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Nest predation of woodland birds in south-east Australia: importance of unexpected predators

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ABSTRACT
For most passerines, nest predation has a major impact on breeding success; however, information on the identity of nest predators is scant. In 2012, we investigated the identity of nest predators that each year depredate about 50% of the nests of 21 species in a south-east coastal bird community in New South Wales, Australia. The current study is a 2-year extension of this study and shows that at this study site (a) predation accounts for at least 90% of nest failures, (b) identified nest predators comprised two reptiles, nine birds and five mammals, (c) the suite of predators changes each season, (d) the two major predators were the Eastern Whipbird (*Psophodes olivaceus*) and the Fan-tailed Cuckoo (*Cacomantis flabelliformis*), (e) the impact of the Red Fox and Feral Cat was minimal, and (f) there was a variable and complex interaction between the parasitic cuckoos and their hosts. The data show definitively the overwhelming importance of nest predation on fledgling production, and bring to light new and important data on several aspects of the suite of nest predators.

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Introduction

Breeding success depends on food availability – this was the accepted paradigm for the international ornithological community for most of the twentieth century. Only recently, in the 1990s, did this perception change to recognise the impact of predation (Birkhead *et al.* 2014). Now it is acknowledged that for most passerines, nest predation is at least a major cause of nest failure (DeGregorio *et al.* 2014). In some cases, if the predator suite is limited, the identity of the predators is known (Holmes 2011), but often the identity is unknown (e.g. McLean *et al.* 2005). One reason for this is that until about 2006, when high-capacity/high-speed memory cards for digital cameras became available, there were inherent difficulties in the continuous observation of nests (Ribic *et al.* 2012). In addition, studies usually involved only one or two species, or took place over a single breeding season (e.g. Brown *et al.* 1998). There are exceptions, however, such as the comprehensive study by Holmes (2011) and that by Pietz and Granfors (2000) which involved 10 passerine species. In Australia, there are studies that were undertaken as late as 2009, but again, most are at least 10 years old, and targeted single species for one season (reviewed in Guppy *et al.* 2014).

Guppy *et al.* (2014) took advantage of improved surveillance camera technology to investigate nest predation in a woodland bird community in south-east Australia over 1 year (the 2012–2013 breeding season); 126 nests of 21 species were found. The study recorded seven species of nest predator (four birds and three mammals) that depredated seven species of nesting birds. These data raised the question: does the suite of predators vary between breeding seasons? If so, could this explain the absence of some of the expected and anecdotal native predators that are common on the site, namely Pied Currawong (*Strepera graculina*), Lace Monitor (*Varanus varius*) and Red-bellied Black Snake (*Pseudechis porphyriacus*), and the absence of the two expected feral predators, the Red Fox (*Vulpes vulpes*) and Feral Cat (*Felis catus*).

Here, we present the data from the subsequent two breeding seasons (2013 and 2014) from the same field-site which, together with the data from 2012, present a more comprehensive picture of nest predation in this habitat.

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Methods

The study site (35° 52′ S, 150° 03′ E) was 10 ha of temperate woodland (approximately 200 m × 500 m; 100 m above sea level), 6 km north-west of Moruya, New South Wales (NSW), Australia. This type of woodland is widespread immediately inland of the coast between Ulladulla and Bermagui, NSW (Austin 1978). Our site adjoins state forest and is situated in a mixed landscape with forest as the dominant component extending for at least 20 km in three directions. Aerial photos of the nearby state forest (pers. comm., Forestry Corporation of NSW, Southern Region) show that few and only small changes to the area of forested land have occurred since 1949. This site has been described in detail previously (Guppy *et al.* 2014).

