THE SUNBIRD

Journal of the
QUEENSLAND ORNITHOLOGICAL SOCIETY
Birds Queensland

Volume 44 Number 1 June 2014

THE SUNBIRD

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Front cover: Capricorn Silvereye and mainland Silvereye captured on Heron Island, June 2012. Photograph by Sonya Clegg.

ISSN 1037-258X

SUNBIRD 44(1) **JUNE 2014**

CONTENTS

FIRST EVIDENCE OF AVIAN MALARIA IN CAPRICORN SILVEREYES (*ZOSTEROPS LATERALIS CHLOROCEPHALUS*) ON HERON ISLAND

NICHOLAS J. CLARK, ROBERT D. ADLARD & SONYA M. CLEGG

ABSTRACT

Island and mainland populations of animals can experience substantial differences in their interactions with other species. One possible outcome of island colonisation is a reduction in parasite pressure on the island in comparison to the mainland, leading to ecological release for the host. We carried out a molecular survey for avian malaria (*Plasmodium* and *Haemoproteus* spp.) infections in Capricorn Silvereyes (*Zosterops lateralis chlorocephalus*) from a small island population previously thought to be free from the disease (Heron Island, Australia). We also screened mainland Silvereyes (*Z. lateralis cornwalli*) that arrived on the island as vagrants. Nested-PCR revealed an avian haemosporidian blood parasite prevalence of 6.2% in resident island Silvereyes and 100% for mainland vagrants (n=3). We report the first evidence of avian malaria infection in Silvereyes from Heron Island, indicating that island residents have not entirely escaped their avian malaria parasites. Additionally, we suggest that mainland vagrants play important roles in maintaining the stability of Heron Island's avian parasite community.

INTRODUCTION

Island communities are often depauperate compared to mainland communities, a feature that has led to the development of numerous theories about the importance of reduced competition and predation (MacArthur 1967; Diamond 1975; Adler & Levins 1994). Less attention has been paid to reduced parasite pressures in island communities. The loss of parasites during the colonisation of islands has been proposed to be important for the success of population establishment (Clay 2003). This reduction in parasite pressure on island populations can lead to ecological release for the host (Marzal *et al.* 2011; Lima *et al.* 2010), with increased opportunities to invest in reproductive effort and growth (Sheldon & Verhulst 1996; Williams 2005). Here we test for avian haemosporidian infection in a population of an island passerine where infection has not previously been detected (Peirce & Adlard 2004).

The Capricorn Silvereye (*Zosterops lateralis chlorocephalus*) is the only regularly breeding passerine on Heron Island (23º26'S, 151º57'E), a small,

wooded cay lying approximately 70 km off the Australian mainland (Kikkawa 1970). The population size ranges between 200 to 400 adult individuals (McCallum *et al.* 2000). The Capricorn Silvereye is a distinct subspecies, being significantly larger (up to 40% in some morphological traits; Figure 1) and exhibiting rapid genetic divergence compared to the mainland form *Z. l. cornwalli* (Clegg *et al.* 2002; Higgins *et al.* 2006; Clegg *et al.* 2008). While individuals from the mainland arrive sporadically as vagrants, usually in the winter months, they do not persist on the island or breed with island birds (Kikkawa 1970).

On the Australian mainland, Silvereyes exhibit a high prevalence of haemosporidian blood parasites (*Haemoproteus* and *Plasmodium* spp; NJC unpublished data), which are transmitted by arthropod vectors such as biting midges (Ceratopogonidae) and hippoboscid flies (Hippoboscidae) for *Haemoproteus* spp. and mosquitoes (Culicidae) for *Plasmodium* spp. (Valkiūnas 2005). These parasites can impact the health and reproductive success of their hosts, and may even cause mortality (Atkinson *et al.* 2000).

Figure 1. Capricorn Silvereye (*Z. lateralis chlorocephalus*; left) and vagrant mainland Silvereye (*Z. lateralis cornwalli*; right) captured on Heron Island in June 2012. Photo: Sonya Clegg.

