

Breeding diets of four raptor species in the Australian tropics

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The breeding diets of four diurnal raptor species were studied, by analysis of pellets, prey remains, stomach flushes of trapped birds and feeding observations, in the Top End of the Northern Territory and in the Kimberley region (northern Western Australia) in 1988–89. These were the Black-breasted Buzzard *Hamirostra melanosternon*, Brown Goshawk *Accipiter fasciatus*, Little Eagle *Hieraaetus morphnoides* and Australian Hobby *Falco longipennis*. The Buzzard and Brown Goshawk were vertebrate generalists (mammals, birds and reptiles), the former also taking birds' eggs, and the latter also taking many invertebrates. The Little Eagle took mostly birds, with few reptiles and even fewer mammals. The Hobby took small birds and flying insects. This study complements another, concurrent study of the raptor community in the Top End, by characterising the feeding niches of an additional four diurnal species out of the ten now studied in some detail. The remaining 14 species (of the 24 that make up the diurnal raptor assemblage in northern mainland Australia) require further attention in the tropics.

INTRODUCTION

The diets of many raptor species in the Australian tropics are poorly known, although Corbett *et al.* (2014) provided comprehensive dietary samples for four diurnal species and reviewed prior studies on two others in the Top End of the Northern Territory (NT). Aumann and Baker-Gabb (1991) and Marchant and Higgins (1993) provided a summary of the diets of four additional raptor species in the Top End and the Kimberley region (northern Western Australia (WA)): the Black-breasted Buzzard *Hamirostra melanosternon*, Brown Goshawk *Accipiter fasciatus*, Little Eagle *Hieraaetus morphnoides* and Australian Hobby *Falco longipennis*. Here we provide the data supporting those summaries (which gave only percentages of each prey class), as foreshadowed by Aumann and Baker-Gabb (1991, p. 46). The context of those prey collections is given elsewhere (Aumann 1991; Aumann and Baker-Gabb 1991), i.e. an ecological study of the Red Goshawk *Erythrotriorchis radiatus*, and a survey of the other raptor species and aspects of their biology, in the Top End in 1988–89 and the Kimberley region in 1989.

The four subject species in this paper were identified as potential competitors of the Red Goshawk for avian prey. Fortuitously, these raptor species are the same four for which Corbett *et al.* (2014) obtained few dietary samples, during their study concurrent with ours. Further, we here correct an error in the previously published dietary table and summary statistics for the Little Eagle in the tropics (Table 5 of Aumann and Baker-Gabb (1991), p. 23, and text of Marchant and Higgins (1993), p. 183).

METHODS

The study locations are described elsewhere, i.e. near-coastal open eucalypt forest and subcoastal riparian gallery forest and flanking woodland in and near Kakadu National Park in the Top

End, and riparian gallery forest and woodland on the middle and upper reaches of Kimberley rivers (Aumann 1991; Aumann and Baker-Gabb 1991; Debus *et al.* 2015). Collections of dietary samples were obtained as follows, with prey individuals in each sample identified, counted and quantified (by number) according to the methods of Aumann (2001). For all four raptor species, the number of vertebrate items identified only to order or family level, and the nature of their remains or pellets (e.g. size/age of larger items, whether live kill or carrion, fur or feathers only), precluded accurate estimates of prey biomass.

Black-breasted Buzzard

Pellets and orfts (prey remains) were collected from beneath six active nests (four in the NT and two in WA), and there were two observations of individuals feeding, both in the Kimberley. Information for the Top End was obtained in 1988 and 1989, for the Kimberley in 1989. Pellets = 38 (85 prey items); orfts = 20 (20 prey items); feeding observations = two prey items.

Brown Goshawk

Pellets and orfts were collected from beneath two active nests (one in the NT and one in WA, in 1989), and stomach flushes (all from the NT in 1989; e.g. see Marti *et al.* (2007) on the method) occurred for 12 captured individuals (discounting stomach flushes of two other captured individuals that yielded only plant material). Pellets = 10 (18 prey items); orfts = seven (seven prey items); stomach flushes = 21 prey items.

Little Eagle

Pellets and orfts were collected from beneath three active nests (one in the NT and two in WA), and stomach flushes occurred for two captured individuals (NT). All information was collected in 1989. Pellets = one (two prey items); orfts = 46 (46 prey items); stomach flushes = four prey items.

Table 1

Summary of breeding diets (% *n* of prey classes) of four raptor species in the Top End (NT) and Kimberley (WA), 1988–1989; *n* = prey items in parentheses. Note correction of percentages for Little Eagle concerning reptiles and fish (cf. Table 5 of Aumann and Baker-Gabb 1991, p. 23, and Marchant and Higgins 1993, p. 183).