Between 1 August and 31 January in the 2013 and 2014 breeding seasons, M. G. and S. G. spent an average of 2.8 h a day searching the study site for nests. For most of the species studied, all the nests were found, because all pairs contained at least one colour-banded bird. Therefore it was simply a matter of finding the nest for each pair. For the species that were not colour-banded the numbers of breeding pairs were known accurately because the nests or the activity of the breeding pairs were obvious and there were few individuals on the site. For two species, the Eastern Spinebill (*Acanthorhynchus tenuirostris*) and the White-naped Honeyeater (*Melithreptus lunatus*), there was some doubt and one nest may have been missed in some years. All nests were inspected every 1–3 days. Fifteen cameras were used each breeding season, the details of which, and their deployment, have been described elsewhere (Guppy *et al.* 2014). A nest monitored with a camera was termed a camera-nest. Where it was not possible to view the contents of the nest directly, cameras were not installed (non-camera-nest). In non-camera-nests breeding outcome was assessed using known brooding and fledging times in conjunction with observations of the activity of the breeding pair. It was not possible to determine the cause of failure for non-camera-nests. The data collected were from nests that represented between 71% and 82% of the total number of pairs that bred on the site. To determine whether the presence of cameras affected nesting success we recorded the number of nests that failed or succeeded with or without a camera and then calculated a chi-squared value for this contingency table. For the purposes of this study, any vertebrate that interfered with a nest in any way, resulting in the failure of that nest, was considered a nest predator. The data that are presented and analysed here include published and unpublished observations from the 2012 study, included for comparison with the later years, and to provide the rigour of a 3-year rather than a 1- or 2-year study.

Results

The nests of 26 species (in both 2013 and 2014) were found, which comprised 165 (2013) and 114 (2014) nests that progressed to at least one egg. The annual success rate of all nests over the three breeding seasons varied from 43% to 55%, suggesting little change between years. The total success rates of nests, with or without a camera, over the three breeding seasons, did not differ significantly (chi-squared = 1.558, $p = 0.212$, $n = 382$). A nest was never abandoned due to the immediate effects of camera placement, and brooding or feeding parents returned to the nest within minutes of a camera being installed at the nest.

Cameras were installed at 54 nests of 11 species in 2013, and 61 nests of 14 species in 2014. The percentage of the total number of nests of each species found over the three seasons (including 2012), on which a camera was deployed, was between 6% and 100% (supplementary material, Table S1). At nests with cameras, predation accounted for at least 89% of nest failures, while abandoned (always due to death of one of the pair, or to weather damage) nests accounted for 9%, 11% and 3% of nests in the three breeding seasons respectively. Over the three breeding seasons, the total number of camera-nests depredated at the egg stage was 29, and at the nestling stage 27. It was important to establish that the cameras did not affect nesting success. Our analysis showed that this was indeed the case, which is in line with other studies (Brown *et al.* 1998; Pietz and Granfors 2000).

In the 2013 and 2014 breeding seasons, the cameras detected 45 predatory events at nests of 12 species (Table 1). At least 15 (there is some difficulty distinguishing between the Brown Goshawk (*Accipiter fasciatus*) and Collared Sparrowhawk (*A. cirrocephalus*)) species of predator were recorded; two reptiles, eight (possibly nine) birds and five mammals. Two genera of small mammal were positively identified as nest predators, a rat (*Rattus* spp.) and an antechinus (*Antechinus* spp.). However, it was not always possible to distinguish between these two genera, or between these genera and other similar-sized mammals. If the two accipiters and the small mammals are each taken as single predators, six predators were identified in 2012 (Guppy *et al.* 2014), 10 in 2013 and 11 in 2014 (Table 2).

Our extended study revealed seven new species whose nests were predated: Golden Whistler (*Pachycephala pectoralis*), Spotted Pardalote (*Pardalotus punctatus*), Brown Gerygone (*Gerygone mouki*), White-

Table 1. Predators and number of nests depredated each breeding season.

