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Impact of feral Water Buffalo *Bubalus bubalis* grazing on White-bellied Sea-Eagle *Haliaeetus leucogaster* breeding success in subtropical river habitat in the Northern Territory, Australia

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Diet and breeding success of White-bellied Sea-Eagles *Haliaeetus leucogaster* in Kakadu National Park were compared between years with (1980–85) and without (1992–94) high densities of feral Water Buffalo *Bubalus bubalis*. Overall, prey comprised turtles (39.8%), fish (26.5%), birds (28.3%), mammals (4.4%) and snakes (0.9%) and there was no significant difference in diet between years with and without Buffalo. However, significantly more Sea-Eagle pairs attempted to breed (100%) and fledge young (83%) in years without Buffalo than in years with Buffalo when 63 percent of Sea-Eagle pairs attempted breeding of which 46 percent were successful. The increased breeding success was likely due to increased hunting success during the dry season when Sea-Eagles breed. Following Buffalo removal and the subsequent vegetative covering of water-bodies, Sea-Eagles were able to reach striking distance before detection by prey. The results of this study will be useful for wildlife managers in the Top End where Buffalo are feral or are farmed.

INTRODUCTION

Water Buffalo *Bubalus bubalis* were introduced into the Northern Territory of Australia from South-east Asia in the mid 19th Century and soon became feral when the British coastal settlements were abandoned (Letts 1962). A century later, Water Buffalo populations peaked (mean 5.6 buffalo/km² in Kakadu National Park) following the collapse of the hide industry and the ensuing reduction in harvesting. Local densities in the Alligator Rivers region were up to 34 buffalo per square kilometre (Ridpath *et al.* 1983). In the 1980s numbers were reduced to less than 0.1 buffalo per square kilometre as a result of an intensive effort to eradicate bovine tuberculosis of which feral Water Buffalo and feral cattle are hosts (Ridpath and Waithman 1988; Freeland and Boulton 1990).

At high densities, Water Buffalo had severe environmental impacts on coastal rivers and swamps from trampling, wallowing, grazing and contamination by their faeces and urine and most water-bodies, including the West Alligator River in Kakadu National Park, were devoid of surface vegetation (Skeat *et al.* 1996). However, 2–3 years after Water Buffalo were effectively eradicated the aquatic vegetation returned and covered the surface of most water-bodies in the dry season when White-bellied Sea-Eagles *Haliaeetus leucogaster* breed in the Northern Territory (Corbett and Hertog 2011).

This long-term study contrasts the diet and breeding success of White-bellied Sea-Eagles on the West Alligator River between years of high (1980–85) and low (1992–94) densities of Water Buffalo.

METHODS

Study site

The West Alligator River study site has approximate coordinates 12°27'S to 12°43'S and 132°19'E. It is about 170 kilometres east of Darwin and situated within Kakadu National Park. The climate is hot all year and similar to Jabiru, the nearest weather station about 50 kilometres east of the study site. 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 1287 millimetres with 93 percent of the rain falling between November and March, which is outside the White-bellied Sea-Eagle breeding season (May – October: Corbett and Hertog 2011).

All White-bellied Sea-Eagle nests sampled were within a 35-kilometre stretch of the West Alligator River where the major habitats are dense paperbark forest (*Melaleuca* spp.) and open forest/woodlands (*Eucalyptus* and other spp.). During the Sea-Eagles' breeding season the West Alligator River reduces to a series of isolated and shallow waterholes, and all nests were located within 50 metres of a waterhole.

Assessing diet

Assessment of the diet of the White-bellied Sea-Eagle was mainly based on prey remains (including those recovered from pellets) which were either collected from nests, under the nest tree or from under nearby roosting/feeding trees. Other prey types were identified from observations of prey captured by adults. Samples were collected and labeled in the field and later identified to species level, where possible, 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

Surveys were conducted in June to August to detect nesting activity and record clutch size. Subsequent surveys in September and October were conducted to confirm clutch size and to record nestling survival 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 White-bellied Sea-Eagles, Wedge-tailed Eagles *Aquila audax* and Torresian Crows *Corvus orru*; and/or a nest or nest-building activity was observed; and/or one member of the pair had a brood patch.

White-bellied 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 inspected by climbing to nests with the aid of a rope ladder or by using a 10-metre extension ladder and a swivel-head mirror fitted to an 8-metre extendable pole.

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) or successful (one or two young fledged).

Although eight White-bellied Sea-Eagle territories were detected along the West Alligator River study site, we were able to confidently assess breeding success for four territories, each at the same location, over each of the nine study years.

Statistical methods and nomenclature

Many data presented are summarised as mean ± standard deviation. Differences in White-bellied Sea-Eagle breeding attempts and breeding success between years when Water Buffalo were present or not present were tested using the Wilcoxon Rank Sum Test with significance at $P \leq 0.05$. Nomenclature is based on Clayton *et al.* 2006.

RESULTS

Diet

A total of 113 prey items was recorded at nests and feeding trees of eight White-bellied Sea-Eagle territories, comprising reptiles (40.7%, mostly Northern Long-necked Turtles *Macrochelodina rugosa* 39.8%); birds (28.3% including Magpie Geese *Anseranas semipalmata* 18.6%, Egrets Ardeidae 2.7%, Little Corellas *Cacatua sanguinea* 2.7% and Australasian Darters *Anhinga novaehollandiae* 0.9%); fish (26.5% including Barramundi *Lates calcarifer* 11.5%, Catfish undetermined spp. 7.1%, Freshwater Long Tom *Strongylura krefftii* 2.7% and Bony Herring *Nematalosa erebi* 0.9%); and mammals (4.4% mostly Flying-foxes *Pteropus* sp. 3.5%).

