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Diet of 25 sympatric raptors at Kapalga, Northern Territory, Australia 1979–89, with data on prey availability

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This study describes prey availability and the diet of 25 sympatric diurnal and nocturnal raptors over 11 years 1979–89 in tropical Australia, at Kapalga in Kakadu National Park. Rainfall is seasonal: most falls from January to early March, resulting in pronounced annual wet and dry seasons. The major habitats include tidal rivers, seasonally inundated floodplains, upland open forests and woodlands, seasonal and permanent streams, and billabongs. About 365 vertebrate species have been recorded at Kapalga including Magpie Geese *Anseranas semipalmata* and many other waterfowl, Dusky Rats *Rattus colletti* and other small mammals, aquatic reptiles, frogs and invertebrates on the floodplains of the two tidal rivers. Sixteen raptor species were recorded breeding at Kapalga and another ten species were recorded breeding elsewhere in the Top End of the Northern Territory. Whistling Kites *Haliastur sphenurus*, the most numerous raptor at Kapalga, mostly breed on the edge of the floodplains, with nest densities up to seven nests per square kilometre. Magpie Geese were a major prey for many raptors, and adult populations up to 70 000 were available annually, as well as eggs (up to ¼ million) and flightless young during their late wet-early dry season breeding period. Dusky Rats were also a major prey species and their populations fluctuated between highs (up to ½ million) and lows on a 2-year cycle. Other prey including small mammals, snakes, frogs and insects greatly increased in numbers in response to increased dry-season vegetation on the floodplains after Swamp Buffalo *Bubalus bubalis* were removed about midway through this 11-year study.

Raptor dietary records were based mainly on pellets and prey remains collected at roosts, nests and feeding sites; and also on observations of prey hunted and captured by adult raptors. In total, prey identified comprised at least 49 bird species, 18 mammals, nine reptiles, eight fish, seven invertebrates and one frog. For the ten well-studied raptor species (≥20 diet samples), the major prey types of the Whistling Kite, Black Kite *Milvus migrans* and Black Falcon *Falco subniger* were mammals and birds; mammals and invertebrates for the Barking Owl *Ninox connivens*; mammals for the Rufous Owl *Ninox rufa*, Eastern Barn Owl *Tyto javanica* and Eastern Grass Owl *T. longimembris*; birds for the Red Goshawk *Erythrotriorchis radiatus*; and reptiles for the White-bellied Sea-Eagle *Haliaeetus leucogaster* and Brown Falcon *Falco berigora*. These diets were generally similar to those reported for these species elsewhere in Australia, although the Black Falcon took more rats than birds at Kapalga, and the Barn Owl and Grass Owl had a narrower food niche (rats only) than elsewhere.

INTRODUCTION

The tropical Top End of Australia has largely undisturbed habitats and consequently stable populations of raptors and other native fauna, but the raptor assemblage has been little studied compared to raptor assemblages elsewhere in Australia. At the start of this study 35 years ago, there was virtually no development adjacent to the Arnhem Highway from Darwin to Kakadu National Park, a distance of about 150 kilometres. Since then, about half of the native forests and woodlands have been cleared along this route for commercial crops and tourism, and this habitat alteration continues unabated.

Australian history clearly indicates that large-scale removal of natural habitat can and does have devastating negative impacts on the populations of many native species. For example, White-bellied Sea-Eagles *Haliaeetus leucogaster* are common along the coastal wetlands and adjacent forests of the Top End (Corbett and Hertog 2011), but in the densely settled and habitat-modified regions of south-eastern Australia their populations have declined, mainly owing to loss or alteration of their feeding and breeding habitats (Dennis *et al.* 2011a,b). Similarly, decreases in prey diversity and abundance of many raptors caused by exotic species have also occurred since this study was completed. Examples include Cane Toads *Bufo marinus* that were first recorded in Kakadu National Park in March 2001 (Molloy and Henderson 2006; Kearney *et al.* 2008), Yellow Crazy Ants *Anoplolepis gracilipes* first recorded in Arnhem Land in the late 1970s, and African Big-headed Ants *Pheidole megacephala* first recorded in Kakadu National Park in the late 1990s (Hoffmann and O'Connor 2004).

This study provides basic information on diet and prey availability for 25 diurnal and nocturnal raptor species in the Top End of the Northern Territory that will assist wildlife managers to protect raptor breeding habitats and foraging grounds, and also assist developers planning coastal residential and industrial infrastructures in northern Australia. A major contribution of this study is the large dietary data sets for several raptor species previously unstudied in the Australian tropics: Black Kite *Milvus migrans*, Whistling Kite *Haliastur sphenurus*, Brown Falcon *Falco berigora*, Black Falcon *F. subniger*, Barking Owl *Ninox connivens*, Eastern Barn Owl *Tyto javanica* and Eastern Grass Owl *T. longimembris*. Also of note is a breeding population of the Black Falcon in the Top End, and a further Top End dietary data set for the little-studied Rufous Owl *Ninox rufa*.

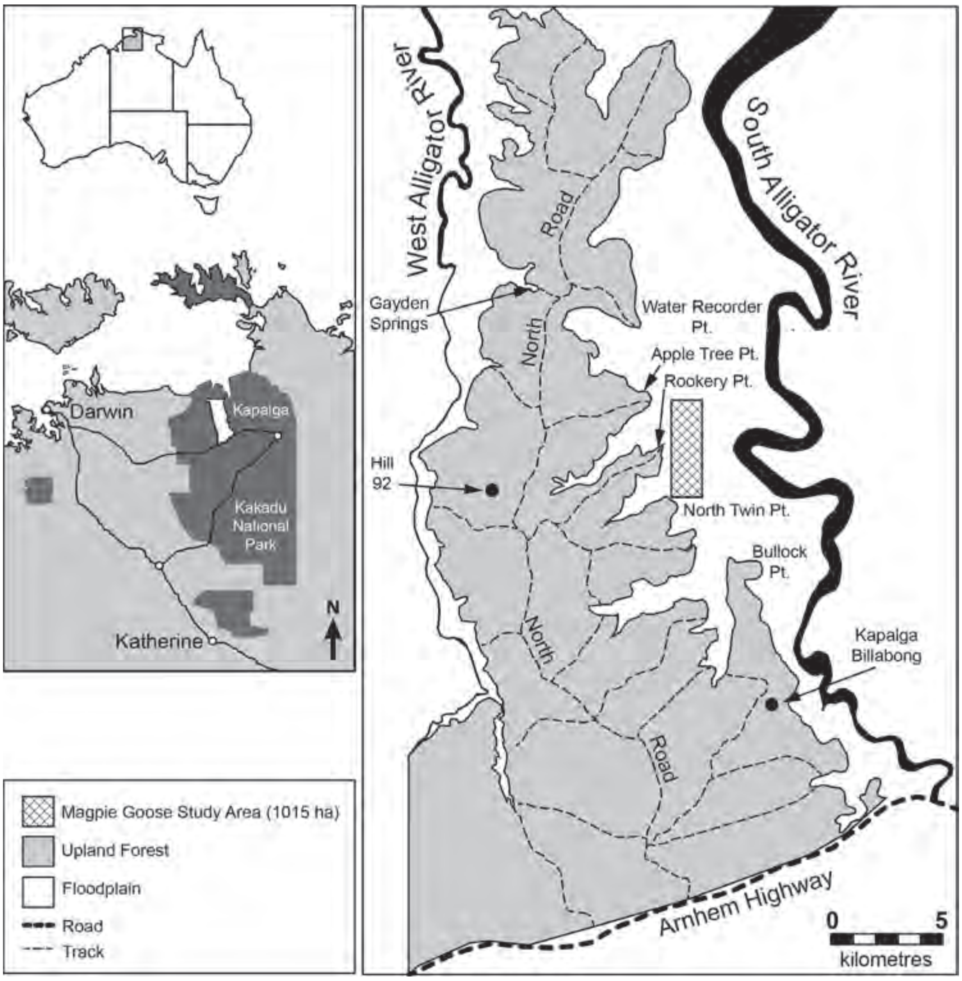

Figure 1. *Kapalga study area.*

METHODS

Study areas

Most data (99% of 3537 records of dietary remains and hunting/feeding observations) were collected at Kapalga within Kakadu National Park in the Top End of the Northern Territory between 1979 and 1989. Kapalga (670 km^2; between 12º19'S, 132º15'E and 12º44'S, 131º29'E) is about 160 kilometres east of Darwin and bounded by the West and South Alligator Rivers, the Arnhem Highway in the south, and the Timor Sea in the north (Fig. 1). An additional 23 records (1%) from similar Top End habitats between Darwin and Jabiru were included to bolster data for nine raptor species.

The major habitats at Kapalga include about 35 kilometres of each of the South Alligator River (Fig. 2) and the West Alligator River (Fig. 3), seasonally inundated black-soil floodplain of the South Alligator River (Fig. 4), an ecotone of paperbark forest (*Melaleuca* spp.) between the floodplains and upland habitats, and upland open forests and woodlands with *Eucalyptus* and other species (Cook and Corbett 2003). About 20 temporary shallow streams drain the uplands and about 15 seasonal and permanent water-bodies (billabongs) also occur there (Fig. 5).

The climate is hot all year, with mean daily maximum temperatures between 31 and 38°C and mean daily minimum temperatures between 18 and 25°C.

Rainfall is markedly seasonal, and most rain falls during the peak monsoon season of January to early March (Ridpath 1985) when the rivers, billabongs and plains become flooded, resulting in full vegetative cover (Figs. 4 and 6). However, during the ensuing dry season of negligible rain, the non-tidal area of the West Alligator River reduces to a series of isolated shallow swamps (Fig. 7), and the South Alligator floodplain is essentially dry (Corbett and Hertog 2011, 2012). Vegetative cover along the rivers and on the floodplains increased markedly following the removal of Swamp Buffalo *Bubalus bubalis* (Fig. 8) (Corbett *et al.* 1996).

Fire, as a consequence of lightning and prescribed burning, increasingly occurs in frequency and extent throughout the dry season (May–December) (Cook and Corbett 2003). Prey killed or fleeing from fire, or exposed in post-fire denuded habitats, all provide increased access to food for many raptors at Kapalga (Corbett *et al.* 2003) and elsewhere in the Northern Territory (Woinarski *et al.* 1999).

A total of 365 vertebrate species is known for Kapalga, comprising 20 nonvolant mammals, 12 bats, 6 feral mammals, 224 birds, 45 lizards, 23 snakes, 3 turtles, 2 crocodiles, 20 frogs and 10 freshwater fish (Corbett *et al.* 2003). However, ants and termites are probably the most numerous upland fauna (Andersen *et al.* 2003).

Large aggregations of Magpie Geese *Anseranas semipalmata* and other waterfowl, aquatic reptiles, frogs and invertebrates occur on the floodplains of the two tidal rivers (Press *et al.* 1995; Corbett *et al.* 1996).

Thirty-five diurnal and nocturnal raptor species have been recorded in Australia, including Christmas Island. Of these, 29 species were recorded at Kapalga during this study (Table 1), and dietary data were collected on 25 of them.

Assessing raptor relative abundance and activity

Whistling Kite numbers and active nests:

Data were recorded monthly at eleven standard plots (~10 000 m^2) predominantly in ecotone habitat adjacent to the South Alligator River floodplain, over 30 months in 1980–82. Most Whistling Kite nests were in the Water Recorder Point plot, with fewer numbers at Rookery Point, Kapalga Billabong, Apple Tree Point and Bullocky Point plots.

Other raptors:

Random records of raptors were collected by CSIRO staff and research visitors over 15 years (1980–94). The date, location, number and activity of raptors were recorded on standard data sheets.

Assessing prey availability and abundance

Dusky Rats *Rattus colletti* were a major prey of many raptors, and Dusky Rat population densities were sampled in Elliot traps at four sites: the South Alligator River floodplain at Rookery Point and Apple Tree Point, the upland forest at Hill 92 and the West Alligator River floodplain at Gaden Springs. Up to 400 traps were set per site for up to four nights per site. Trap baits varied over time between 'the lot' (a mixture of oats, bacon, bird seed and peanut butter), leather soaked in linseed oil, and oats. Other likely prey species, also captured in Elliot traps, were Grassland Melomys *Melomys burtoni*, Fawn Antechinus *Antechinus bellus*, Common Planigale *Planigale maculata*, Northern Brown Bandicoot *Isoodon macrourus*, Northern Quoll *Dasyurus hallucatus*, Orange-sided Bar-lipped Skink *Glaphyromorphus douglasi*, Slaty-grey Snake *Steganotus cucullatus*, Freshwater Snake *Tropidonophis mairii*, Spotted Tree Monitor *Varanus scalaris*, Giant Frog *Cyclorana australis*, Dahl's Aquatic Frog *Litoria dahli* and Rocket Frog *Litoria nasuta* (Skeat *et al.* 1996).

At the two South Alligator River sites, sampling occurred over eight years (1979–86), and Dusky Rat trap success per quarter was calculated as: (# rats trapped x 100) ÷ {(# trap – nights) – [(# other spp. + recaptures) ÷ 2]}.

This formula was based on the assumption there was a 50 percent chance that a 'new' Dusky Rat would find a trap before a recaptured (tagged) Dusky Rat or another species. Trap success for other species (mammals other than Dusky Rats, reptiles and frogs) was calculated as the quarterly number of captures per 100 trap-nights.

At the Gaden Springs and Hill 92 sites, Elliot trapping occurred over two years (1981–82). Trap success rates for Dusky Rat and other prey (mammals other than Dusky Rats, reptiles and frogs) were each calculated as the number of captures per 100 trap-nights.

Magpie Geese were also a major prey of many predators, especially during the late wet-early dry seasons when these geese breed on the floodplains. Only about 41 percent of the population breeds each year, clutch size varies from one to 14 (mean 7.3) and eggs hatch after 24–25 days of incubation. The young are nidifugous and spend 1–3 days in the nest before being led to feeding areas by the parents. Recruitment of young to the population is low, owing to heavy predation of eggs by pythons and predation of young geese by raptors and dingoes before they fledge at about 10 weeks of age (Frith and Davies 1961).

A 1015-hectare study area within the main breeding colony on the South Alligator River floodplain was selected (Fig. 1) and breeding success was assessed over nine years (1980–88) by aerial photography, conducted at a standard height, direction and air-speed (Corbett *et al.* 1996). Flights were conducted in June–July, after vegetation had collapsed and nests were more easily seen from the air. Each photographic frame was

Figure 2. *South Alligator River at Kapalga in the buffalo era.*

Figure 3. *Tidal area of the West Alligator River.*

Figure 4. *South Alligator River floodplains in the wet season in the buffalo era. Note the buffalo trails.*

Figure 5. *An upland billabong in the dry season. Note the Whistling-Ducks.*

Figure 6. *West Alligator River in the wet season.*

Figure 7. *West Alligator River in the dry season.*

Figure 8. *Co-author Tony Hertog in the South Alligator floodplains in the dry season in the post-buffalo era.*

subdivided into 30 'quadrats' equivalent to a ground area of about 400 square metres and the numbers of nests recorded and used as the basis to estimate the annual number of young in the study area, and subsequently to estimate the annual number of young produced in the South Alligator River floodplain at Kapalga.

Assessing raptor diet

The analysis of raptor diet was mainly based on pellets and prey remains collected at roosts, nests and feeding sites. Barking Owl pellets were also collected in wire-netting sheets (Fig. 9) suspended under roosts and above the dense wet-season ground vegetation. Other prey were identified from observations of prey hunted and captured by adult raptors.