Prey class	Black-breasted Buzzard (107)	Brown Goshawk (46)	Little Eagle (52)	Australian Hobby (56)
Mammals	16.8	28.3	5.8	0
Birds	38.3	19.6	76.9	53.6
Birds' eggs	11.2	0	0	0
Reptiles	27.1	19.6	11.5	0
Fish	0	0	3.8	0
Invertebrates	6.5	32.6	1.9	46.4

Australian Hobby

Pellets and orsts were collected from beneath four active nests (two in the NT and two in WA), and there were two observed captures of food items (both in WA). Information for the Top End was obtained in 1988 and 1989, for the Kimberley in 1989. Pellets = 20 (38 prey items); orsts = 16 (16 prey items); observed prey captures = two prey items.

RESULTS

Although taking a range of vertebrate prey classes, the Black-breasted Buzzard and Little Eagle were primarily bird-eaters, whereas the Brown Goshawk took mostly mammals, and as many reptiles as birds (Table 1; Appendices 1–3, which give scientific names of prey). Brown Goshawks also took many invertebrates (mostly beetles and orthopterans), although this result may have been biased by the number of stomach flushes for this species. Some invertebrates could also have been the stomach contents of Goshawk prey items. Vertebrates would have greatly predominated by biomass in the Goshawk's diet (mammals and birds up to >100 g in size, vs invertebrates ~1 g each).

The Black-breasted Buzzard also took many mammals and reptiles, and was the only species to take birds' eggs. Large mammals (pig, cattle and goat) were presumably obtained as carrion. Some of the other mammals (quoll, bandicoot) may have been road kill, given that they are largely nocturnal (e.g. Van Dyck and Strahan 2008), which therefore need not imply foraging in low-light conditions by Buzzards. Invertebrates (beetles and grasshoppers, ~1 g each) were trivial by number and especially by biomass in the Buzzard's dietary sample. For the Buzzard and/or Brown Goshawk, 'unidentified Gruiformes' (Appendices 1 and 2) could have included Turnicidae (button-quail *Turnix* sp.), classified in the order Gruiformes at the time of the dietary analysis.

The Little Eagle took mostly birds, and some reptiles. The freshwater turtles taken may have been on land, at the water's edge (e.g. basking) or robbed from Whistling Kites *Haliastur sphenurus* (or scavenged from the latter's prey discards), and the few fish may have been taken from the water surface or robbed from kites. From the dietary profile (Appendix 3), birds would have contributed most by biomass. Some large items (e.g. Bustard; Sulphur-crested Cockatoo, albeit the small northern subspecies), and the macropod, were possibly obtained as carrion.

The Australian Hobby was primarily a bird-eater, but took almost as many invertebrates as birds. Birds (up to ~50 g in size) would have contributed the bulk of prey biomass compared with invertebrates (mainly beetles, winged hymenopterans and dragonflies, ~1 g each). The 'unidentified Galliformes' (Appendix 4) was presumably a quail (Phasianidae).

DISCUSSION

The results for the subject raptor species of our study (Appendices 1–4) complement the data set of Corbett *et al.* (2014) for four diurnal raptor species. Our data greatly extend their samples, and confirm their findings, for the Black-breasted Buzzard, Brown Goshawk, Little Eagle and Australian Hobby. Among the raptor community in the Top End, as discussed by Corbett *et al.*, the Buzzard and Brown Goshawk can be categorised as generalists focussed on three or four main prey categories (mammals, birds and reptiles), with the former also robbing birds' nests for eggs, and the latter also taking many invertebrates. The Little Eagle and Hobby are more specialised, the former mostly taking birds, with a few items from the other vertebrate categories, and the latter taking many aerial insects as well as birds.

All four species overlap with the Red Goshawk in avian prey species, although the Hobby, and apparently the Brown Goshawk, take smaller birds than does the Red Goshawk (see Aumann and Baker-Gabb (1991) and Marchant and Higgins (1993) for the Red Goshawk; also Johnstone and Storr (1998)). Johnstone and Storr (1998) gave a comprehensive prey list (and other biological data) for the Red Goshawk in the Top End, summarised from a study by T. Van Der Zwan that has, regrettably, remained unpublished. Johnstone and Storr (1998) also gave anecdotal prey records for several raptor species in the Kimberley (and elsewhere in WA).

The diet of the Black-breasted Buzzard in the Top End and Kimberley is broadly similar to that in the arid zone, although a much larger dietary sample detected many more invertebrates as prey in the arid zone (see Marchant and Higgins 1993; Aumann 2001; Nunn and Pavey 2014).

