in August–September 2003 and calculated the GMPW, but there are few other published studies of the Whistling Kite's breeding-season diet (Debus 1983; Baker-Gabb 1984a,b; Marchant and Higgins 1993; Aumann 2001).

Although the White-bellied Sea-Eagle and Whistling Kite are taxonomically close, both take aquatic prey and scavenge (Marchant and Higgins 1993), their diets have not been compared quantitatively for the same region and time period. Female Sea-Eagles weigh approximately 3.8 kilograms, males approximately 3.2 kilograms (Olsen *et al*. 2006a); female Whistling Kites weigh approximately 907 grams, males approximately 632 grams (Debus 1998), so differences in the size of prey taken could be expected.

This study compares the diet of the two species, in territories in or adjoining the ACT, using new data collected from October 2003 to November 2008, i.e. after those collected for the respective species in 2002–04 and previously reported on (Fuentes *et al.* 2005; Olsen *et al.* 2006a). As breeding White-bellied Sea-Eagles are considered to be adversely affected by human disturbance (e.g. Dennis *et al.* 2011a,b), during 2002–2010 we determined where the two species were breeding on the main water bodies or stretches of river in the study area, and ranked the locations as experiencing high, medium, or low levels of human disturbance.

METHODS

The study area, habitats and field methods were as previously described for related studies around Canberra in the ACT (Fuentes *et al.* 2005, 2007; Olsen *et al.* 2006a,b, 2008, 2010a). Collections of prey remains and pellets from occupied nests and nearby roosts were as follows.

White-bellied Sea-Eagle: seven collections from four nest sites in three territories (six nest-years) August 2004–November 2008, mostly in the breeding season (August–December); one of these collections (in 2004) was made from a collapsed nest.

Whistling Kite: 17 collections over three sites (seven nest-years) October 2003–February 2007, in the breeding season (October–February), with one collection in July.

Methods for identifying prey items, calculating the minimum number of prey individuals, correction factors and their adjusted biomasses, and statistically treating the data, are described elsewhere (Fuentes *et al.* 2005; Olsen *et al.* 2006a, 2010a). The sources of prey weights were as for other papers in this series (Fuentes *et al.* 2005, 2007; Olsen *et al.* 2004, 2006a,b, 2008, 2010a). All the aforementioned study area and methods papers are available from the Institute for Applied Ecology website (www.canberra.edu.au/centres/iae) and the Global Raptor Information Network (www.globalraptors.org).

During 2002–2010, eight water bodies in the study area were surveyed for Sea-Eagle and Whistling Kite breeding activity, and each was ranked in a disturbance category (the following surface areas of reservoirs apply when at capacity). Low Disturbance (no boating, no water-skiing, no public vehicle access other than at the dam wall, little walking, some stock grazing) was assigned to Corin Dam (283 ha), Cotter Dam (47 ha), Bendora Dam (80 ha) and Lower Molonglo River; Medium Disturbance (water-skiing, fishing from motor boats, public vehicle access at several points along the water's edge, stock grazing, some walking) was assigned to Burrinjuck Dam (5500 ha), Googong Dam (680 ha) and Murrumbidgee River west of the ACT; and High Disturbance (considerable walking, considerable vehicle access, unrestricted recreational fishing from the shore) was assigned to an urban lake in Canberra city (Lake Burley Griffin, 66 ha). Many of these water bodies contain populations of introduced European Carp *Cyprinus carpio*, exceptions being Corin, Cotter, Bendora and Googong reservoirs, although these lakes contain native fish and are stocked with introduced trout (M. Lintermans pers. comm.). Except for annual variation in rainfall and hence water levels, other conditions at these water bodies were consistent during the study.

RESULTS

Diet

In pellets and prey remains collected during 2003–08, White-bellied Sea-Eagles took, by number, 8 per cent mammal prey, 42 per cent birds (33% waterbirds), 9 per cent reptiles (all aquatic, i.e. turtles) and 40 per cent fish; 1 per cent consisted of macropod and 1 per cent lagomorph (hare, but no rabbits). Whistling Kites took, by number, 45 per cent mammal prey (26% rabbits, 2% juvenile rabbits), 43 per cent birds (13% waterbirds), four per cent reptiles (all terrestrial) and seven per cent fish (Table 1; see Appendix 1 for scientific names).