There was no significant difference in major diet items between years when Water Buffalo were present and years when Water Buffalo were absent (Table 1).

Table 1

Occurrences of prey remains found in and under eight White-bellied Sea-Eagle nests in years with and without Water Buffalo.

Prey	with Buffalo (1982-85)		without Buffalo (1992-94)	
	n	%	*n*	%
Turtles	31	39.7	14	40.0
Fish	22	28.2	8	22.9
Birds	19	24.4	13	37.1
Mammals	5	6.4	0	
Snakes	1	1.3	0	

Breeding attempts and breeding success

Breeding data in each of the nine study years were obtained at four White-bellied Sea-Eagle territories. All four pairs attempted to breed in each year sampled when Water Buffalo were not present compared to 63 percent of pairs in years when Water Buffalo were present ($U=1.5$, $P<0.05$); Table 2). Similarly, significantly more Sea-Eagle territories fledged chicks (83%) in years when Water Buffalo were not present compared to 46 percent of territories in years when Water Buffalo were present ($U=1.0$, $P<0.05$; Table 2).

DISCUSSION

Habitat disturbance by Water Buffalo had no significant impact on the major prey types taken by White-bellied Sea-Eagles at the West Alligator River. The diet of this population was similar to that elsewhere in Kakadu National Park over similar years 1980–86 (turtles 33.8%, fish 28.1%, birds 23.9%, snakes 6.0% and mammals 2.6%; Corbett and Hertog 2011).

However, Water Buffalo activities clearly had detrimental impacts on breeding attempts and breeding success of Sea-Eagles, and this was likely due to buffalo-induced changes to aquatic hunting areas and consequent low hunting success. At

Table 2

Territories where White-bellied Sea-Eagles attempted to breed in years with and without Water Buffalo (*one or **two young fledged)

Territory	with Buffalo						without Buffalo		
	1980	1981	1982	1983	1984	1985	1992	1993	1994
Flying Fox Creek	●	●*	●		●*	●*	●*	●	●
Tims Hole	●		●**				●	●*	●**
Red Lily South	●*			●	●*		●*	●**	●*
Gayden Springs	●	●*		●*	●*	●*	●*	●*	●

high Water Buffalo densities there was no surface vegetation on water-bodies in the 'dry season' and aquatic prey apparently could more easily detect approaching Sea-Eagles and take avoidance behaviour. This advantage was apparently lost following Water Buffalo removal and the subsequent vegetative covering of water-bodies, allowing Sea-Eagles to approach within striking distance before detection by prey. Consequently, the more accessible food supply enabled all Sea-Eagle pairs to attempt breeding and almost twice as many to successfully fledge young.

The impacts of feral Water Buffalo grazing, trampling, wallowing and pollution on vegetation, soils, water quality and biota in Kakadu National Park have been previously described (Stocker 1970; Hill and Webb 1982; Braithwaite *et al.* 1984; Taylor and Friend 1984; Considine 1985; Skeat *et al.*1996; Bradshaw *et al.* 2007). Impacts on other native fauna are summarised below.

The removal of vegetative cover in the South Alligator River flood-plains caused significant population declines in small vertebrates from reduced food availability, and/or increased predation by all local predator species: Dusky Rats *Rattus colletti*, Northern Brown Bandicoot *Isoodon macrourus*, Grassland Melomys *Melomys burtoni*, Common Planigale *Planigale maculata*, Slaty-grey Snake *Stegonotus cucullatus*, Keelback Snake *Styporhynchus mairii*, Spotted Tree Monitor *Varanus scalaris*, the skink *Sphenomorphus douglasi*, and frogs *Cyclorana australis*, *Litoria dahlia*, *L. nasuta* (Friend and Taylor 1984; Friend *et al.* 1988; Skeat *et al.*1996).

Declines in Northern Territory Magpie Goose populations in 1950–72 were largely attributed to loss of swamp vegetation and soil compaction due to Water Buffalo trampling (Frith and Davies 1961; Tulloch and McKean 1983). Magpie Geese had difficulty in digging for their staple dry season food (*Eleocharis* corms) with consequent increases in starvation and vulnerability to predators. A later experimental study (1980–88: Corbett *et al*. 1996) in the South Alligator River flood-plains showed that Water Buffalo trampling, grazing and wallowing influenced the location of Magpie Goose nests. After Water Buffalo were removed, significantly more nests were built in deep water areas at the forest edge of the flood-plains.

Recruitment to Pig-nosed Turtles *Carettochelys insculpta* populations in the South Alligator River flood-plains was greatly diminished in 1988 because of trampling of nests and habitat destruction in billabongs (Georges and Kennett 1989).

Bradshaw *et al.* (2007) suggested that feral Water Buffalo, Pigs *Sus scrofa* and Horses *Equus caballus* are the most ecologically threatening species in Kakadu National Park and that management responses to impacts were largely *ad hoc* and poorly evaluated. They argued that improved Park management requires, *inter alia*, research findings to stimulate the development of cost-effective control and monitoring programs. We hope this paper contributes to that end.

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