Samples were collected and labelled 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. The minimum number of individuals (MNI) in pellets was estimated to enable direct comparison with the visual number of individuals recorded in single hunting/feeding observations.

Previously published raptor dietary data for Kapalga were included in the prey profiles in this study (White-bellied Sea-Eagle: Corbett and Hertog 2011; Red Goshawk *Erythrotriorchis*

Figure 9. *Wire-netting trap set under an owl roost to sample pellets.*

radiatus: Aumann and Baker-Gabb 1991; Marchant and Higgins 1993) to enable direct comparison of prey types between raptor species at Kapalga.

Statistical methods and nomenclature

In analysing the prey data, an adequate sample size (n ≥20 prey items) was arbitrarily used to assess prey types and consequently to categorise raptors as specialists or generalists. Where appropriate, data are summarised as mean ± standard deviation. Raptor and prey nomenclature are primarily based on Clayton *et al.* (2006), with updates by Wilson and Swan (2013) (reptiles), Tyler and Knight (2011) (frogs), Menkhorst and Knight (2010) (mammals), and Christidis and Boles (2008) (birds). Fish nomenclature is based on Larson and Martin (1989).

Table 1

Seasonal relative abundance of 29 raptors and breeding records at Kapalga 1980-94.

Relative abundance	Species	Habitat		Presence at Kapalga	
		Floodplains including fringe	Upland forest	All year	Emigrate*
Very common	Whistling Kite *Haliastur sphenurus*† ‡	√		√	
	Black Kite *Milvus migrans* ‡	√	√		√
	Brown Falcon *Falco berigora* ‡	√	√		√
	Barking Owl *Ninox connivens* ‡	√	√	√	
Common	Black-breasted Buzzard *Hamirostra melanosternon* ‡	√	√		√
	White-bellied Sea-Eagle *Haliaeetus leucogaster* ‡	√		√	
	Australian Hobby *Falco longipennis* ‡	√	√	√	
	Southern Boobook *Ninox novaeseelandiae* ‡		√	√	
Uncommon	Black Falcon *Falco subniger* ‡	√	√		√
	Black-shouldered Kite *Elanus axillaris* ‡	√		√	
	Letter-winged Kite *Elanus notatus* ‡	√			
	Square-tailed Kite *Lophoictinia isura*		√		√
	Brown Goshawk *Accipiter fasciatus*† ‡	√	√	√	
	Collared Sparrowhawk *Accipiter cirrocephalus* §	√	√	√	
	Grey Goshawk *Accipiter novaehollandiae* §	√	√	√	
	Spotted Harrier *Circus assimilis* ‡	√			√
	Swamp Harrier *Circus approximans*† §	√		√	
	Wedge-tailed Eagle *Aquila audax* ‡		√	√	
	Nankeen Kestrel *Falco cenchroides* §	√		√	
	Rufous Owl *Ninox rufa* §	√	√	√	
	Eastern Barn Owl *Tyto javanica*	√	√	√	
Rarely recorded	Eastern Osprey *Pandion cristatus* §	√			
	Pacific Baza *Aviceda subcristata* §	√	√	√	
	Brahminy Kite *Haliastur indus* §	√		√	
	Red Goshawk *Erythrotriorchis radiatus* ‡		√	√	
	Little Eagle *Hieraaetus morphnoides* † §		√	√	
	Grey Falcon *Falco hypoleucos*		√		
	Peregrine Falcon *Falco peregrinus* §	√	√		
	Eastern Grass Owl *Tyto longimembris* ‡	√		√	

* Species that usually emigrate south of the annual monsoonal wet-season belt
† Species where some individuals emigrate south of the monsoonal wet-season belt
‡ Species recorded breeding at Kapalga
§ Species recorded breeding elsewhere in the Top End of the Northern Territory

RESULTS

Relative abundance of 29 raptors at Kapalga 1980-94

Table 1 summarises the relative frequency with which raptors were recorded at Kapalga over 15 years (1980–94) by CSIRO staff and research visitors, and whether raptors remain year round or are regular migrants. It should be noted that the probability of observing a raptor was strongly influenced by observer access to habitats, so that the commonly recorded raptors (8 spp.) were more closely associated with access roads and research sites; and conversely so for uncommon and rarely recorded raptors (21 spp.).

Nineteen raptor species were present at Kapalga all year, of which seven were recorded only in floodplain and ecotone habitats, four were recorded only in upland forests and eight were recorded in all habitats. Another six species usually emigrated annually to areas south of the monsoonal wet-season belt, and some individuals of another four species emigrated south in at least some years (Table 1).

Sixteen species were recorded breeding at Kapalga, of which six species were recorded breeding only in floodplain and ecotone habitats, three species were recorded breeding only in upland forests and seven species were recorded breeding in all habitats (Table 1).

Whistling Kite monthly abundance at Kapalga

Whistling Kites were recorded in all months, with relatively more Kites in the late dry season (October–December) when the young of the year had joined the population, and fewest during the late monsoon season (March–April) after many Whistling Kites had emigrated south of the monsoonal belt (Fig. 10), including one record of a tagged Whistling Kite recovered at Cobar in New South Wales (Estbergs unpublished data).

Whistling Kite breeding activity at Kapalga

Whistling Kite nests with eggs were recorded from March to September, peaking in June, and the greatest nest densities (up to 7 nests/km^2) were recorded in ecotone habitat at Rookery Point (Estbergs unpublished data).

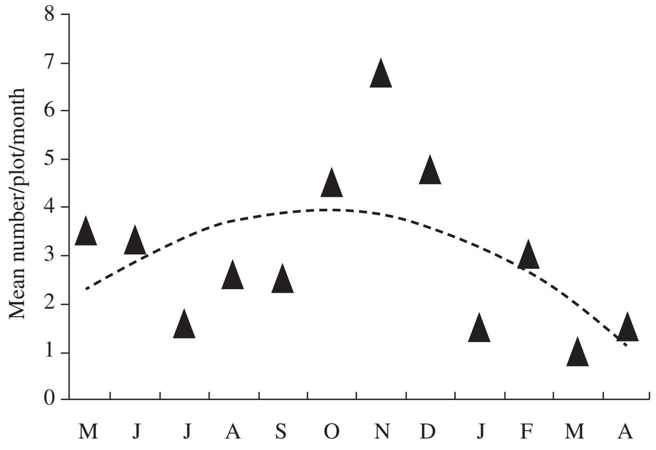

Figure 10. *Whistling Kite monthly abundance, Kapalga 1980 – 1982.*

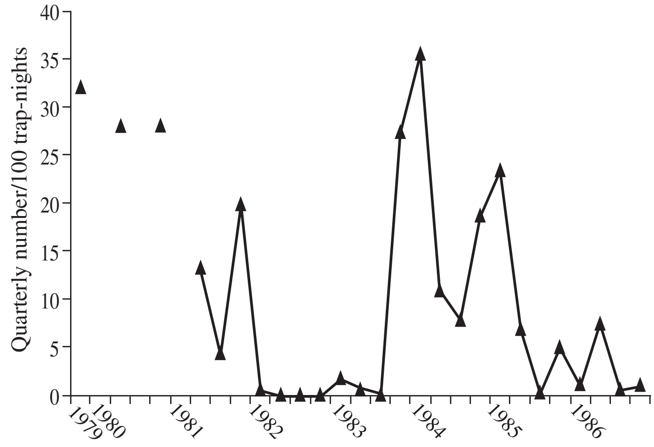

Figure 11a. *Dusky Rat abundance, Appletree and Rookery Points.*

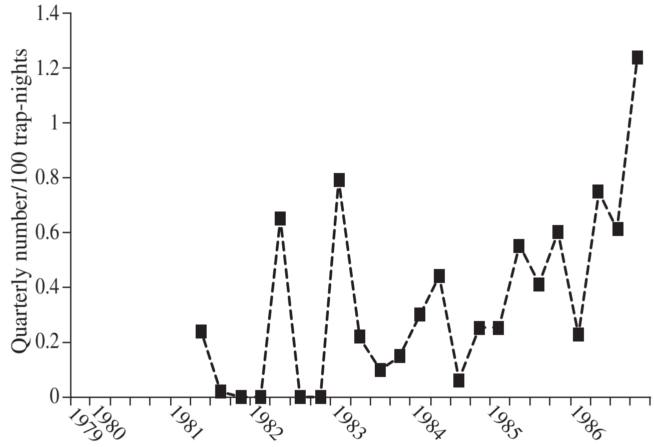

Figure 11b. *Other prey abundance, Appletree and Rookery Points.*

Raptor pellet characteristics

There were relative differences in mean values of length, diameter and weight of pellets produced by eight raptor species at Kapalga (Table 2). Owl pellets averaged heavier than those of the diurnal raptors, which is consistent with the greater amount of undigested bone ejected by owls.

Prey availability and abundance

Dusky Rat:

The quarterly mean number of Dusky Rats trapped on the South Alligator River floodplain over eight years (1979–86) was 10.6 ± 10.2 (range 0–36, total ~16 000 trap-nights). The population fluctuated between peaks (1979–81, 1984–85) and lows (1982–83, 1985–86) with a mean duration of two years (Figure 11a); subsequently, a reduced sampling effort suggested that the population peaked again in 1988–89 (Corbett unpublished data). Based on these data, the estimated peak Dusky Rat population on the South Alligator River floodplain at Kapalga was about 0.5 million (Corbett unpublished data).

Dusky Rat abundance was lower on the West Alligator River floodplain and in the upland forest. At Gaden Springs, the mean number of Dusky Rats captured per 100 trap-nights during 1981–82 was 4.2 ± 3.6 (range 0–11, total 10 800 trap-nights); and at Hill 92, the mean number captured per 100 trap-nights during 1981–82 was 9.3 ± 11.2 (range 0–42, total 8330 trap-nights).

The body weight of 1215 Dusky Rats (males and females) varied between 30 and 250 grams, with most (29%) in the 50–70 gram range (Corbett unpublished data).

Magpie Goose:

The mean number of eggs laid annually on the South Alligator River floodplain at Kapalga between 1980 and 1988 was estimated as 106 000 ± 71 000; range 29 000–248 000 (Table 3). This is compatible with the value of 70 000 adult geese recorded by Tullock and McKean (1983) on the floodplains of the West and South Alligator Rivers over 23 years (1958–80).

The yearly numbers of fledged geese fluctuated considerably over the 9-year study, with an overall decline in numbers (Table 3). This trend was associated with the pattern of rainfall, where few geese are likely to breed if the annual rainfall is less than 700 millimetres, and maximal numbers will breed if the annual rainfall is about 1600 millimetres (Corbett 1988).

Other potential prey:

At Appletree and Rookery Points on the South Alligator River floodplain, other species captured over six years (1981–86) were Grassland Melomys, Fawn Antechinus, Common Planigale, Northern Brown Bandicoot, Northern Quoll, frogs, snakes and lizards; and the combined quarterly capture success was 0.4 ± 0.3 per 100 trap-nights (range 0–1; 11 190 trap-nights; Figure 11b)

Other species captured at Gaden Springs over two years (1981–82) were Grassland Melomys, Northern Brown Bandicoot, Fawn Antechinus, frogs, snakes and lizards; and the combined capture success was 0.4 ± 0.5 per 100 trap-nights (range 0–2; 10 800 trap-nights).

At Hill 92, other species captured over two years (1981–82) were Fawn Antechinus, Northern Brown Bandicoot, Northern Quoll, frogs and lizards; and the combined capture success was 0.2 ± 0.3 per 100 trap-nights (range 0–1; 8330 trap-nights).

Table 2

Raptor pellet size (mm) and weight (g).

Species	Number of pellets	Length		Maximum Diameter		Minimum Diameter		Weight	
		Mean ± SD	Range	Mean ± SD	Range	Mean ± SD	Range	Mean ± SD	Range
Whistling Kite	2066	34.4 ± 11.8	11 - 85	20.2 ± 4.9	1 - 44	14.9 ± 3.9	1 - 31	2.3 ± 1.6	0.2 - 8.8
Black Kite	93	27.5 ± 9.9	13 - 82	17.1 ± 5.2	1 - 35	10.9 ± 4.1	3 - 22	1.5 ± 1.1	0.6 - 4.4
Brown Falcon	4	25.8 ± 3.9	22 - 31	19.8 ± 3.8	16 - 25	12.3 ± 2.5	9 - 15	1.2 ± 0.2	1.1 - 1.4
Black Falcon	54	33.1 ± 9.5	18 - 57	20.5 ± 2.5	14 - 28	16.8 ± 2.8	10 - 23	2.2	nd
Rufous Owl	30	38.9 ± 16.8	17 - 85	22.4 ± 5.8	11 - 34	16.8 ± 4.9	7 - 28	2.2 ± 3.6	0.3 - 7.8
Barking Owl	78	31.2 ± 8.9	14 - 60	18.1 ± 4.3	9 - 32	12.9 ± 3.5	6 - 22	4.7 ± 2.5	0.1 - 9.5
Eastern Barn Owl	60	36.0 ± 7.0	20 - 55	26.0 ± 4.9	14 - 42	18.6 ± 3.4	12 - 30	4.1 ± 1.0	3.3 - 5.8
Eastern Grass Owl	15	nd	nd	nd	nd	nd	nd	3.2	nd

nd - no data, unable to measure old fragile pellets; SD - Standard Deviation

Elsewhere in the upland forest at Kapalga, Friend (1985, 1987) recorded mean densities of 1.3 per 100 trap-nights and 1.9 respectively for the Fawn Antechinus and the Black-footed Tree-rat *Mesembriomys gouldi* at two sites over the years 1980–83. And, in an eight-year study (1988–95) at 24 sites throughout the upland forest, Corbett *et al.* (2003) amassed 19 950 records of terrestrial vertebrates comprising 23 species.

Raptor diet at Kapalga

The proportions of the major prey types for 25 raptor species at Kapalga over 11 years (1979–89) are summarised in Table 4. In total, prey identified comprised at least 49 bird species, 18 mammals, nine reptiles, eight fish, seven invertebrates and one frog.

For the ten well-studied species, three raptors (Red Goshawk, Eastern Barn Owl, Eastern Grass Owl) focussed on 1–2 prey types and were categorised as specialists, whereas the other seven (Whistling Kite, Black Kite, Brown Falcon, Black Falcon, White-bellied Sea-Eagle, Rufous Owl, Barking Owl) were categorised as generalists that focussed on 3–6 prey types. Among the specialists, the Red Goshawk focussed on birds and the two *Tyto* owls focussed on rats. Among the generalists, the Whistling Kite focussed on mammals, birds and invertebrates, the White-bellied Sea-Eagle took mostly aquatic prey, the Brown Falcon took many reptiles, the Black Kite, Black Falcon and Barking Owl took many rats, and the Rufous Owl took mostly arboreal mammals.

The species and proportions of prey recorded for the ten well-studied raptors are shown in Table 5:

- Mammalian prey comprised Muridae (12 occurrences); Pteropodidae (5 occurrences); Phalangeridae (3 occurrences); Macropodidae (3 occurrences); and single occurrences of Tachyglossidae, Peramelidae, Petauridae, Felidae, Bovidae, and a micro-bat.
- Avian prey comprised Psittacidae (14 occurrences); Ardeidae (7 occurrences); Anseranatidae (6 occurrences); Halcyonidae (6 occurrences); Anatidae (6 occurrences); Columbidae (4 occurrences); Threskiornithidae (3 occurrences); Meropidae (2 occurrences); Scolopacidae (2 occurrences); single occurrences of Centropodidae, Rallidae, Recurvirostridae, Podargidae, Artamidae, Anhingidae, Phasianidae, Caprimulgidae, Cuculidae, Gruidae; and unidentified birds (8 occurrences).