By biomass, Sea-Eagles took 52 per cent fish and Whistling Kites took 64 per cent mammals, mostly rabbit (Table 1; Appendix 1), so there was little overlap in diet between the two raptors. This difference was reflected in the low Pianka Index (overlap) of 0.12. The GMPW for Sea-Eagles was 995 grams and for Whistling Kites 606 grams, indicating further niche separation. However, these values did not reflect the difference in mass between the two raptors (Sea-Eagles are close to five times heavier than Whistling Kites, ~3500 g versus ~770 g, when males and females are averaged together).

TABLE 1

Summary table of dietary parameters of White-bellied Sea-Eagles (WBSE) and Whistling Kites (WK) breeding sympatrically in the ACT, 2003–2008 (see Appendix 1 for itemised prey items).

	% *n*		% biomass	
	WBSE (*n* = 78)	WK (*n* = 136)	WBSE	WK
Mammals	8	45	19.5	63.9
Rabbit: adult	0	24	0	38.5
juvenile	0	2	0	1.6
Birds	42	43	23.4	28.4
Reptiles	9	4	4.8	3.1
Fish	40	7	52.1	4.6
Invertebrates	1	<1	0.23	<0.01
GMPW	995.2	605.5		
Shannon Index	2.68	3.24		
Overlap (Pianka Index)	0.12			

Dietary diversity (species richness and evenness), as measured by the Shannon Index, was higher for the Whistling Kite (3.24) than for the White-bellied Sea-Eagle (2.68). Typically, the value of the Shannon Index ranges from 1.5 (low species richness and evenness) to 3.5 (high species evenness and richness) (Marti *et al*. 2007), as reflected in Table 1 and Appendix 1. Sea-Eagles took approximately 28 species while Whistling Kites took approximately 40. For Sea-Eagles, three species predominated by number in the diet: 19 per cent Golden Perch, 18 per cent European Carp and approximately 9 per cent Eastern Snake-necked Turtle. Although Whistling Kites took approximately 25 per cent European Rabbit, the other 39 species in their diet were found in much smaller percentages, hence greater evenness in the Shannon Index.

Disturbance

Results for breeding attempts by White-bellied Sea-Eagles and Whistling Kites on water bodies checked during 2002–2010 were as follows:

Low Disturbance: no breeding Whistling Kites or Sea-Eagles, although solitary Sea-Eagles were present each year.

Medium Disturbance: breeding Sea-Eagles and Whistling Kites each year.

High Disturbance: breeding Whistling Kites each year, but no breeding Sea-Eagles, and only occasional solitary Sea-Eagles (Table 2).

However, there was one failed Sea-Eagle breeding attempt at a Low Disturbance area (the Molonglo/Murrumbidgee junction) in 1995, in a long-established nest normally used by Wedge-tailed Eagles (Debus 2005). Furthermore, all of the Low Disturbance lakes were probably too small (<300 ha) to support sufficient prey for breeding Sea-Eagles, and all of these lacked carp, an abundant introduced species that has inflated

TABLE 2

Breeding by White-bellied Sea-Eagles (WBSE) and Whistling Kites (WK) on water bodies in and near the ACT during 2002–2010, according to human disturbance level: Y = yes, N = no.

Disturbance rating	WBSE	WK
Low (n = 4[a])	N[b]	Y
Medium (n = 3[c])	Y	Y
High (n = 1)	N	Y

[a]Rivers and small (47–283 ha) reservoirs

[b]Solitary eagles only, excepting a failed breeding attempt in 1995

[c]Large reservoirs (680–5500 ha)

the food supply of Sea-Eagles elsewhere in the Murray-Darling Basin (e.g. Marchant and Higgins 1993; Olsen *et al.* 2006a).