Predator (% nests where eggs taken) Species depredated	**2012**[a]	2013	2014
Lace Monitor (25)			
Superb Fairy-wren		2(4e, 2y)[b]	
Golden Whistler		1(2y)	
Eastern Yellow Robin		1(2y)	
Red-bellied Black Snake (0)			
Brown Thornbill			1(3y)
Spotted Pardalote			2(1A, ?)
Accipiter sp.[c] (40)			
Superb Fairy-wren		1(?y)	
Brown Thornbill	1(?)		1(3e)
Yellow-faced Honeyeater	1(2y, 1e)		
Eastern Yellow Robin	1(2y)		
Bronze-cuckoo sp. (0)			
Brown Gerygone			1(1y)
Fan-tailed Cuckoo (50)			
Superb Fairy-wren		1(3y)	2(1e, 1e)
Variegated Fairy-wren	1(1e)		
White-browed Scrubwren			3(3e, 2y, ?)
Brown Thornbill	3(3y, 3y, 3e)		1(3y)
Laughing Kookaburra (0)			
Superb Fairy-wren		1(2y)	
Yellow-faced Honeyeater	1(2y)		
Silvereye	1(2y)		
Eastern Spinebill[a] (100)			
Brown Thornbill			2(3e, 3e)
Yellow-faced Honeyeater			1(2e)
Eastern Whipbird (100)			
Superb Fairy-wren	1(3e)		1(2e)
White-browed Scrubwren		1(2e)	1(E)
Brown Thornbill			3(E, 3e, 3e)
Yellow-faced Honeyeater	2(2e, 2e)		1(2e)
New Holland Honeyeater	2(1e, 2e)		
Olive-backed Oriole (50)			
Yellow-faced Honeyeater		1(2y)	
Eastern Yellow Robin			1(2e)
Pied Currawong (20)			
Common Bronzewing		1(1y)	
Variegated Fairy-wren			1(2y)
Brown Thornbill			2(2y, 2y)
Grey Fantail			1(3e)
Sugar Glider (33)			
Brown Thornbill		1(1y)	
Eastern Yellow Robin	1(2e)		1(1y)
Rat (*Rattus* spp.) (0)			
Variegated Fairy-wren	1(2y)		
Antechinus (*Antechinus* spp.) (50)			
Brown Thornbill	1(?y)		
Eastern Yellow Robin		1(2e)	
Unknown small mammal (67)			
Superb Fairy-wren		1(2e)	
White-cheeked Honeyeater		2(2y, 2y)	1(3e)
Red Fox (0)/Feral Cat (100)			
Superb Fairy-wren		1 (Fox; ?y)	1 (Fox; ?y)
Brown Thornbill			1 (Cat; 3e)
Total predations recorded	**17**	**16**	**29**
Predations missed by camera	7	4	13

[a]Previously published in Guppy *et al*. (2014, 2016).
[b]What was taken from each nest: e (*eggs*), y (*young*), ? (number or items unknown), E (nest was empty at time of predation, but was destroyed), A (adult taken at nest).
[c]Possibly includes Collared Sparrowhawk and Brown Goshawk.

Table 2. Percentage of all depredated nests attributed to the various predators.

Predator	2012	2013	2014	2012–14
Lace Monitor		25		7
Red-bellied Black Snake			10	5
Accipiter sp.	17	6	3	8
Bronze-cuckoo sp.			3	2
Fan-tailed Cuckoo	23	6	21	16
Laughing Kookaburra	12	6		5
Eastern Spinebill			10	5
Eastern Whipbird	29	6	21	20
Olive-backed Oriole		6	3	3
Pied Currawong		6	14	8
Sugar Glider	6	6	3	5
Small mammals	12	25	3	11
Red Fox/Feral Cat		6	7	5

browed Scrubwren (*Sericornis frontalis*), Common Bronzewing (*Phaps chalcoptera*), Grey Fantail (*Rhipidura albiscapa*) and White-cheeked Honeyeater (*Phylidonyris niger*) (Tables 1 and 2).