Table 3

Magpie Geese estimated numbers of nests and eggs, South Alligator floodplain Kapalga 1980–88.

Year	Study area (1015 ha)	South Alligator River Floodplain	
	No. nests	Estimated no. nests	Estimated no. eggs†
1980	733	12 278	89 628
1981	2028	33 969	247 973
1982	1022	17 118	124 965
1983	239	4003	29 224
1984	1273	21 323	155 656
1985	476	7973	58 203
1986	375	6281	45 853
1987	7*	–	–
1988	795	13 316	97 209
Means	868	14 533	106 088

* Many nests were built & produced young but most were destroyed in a cyclone prior to the aerial survey.

† Calculation based on a mean clutch size of of 7.3 (Frith and Davies 1961).

- Reptilian prey comprised Chelidae (3 occurrences); Varanidae (2 occurrences); single occurrences of Colubridae, Agamidae, Scincidae and Acrochordidae; and unidentified lizards (3 occurrences) and snakes (2 occurrences).
- Amphibian prey comprised Hylidae (1 occurrence).
- Fish prey comprised single occurrences of Eleotrididae; Osteoglossidae; Centropomidae; Belonidae; Clupeidae; Mugilidae; and unidentified catfish (2 occurrences) and other fish species (3 occurrences).
- Invertebrates comprised beetles (3 occurrences); grasshoppers (2 occurrences); crabs (2 occurrences); dragonfly (1 occurrence); and unidentified insect species (4 occurrences).

Dusky Rats and/or Magpie Geese were common to major prey species of seven raptors: Whistling Kite, Black Kite, Brown Falcon, Black Falcon, Barking Owl, Eastern Barn Owl and Eastern Grass Owl. Birds, mainly lorikeets, parrots, kookaburras and doves were the major prey of the Red Goshawk; aquatic reptiles and aquatic birds were the major prey of the White-bellied Sea-Eagle; and arboreal and flying mammals, and insects were the major prey of the Rufous Owl.

Table 4

Summary of diet of 25 raptors, Kapalga 1979-89.

Species	No. samples	Prey											
		Mammals		Birds		Reptiles		Amphibians		Fish		Invertebrates	
		No. spp.	% occur	No. spp.	% occur	No. spp.	% occur	No. spp.	% occur	No. spp.	% occur	No. spp.	% occur
Eastern Osprey	5	0	–	0	–	0	–	0	–	1	100.0	0	–
Black-shouldered Kite	9	1	100.0	0	–	0	–	0	–	0	–	0	–
Square-tailed Kite	3	0	–	1	25.0	1	75.0	0	–	0	–	0	–
Black-breasted Buzzard	3	1	33.3	1	33.3	1	33.3	0	–	0	–	0	–
Pacific Baza	4	0	–	0	–	0	–	0	–	0	–	2	100.0
White-bellied Sea-Eagle	493	5	2.4	17	28.9	5	57.9	0	–	6	10.6	0	-
Whistling Kite	2108	9	41.4	10	40.6	3	2.9	0	–	3	4.7	3	10.4
Black Kite	96	1	55.6	3	29.6	0	-	1	3.7	0	–	3	11.1
Brown Goshawk	7	0	–	5	85.7	1	14.3	0	–	0	–	0	–
Collared Sparrowhawk	4	0	–	1	25.0	0	–	0	–	0	–	3	75.0
Grey Goshawk	3	0	–	1	100.0	0	–	0	–	0	–	0	–
Swamp Harrier	3	0	–	2	66.6	0	–	0	–	1	33.3	0	–
Red Goshawk	501	1	0.1	13	99.9	0	–	0	–	0	–	0	–
Wedge-tailed Eagle	8	5	71.5	1	28.6	0	–	0	–	0	–	0	–
Little Eagle	2	0	–	1	50.0	1	50.0	0	–	0	–	0	–
Nankeen Kestrel	5	0	–	0	–	0	–	0	–	0	–	3	100.0
Brown Falcon	40	2	21.7	4	17.4	2	56.5	0	–	0	–	1	4.3
Australian Hobby	6	2	33.3	2	50.0	0	–	0	–	0	–	1	16.7
Black Falcon	100	1	73.9	6	19.6	2	4.4	0	–	0	–	1	2.2
Peregrine Falcon	4	0	–	4	100.0	0	–	0	–	0	–	0	–
Rufous Owl	44	5	82.6	1	4.3	0	–	0	–	0	–	2	13.0
Barking Owl	94	4	44.1	5	10.8	1	2.2	0	–	1	1.1	3	41.9
Southern Boobook	5	0	–	0	–	0	–	0	–	0	–	1	100.0
Eastern Barn Owl	60	1	100.0	0	–	0	–	0	–	0	–	0	–
Eastern Grass Owl	20	1	100.0	0	_	0	_	0	_	0	–	0	–

Whistling Kites, Brown Falcons, and Black Kites also took fire-killed prey in the wake of fires in ecotone and upland forest habitats at Kapalga.

For the 15 raptor species with fewer than 20 prey records, the following hunting/feeding records were obtained:

- Nankeen Kestrel: one cricket sp., one beetle sp., three unidentified insects.
- Australian Hobby: two Peaceful Doves *Geopelia striata*, one each of Little Friarbird *Philemon citreogularis*, Dusky Rat, unidentified bat, unidentified insect.
- Peregrine Falcon: one each of Peaceful Dove, Red-winged Parrot *Aprosmictus erythropterus*, Magpie-lark *Grallina cyanoleuca*, Tree Martin *Cecropis nigricans*.
- Eastern Osprey: five unidentified fish.
- Pacific Baza: two stick insects (Phasmatidae), two unidentified insects.
- Square-tailed Kite: two Spotted Tree Monitors, one Rainbow Lorikeet *Trichoglossus haematodus*.
- Black-breasted Buzzard: one each of Galah *Eolophus roseicapillus*, lizard sp., Swamp Buffalo carcass.
- Black-shouldered Kite: nine Dusky Rats.
- Swamp Harrier: two Cattle Egrets *Ardea ibis*, one fish sp.
- Grey Goshawk: three unidentified birds.
- Brown Goshawk: two Partridge Pigeons *Geophaps smithii*, one each of Bar-shouldered Dove *Geopelia humeralis*, Red-backed Kingfisher *Todiramphus pyrrhopygius*, Pheasant Coucal *Centropus phasianinus*, unidentified bird, unidentified snake.
- Collared Sparrowhawk: one kingfisher sp., three unidentified insects.
- Wedge-tailed Eagle: two Magpie Geese, one each of Agile Wallaby *Macropus agilis*, Antilopine Wallaroo *Macropus antilopinus*, Flying-fox sp., Swamp Buffalo carcass, European Cattle *Bos Taurus* carcass.
- Little Eagle: one each of Torresian Crow *Corvus orru*, Common Tree-Snake *Dendrelaphis punctulata*.
- Southern Boobook: five unidentified insects.

Whistling Kite predation on Dusky Rats and Magpie Geese

Dusky Rats and Magpie Geese were major prey species of Whistling Kites on the South Alligator River floodplain, particularly in years when Dusky Rats were abundant, and for Magpie Geese during their annual breeding period in the late wet-early dry seasons. However, the proportions of these prey

Table 5

Raptor prey species based on pellets and hunting[1], Kapalga 1979-89.

Raptors				Prey[2]									
	No. samples / observations			Mammals		Birds		Reptiles & Amphibians		Fish		Invertebrates	
Species	Pellets under roost / nest	Hunting / Feeding	Prey remains under nest	Species	% occur	Species	% occur	Species	% occur	Species	% occur	Species	% occur
Whistling Kite	2098	10		Dusky Rat	34.5	Magpie Goose	34.5	Spotted Tree Monitor	0.7	Catfish unid sp.	3.2	Beetle unid spp.	5.8
				Common Brushtail Possum	2.5	Wandering Whistling-Duck	0.7	Lizard unid sp.	1.4	Sleepy Cod	0.7	Grasshopper unid spp.	1.4
				Swamp Buffalo carcass	1.4	Rainbow Lorikeet	0.7	Snake unid sp.	0.7	Fish unid sp.	0.7	Crab unid sp.	3.2
				Pig carcass	0.7	Varied Lorikeet	0.4						
				Flying-fox unid sp.	0.7	Unid Lorikeet	0.4						
				Agile Wallaby	0.4	Rainbow Bee-eater	0.4						
				Short-beaked Echidna	0.4	Black-winged Stilt	0.4						
				Water-rat	0.4	Intermediate Egret	0.4						
				Small Mammal unid sp.	0.4	Forest Kingfisher	0.4						
						Little Corella	0.4						
						Duck unid sp.	0.4						
						Bird unid sp.	0.4						
						Eggshell unid bird sp.	1.4						
Black Kite	93	3		Dusky Rat	55.6	Magpie Goose	22.2	Giant Frog	3.7			Crab unid sp.	3.7
						White-browed Crake	3.7					Insect unid spp.	7.4
						Bird unid sp.	3.7						
Red Goshawk[3]			501	Little Red Flying-fox	0.1	Rainbow Lorikeet	32.1						
						Red-tailed Black-Cockatoo	4.2						
						Varied Lorikeet	3.6						
						Red-winged Parrot	3.0						
						Unid Parrot spp.	8.4						
						Blue-winged Kookaburra	8.8						
						Unid kookaburra/kingfisher spp.	0.8						
						Bar-shouldered Dove	2.2						
						Peaceful Dove[5]	0.1						
						Common Bronzewing	1.4						
						Unid Dove/Pigeon spp.	5.4						
						Cuckoo unid spp.	1.8						
						Heron/Ibis unid spp.	0.4						
						Crane unid spp.	0.4						
						Nightjar unid spp.	0.4						
						Quail/Scrubfowl unid sp.	0.2						
						Passerines unid spp.	15.3						
						Bird unid spp.	11.4						
Brown Falcon	19	21		Dusky Rat	17.4	Magpie Goose	4.3	Dragon unid sp.	4.3			Dragonfly unid sp.	4.3
				Bat unid sp.	4.3	Peaceful Dove	4.3	Lizard unid sp.	52.2				
						Little Corella	4.3						
						Bird unid sp.	4.3						

Table 5 *(continued)*

Raptor prey species based on pellets and hunting[1], Kapalga 1979-89.

Raptors				Prey[2]									
	No. samples / observations			Mammals		Birds		Reptiles & Amphibians		Fish		Invertebrates	
Species	Pellets under roost / nest	Hunting / Feeding	Prey remains under nest	Species	% occur	Species	% occur	Species	% occur	Species	% occur	Species	% occur
Black Falcon	93	7		Dusky Rat	73.9	Magpie Goose	4.3	Spotted Tree Monitor	2.2			Insect unid sp.	2.2
						Tawny Frogmouth	4.3	Turtle unid sp.	2.2				
						Whimbrel	4.3						
						Pheasant Coucal	2.2						
						Rainbow Lorikeet	2.2						
						Little Curlew	2.2						
White-bellied Sea-Eagle[4]			493	Flying-fox unid sp.	1.4	Magpie Goose	16.2	Northern Long-necked Turtle	51.3	Catfish unid sp.	3.9		
				Agile Wallaby	0.4	Glossy Ibis	4.5	Turtle unid spp.	3.4	Barramundi	3.7		
				Dusky Rat	0.2	Little Corella	1.4	Arafura Filesnake	0.2	Freshwater Longtom	0.6		
				Northern Brown Bandicoot	0.2	Intermediate Egret	0.4	Macleay's Water Snake	0.2	Diamond Mullet	0.6		
				House Cat	0.2	Eastern Great Egret	0.2	Centralian Blue-tongue	0.2	Bony Bream	0.4		
						Unid Egret spp.	1.0	Snake unid spp.	2.6	Saratoga	0.2		
						Radjah Shelduck	0.8			Fish unid spp.	1.2		
						Plumed Whistling-Duck	0.8						
						Hardhead	0.4						
						Pacific Black Duck	0.2						
						Australian White Ibis	0.2						
						Royal Spoonbill	0.2						
						Pied Heron	0.2						
						Red-winged Parrot	0.2						
						Sulphur-crested Cockatoo	0.2						
						Darter	0.2						
						Nankeen Night Heron	0.2						
						Purple Swamphen	0.2						
						Bird unid spp.	1.4						
Rufous Owl	44			Common Brushtail Possum	47.8	Blue-winged Kookaburra	4.3					Beetle unid sp.	4.3
				Little Red Flying-fox[5]	4.3							Insect unid sp.	8.7
				Flying-fox unid sp.	21.7								
				Dusky Rat	4.3								
				Rock-wallaby unid sp.[5]	4.3								
Barking Owl	94			Dusky Rat	39.8	Magpie Goose	4.3	Lizard unid sp.	2.2	Fish unid sp.	1.1	Beetle unid spp.	15.1
				Common Brushtail Possum	1.1	Rainbow Bee-eater	1.1					Grasshopper unid spp.	7.5
				Sugar Glider	1.1	Butcherbird unid sp.	1.1					Insect unid spp.	19.4
				Unid small mammal	2.2	Kingfisher unid sp.	1.1						
						Bird unid sp.	3.2						
Eastern Barn Owl	60			Dusky Rat	100.0								
Eastern Grass Owl	20			Dusky Rat	100.0								

[1]based on ≥20 samples, [2]minimum number of individuals, [3]data ex. Aumann and Baker-Gabb 1991 (9 nests in NT including Kapalga 1987-89 and 4 nests in Kimberley 1989), [4]data ex. Corbett and Hertog 2011a, [5]additional data from sites between Darwin and Jabiru.

See Appendix 1 for scientific names of species.

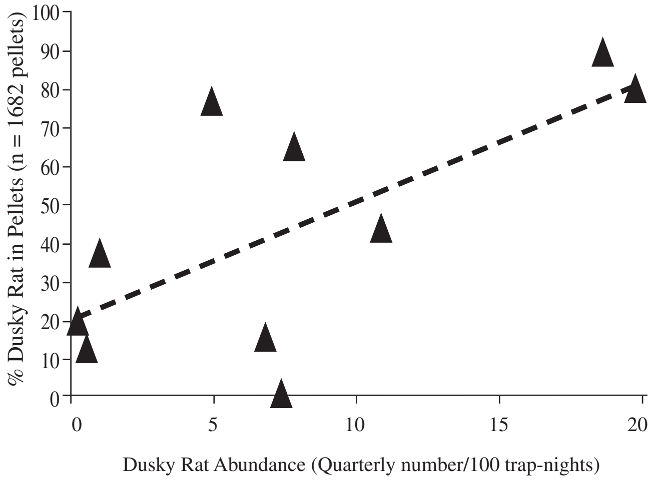

Figure 12a. *Whistling Kite prey Dusky Rat, 1981, 1984 – 1986.*

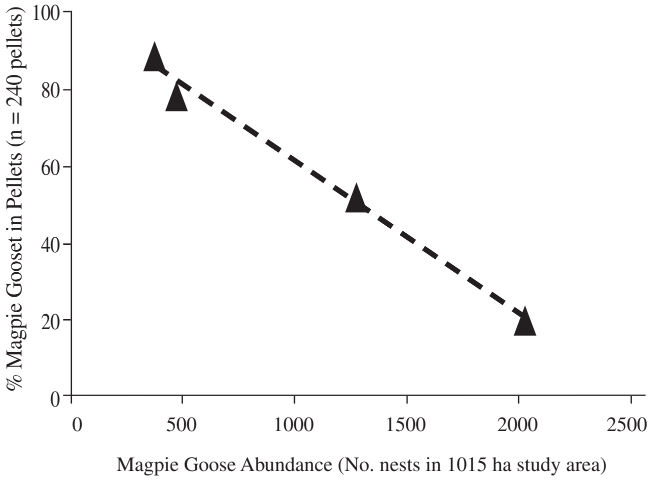

Figure 12b. *Whistling Kite prey Magpie Goose, 1981, 1984 – 1986.*

taken by Whistling Kites during the Magpie Goose breeding season were primarily determined by the availability of Dusky Rats. When few Dusky Rats were available, Whistling Kites focussed on and ate relatively more Magpie Geese, but during the years when the Dusky Rat population surged, Whistling Kites increasingly ate them and increasingly ignored Magpie Geese despite their high availability (Figure 12a,b).