DISCUSSION

Diet

Dietary proportions, by number and species, were similar to those found previously for White-bellied Sea-Eagles and Whistling Kites in the same area (see Fuentes *et al.* 2005; Olsen *et al.* 2006a). This study added nine new prey species for the Sea-Eagle in the ACT region, and trebled the previous ACT sample size for the Whistling Kite, adding 22 new food species for the latter in the region. As reported by Olsen *et al.* (2006a), and confirmed in this study, White-bellied Sea-Eagles in the ACT specialise on fish, aquatic reptiles and birds, and take few mammals (i.e. lagomorphs). Similar results were reported from freshwater sites in other regions (Debus 2008; Corbett and Hertog 2011, 2012), and appear to confirm a likely misinterpretation in earlier studies, where rabbit remains may have been incorrectly attributed to Sea-Eagles using vacant Wedge-tailed Eagle nests (Debus 2005).

Previously, Olsen *et al.* (2006a) found that Sea-Eagles in the ACT took 54 per cent fish by biomass, and a GMPW of 887 grams was similar to that (995 g) found in this study. For Whistling Kites, Fuentes *et al.* (2005) reported 57 per cent mammal prey (mostly rabbit) by biomass, which is similar to that reported here (64%, Table 1), but the GMPW of 606 grams found in the present study is higher than that (227 g) found by Fuentes *et al*. (2005), and most likely attributable to the larger sample size in this study. Also, comparative GMPW for the Sea-Eagle and Whistling Kite found in this study does not reflect the fivefold difference in body mass for the two raptors, probably because Whistling Kites relied so heavily on large carrion animals.

Although White-bellied Sea-Eagles and Whistling Kites are taxonomically close, and both are aquatic or marine foragers (the Whistling Kite less strictly so), little overlap in diet was found. In terms of dietary proportions by frequency and biomass, dietary overlap and GMPW, the findings of this study reflect the niche separation found in studies of the White-bellied Sea-Eagle and the similarly sized Wedge-tailed Eagle breeding in sympatry in the ACT (Olsen *et al.* 2006a, 2010a). Therefore, the main ecological difference between the two raptors in this study may rest in the Whistling Kite's much greater reliance on scavenging and the capture of some terrestrial prey, findings that require further investigation.

The lamb and many other mammal prey items from White-bellied Sea-Eagle sites may have been taken as carrion, although some may have been captured (see discussion by Olsen *et al.* 2006a). Among the reptile prey items, turtles were taken by Sea-Eagles but not Whistling Kites, and terrestrial lizards were taken by Whistling Kites but not Sea-Eagles. Fish were taken by both species, probably from the water surface, pirated from other birds, or as carrion. Most of the mammal items found at Whistling Kite nests were probably taken as carrion, although some of the smaller mammals, such as rats, may have been captured. Most of the mammals, some bird species and the terrestrial reptile prey items collected from Whistling Kite and Sea-Eagles nests are commonly observed as road-kill in the ACT region (JO and DJ pers. obs.), which may be a main dietary source of these species. Similarly, many of the larger waterbirds may have been scavenged by Whistling Kites, although they may have captured some of the smaller species, whereas White-bellied Sea-Eagles were likely to have captured the larger waterbirds (Marchant and Higgins 1993; Debus 2008).

The Whistling Kite's GMPW of 606 grams is greater than found for the similar-sized Little Eagle *Hieraaetus morphnoides* in the same region (349 g: Olsen *et al*. 2010a), probably because Whistling Kites ate more adult rabbits as carrion. Both these raptor species had all but disappeared as breeders in the ACT by 2011 (J. Olsen unpubl. data), possibly related to their reliance on rabbits and the rabbit control measures used in the region (Olsen *et al.* 2010b). Such measures have increased in the ACT with increasing rabbit numbers, and Whistling Kites could have taken rabbits poisoned by Pindone (Olsen *et al*. in prep.).