In 2013, the Lace Monitor and small mammals together accounted for half of all nest predations. The remaining 50% comprised one predation each from eight different predators, three of which were not recorded in 2012. In 2014, the Eastern Whipbird and Fan-tailed Cuckoo were the most common predators, each accounting for about 20% of predations. The Red-bellied Black Snake, Eastern Spinebill, and Pied Currawong accounted for at least 10% each of the predations, whereas the contributions of the accipiters, Bronze-cuckoo (*Chalcites* spp.), Olive-backed Oriole (*Oriolus sagittatus*), Sugar Glider (*Petaurus breviceps*), small mammals, Red Fox and Feral Cat were less than 10% (Table 2).

Discussion

Apart from our earlier study (Guppy *et al.* 2014), there is only one study of nest predation on a bird community (Holmes 2011). The suite of predators was small in this case, but it showed that nest predation is one of two major factors that limit bird fecundity. The aim of this current study was to investigate whether the suite of nest predators active within this particular community varied with breeding season. It is now clear that this was the case, and that the changes were marked (Tables 1 and 2). Some of this variation may be the result of a limited sample size, and the study area being smaller than the territories of some of the predators. Some predators were recorded each breeding season, while others were recorded in only one or two breeding seasons. This variation suggests that the effects of predators such as the Pied Currawong, Lace Monitor, Red-bellied Black Snake, Red Fox and Feral Cat may not be as pervasive or significant as previously thought in this habitat. Studies of Pied Currawongs have shown them to be nest predators of a variety of passerines (Major *et al.* 1996; Fulton and Ford 2001; Higgins *et al.* 2006), and a pair bred on or close to the study site each year. Nevertheless, on this site, the Pied Currawong was an irregular nest predator. There are documented observations of the Lace Monitor taking eggs and young of non-passerines at Lake Cowal, NSW (Vestjens 1977), and this species accounted for 2% of visits (to artificial nests) by ground-nest predators in an Australian tropical rainforest (Laurance and Grant 1994). This study documents for the first time that Lace Monitors take eggs and young from the nests of passerines, but on this site it too appears to be an irregular nest predator. Two studies in eastern Australia showed that birds or eggs were a rare item in the diet of the Black Snake (Shine 1977, 1987). The results from this study suggest that the Black Snake is an irregular predator. The Red Fox and Feral Cat are documented predators (May and Norton 1996; Kinnear *et al.* 2002), but hard evidence of nest predation by either does not exist. This study has documented nest predation by both these animals, but it has also demonstrated that at this study site they are irregular and minimal-impact nest predators.

The current study brought to light other unexpected but important details about nest predation in this habitat. First, nest predation on this site was the only cause of nest failure that was detected, demonstrating the importance of predation relative to food supply, climatic variables and disease during the course of our study. This is consistent with the 9 years of data we have collected on this site, which shows that with the exception of some desertions on one uniquely hot day (Guppy *et al.* 2012) nest abandonment occurs only as a result of weather damage or the death of one of the pair. This finding is important for our understanding of the factors influencing the nesting phase of independent young production in woodland bird communities. Second, our study has shown that the Eastern Whipbird and the Fan-tailed Cuckoo (unknown as nest predators before the initial study in 2012) are the two major predators. The Fan-tailed Cuckoo 'depredates' nests in two ways. It can parasitise them (which involves removing an egg) or, if the cuckoo has missed the nest stage suitable for parasitism, it can 'spoil' them by removing eggs or young, which is termed farming (forcing the pair to rebuild so the cuckoo can monitor and target the new nest). The Fan-tailed Cuckoo was the second most frequent predator and depredation by this species varied both quantitatively and qualitatively each season. This variation could reflect different cuckoo individuals breeding on the site each year, with differing host specificity, as is the case for the Common Cuckoo (*Cuculus canorus*) (Davies 2015).

Finally, the contribution of nest cameras to this study needs to be acknowledged. The study demonstrated the importance of nest predation on fledgling production, and it identified an unexpected suite of nest predators which changed markedly with season; but it also highlights the essential role of the nest cameras in collecting these data.

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