DISCUSSION

Of the 29 raptor species recorded at Kapalga, ten species were frequently recorded throughout the 11-year study period and their diet was probably assessed accurately. However, data are few for the other 19 raptors because of infrequent observer access to some habitats, natural rarity of some raptors, or both reasons; so that our assessments of their diets are indicative.

The Black Kite, Brown Falcon, Black-breasted Buzzard, Black Falcon and Spotted Harrier were dry-season breeding migrants to Kapalga, and the Square-tailed Kite was a non-breeding dry-season migrant. For the species that emigrated from the Top End in the wet season, the seasonal trend at Kapalga was consistent with published knowledge on most of them (e.g. Marchant and Higgins 1993; Barrett *et al.* 2003). However, the Black Falcon as a regular dry-season breeding migrant to the floodplains and adjacent forests of the Top End is previously unremarked, and adds to understanding of the ecology of this species in the tropics.

Raptor pellets

Despite relative differences in mean pellet sizes of the eight species sampled, the considerable overlap in the range of values indicates that additional data, such as collection site (roost, nest, feed tree), are also required to reliably identify the pellets of raptor species.

For the Rufous Owl, measurements of 21 pellets sampled elsewhere in Kakadu National Park (near Cooinda) by Estbergs and Braithwaite (1985) were within the range of values recorded in this study. Pellet dimensions at Kapalga were within the published range for the owls and the Black Falcon elsewhere in Australia (e.g. Higgins 1999; Barnes *et al.* 2005; Debus *et al.* 2005, 2010), but there are no comparative data for the other diurnal raptors studied at Kapalga.

Prey

Dusky Rats and/or Magpie Geese were major prey species of the Whistling Kite, Black Kite, Black Falcon and Barking Owl. Dusky Rats were also important prey of the Black-shouldered Kite, Eastern Barn Owl and Eastern Grass Owl; and Magpie Geese were also important prey of the White-bellied Sea-Eagle and Wedge-tailed Eagle.

Dusky Rats occurred throughout Kapalga, but populations were greater on the South Alligator River floodplain than elsewhere. Dusky Rat populations fluctuated between highs (up to ½ million) and lows on a 2-year cycle over eight years, and during peak populations they were the dietary mainstay of many raptors. Friend *et al.* (1988) also found that Dusky Rat populations at other nearby sites on the South Alligator River floodplain at Kapalga were characterized by short-term seasonal shifts between habitats and longer-term irregular patterns of prolonged breeding and population irruption, followed by periods of relative rarity.

Large numbers of Magpie Geese (up to about 70 000 adults) were available throughout each year, as well as eggs (up to ¼ million) and flightless young during their late wet-early dry season breeding period.

Other prey, including small mammals, snakes, frogs and insects, greatly increased in numbers in response to increased dry-season vegetation on the floodplains after Swamp Buffalo were removed in 1983.

With reference to the above prey availabilities, it so happened that prey were plentiful over the entire 11-year study period. When Dusky Rat populations were low in 1982–83 and 1985–86, the relative lack of this major prey was compensated by average availability of Magpie Geese (adults, eggs, young) and higher numbers of other prey.

Raptor diet at Kapalga

There were adequate data to categorise only ten of the 25 raptor species as specialists or generalist predators. The Red Goshawk specialised on birds (at least 15 species) and the Eastern Barn Owl and Eastern Grass Owl exclusively preyed on Dusky Rats.

Two (Whistling Kite, Barking Owl) of the seven generalist raptors included prey species from all five major prey categories (mammals, birds, reptiles, fish, invertebrates), four generalists (Brown Falcon, Black Falcon, Black Kite, White-bellied Sea-Eagle) focussed on four prey categories, and one generalist (Rufous Owl) focussed on three prey categories.

The proportions of the main prey species within the prey categories were similar for four generalists, of which Whistling Kites, Black Kites, Black Falcons and Barking Owls primarily focussed on mammals (mainly Dusky Rats), then birds; whereas Brown Falcons and White-bellied Sea-Eagles primarily focussed on reptiles (lizards and turtles respectively), then birds and mammals; and Rufous Owls primarily focussed on mammals (possums, flying-foxes), then insects.

The diurnal raptor community was richer at Kapalga than in arid or southern temperate Australia (cf. Baker-Gabb 1984a,b; Aumann 2001), with a foliage insectivore (Pacific Baza), foliage vertebrate predator (Square-tailed Kite) and two additional accipiter-type hawks (Red Goshawk and Grey Goshawk) not present in the other study areas, and the generalist Black-breasted Buzzard absent from the temperate zone. The raptor guild at Kapalga was dominated by medium-sized generalists (Whistling Kite, Black Kite, Brown Falcon), with the Black-breasted Buzzard, White-bellied Sea-Eagle and Australian Hobby also common (at least seasonally), whereas the Wedge-tailed Eagle and Nankeen Kestrel were uncommon. This basic pattern of abundant generalists, with variations in the less abundant species, seems typical for the Australian tropics (e.g. Gosper and Holmes 2008). Among the owls, the Barking Owl was very common at Kapalga, the reverse of the temperate zone (e.g. Higgins 1999; Debus 2009; Olsen 2011).

Raptor diets at Kapalga and elsewhere in Australia

Elsewhere in Kakadu National Park at Cooinda, the dry-season diet of Rufous Owls in 1980–82 mostly comprised arboreal and terrestrial mammals (mainly Fawn Antechinus, Pale Field-rat *Rattus tunneyi*, Dusky Rat, Western Chestnut Mouse *Pseudomys nanus*), with some flying-foxes (*Pteropus* spp.), birds and insects (Estbergs and Braithwaite 1985), which is similar to their diet at Kapalga in this study.

For most of the well-studied species at Kapalga (≥20 dietary samples in Table 5), their diets were generally similar to results from terrestrial and/or freshwater habitats (as applicable) elsewhere in Australia (studies reviewed or cited by Marchant and Higgins 1993, Higgins 1999 and Debus 2009, 2012; Goulding and Venables 2012; Olsen *et al.* 2013). However, the Black Falcon took many mammals at Kapalga, as in the arid zone when rats or Rabbit *Oryctolagus cuniculus* kittens are abundant (Marchant and Higgins 1993), although it is usually a bird-catcher (Debus *et al.* 2005; Debus and Olsen 2011; Debus and Tsang 2011). The Barn Owl and Grass Owl appear to have a narrower feeding niche at Kapalga, where Dusky Rats are abundant, than elsewhere in Australia (cf. studies in Higgins 1999 and Debus 2009; Debus *et al.* 2010; Clulow *et al.* 2011), although larger samples of pellets may detect additional prey species.

For the less-studied species at Kapalga, it appears that at least the Osprey, Black-shouldered Kite, Brown Goshawk and Peregrine Falcon have diets similar to elsewhere in Australia (cf. studies in Marchant and Higgins 1993; Debus 2012). Arboreal (small) monitor lizards and adult birds as prey records for the Square-tailed Kite throw additional light on the non-breeding diet of this species wintering in the tropics. The Grey Goshawk has a broader dietary niche in the Top End, including mammals and reptiles, than indicated by the few prey records in this study (see Riddell 2011, 2013). Although prey records for the Little Eagle at Kapalga are few, they support the notion that Little Eagles take mostly birds and reptiles, rather than mammals, in the tropics (e.g. Fisher 2010). The snake prey record at Kapalga is also of note, for an eagle that rarely takes snakes elsewhere (Marchant and Higgins 1993; Debus 2012). Caution is required in interpreting the meagre dietary data for the Southern Boobook at Kapalga, as even in the tropics (as in the temperate zone) it is likely to prey largely on vertebrates, at least by biomass, when breeding (e.g. Olsen 2011).

Among the raptor species with genera represented overseas, of note is the monitor lizard taken by the Black Falcon at Kapalga, as there are otherwise few verified records of reptiles taken by this species. In its generalised diet, including some reptiles, the Black Falcon resembles its genetic, morphological and ecological counterpart, the Lanner Falcon *Falco biarmicus* of the African tropics (cf. Ferguson-Lees and Christie 2001; Debus and Olsen 2010).

Concluding remarks

Future development in tropical northern Australia, including the Top End of the Northern Territory, which involves large-scale clearing of native vegetation will pose a severe threat to the health of raptor and other native species populations. Governments and developers need to be aware of the likely consequences of mass forest clearing on native fauna populations, and provide refugia of adequate size and distribution within proposed development areas, if they are to avoid the adverse impacts that have affected raptors and their prey base in southern Australia (e.g. see Debus (2009, 2012), Garnett *et al.* (2011) and Curtis *et al.* (2012) for national and state conservation status of threatened raptors and owls, and their threats). The future of the prey base (small native mammals) in the Australian tropics is also now of grave concern (Fitzsimons *et al.* 2010; Curtis *et al.* 2012).

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Appendix 1

List of species scientific names as they appear on Table 5

Mammals

Dusky Rat *Rattus colletti*
Common Brushtail Possum *Trichosurus vulpecula*
Swamp Buffalo *Bubalis bubalis*
Pig *Sus scrofa*
Flying-fox unid *Pteroptus* sp.
Agile Wallaby *Macropus agilis*
Short-beaked Echidna *Tachyglossus aculeatus*
Water-rat *Hydromys chrysogaster*
Little Red Flying-fox *Pteropus scapulatus*
Northern Brown Bandicoot *Isoodon macrourus*
House Cat *Felis catus*
Sugar Glider *Petaurus breviceps*

Birds

Magpie Goose *Anseranas semipalmata*
Wandering Whistling-Duck *Dendrocygna arcuata*
Rainbow Lorikeet *Trichoglossus haematodus*
Varied Lorikeet *Psitteuteles versicolor*
Rainbow Bee-eater *Merops ornatus*
Black-winged Stilt *Himantopus himantopus*
Intermediate Egret *Ardea intermedia*
Forest Kingfisher *Todiramphus macleayii*
Little Corella *Cacatua sanguinea*
White-browed Crake *Amaurornis cinerea*
Red-tailed Black-Cockatoo *Calyptorhynchus banksii*
Red-winged Parrot *Aprosmictus erythropterus*
Blue-winged Kookaburra *Dacelo leachii*
Bar-shouldered Dove *Geopelia humeralis*
Peaceful Dove *Geopelia striata*
Common Bronzewing *Phaps chalcoptera*
Tawny Frogmouth *Podargus strigoides*

Birds *(Continued)*

Whimbrel *Numenius phaeopus*
Pheasant Coucal *Centropus phasianinus*
Little Curlew *Numenius minutus*
Glossy Ibis *Plegadis falcinellus*
Intermediate Egret *Ardea intermedia*
Eastern Great Egret *Ardea modesta*
Radjah Shelduck *Tadorna radjah*
Plumed Whistling-Duck *Dendrocygna eytoni*
Hardhead *Aythya australis*
Pacific Black Duck *Anas superciliosa*
Australian White Ibis *Threskiornis molucca*
Royal Spoonbill *Phatalea regia*
Pied Heron *Egretta picata*
Sulphur-crested Cockatoo *Cacatua galerita*
Darter *Anhinga novaehollandiae*
Nankeen Night Heron *Nycticorax caledonicus*
Purple Swamphen *Porphyrio porphyrio*

Reptiles & Amphibians

Spotted Tree Monitor *Varanus scalaris*
Giant Frog *Cyclorana australis*
Northern Long-necked Turtle *Macrochelodina rugosa*
Arafura Filesnake *Acrochordus arafurae*
Macleay's Water Snake *Enhydris polylepis*
Centralian Blue-tongue *Tiliqua multifasciata*

Fish

Sleepy Cod *Oxyeleotris lineolata*
Barramundi *Lates calcarifer*
Freshwater Longtom *Strongylura kreffti*
Diamond Mullet *Liza alata*
Bony Bream *Nematalosa erebi*
Saratoga *Scleropages jardinii*

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Breeding ecology of Welcome Swallows *Hirundo neoxena* in the Yarra Valley, Victoria: the nestling stage

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Breeding ecology studies encompassing multiple seasons, sites and breeding attempts help in determining which aspects of a species' breeding ecology are widespread, which vary temporally and spatially, and the reasons for such variation. The nestling stage of Welcome Swallows *Hirundo neoxena* breeding in eleven sites less than or equal to 12 kilometres apart in the Yarra Valley, southern Victoria was studied over three successive seasons. The seasonal timing of the nestling stage (late Sept. –early Jan.), degree of hatching synchrony (53%) and the length of the nestling period (20–24 days) were similar to findings of other Welcome Swallow studies in SE Australia and suggested that these features may be genetically regulated. In contrast, values for features likely to be more proximally influenced by environmental variation were more at variance with values reported in some other investigations, e.g. absolute hatching success (68%), fledging success and, to some extent, the causes of nestling mortality. There was some variation among years in the seasonal timing of hatching, and among years and colonies in the causes of nestling losses. The role of predation in nestling mortality was equivocal; there was little direct evidence for it, but it may have contributed to the high frequency of nestling disappearance.

INTRODUCTION

Major advances in understanding the evolution and adaptive significance of life history strategies depend on the acquisition and synthesis of information for a wide array of species and populations. For this information to be truly representative, it should encompass the temporal and spatial variation in life history traits that can occur *within* a species. In birds this kind of information base has enabled authors to formulate plausible 'global' hypotheses about the evolution of such breeding and developmental life history traits as egg and clutch size, egg composition, developmental mode, embryonic and nestling growth rates and energetics and the timing of breeding (Lack 1968; Martin 2008; Martin and Briskie 2009; Ricklefs 1969, 1987, 2008; Ricklefs and Starck 1998; Sotherland and Rahn 1987 and Weathers 1992). This in turn has stimulated many researchers to test these hypotheses on particular taxa (e.g. Murphy 2000; Dobson and Jouventin 2007). However, despite the publication of some valuable syntheses of breeding adaptations and life history strategies of Australian birds (Nix 1976; Yom-Tov 1987; Cockburn 1996; Russell 2000; Russell *et al*. 2004), our understanding of the evolution of their life history adaptations is still comparatively limited.

Five of the 83 species in the family Hirundinidae inhabit Australia. The Welcome Swallow *Hirundo neoxena* is a partial migrant that is widely distributed through mesic eastern, southern and south-western Australia, from the tropics to temperate latitudes, in grassland, farmland, shrub land, woodland and open forest (Higgins *et al*. 2006). Its habit of attaching its conspicuous mud nest to human-made structures has resulted in its breeding biology being relatively well documented from a compendium of records from widely dispersed locations (Marchant and Fullagar 1983; Higgins *et al*. 2006). There have also been four focused studies of its breeding biology at different locations in temperate Australia (Schrader 1976; Park 1981; Brown and Brown 1991; Tarburton 1993). However, only one of these studies (analysis of Brown and Brown's data by Simojoki and Davies 2013) has involved monitoring large numbers of breeding attempts at multiple sites over more than one breeding season in a way that representatively captures variability among years and on a local spatial scale.