Disturbance

Except for one abortive breeding attempt at the Molonglo-Murrumbidgee river junction (Debus 2005), water bodies relatively free from human disturbance, such as Bendora Dam, Corin Dam and the lower Molonglo River, supported no breeding White-bellied Sea-Eagles. Sea-Eagles may need large water bodies with abundant fish, aquatic birds, turtles and other reptiles, and surface-feeding fish such as carp and redfin, in order to breed (Olsen *et al*. 2006a; Debus 2008; Corbett and Hertog 2011, 2012; Appendix 1, this study). Although no carp are known to occur in Googoong Dam, Sea-Eagles there brought in two carp, possibly taken from local farm dams (Olsen *et al*. 2006a). (*Contra* Corbett and Hertog (2011), Sea-Eagles have never been recorded breeding in the ACT, other than the failed event discussed by Debus (2005); the quoted doubling of breeding density on a 'Canberra lake' refers to a lake outside the ACT, in adjoining NSW.)

The larger and more powerful Wedge-tailed Eagle may inhibit White-bellied Sea-Eagle nest-site selection, interfere with foraging in certain areas, or take over Sea-Eagle nest sites (Olsen *et al*. 2006a; Debus 2005, 2008; Dennis *et al.* 2011b; Hodge and Hodge 2011). In South Australia, studies of White-bellied Sea-Eagles found nest productivity adversely affected by human disturbance (Dennis *et al*. 2011b), and that state's mainland Sea-Eagle population is in decline (Dennis *et al*. 2011a). Conversely, numbers of breeding Wedge-tailed Eagles remain high in some regions (Dennis 2006). In future studies, it will be important to assess the influences of interspecific conflict and competition (for space, nest sites and prey), prey availability and human disturbance (direct and indirect, e.g. habitat modification), and their interactions, as factors affecting White-bellied Sea-Eagle populations in Australia. Furthermore, long-term climatic change needs to be considered as a factor in changing Sea-Eagle populations (Shephard *et al.* 2005).

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APPENDIX 1

Diets of White-bellied Sea-Eagles (WBSE) and Whistling Kites (WK) breeding sympatrically in the ACT, 2003–2008. *New prey species in the ACT for the respective raptor species.