The diet of the Brown Goshawk in the tropics is similar to that determined by other studies, including in the Kimberley (see Aumann 1990; Burton and Olsen 1997a,b; Johnstone and

Storr 1998; Riddell 2011a), though with regional variation in the proportions of birds and reptiles. For instance, a study in urban Darwin in 2013–14 recorded more birds (20) than mammals (four) or reptiles (14, $n = 38$; Riddell 2015). Diet is also similar to that of the Brown Goshawk in arid and southern Australia, although the small tropical subspecies *A. f. didimus* appears to take smaller prey than does the large nominate subspecies (see Marchant and Higgins 1993; Aumann 2001).

The diet of the Little Eagle in the tropics, as suspected where there are few Rabbits *Oryctolagus cuniculus* or other suitably sized mammals (as also in the dry subtropics: Fisher 2010), consists largely of birds, whereas in the arid and southern zones it consists largely of reptiles or mammals, respectively (e.g. Aumann 2001; Olsen *et al.* 2013 and studies cited therein). Anecdotal and circumstantial evidence suggests that in tropical forests and woodlands, Little Eagles in soaring flight capture birds by a dive attack to the tree or tall shrub canopy (Garstone 1986; Debus and Searle 2014): a subject for further study.

The diet of the Australian Hobby in the tropics consists of small birds and flying insects (and micro-bats: Corbett *et al.* 2014), as elsewhere in Australia, as revealed by the surprisingly few studies conducted on this species, given its widespread distribution and abundance even in urban and rural areas (see Marchant and Higgins 1993; Aumann 2001; Olsen *et al.* 2006, 2008).

The diets of almost half of the diurnal raptors regularly occurring in the Top End (10 out of 24 species: Corbett *et al.* 2014) have now been described from substantial sample sizes of data, such that many species can now be characterised in terms of their feeding niches within the tropical raptor community. Significant knowledge gaps still exist for the remainder, notably the biology and ecology in the tropics of, for example: the Pacific Baza *Aviceda subcristata* (although a study in the subtropics is in progress by K.D. Fisher and F. Hill, in prep.); the Square-tailed Kite *Lophoictinia isura* (still unconfirmed whether it breeds in the Kimberley, Top End or Cape York Peninsula); the Brahminy Kite *Haliastur indus* (see Riddell 2013a); the Grey Goshawk *Accipiter novaehollandiae* in the monsoonal tropics (although studies by Riddell (2011b, 2013b) are a significant start); the Collared Sparrowhawk *A. cirrocephalus* in e.g. urban Darwin (though briefly studied in the subtropics by Barnes and Debus (2014)); and the Grey Falcon *Falco hypoleucos* breeding in the Kimberley (previous studies having addressed the arid zone, e.g. see Janse *et al.* (2015) for a review). Most of these are endemics or near-endemics worthy of further attention in the tropics and elsewhere.

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Appendix 1

Diet of the Black-breasted Buzzard in the Top End of the Northern Territory, 1988–89, and Kimberley region of WA, 1989, by number.

	Prey species	Total	
Mammals:	Northern Quoll <i>Dasyurus hallucatus</i>	3	
	Red-cheeked Dunnart <i>Sminthopsis virginiae</i>	2	
	Northern Brown Bandicoot <i>Isodon macrourus</i>	7	
	Rat <i>Rattus</i> sp.	1	
	Feral Pig <i>Sus scrofa</i>	1	
	European Cattle <i>Bos taurus</i>	1	
	Feral Goat <i>Capra hircus</i>	1	
	Unidentified	2	
	Subtotal	18	
	Birds:	Plumed Whistling-Duck <i>Dendrocygna eytoni</i>	1
		Australian Owlet-nightjar <i>Aegotheles cristatus</i>	1
Hawk <i>Accipiter</i> sp.		1	
Unidentified Gruiformes		1	
Galah <i>Eolophus roseicapillus</i>		1	
Rainbow Lorikeet <i>Trichoglossus haematodus</i>		18	
Red-winged Parrot <i>Aprosmictus erythropterus</i>		1	
Unidentified Psittaciformes		4	
Unidentified Cuculiformes		1	
Forest Kingfisher <i>Todiramphus macleayi</i>		1	
Unidentified Passeriformes		2	
Unidentified birds		9	
Subtotal		41	
Reptiles:	Frilled Lizard <i>Chlamydosaurus kingii</i>	1	
	Unidentified dragon (Agamidae)	6	
	Skink <i>Carlia</i> sp.	1	
	Bluetongue <i>Tiliqua</i> sp.	1	
	Unidentified skink (Scincidae)	18	
	Unidentified monitor (Varanidae)	2	
Subtotal	29		
Insects:	Unidentified Scarabaeidae	1	
	Unidentified Tenebrionidae	1	
	Unidentified Coleoptera	3	
	Unidentified Orthoptera	2	
	Subtotal	7	
	Eggs of birds	12	
TOTAL	107		

Appendix 2

Diet of the Brown Goshawk in the Top End of the Northern Territory, 1988–89, and Kimberley region of WA, 1989, by number.