In this study, data were collected on the Welcome Swallow's breeding ecology at several sites in the Yarra Valley, southern Victoria over three successive breeding seasons to document the timing and success of hatching and fledging and the causes of nestling mortality. The main aims were to: (1) identify features of breeding ecology at the nestling stage that lacked temporal and/or spatial variation and which therefore may be genetically regulated, and (2) examine the possible causes of disparities in those features that exhibited such variation within the study. Breeding ecology of the laying and incubation stages at this location has been reported previously (Lill 2014).

METHODS

Study area

The study was conducted over the breeding seasons (Aug.–Jan.) of 2009–10, 2010–11 and 2011–12 in the Yarra Valley near Yarra Glen township (37º 39'S, 145º 22'E). Seven breeding sites were monitored in 2009 and eleven in 2010 and 2011. Four sites were in culverts under roads and the rest under road bridges. Sites were 1.4–12.1 kilometres apart and the four largest colonies were 3.9–6.4 kilometres apart. Nine sites were on permanent or intermittent watercourses and most adjoined agricultural land, but had riparian vegetation nearby. The range in long-term mean monthly weather statistics for the study period in the area is: mean maximum ambient temperature (T_a) 14.8ºC in August to 27.7ºC in January; mean minimum T_a 4.1ºC in August to 11.6ºC in January; mean monthly rainfall 68.4 millimetres in September to 46 millimetres in January.

Monitoring broods

Low nests were inspected directly and higher nests with an extendable pole, mirror and flashlight and/or by ladder. I assumed that during a season re-use of a particular nest or construction and use of a new one very close by after nest destruction was by the same pair of birds; however, most adults were not banded and in other swallow species pairs sometimes switch nests after a breeding failure (del Hoyo *et al*. 2004), so this was not completely certain. Active nests were checked (a) on alternate days throughout incubation if the timing of hatching was unpredictable or (b) daily around the projected hatching time if it was predictable. In 2009 and 2010, all nestlings were weighed with a Pesola™ balance (± 0.25 g) at hatching and on Day 12 when asymptotic mass is attained before mass regression commences (Simmons and Lill 2006), so nestling survival and mass gain to Day 12 could be determined accurately. In 2009 nestlings were also weighed on Day 5. Fledging was monitored systematically in 2010 and 2011, but only in terms of whether one or more nestlings was still present three days before the estimated fledging date. This procedure was adopted to avoid initiating large-scale premature fledging (Marchant and Fullagar 1983).

Data analysis

Statistical analyses were conducted with *Systat* v. 13 (Systat Software, Chicago) and R (R Development Core Team, 2011). Comparisons among years and colonies were mostly made with tests of independence for frequencies (chi squared, Fisher's exact and Kolmogorov Smirnov) and *t* tests, general linear models (GLM), analyses of variance (ANOVA) and analyses of covariance (ANCOVA) for continuous variables. Data were transformed to meet the requirements of parametric tests where appropriate (e.g. percentage absolute hatching success). Statistical comparisons among colonies were necessarily mostly restricted to the four which had a substantial number (> 10) of active nests per season, namely Yeringberg Creek (Yc), Stringybark Creek (Sbk), Tarrawarra Road (Tarr) and Healesville-Yarra Glen Road (Hyg). Results are presented as a mean ± standard error (SE).

RESULTS

Timing of hatching of first broods

As most adults were not individually recognisable, first broods of the season were defined as the first to be produced in a particular nest or individual nest site. The timing of hatching of first broods varied among years ($\chi^2_{(12)} = 33.605$, $P < 0.001$, last two fortnights in which hatching frequencies were very low in all years omitted from analysis).

In 2009, hatching of 74 accurately monitored first broods extended over 14 weeks (18–24 Sept., week 6 [Wk 6] to 1–24 Dec., Wks 16–19); 93 percent of these broods hatched over 10 weeks between 18–24 September and 20–26 November. Peak hatching periods were 18 September–1October, 23–29 October and 20–26 November (Fig 1).

In 2010, hatching of accurately monitored first broods (*n*= 86) began at a similar time as in 2009 but extended longer into early January; 95 percent of broods hatched over 12 weeks between 18–24 September and early December. Peak hatching periods were 25 September–8 October and 16–22 Oct (Fig 1).

In 2011, hatching of accurately monitored first broods (*n*= 89) extended over 15 weeks and 90 percent hatched over 9 weeks between 11–17 September and 20–26 November. In the peak hatching period (18 Sept.–1Oct.), 34 percent of first broods hatched (Fig 1).

Timing of hatching of subsequent broods

Second and third broods were defined as the second or third to be produced in a particular nest or individual nest site in a season.

2009: Eighteen accurately monitored second broods hatched over 12 weeks (9–15 Oct. to late Dec.) and hatching was fairly evenly spread during this period (Fig 1).

2010: Accurately monitored second broods (*n*=33) hatched over 17 weeks, commencing earlier and finishing later than in 2009. Peak hatching (42% of broods) occurred between 20 November–3 December (Wks 15 and 16).

2011: The chronology of hatching of 28 second broods resembled that in 2009, except that there was a definite peak (54% of broods) from 13–26 November (Wks 14 and 15), slightly earlier than the 2010 peak.

The small numbers of second broods precluded meaningful significance testing of among-year variation in the timing of their hatching. Five third broods hatched in the second half of December in 2010 and the only 2011 third brood hatched in late November/early December.

Hatching success

Over the entire study, 78 percent of clutches whose hatching could be accurately monitored produced at least one hatchling, but the percentage varied among years (88% in 2009, *n* = 100; 78% in 2010, *n* = 174 and 72% in 2011, *n* = 137; $\chi^2_{(2)} = 8.541$, $P = 0.014$). Absolute hatching success (i.e. the percentage of eggs hatching per clutch) averaged 68 ± 2 percent (*n* = 386 clutches) over the entire study. It did not vary with clutch size, breeding attempt number (1st, 2nd or 3rd), among years or among the four largest colonies (Table 1 and legend). However, it did increase later in the breeding season (Tables 1 and 2), particularly in larger clutches, and when *all* colonies were considered there was a modest colony effect on hatching success, with the Old Healesville Road colony (OHR) having significantly lower hatching success than four other colonies (Table 1 and legend). In each year, hatching success of the first and second clutches laid in a particular nest or individual nest site was similar (mean difference in success: 2009, 5%, paired $t_{(19)} = 0.663$, $P = 0.515$; 2010, 2%, paired $t_{(39)} = 0.364$, $P = 0.718$; 2011, 0.7%, paired $t_{(27)} = 0.095$, $P = 0.925$).

Hatching synchrony and early growth

In the three seasons combined, 53 percent of 230 broods whose hatching was accurately monitored visually and/or through weighing hatchlings did so synchronously (i.e. on same day), 47

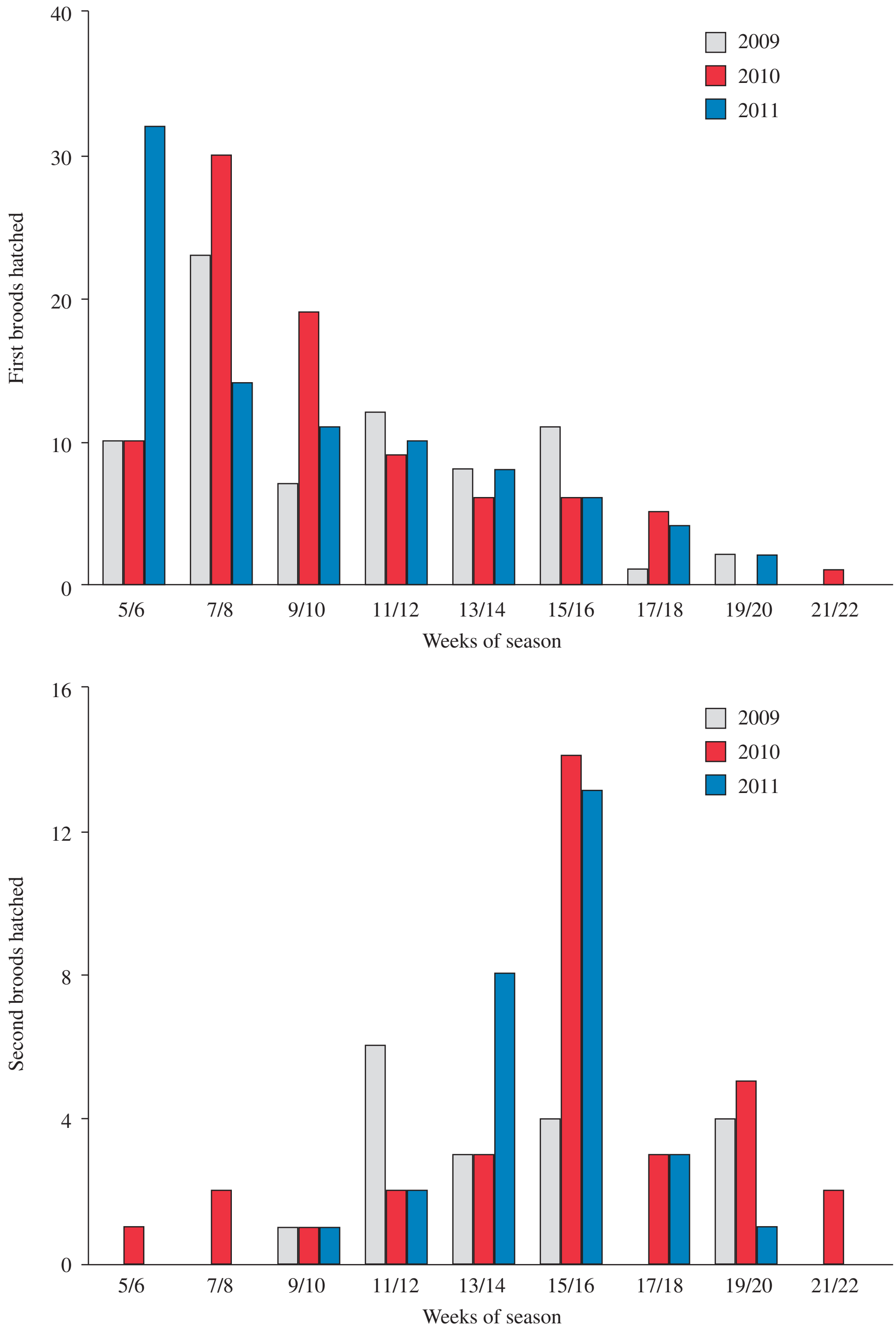

Figure 1a. *Timing of hatching (Figure 1a) of the first and second broods in a particular nest or individual site in all breeding locations. Time in the season is indicated in two-week periods; Weeks 5/6 were 11– 24 Sept., Weeks 7/8 25 Sept. – 8 Oc.t, weeks 13/14 6 – 19 Nov. and Weeks 23/24 were 14 – 27 Jan. Hatching data are for all three seasons combined and fledging data for 2010 and 2011 combined. Note that in 2010 a very small number of first broods that hatched early in the season were not sufficiently accurately monitored to include in the second graph.*

percent took at least two days and less than one percent took at least three days. Synchronous hatching (SH) was less common in larger broods; the percentage of broods hatching synchronously was 71 (for broods of 2), 61 (broods of 3), 48 (broods of 4) and 29 (broods of 5) ($\chi^2_{(30)} = 9.128$, P = 0.028). However, this trend was particularly influenced by a bias towards asynchronous hatching (AH) in broods of four in 2009 (67% AH).

Mean intra-brood mass disparity (the mass difference between the heaviest and lightest brood-member) was 1.8 times greater at hatching in AH than SH broods (r^2 0.237, $F_{(89)}$ = 14.609, P <0.001) (Table 3), potentially giving scope for brood reduction through malnutrition. In 2009, mean intra-brood mass disparity typically increased from hatching to Day 5 and then decreased to Day 12, and similar percentages of AH and SH

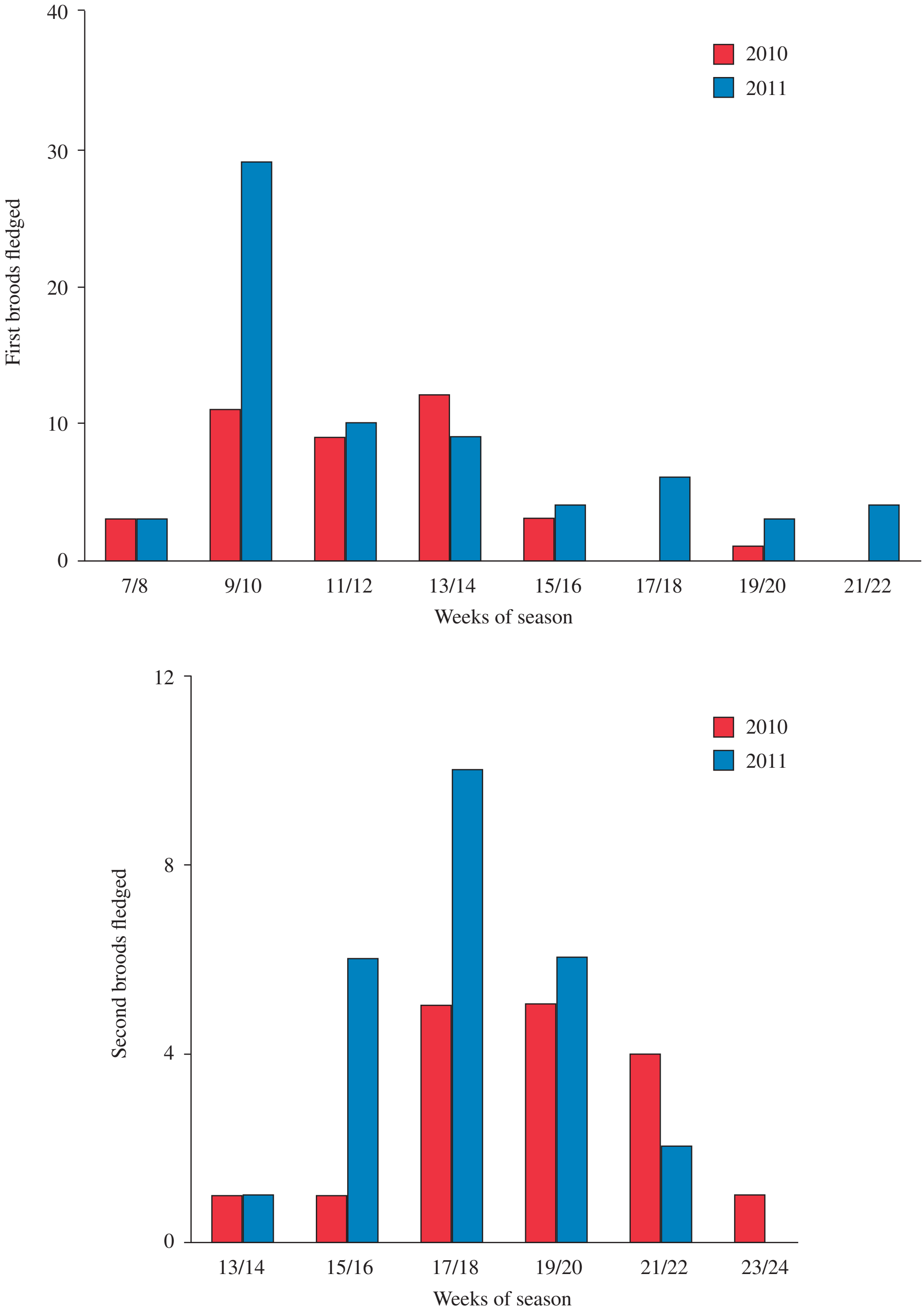

Figure 1b. *Timing of fledging (Figure 1b) of the first and second broods in a particular nest or individual site in all breeding locations. Time in the season is indicated in two-week periods; Weeks 5/6 were 11– 24 Sept., Weeks 7/8 25 Sept. – 8 Oc.t, weeks 13/14 6 – 19 Nov. and Weeks 23/24 were 14 – 27 Jan. Hatching data are for all three seasons combined and fledging data for 2010 and 2011 combined. Note that in 2010 a very small number of first broods that hatched early in the season were not sufficiently accurately monitored to include in the second graph.*

broods showed and did not show this increase-decrease pattern (Fisher exact P = 1 and $\chi^2_{(1)} = 0.190$, P = 0.863), respectively. In 2010, the percentages of SH and AH broods in which intra-brood mass disparity increased between hatching and Day 12 were also similar (Fisher exact P = 1). Pertinently, with respect to the scope for brood reduction through asynchronous hatching, intra-brood mass disparity did not differ between the two hatching profiles on either Day 5 of development in 2009 ($t_{(60)} = 1.958$, P = 0.055) or Day 12 in that year and 2010 combined ($t_{(147)} = 1.013$, P = 0.313).