Species	Mass (kg)	*n*		% *n*		Adj. biomass (kg)		% biomass	
		WBSE	WK	WBSE	WK	WBSE	WK	WBSE	WK
Common Ringtail Possum *Pseudocheirus peregrinus*	0.9		1*		<1		0.6		0.97
juv.	0.7	1			1.3	0.47		0.6	
Common Brushtail Possum *Trichosurus vulpecula*	2.875		5		3.7		3.7		6
juv.	1.3	1*			1.3	0.87		1.1	
Eastern Grey Kangaroo *Macropus giganteus*	35		1*		<1		0.74		1.2
juv.	17.2	1*		1.3		3.8		4.81	
Swamp Wallaby *Wallabia bicolor*	2.5		1*		<1		0.74		1.2
juv.									
Black Rat *Rattus rattus*	0.28		6		4.4		1.39		2.26
juv.	0.14		1		<1		0.12		0.19
Rabbit *Oryctolagus cuniculus*	1.5		32		23.5		23.7		38.5
juv.	0.5		3		2.2		1		1.62
Hare *Lepus capensis*	4	1	3	1.3	2.2	2.68	2.22	3.39	3.6
juv.	2		1		<1		0.74		1.2
Lamb *Ovis aries*	15	1*	2	1.3	1.5	3.8	1.48	4.81	2.4
Cow *Bos taurus* bone (sawn human discard)	?		1*		<1				
Fox *Vulpes vulpes*	9	1	3*	1.3	2.2	3.8	2.2	4.81	3.57
cub	3		1		<1		0.74		1.2
TOTAL MAMMALS		**6**	**61**	**7.7**	**44.9**	**15.42**	**39.4**	**19.5**	**63.9**
Black Swan *Cygnus atratus*	5.685		1*		<1		0.74		1.2
Australian Wood Duck *Chenonetta jubata*	0.808	10	2	12.8	1.5	6.46	1.29	8.19	2.1
Australasian Shoveler *Anas rhynchotis*	0.65	1		1.3		0.52		0.66	
Grey Teal *Anas gracilis*	0.504	2	1*	2.6	<1	0.81	0.4	1.02	0.65
Pacific Black Duck *Anas superciliosa*	1.036	6		7.7		4.97		6.3	
Duck sp.	0.75		2		1.5		1.2		1.95
Australasian Grebe *Tachybaptus novaehollandiae*	0.165	1		1.3		0.15		0.18	
Hoary-headed Grebe *Poliocephalus poliocephalus*	0.24		2		1.5		0.42		0.69
juv.	0.2		1		<1		0.18		0.29
Great Crested Grebe *Podiceps cristatus*	1.1	1		1.3		0.88		1.11	
Rock Dove *Columba livia*	0.308		9		6.6		2.22		3.6
Crested Pigeon *Ocyphaps lophotes*	0.205	1*	1*	1.3	<1	0.18	0.18	0.23	0.29
Little Black Cormorant *Phalacrocorax sulcirostris*	0.819	2*	2*	2.6	1.5	1.31	1.31	1.66	2.13
Cormorant sp.	0.732		1		<1		0.59		0.95
Cattle Egret *Ardea ibis*	0.363		2*		1.5		0.58		0.94
Buff-banded Rail *Gallirallus philippensis*	0.18		1		<1		0.16		0.26
Eurasian Coot *Fulica atra*	0.545	2	2*	2.6	1.5	0.87	0.87	1.1	1.42
Whiskered Tern *Chlidonias hybrida*	0.084		1*		1		0.07		0.12
Galah *Eolophus roseicapillus*	0.335	1	5	1.3	3.7	0.27	1.34	0.34	2.17
Sulphur-crested Cockatoo *Cacatua galerita*	0.804		3		2.2		1.93		3.13
Crimson Rosella *Platycercus elegans*	0.135	1*	3*	1.3	2.2	0.12	0.36	0.15	0.58
Eastern Rosella *Platycercus eximius*	0.106	1*	1*	1.3	<1	0.09	0.09	0.12	0.15
Laughing Kookaburra *Dacelo novaeguineae*	0.345	1	3*	1.3	2.2	0.28	0.83	0.35	1.34
Red Wattlebird *Anthochaera carunculata*	0.108		1*		<1		0.1		0.15
Australian Magpie *Cracticus tibicen*	0.329	1*	6	1.3	4.4	0.26	1.58	0.33	2.56
Pied Currawong *Strepera graculina*	0.27	1		1.3		0.24		0.3	
Raven *Corvus* sp.	0.593		1*		<1		0.47		0.77
Magpie-lark *Grallina cyanoleuca*	0.09		3*		2.2		0.24		0.39
Common Starling *Sturnus vulgaris*	0.075		2*		1.5		0.13		0.21
Bird	0.075		3		2.2		0.2		0.32
TOTAL BIRDS		**33**	**59**	**42.3**	**43.4**	**18.45**	**17.5**	**23.4**	**28.4**

APPENDIX 1 (Cont.)

Species	Mass (kg)	*n*		% *n*		Adj. biomass (kg)		% biomass	
		WBSE	WK	WBSE	WK	WBSE	WK	WBSE	WK
Common Bluetongue *Tiliqua scincoides*	0.4		6		4.4		1.92		3.12
Eastern Snake-necked Turtle *Chelodina longicollis*	0.677	7		9		3.79		4.8	
TOTAL REPTILES		**7**	**6**	**9**	**4.4**	**3.79**	**1.92**	**4.8**	**3.12**
Golden Perch *Macquaria ambigua*	1	15		19.2		12		15.2	
Goldfish *Carassius auratus*	0.33		1*		<1		0.26		0.42
European Carp *Cyprinus carpio*	2.5	14		17.9		28		35.5	
small	0.4		2*		1.5		0.53		0.9
Redfin *Perca fluviatilis*	0.3		4		2.9		1.06		1.72
Fish sp.	0.7	2		2.6		1.12		1.42	
small	0.55		2		1.5		0.88		1.43
TOTAL FISH		**31**	**9**	**39.7**	**6.6**	**41.12**	**2.84**	**52.1**	**4.61**
Crayfish	0.2	1		1.3		0.18		0.23	
Locust	0.002		1*		<1		<0.1		<0.1
TOTAL INVERTEBRATES		**1**	**1**	**1.3**	**<1**	**0.18**	**<0.1**	**0.23**	**<0.1**
TOTAL		**78**	**136**	**100**	**100**	**79**	**61.6**	**100**	**100**