	Prey species	Total
Mammals:	Sugar Glider <i>Petaurus breviceps</i>	6
	Rat <i>Rattus</i> sp.	6
	Unidentified	1
	Subtotal	13
Birds:	Unidentified Gruiformes	1
	Rainbow Lorikeet <i>Trichoglossus haematodus</i>	1
	Unidentified Passeriformes	2
	Unidentified birds	5
	Subtotal	9
Reptiles:	Unidentified dragon (Agamidae)	1
	Unidentified skink (Scincidae)	7
	Unidentified lizard (Sauria)	1
Subtotal	9	
Spiders:	Unidentified Araneae	1
Insects:	Unidentified Scarabaeidae	2
	Unidentified Tenebrionidae	1
	Unidentified Coleoptera	3
	Unidentified Hymenoptera	3
	Unidentified	5
	Subtotal	14
TOTAL	46	

Appendix 3

Diet of the Little Eagle in the Top End of the Northern Territory and Kimberley region of WA, 1989, by number.

	Prey species	Total
Mammals:	Unidentified Macropodidae	1
	Unidentified	2
Subtotal	3	
Birds:	Tawny Frogmouth <i>Podargus strigoides</i>	1
	Australian Bustard <i>Ardeotis australis</i>	2
	Sulphur-crested Cockatoo <i>Cacatua galerita</i>	1
	Rainbow Lorikeet <i>Trichoglossus haematodus</i>	2
	Northern Rosella <i>Platycercus venustus</i>	2
	Unidentified Psittaciformes	1
	Blue-winged Kookaburra <i>Dacelo leachii</i>	6
	Sacred Kingfisher <i>Todiramphus sanctus</i>	3
	Black-faced Cuckoo-shrike <i>Coracina novaehollandiae</i>	4
	White-bellied Cuckoo-shrike <i>Coracina papuensis</i>	1
	Rufous Whistler <i>Pachycephala rufiventris</i>	1
	Torresian Crow <i>Corvus orru</i>	2
	Unidentified Corvidae	3
	Maggie-lark <i>Grallina cyanoleuca</i>	1
Unidentified birds	10	
Subtotal	40	
Reptiles:	Skink <i>Ctenotus</i> sp.	1
	Bluetongue <i>Tiliqua</i> sp.	1
	Unidentified skink (Scincidae)	1
	Unidentified monitor (Varanidae)	1
	Red-faced Turtle <i>Emydura victoriae</i>	1
Northern Snake-necked Turtle <i>Macrochelodina rugosa</i>	1	
Subtotal	6	
Fish:	Unidentified	2
Insects:	Unidentified	1
TOTAL	52	

Appendix 4

Diet of the Australian Hobby in the Top End of the Northern Territory, 1988–89, and Kimberley region of WA, 1989, by number.

	Prey species	Total
Birds:	Unidentified Galliformes	1
	Peaceful Dove <i>Geopelia striata</i>	1
	Unidentified Columbiformes	4
	Varied Lorikeet <i>Psitteteles versicolor</i>	3
	Horsfield's Bronze-Cuckoo <i>Chalcites basalis</i>	1
	Unidentified Cuculiformes	1
	Sacred Kingfisher <i>Todiramphus sanctus</i>	2
	Unidentified Coraciiformes	3
	Little Woodswallow <i>Artamus minor</i>	2
	Unidentified Passeriformes	6
	Unidentified birds	6
	Subtotal	30
	Arachnids:	Scorpionidae <i>Urodacus</i> sp.?
Insects:	Unidentified Elateridae	1
	Unidentified Scarabaeidae	2
Coleoptera	Unidentified Tenebrionidae	7
	Unidentified Curculionidae	3
	Unidentified Coleoptera	2
Insects:	Unidentified Halictidae	1
	Hymenoptera	Unidentified Colletidae
Insects:	Unidentified Apoidae	2
	Unidentified Sphecidae	1
	Formicidae <i>Polyractus</i> sp.	2
Insects: Hemiptera	Unidentified Cicadidae	1
Insects: Odonata	Unidentified	2
Subtotal	25	
TOTAL	56	