Brood reduction through death *in situ* or disappearance of one or two members (i.e. potentially consistent with brood reduction through malnutrition) occurred in 15 percent and 42 percent of accurately monitored AH broods and 16 percent and

Table 1

Mean ± SE [*n*] percentage absolute hatching success as a function of clutch size and colony identity. SE in round brackets and sample size in square brackets.

	Year								
	2009			2010			2011		
Clutch size									
1							0		[2]
2	0		[2]	69.1	(13.58)	[11]	0		[8]
3	86.7	(7.38)	[10]	69.4	(8.25)	[24]	66.7	(10.2)	[19]
4	82	(3.93)	[61]	70.5	(4.15)	[88]	75.8	(10.2)	[100]
5	58.2	(8.72)	[22]	74.2	(7.56)	[24]	66.7	(11.9)	[12]
6	100		[1]						
All sizes	75.5	(3.61)	[96]	70.8	(3.22)	[147]	68.4	(7.6)	[141]
Colony									
Yc	64.1	(8.4)	[22]	77.4	(6.2)	[28]	48.9	(8.1)	[29]
Sbk	64.5	(9.4)	[19]	53.8	(7.3)	[36]	51.5	(10.5)	[22]
Tarr	90.6	(3.5)	[19]	59.3	(7.7)	[32]	76.1	(6.2)	[30]
Hyg	64.5	(10.2)	[20]	84.4	(8.5)	[16]	66.5	(9.6)	[22]

Statistical analysis:

Effect of clutch size on hatching success (GLM):-

Variable	Df	F-value	P-value
Clutch size	1	3.486	0.063
Year	1	0.249	0.618
Time in season	1	4.677	**0.031**
Attempt no.	1	0.500	0.480
Colony	10	2.948	**0.002**
Clutch size ×	1	5.469	**0.020**

Post hoc Tukey test (α = 0.05) summary for colony effect: The OHR colony had significantly lower absolute hatching success than four other colonies (Yarra Grange, Watts River, Stringybark Creek and Badger Creek Rd-Maroondah Hwy junction), but not the remaining six.

Effect of Colony Identity on Hatching Success (four largest colonies only) (GLM):-

Variable	Df	F-value	P-value
Clutch size	1	1.373	0.243
Year	1	0.001	0.977
Time in season	1	11.353	**0.001**
Attempt no.	1	0.049	0.824
Colony	3	1.863	0.136

14 percent of SH broods in 2009 and 2010, respectively. The mean intra-brood mass disparity at hatching was similar in AH broods that lost and did not lose 1–2 members through death or disappearance in both years (2009, 0.6 and 0.7g, $t_{(10)} = 0.551$, P = 0.594; 2010, 0.8 and 0.7g, $t_{(8)} = 0.176$, P = 0.865).

Causes of nestling mortality

Nestling periods lasted from 20 to 24 days (*n*=12, with an accuracy of 1–2 days), with eight being 21 or 22 days long. Seven 'causes' of mortality were identified among 204 nestlings whose loss was accurately documented (Table 4). Disappearance from the nest for unknown reasons, exposure and starvation resulting from desertion by parents in low T_a and death *in situ* due to poor health or nutrition collectively accounted for 77 percent of nestling losses. However, the causes of nestling loss varied among years (with some category pooling, $\chi^2_{(8)} = 101.871$, P <0.001) (Table 3). Disappearance was by far the principal 'mortality agent' in 2010 and 2011, but in 2009 desertion by parents at low T_a caused most mortality. Nestling losses through flooding were restricted to 2010.

Table 2

Variation in mean ± SE (n) absolute hatching success of all Welcome Swallow clutches during the course of the breeding season. Absolute hatching success is percentage of eggs in a clutch that hatched. Data are for the three study seasons and all breeding sites combined.

Two-week period of breeding season	Mean percentage hatching success (no. broods)	
14 – 27 Aug.	68 ± 9.88	(20)
28 Aug. – 10 Sept.	75 ± 4.11	(81)
11 – 24 Sept.	64 ± 5.16	(64)
25 Sept. – 8 Oct.	77 ± 6.03	(36)
9 – 22 Oct.	82 ± 4.72	(28)
23 Oct .– 5 Nov.	87 ± 4.03	(37)
6 – 19 Nov.	81 ± 4.95	(42)
20 Nov.– 3 Dec.	70 ± 11.19	(16)
4 – 17 Dec.	89 ± 4.00	(15)
18 – 31 Dec.	77 ± 15.74	(4)

Data on the causes of nestling mortality for the four largest colonies were too few to permit significance testing. Disappearance was 1.7 to 3 times more common than the second most common cause of nestling loss in these colonies, but only one colony experienced nestling mortality from flooding and only one was immune from nestling loss through parental desertion at low T_a.

Timing of fledging

The timing of fledging of first broods was similar in 2010 and 2011 (Kolmogorov Smirnov two-sample test, d = 0.166, P> 0.05). There were too few second and third broods to test whether the timing of their fledging differed between years.

2010: Fledging of 39 accurately monitored first broods stretched over 14 weeks (25 Sept.–1 Oct. to late Dec.), with 92 percent fledging between early October and 20–26 November (Fig 1). Peak fledging week for first broods was 16–22 October, when 26 percent of them fledged. The fledging of 17 accurately monitored second broods was spread fairly evenly over 11 weeks (mid-Nov. to late Jan.) (Fig 1) and the two third broods produced fledged between 8–20 January.

2011: Fledging of 66 monitored first broods occurred over 15 weeks (2–8 Oct. to 8–14 Jan.), 72 percent of them fledging in the first six of those weeks (i.e. early Oct. to13–19 Nov.) (Fig 1). Peak fledging period for first broods was 9–22 October. Twenty-five second broods fledged over 10 weeks (early Nov. to 8–14 Jan.) and the two third broods produced fledglings between 11–24 December (Wks 18 and 19).

Nestling survival and fledging success

The percentage of all accurately monitored broods in which at least one nestling survived to Day 12 (asymptotic mass attainment) varied among years, being particularly high in 2011 (2009, 67%, *n* = 86; 2010, 72%, *n* = 114 and 2011, 90%, *n* = 132) ($\chi^2_{(2)}$ = 19.401, P <0.001). However, the mean percentage of hatchlings in a brood surviving to this stage was similar in 2009 and 2010 (independent $t_{(199)}$ = 1.484, P = 0.139) (Table 5). This metric was not obtained in 2011.

Successful fledging was defined as one or more nestling(s) in a brood fledging. In 2010 and 2011 combined, success occurred in 82 percent of 220 accurately monitored broods of all sizes and it was similar in the two years ($\chi^2_{(1)}$ = 0.551, P = 0.458) (Table 4). Success was greater in larger broods in 2011 (mean number of hatchlings in broods where fledging occurred 3.7 ± 0.5 *versus* failing broods 2.9 ± 1.5, $t_{(17)}$ = 2.481, P = 0.024), but not 2010 (fledging broods 3.5 ± 0.1*versus* failing broods 3.0 ± 0.3 hatchlings, $t_{(22)}$=1.703, P = 0.103). Fledging success for all broods was similar among the four largest colonies in both 2010 and 2011(Table 5) (2010, Fisher exact P = 0.331, *n*= 72; 2011, P = 0.625, *n* = 89).

Retention of dead nestlings and death of parents

When one or two nestlings in a brood of one or more died during development, they were also usually removed by the adults within a few days. However, occasionally they were retained underneath the living brood-members for a considerable time. When an entire brood died, the adults usually removed the bodies before re-using the nest, but on two occasions a new clutch was laid and incubated over a dead nestling from a previous brood. On three occasions one or two dead adults were found in a nest containing, or which had very recently contained, nestlings. In one of these nests the nestlings had died just one day earlier and in another a pair of adults subsequently conducted a successful breeding attempt on top of the dead adult. In two cases nestlings fledged despite the presence of (one and two) dead adults in the nest, probably because they were very close to fledging when the adult(s) died.

Table 3

Mean (± SE) (*n*) intra-brood mass disparity (heaviest – lightest nestling) at hatching and on Days 5 and 12 of nestling development in asynchronously and synchronously-hatching broods. IBMD (g) = intra-brood mass disparity in grams. -> indicates direction of increase or decrease.

Hatching profile	Mean ± SE (n) IBMD (g)			Percent broods with IBMD:	
	Hatching (H)	Day 5	Day 12	increase H –> D5	decrease D5 -> D12
2009:					
Asynchronous	0.60 ± 0.08	2.21 ± 1.18	1.87 ± 0.25	95	62
	(23)	(42)	(40)		
Synchronous	0.45 ± 0.07	1.68 ± 0.20	1.55 ± 0.23	92	56
	(14)	(27)	(26)		
2010:				increase H -> D12	
Asynchronous	0.77 ± 0.14		1.49 ± 0.14	86	
	(15)		(45)		
Synchronous	0.31 ± 0.04		1.25 ± 0.13	88	
	(41)		(52)		

Statistical analysis:

ANCOVA: Effect of hatching synchrony on hatching IBMD:-

	df	**F ratio**	**P**
Factor: Synchrony	1	14.609	**<0.001**
Covariates: Year	1	0.020	0.887
Brood size	1	6.840	**0.010**

Table 4

Percentage of nestling mortality attributable to various causes in (a) all breeding sites combined in the three breeding seasons and (b) the four largest colonies in all seasons combined. *n* = number of nestling losses, Ta = ambient temperature.

(a)

Cause of nestling mortality	Year			All years
	2009	2010	2011	
All sites				
Disappearance	18.9	66.7	55.8	47.1
Poor health/nutrition	10.8	13.8	23.3	14.7
Nest collapse	8.1	9.2	*	6.9
Flooding		10.4		4.4
Water seepage	5.4			2
Ejected from nest	14.9		20.9	9.8
Parental desertion due to low Ta	41.9			15.1
n	74	87	43	204

(b)

Larger colonies	Yc	Sbk	Tarr	Hyg
Disappearance	68.2	60	41.3	42.3
Poor health/nutrition	22.7	16.7	19.6	25.0
Nest collapse	*	0	0	11.5
Flooding	0	0	13	0
Water seepage	0	0	0	7.7
Ejected from nest	9	0	6.5	0
Parental desertion due to low Ta	0	23.3	19.6	13.5
n	22	30	46	32

* one brood of unknown size lost due to nest collapse

Table 5

Nestling survival to asymptotic mass and fledging success as functions of study year and colony identity. Upper row is mean ± SE percentage of nestlings per brood surviving to Day 12; row below (in italics) is fledging success, defined as at least one nestling in a brood fledging. Number of broods on which fledging success was based is given in parenthese

Sites	Year		
	2009	2010	2011
All sites	79.2 ± 3.9	84.9 ± 2.8	
		80.2	*84*
		(101)	*(119)*
Larger colonies:			
Yc	90 ± 3.7	91 ± 4.6	
	(17)	(24)	
		87.5	*76.7*
		(24)	*(30)*
Sbk	72.1 ± 9.3	79 ± 7.7	
	(17)	(23)	
		80	*88.2*
		(15)	*(17)*
Tarr	79.2 ± 8.7	91.1 ± 6.3	
	(18)	(18)	
		76.5	*85.2*
		(17)	*(27)*
Hyg	73.3 ± 11.8	65.5 ± 11.9	
	(15)	(14)	
		62.5	*78.6*
		(16)	*(15)*

DISCUSSION

Comparisons with other studies

Concurrence with the findings of other Welcome Swallow studies in SE Australia was evident in (a) the seasonal timing of the nestling stage (late Sept.–early Jan.), (b) the degree of SH (53%) and (c) nestling period duration (20–24 days) (del Hoyo *et al*. 2004; Higgins *et al*. 2006). This agreement is not surprising in an evolutionarily conservative family (del Hoyo *et al*. 2004) and suggests that these features are probably genetically regulated. In contrast, disparities with published findings occurred in features likely to be influenced more proximally by environmental factors. Thus absolute hatching success (68% of eggs) was fairly comparable with six other records based on large sample sizes for various regions of Australia (63.2–79.3%), but much lower than eight records (94.4 – 98.5%) and much higher than another record (55%) (Higgins *et al*. 2006). Similarly, mean fledging success (percentage broods in which at least one nestling fledged) was 82 percent in the Yarra Valley, which was similar to two published records (75.1 and 78.9%) but much greater than ten others for various regions of Australia (54.1–71.3%) (Higgins *et al*. 2006). The causes of nestling mortality were qualitatively similar to those reported in other investigations, but predation appeared to be less prevalent (Higgins *et al*. 2006).

Temporal variation

The period of hatching of first broods was more protracted (by 2–3 weeks) in 2010 than in the other two years, extending into early Jan. It reflected the relative extension of the period of laying of first clutches by two weeks into mid-December in that year. Although it was not amenable to significance testing, the hatching of second broods also appeared to be more protracted (by 5–6 weeks) in 2010 than in 2009 or 2011 and also extended into early January, although the laying of second clutches was not relatively extended in 2010 (Lill 2014). Conceivably the La Niña weather conditions in Spring 2010 may have extended the period of favourable conditions for egg-laying and incubation (Lill 2014).

The percentage of clutches that produced at least one hatchling decreased over the three study seasons, but absolute hatching success was similar in all years despite variation in nestling mortality agents. A cold 'snap' (maximum daily T_a 10.1 –13.5^{0}C) lasting several days in late September was responsible for 42 percent of nestling losses in 2009, but did not recur in 2010 or 2011. Such cold and wet spells commonly cause desertion of broods in temperate zone swallows because the abundance of their aeroplankton diet is reduced dramatically at low T_a and in rain (Turner 2006). Flash flooding occurred in all breeding seasons, but caused nestling mortality only in 2011; in the previous two years it occurred earlier in the season, causing egg rather than nestling losses (Lill 2014). Flooding was more frequent in 2010 and 2011, which had above average rainfall in spring. Nestling mortality due to flooding also occurs in other hirundines that nest over water (del Hoyo *et al*. 2004). Absolute hatching success was greater later in the breeding season, conceivably partly because the higher T_a boosted aerial insect abundance and permitted greater incubation constancy.

Spatial variation

Absolute hatching success was lower in the OHR colony than in four of the other colonies; this colony was particularly susceptible to flooding. However, the only feature of the nestling stage that varied among the four largest colonies was the cause of nestling mortality. Only one of the four larger colonies (Tarr) and one of the seven smaller nesting sites had nestling mortality caused by flash flooding. Flooding occurred at the other sites, but nests were situated above the high water mark. Three of the four largest colonies had significant nestling losses (14–23% of mortality) resulting from parental desertion at low T_a in September 2009; it was unclear why the Yc colony had no such losses, as it experienced similarly low T_a at this time. However, disappearance was the predominant 'cause' of nestling losses in all four larger colonies and fledging success did not vary among them.

Given the Welcome Swallow's large geographical range in temperate Australia and the marked influence of weather conditions on breeding in birds that feed mainly on aeroplankton (O'Connor 1984), considerable spatio-temporal variation in breeding productivity is to be expected and it emphasises the need for data drawn from many years and locations in obtaining a representative estimate of fecundity for this species.

Hatching asynchrony and early growth

Nearly half of the broods in the study area hatched asynchronously and the phenomenon was not site-specific. In altricial birds AH can create a size hierarchy within the brood which the *Brood Reduction Hypothesis* proposes facilitates reduction of broods through food limitation and scramble competition to a size that the parents can rear if feeding conditions deteriorate (Lack and Lack 1951). Although parents can manipulate this hierarchy in some species (Krebs 2002), we might predict that if the hypothesis is correct it would usually be adaptive for the size disparities in AH broods to persist for at least the early part of the nesting period. This was the case in Welcome Swallow nestlings in the study area. In 2009 there was still a mean intra-brood mass disparity of about two grams on Days 5 and 12 of development in AH broods (i.e. ~ 33% and 11% of mean mass on Days 5 and 12, respectively), which might afford some scope for brood reduction through starvation. However, the values for SH broods (~ 20% and 9% of mean mass, respectively) did not differ from those for AH broods. Similarly, in 2010 mean intra-brood mass disparity on Day 12 was still approximately 7–8 percent of mean mass at that stage of development, but again did not differ between AH and SH broods. Fifteen and 42 percent of AH broods lost nestlings in a manner consistent with brood reduction (i.e. through death *in situ* or disappearance) in 2009 and 2010, respectively, but mean intra-brood mass disparity at hatching was similar in AH broods that lost and did not lose nestlings in these ways. Overall, these findings are not particularly consistent with the *Brood Reduction Hypothesis*.

Predation and nestling mortality

Ricklefs (1969) and Martin (1995) showed that predation is a major determinant of altricial birds' fledging success. There was no direct evidence of predation of nestlings in my study, although it has been recorded in other investigations of Welcome Swallows (Higgins *et al*. 2006). Disappearance 'accounted for' most nestling losses and could potentially have been due to predation. However, it was rarely accompanied by nest damage which might indicate resistance shown to a predator. Moreover, given that Welcome Swallow nests are hard for predators to access, a predator might reasonably be expected to take the whole brood (possibly in several visits), but the entire brood vanished in only 23 percent of instances of disappearance. It is likely that only light, agile birds could have preyed upon the swallow nestlings, because nests were mostly attached high up on vertical surfaces and often over water. A likely candidate, the Grey Shrike-thrush *Colluricincla harmonica*, is a known predator on other species' nestlings (Major *et al*. 1999; Berry 2002) and was present in or near several swallow colonies. If disappearance was not attributable to predation, a plausible alternative explanation is that parents removed nestlings that were sick or dead. Neighbouring breeding pairs may also have effected nestling mortality, as reported for other swallow species (del Hoyo *et al*. 2004).

The estimated mean nestling period of Welcome Swallows in the Yarra Valley (22–23 days) was 4–5 days longer than that predicted allometrically from mean asymptotic or fledging mass using allometric equation (6) of Weathers (1992). A relatively protracted nestling period is typical of species with a mass overshoot nestling growth pattern; the pattern has evolved independently in diverse avian taxa whose common feature is that their fledglings need to be particularly functionally mature (O'Connor 1984). Swallows fit this description because fledglings need to fly relatively proficiently in order to begin aerial self-feeding within a few days of leaving the nest (del Hoyo *et al*. 2004). Ricklefs *et al*. (1998) argued that nestling period protraction is necessary to achieve this because tissue growth and attainment of mature function cannot be achieved simultaneously due to molecular/biochemical constraints. Nest sites relatively safe from predation, as appeared to be the case in the study population of Welcome Swallows, allow nestling period protraction and temporal separation of tissue growth and physiological maturation during development without incurring a high cost in nestling losses to predators.

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The utility of closed aluminium and butt-ended stainless steel leg bands for Australian Pelicans *Pelecanus conspicillatus*

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Leg bands are one of the oldest and most widespread of methods used to mark individual birds for study, but different kinds of bands may influence results obtained. We compared recoveries from closed aluminium and butt-ended stainless steel leg bands deployed on Australian Pelicans *Pelecanus conspicillatus* between 1968 and 2004. All 64 recoveries from the 2123 closed aluminium bands deployed exhibited wear, whereas none of the 162 recoveries from the 12 427 butt-ended stainless steel bands deployed were worn. Closed aluminium bands resulted in 2.3 times as many recoveries overall, but half the recoveries within one year of deployment compared to butt-ended stainless steel bands. Only butt-ended stainless steel bands were recorded as "band only found", suggesting they became dislodged from pelicans. This was confirmed with pelicans that were simultaneously marked with leg bands and patagial tags. Together these data show that butt-ended stainless steel bands, while offering greater durability, result in less useful data than closed aluminium bands. A leg band that combines the durability of stainless steel bands and reliability of closed aluminium bands would provide a better proposition for the future studies of Australian Pelicans.

INTRODUCTION

A variety of techniques are now available to measure movements and longevity of birds, including patagial tags, leg flags, and radio or satellite telemetry (Strait and Sloan 1975; Schreiber and Mock 1988; Warnock and Takekawa 2003; Anderson and Anderson 2005; Fuller *et al.* 2005; Roshier *et al.* 2006; Coiffait *et al.* 2009; Martin and Major 2010). Numbered leg-bands (herein referred to as bands) are one of the oldest methods used to mark individual birds. While relatively few banded birds are recovered (Strait and Sloan 1975; Lawler *et al.* 1993; Webster *et al.* 2002; Lowe 1991), the large numbers of bands that have deployed in the past mean they provide an important source of data on fundamental aspects of bird biology. These data may also provide valuable information for conservation and management.

Several factors influence the reporting rate of recovered bands including species, band address, geographic location, the material from which a band is made and band design (Lensink, 1998; Lowe 1991; Anderson and Anderson 2005). Bands may deteriorate relatively quickly on birds that spend much time in and around water (Duwors *et al*. 1987; Lensink 1998). It is important to understand how these factors influence recovery rate and patterns because they have the potential to influence how data should be interpreted. In addition, worn bands may develop sharp scalloped edges which may injure birds (Duwors *et al.* 1987; Sedgwick and Klus 1997; Lensink, 1998; Berggren and Low 2003; Bedrosian and Craighead 2008).

Analysis of banding data has provided important information on pelicans internationally (Strait and Sloan 1975; Schreiber and Mock 1988; Crivelli *et al.* 1988; Anderson and Anderson 2005), but little is known about the movement of pelicans in Australia. As part of a larger study (Manning *et al.* in prep), we noticed differences in recoveries from two different kinds of bands that have been deployed on Australian Pelicans *Pelecanus conspicillatus*. This paper reports these differences in recoveries between closed aluminium bands and butt-ended stainless steel bands and tests whether the two types of bands offer equal utility in studies of movement and survival of Australian Pelicans.

MATERIALS AND METHODS

We analysed data from 14 550 Australian pelicans banded between 28 August 1968 and 20 November 2004. All bands were size 17 series, embossed with a unique number and supplied by the Australian Bird and Bat Banding Scheme (ABBBS). The 2123 bands deployed between 1968 and 1985 were closed (lock on) aluminium bands, whereas the 12 427 bands deployed between 1986 and 2004 were butt-ended stainless steel bands. The closed aluminium bands were similar in general design to the butt-ended band, except that they were closed with two flanges of unequal length. The longer flange was folded over the shorter flange, effectively locking the band in place (Figure 1).

Bands were deployed at six pelican breeding colonies in South Australia. Three thousand, five hundred and thirty-five bands were deployed at Lake Eyre South (29°24'S, 137°20'E,) as described by Waterman and Read (1992). A further 310 bands were deployed on Section Bank near Outer Harbour (34°47'S, 138°29'E) (Johnston and Harbison 2005; Johnston and Wiebkin 2008) and 128 bands at Reedy Point on Lake Alexandrina (35°27'S, 138°59'E) (Eckert 1965). The remaining 10 577 bands were deployed on North Pelican (36°03'S, 139°34'E), Seagull (36°05'S, 139°35'E) and Mellor Island (36°04'S 139°35'E) on the Coorong (Chapman 1963). The majority of birds banded were flightless downy chicks (Vestjens 1977). A small number of juveniles and adults were banded opportunistically, but these were not targeted.

ABBBS records of band recoveries were used to compare recoveries, band survival and degree of wear between the two types of band. Bands recovered from dead pelicans or as "band only found" accounted for 95.2 percent of the recovery records. The remaining 4.8 percent of bands reported were read on free-living birds or on birds that were captured and released. Band recoveries were reported more than once for three birds (1.3%). Only data from the longest time to recovery was used for each individual pelican, so that each bird was included in the analyses only once. We used three measures of band survival. Firstly, we compared the proportion of bands recovered within one year of banding. This analysis avoided the confounding effect of different amount of time since the two kinds of bands had been deployed. Secondly, we compared the proportion of bands recovered in five year intervals (0-5 years, 6-10 years, 11-15 years and 16-20 years) following deployment. This analysis tested the utility of the two kinds of bands over a longer period of time. Thirdly, we compared the proportion the two types of bands that were reported as "band only found" over the entire data set. Statistical comparisons were made with χ^2 tests (Sokal and Rohlf 1995).

RESULTS

Overall 226 (1.6%) bands were recovered of the 14 550 deployed. A higher percentage of closed aluminium bands were recovered (64 recoveries or 3.0% of 2 123 deployed) than butt-ended stainless steel bands (162 recoveries or 1.3% of 12 427 deployed) (χ^2_1 = 31.34, P < 0.001).

In contrast, a smaller percentage (39.1% = 25 of 64) of closed aluminium bands were recovered within one year of being deployed than butt-ended stainless steel bands (75.9% = 123 of 162) (χ^2_1 = 25.98, P < 0.001). Over longer periods of time there were no differences in proportional recoveries between the two band types, except for the period between five and ten years after deployment (Table 1). Then 17.2 percent (11of 64) of Aluminium bands were recovered versus 5.6 percent (9 of 162) of stainless steel bands (χ^2_1 = 5.95, P < 0.025; Table 1). None of the 64 (0%) closed aluminium bands deployed were recovered as "band only found", whereas 20 of 162 (12.3%) butt-ended stainless steel bands deployed were recovered as "band only found" (χ^2_1 = 7.21, P < 0.01).

All closed aluminium bands recovered exhibited band wear. The degree of band wear on closed aluminium bands increased with time, to the extent that abrasion on the margins of the band was evident and often the band number was barely visible after three years. One live Australian Pelican with a readable closed aluminium band was reported 15 years after banding, although the digits had eroded substantially. After 15 years no closed aluminium bands were recovered (Table 1). In comparison, none of the butt-ended stainless steel bands exhibited band wear. Indeed, four butt-ended stainless steel bands recovered from dead chicks that had failed to fledge showed no evidence of wear, even though they had lain in the salt crust of Lake Eyre South for twenty years.

Figure 1. *Butt-ended stainless steel band recovered 10 years and 10 months after banding (left) and closed aluminium band recovered 4 years 6 months after banding (right).*

Table 1

Number *(n)* and percentage (%) of closed aluminium bands and butt-ended stainless steel bands recovered over twenty years, divided into five-year periods following deployment. χ^2 statistic tests the null hypothesis that the two band types were equally likely to be recovered during each period. * P ≤ 0.05.

Period following deployment (years)	Aluminium		Stainless Steel		χ^2
	n	%	n	%	
0–5	49	76.6	142	87.7	0.941
6–10	11	17.2	9	5.6	5.952*
11–15	4	6.2	4	2.4	1.875
16–20	0	0	7	4.3	2.763
	64	100	162	100	

DISCUSSION

Closed aluminium bands and butt-ended stainless steel bands differed in their utility for studies of movement and survival of Australian Pelicans. The legibility of embossed numbers was reduced due to wear on closed aluminium bands, whereas stainless steel bands showed no evidence of wear or loss of legibility. In this respect stainless steel bands would seem preferable to aluminium bands. However, aluminium bands resulted in 2.3 times as many recoveries overall and half the recoveries within one year of deployment compared to stainless steel bands. Furthermore all recoveries recorded as "band only found" involved stainless steel bands. Together these data show that adjustable stainless steel bands, while offering greater durability, result in less useful data than closed aluminium bands.

It is important to note that the two types of bands were not deployed simultaneously, so differences in recovery between the two types of band are temporally confounded. While a study properly designed *a priori* for this purpose would take this into account, this problem was unavoidable in this *post hoc* study.

The higher recovery rate of closed aluminium bands could be attributed by the greater time available for this band type to be recovered (almost 36 years) compared to 19-years for the adjustable stainless steel bands. This does not explain the difference in bands recovered within a year of deployment, though. Nor does it explain the difference in the proportion of "band only found" recoveries. The closed aluminium bands had a seamless seal, which did not allow bands to dislodge from a bird's leg once deployed. On the other hand adjustable stainless steel bands relied on tensile strength to keep them attached to a bird's leg. The high incidence of butt-ended stainless steel bands recovered within a year of deployment and as "band only found", suggests they were prone to becoming dislodged. This possibility has been confirmed with Australian Pelicans that were simultaneously marked with patagial tags and butt-ended stainless steel leg bands (Johnston, unpub. data). Several of those pelicans lost their leg band within a year of deployment, but were identifiable from the patagial tag.

The decision by ABBBS to change to stainless steel bands in 1985 was made because aluminium bands were subject to wear and because worn aluminium bands had the potential to injure birds (Lowe, pers. comm. with M. Waterman). While we found no evidence of injuries from worn aluminium leg bands in the data set available to us, we confirmed a previous observation by Henny (1972 – cited in Schreiber and Mock 1988) that stainless steel bands showed no band wear.

The design and material used to construct leg bands clearly influences their recovery rate and utility for bird studies. Several studies have deployed leg bands on pelicans (Strait and Sloan 1975; Schreiber and Mock 1988; Anderson and Anderson 2005; Murphy 2005; Vanspall *et al*. 2005), but none of these studies refers to the band material and/or band design used. Bands used on Australian Pelicans in the past have either suffered from wear (closed aluminium bands) or increased likelihood of becoming dislodged (butt-ended stainless steel bands). A leg band that combines the characteristics of durability of stainless steel bands and reliability of closed bands would provide a better proposition for the future studies of Australian Pelicans. To this end the ABBBS now uses side opening stainless steel bands for Australian Pelicans.

ACKNOWLEDGEMENTS

This study was made possible by the efforts of numerous volunteers who helped band pelicans. Special thanks to the South Australian National Parks and Wildlife Service rangers Darryl Wanke, Stephen Brown, Herman Bakker and David Farlum. David and Margaret Dadds and the Friends of the Coorong assisted with banding, as did John Read, David Condon, David Connell, Tom Martin, Clayton Cross, Steve Colling, Geoffrey Wanke, Lee Foreman, Ron Bayley, John Zwar and Martin Bennett. Thanks also to David Drynan and Lisa Hardy of the ABBBS who provided the pelican banding data, comments on the manuscript and the photograph for Figure 1.

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Book Review

Finding Australian Birds: A Field Guide to Birding Locations

Tim Dolby and Rohan Clarke 2014. CSIRO Publishing. Paperback, 624 pp, coloured photographs. ISBN: 9780643097667. RRP $49.95.

A brand new addition to the 'where to find' birdwatchers' guide market, *Finding Australian Birds: A Field Guide to Birding Locations* is possibly the most dynamic yet, and has birders the world over swinging their binoculars in excitement. From the introduction to the index, it displays more detailed text than its contemporary *The Complete Guide to Finding the Birds of Australia* (Thomas *et al.* 2011) (for review see *Corella* 35: 60).

The introduction contains an extensive body of information on Australian biogeography, reserve systems and birdwatching/ornithological organisations. This section is more detailed and verbose than the equivalent section in Thomas *et al*. *Finding Australian Birds* also contains fewer subheadings and longer paragraphs, but this does not detract from the useful information displayed throughout. The introduction could be appreciated by beginner and expert local birders alike and provides especially useful information for the international traveller. The ecological context of the introduction also provides for interesting reading and adds a dimension of detail not seen in Thomas *et al*.

High quality photographs are displayed in full colour throughout *Finding Australian Birds*. The use of coloured photography effectively breaks up the text and maintains interest throughout the book. This is the first of the 'where to find' guides to present all of its photographs in full colour.

All of Australia's states and territories are addressed in-depth and each state/territory section is introduced in a landscape and biogeographical context. These sections are then divided into 'birding regions' which are further broken down into bird watching 'sites'. A suggested birdwatching itinerary and list of 'birding highlights' are included for each of the regions discussed. Basic maps are provided for all of the birding regions, however, maps are only provided for some of the sites. Each of the sites is discussed in a concise manner but not at the cost of any additional exciting details such as accounts of recently recorded vagrants.

The 'annotated bird list' is Dolby and Clarke's answer to the 'bird finder guide' in Thomas *et al*. The 'annotated bird list' provides a summary of site locations where each of Australia's resident bird species (and some subspecies) can be found. This section spans only 71 pages, making it more concise than its contemporary and the longer lists of species locations are of heightened value to the birdwatcher/twitcher.

The concise layout of *Finding Australian Birds'* 'annotated bird list' was achieved by avoiding structured sentences and doubling-up of the information already available in the big four bird identification field guides. While the authors have saved on page space in the 'annotated bird list', they have splurged on the information presented throughout the rest of the book, particularly the birdwatching site profiles. However, this makes for an effective layout.

The high level of detail and abundant coloured images in *Finding Australian Birds* span across an additional 144 pages than Thomas *et al*. Unfortunately this also comes at increased costs in weight, at 1160 g *Finding Australian Birds* is about 1.4 times the weight of Thomas *et al.* at 820g. Luckily both books are exactly the same length and height at 21.5 x 14.8 centimetres, although the additional weight will no doubt be an important factor buyers will consider when choosing the book they carry while travelling.

The low retail price of *Finding Australian Birds* combines with its attractive presentation and detailed content to make this book a valuable addition to the library of any Australian or international birdwatcher/twitcher or researcher.

Kurtis Lindsay
Mudgee NSW

RECOVERY ROUND-UP

This section is prepared with the co-operation of the Secretary, Australian Bird and Bat Banding Schemes, Australian Nature Conservation Agency. The recoveries are only a selection of the thousands received each year; they are not a complete list and should not be analysed in full or part without prior consent of the banders concerned. Longevity and distance records refer to the ABBBS unless otherwise stated. The distance is the shortest distance in kilometres along the direct line joining the place of banding and recovery; the compass direction refers to the same direct line. (There is no implication regarding the distance flown or the route followed by the bird). Where available ABBBS age codes have been included in the banding data.

Recovery or longevity items may be submitted directly to me whereupon their merits for inclusion will be considered.

Hon. Editor

The following abbreviations appear in this issue:

AWSG - Australasian Wader Study Group.

VWSG - Victorian Wader Study Group.

Australasian Gannet *Morus serrator*

131-47231. Nestling banded by F.I. Norman on Popes Eye off Queenscliff, Port Phillip, Vic. on 15 Dec. 1993. Recovered, released live with band three times at banding place, twice in 2003 and once in 2006 then recovered dead at the beach SW of Caraar Creek, Vic. on 8 Aug. 2014, over 20 years 7 months after banding. 33 km ENE.

Peregrine Falcon *Falco peregrinus*

111-24960. Nestling male banded by V.G. Hurley at Mount Elephant, Vic. on 2 Nov. 1999. Recovered dead at Timboon House, Camperdown, Vic. on 23 Sep. 2014, over 14 years, 10 months after banding. 28km S.

Australian Pied Oystercatcher *Haematopus longirostris*

100-92430. Nestling banded by G.P. Clancy at Patche's Beach, south-west of Ballina, NSW on 6 Nov. 1998. Colour marking sighted in field, band number inferred five times, all sighting were at South Ballina Beach, Ballina the last occasion by S. Totterman on 1 Aug. 2014, over 15 years, 8 months after banding. 10 km NE.

Red-necked Avocet *Recurvirostra novaehollandiae*

082-90276 plus Leg Flag ARZ. Adult (2+) banded by VWSG at Stockyard Point, Lang Lang, Westernport, Vic. on 21 Aug. 1993. Recaptured, released alive with band at banding place on 12 Sep. 2014, over 21 years after banding.

(This is the oldest recorded for the species.)

Terek Sandpiper *Xenus cinereus*

051-83154. Immature (1) banded by AWSG at Beaches Crab Creek Road, Roebuck Bay, Broome, WA on 30 Apr. 1994. Recaptured, released alive with band at banding place on 3 Apr. 2011, over 16 years, 11 months after banding.

(This is the oldest recorded for the species.)

Common Greenshank *Tringa nebularia*

072-60308. Adult (3+) banded by AWSG at Beaches Crab Creek Road, Roebuck Bay, Broome, WA on 25 Sep. 1998. Recaptured, released alive with band at banding place on 18 Nov. 2009, over 11 years, 1 month after banding.

(This is the oldest recorded for the species.)

Ruddy Turnstone *Arenaria interpres*

051-53107. Adult (2+) male banded by AWSG at Beaches Crab Creek Road, Roebuck Bay, Broome, WA on 27 March 1990. Recaptured, released alive with band at banding place four times, the last occasion on 27 Nov. 2007, over 17 years, 8 months after banding.

(This is the oldest recorded for the species.)

Laughing Kookaburra *Dacelo novaeguineae*

090-41366. Adult (1+) banded by D.C. McFarland at Moggill, Qld. on 5 Oct. 1996. Recaptured, released alive with band at banding place on 16 Sep. 2013, over 16 years 11 months after banding.

(This is the oldest recorded for the species.)

Rufous Treecreeper *Climacteris rufa*

041-89015. Immature (1) male banded by G.Marston at Marradong Timber Reserve near Boddington, WA on 20 March 2004. Recaptured, released alive with band at banding place twice the last occasion on 21 Dec. 2011, over 7 years, 9 months after banding.

(This is the oldest recorded for the species.)

Red-winged Fairy-wren *Malurus elegans*

018-20287. Adult (1+) male banded by A.M. de Rebeira at Smith Brook Nature Reserve, WA on 26 Oct. 2003. Recaptured, released alive with band three times the last occasion at Middlesex Field Study Station on 15 Jan. 2014, over 10 years, 2 months after banding. 6 km N.

(This is the oldest recorded for the species.)

Redthroat *Pyrrholaemus brunneus*

024-58171. Male banded by M.G. Brooker at Woolgorong, WA on 28 July 1997. Recaptured, released alive with band at banding place three times the last occasion on 30 July 2006, over 9 years after banding

(This is the oldest recorded for the species.)

Tasmanian Thornbill *Acanthiza ewingii*

017-67140. Adult (1+) banded by T.G.D. Shannon at Spreyton, Tas. on 30 Apr. 1995. Recaptured, released alive with band at banding place six times the last occasion on 11 Jan. 2003, over 7 years 8 months after banding.

(This is the oldest recorded for the species.)

Singing Honeyeater *Lichenostomus virescens*

035-92620. Adult (1+) banded by J.E. Lewis at Riddell Beach, WA on 7 Sep. 2002. Recaptured, released alive with band at banding place on 7 Sep. 2014, over 12 years after banding.

(This is the oldest recorded for the species.)

White-cheeked Honeyeater *Phylidonyris niger*

035-59555. Adult (2+) male banded by S.J.J.F. Davies 12 km south of Beverley, WA on 20 Jan. 2001. Recaptured, released alive with band at the banding place four times the last occasion on 16 Feb. 2013, over 12 years after banding.

(This is the oldest recorded for the species.)

Australian Magpie *Cracticus tibicen*

091-03431. Adult male banded by A. Exner at Aldgate, SA on 10 Dec. 1992. Recovered dead near banding place on 8 Aug. 2014, over 21 years, 7 months after banding.

Yellow White-eye *Zosterops luteus*

018-31367. Adult (1+) Banded by the Broome Bird Observatory at Crab Creek 3km east of the Bird Observatory on 19 Jan. 2001. Recaptured, released alive with band at banding place on 30 Sept. 2009, over 8 years, 8 months after banding.

(This is the oldest recorded for the species.)

Star Finch *Neochmia ruficauda*

026-78254. Adult (1+) female banded by J.E. Lewis at Pumphouse, King River Road, Wyndham, WA on 26 Apr. 2010. Recaptured, released alive with band at Sepp, King River Road, Wyndham, WA on 30 Jun. 2014, over 4 years, 2 months after banding. 7 km SW.

(This is the oldest recorded for the species.)

Notice to Contributors

Manuscripts relating to any form of avian research will be considered for publication. Field studies are preferred particularly where identification of individual birds, as by banding, has formed an integral part of the study. Some broad areas of research which do not necessarily require individual identification include morphometric analyses, techniques, species diversity and density studies as well as behavioural investigations. Behavioural, plumage and breeding studies can be conducted in captivity but must provide basic ornithological knowledge rather than avicultural interest.

Manuscripts are classified as either major articles (more than 1,500 words) or minor articles (500 to 1,500 words). Minorarticles need no summary. Shorter notes relating to almost any aspect of ornithology are welcomed but must adhere to the aims of the Association. Species lists or sightings which are not discussed in relation to historical evidence or scientific parameters are not suitable for publication in *Corella*. Authors proposing to prepare Seabird Island items should contact the Assistant Editor,Seabird Islands, and obtain a copy of the guidelines.

Contributors are requested to observe the following points when submitting articles and notes for publication in *Corella*.

Manuscripts:

A guide to the format required for tables, figures and manuscripts can be attained by reference to a recent edition of the journal and more specifically to the Publication Style found on the ABSA website.

Articles or notes should be sent via email to the editor as a .doc or .rtf file or typewritten and submitted in triplicate via post. Double spacing is required with typing on one side of the paper only. Margins of not less than 25 mm width at the left hand side and top, with similar or slightly smaller at the right hand side of the page are required.

All pages of the manuscript must be numbered consecutively, including those containing references, tables and captions to illustrations, the latter placed in after the text. No underlining and no abbreviations should be used within the text.

The *Style Manual for Authors,Editors and Printers* (6th edition 2002; John Wiley & Sons Australia, Ltd.) is the guide for this journal. Spelling generally follows the Macquarie Dictionary.

Nomenclature and Classifications follow:

Christidis, L. and Boles, W. E. (2008). 'Systematics and Taxonomy of Australian Birds'. (CSIRO: Collingwood, Victoria).

Proper nouns, particularly place and bird names must commence with a capital letter.

Headings are as follows: **HEADING – capitals and bold** (e.g. **RESULTS**)

Sub Heading – lower case and italics (e.g. *Ecology*)

Referencing:

References to other articles should be shown in the text – '. . . Bell and Ferrier (1985) stated that . . .'or '…. this is consistent with other studies (Jones 1983; Bell and Ferrier 1985).'– and in the Reference Section as:

Bell, H. L. and Ferrier, S. (1985). The reliability of estimates of density from transect counts. *Corella* 9: 3-13.

Jones, J. C. (1983). 'Sampling Techniques in Ornithology.'(Surrey Beatty and Sons: Chipping Norton, NSW.)

Figures (Maps and Graphs) and Tables:

The printable area of the page is 18 cm x 27 cm; double column figures/tables will be 18 cm across; single column figures/tables will be 8.5 cm across; widths between one column and double column can also be accommodated.

The captions for figures should be typed up onto a page separate from the figure.

Maps

Maps should be clear and relevant to the study and can be submitted in a variety of formats (.tif, .eps, .pcx) but the recommended one is a high resolution .jpg file (colour is acceptable). In some instances simply listing the latitude and longitude may suffice instead of a published map. Maps should only show necessary information. Excessive labelling(including names of towns, roads, rivers) will clutter the figure making it difficult to locate key place names. Photocopies of original hand drawn maps are not suitable for publication. They should be submitted only initially. When the paper is accepted for publication, the originals must be submitted so that they can be scanned into an appropriate electronic format.

Graphs

Lines should be thick and dark and any fill used should show a clear distinction between sets of data (colour fills are acceptable). Borders around the graph and the key are not necessary. The recommended format is an .xls file – this makes it very easy to adjust fills, thickness of lines etc, if necessary.

Where possible, please present the figure at final size. Figures that seem satisfactory when they are large, can present problems when they are reduced. Remember that if the figure has to be reduced for publication the figure will reduce equally in all dimensions i.e. both width and height will reduce. This can cause some problems, such as: (i) Line graphs where the lines are very close together can lose clarity. (ii) The typeface will reduce. Please ensure that the final typeface size AFTER reduction will be a minimum of 10 times Times New Roman typeface.

Tables

The recommended format is an .xls file but tables created in Word are acceptable. These should normally have a maximum size of one page but larger tables can be accommodated, if necessary.

FOR MORE DETAILED INFORMATION OR ASSISTANCE IN THE PREPARATION OF FIGURES PLEASE CONTACT THE PRODUCTION EDITOR.

CORELLA

Volume 38 Number 4 December 2014

Diet of 25 sympatric raptors at Kapalga, Northern Territory, Australia 1979–89, with data on prey availability... L. Corbett, T. Hertog and J. Estbergs 81

Breeding ecology of Welcome Swallows *Hirundo neoxena* in the Yarra Valley, Victoria: the nestling stage. .... A. Lill 95

The utility of closed aluminium and butt-ended stainless steel leg bands for Australian Pelicans *Pelecanus conspicillatus.* ....M. H.Waterman, C. E. Manning, G. R. Johnston and O. Fuller 104

Book Review:

Finding Australian Birds: A Field Guide to Birding Locations.......... Kurtis Lindsay 107

Recovery Round-up 108

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