A previous study (Peirce & Adlard 2004) screened for blood parasites (including avian haemosporidians) in a range of Heron Island birds, including Silvereyes. Examinations of Giemsa-stained blood smears revealed no evidence of infection by either *Plasmodium* or *Haemoproteus* spp. Earlier entomological surveys had noted low densities of biting arthropods, attributed to an absence of permanent fresh water (for breeding) on the island (Marks 1969; Fletcher 1973). The apparent absence of haemosporidian parasites in the island avian community was therefore partly attributed to restricted vector densities. However, sample sizes for each avian species examined were too small (for *Z. l. chlorocephalus,* n=15) to be highly confident that infections were absent (Peirce & Adlard 2004). Moreover, sensitive molecular tools are now available that may increase detection of avian haemosporidians, particularly for low-intensity infections that may be overlooked using microscopic analysis (Waldenström *et al.* 2004). In this study, we used molecular techniques to screen vagrant and resident Silvereyes on Heron Island for the presence of infection by *Haemoproteus* and *Plasmodium* spp.

METHODS

Resident and vagrant Silvereyes were captured on Heron Island using baited, hand-operated traps over a 10 day period in June 2012. A small blood sample (~ 20 to 40 μL) was taken by pricking the brachial vein, collecting the blood droplet in a capillary tube and transferring the blood to a labeled microfuge tube containing lysis buffer (1% SDS, 20 mM NaCl, 10 mM TRIS pH 8.0, 10 mM EDTA pH 8.0). Each bird was banded with an Australian Bird and Bat Banding Scheme (ABBBS) metal band and a unique combination of three colour bands, and released at the site of capture. Given the size disparity between island residents and mainland vagrants, the two subspecies can be readily differentiated using standard measurements of length, weight and bill shape (Clegg *et al.* 2002; Higgins *et al.* 2006). We therefore measured each bird using the techniques described in Clegg *et al.* (2002) to differentiate between island residents and mainland vagrants (Table 1).

DNA extractions were performed using standard ammonium acetate/ ethanol precipitation (Richardson *et al.* 2001). Extracted DNA from each sample was re-suspended in 150 μL of 0.1X TE Buffer (10 mM TRIS pH 8.0, 1 mM EDTA pH 8.0). Each sample was screened for the presence of *Haemoproteus* and *Plasmodium* spp. using a nested-polymerase chain reaction (PCR) protocol to target the parasite cytochrome-b (cyt-b) gene. The first round of PCR, using primers HAEMNF and HAEMNR2 (Waldenström *et*

Table 1. Morphological measurements for island (n=195) and vagrant mainland (n=3) Silvereyes captured on Heron Island. Following Clegg *et al.* (2002), wing length was measured as maximum flattened chord of the longest primary feather and tail length of central tail feathers was measured from base to tip. Dial calipers were used to measure metatarsal length and head length from rear of skull to tip of bill. Additional bill measurements, also taken with dial calipers, were mandible length and width at the posterior nostril opening (billLp and billWp, respectively) and mandible length and depth at the anterior nostril opening (billLa and billDa, respectively). Body weight was measured to the nearest 0.5 g using a 30 g Pesola spring balance (Pesola AG, Baar, Switzerland). Aside from weight, all measurements are given in mm.

	Measurement								
	Wing	**Tail**	**Tarsus**	**Head**	**BillLp**	**BillLa**	**BillDa**	**BillWp**	**Weight (g)**
Range									
Island	59.0–68.0	42.5–52.0	17.9–20.6	28.1–35.5	9.4–13.0	6.9–9.9	3.3–4.0	3.0–3.7	8.5–16.5
Vagrant	54.5–60.0	39.0–44.5	16.1–16.4	28.3–28.8	9.4–10.2	7.1–7.4	2.7–3.0	2.6–2.8	8.5–10.5
Mean									
Island	63.6	48.2	19.3	31.1	11.8	8.7	3.6	3.3	12.7
Vagrant	57.3	41.8	16.2	28.6	9.9	7.2	2.9	2.7	9.7

al. 2004), consisted of 20 μL reactions containing 10 μL TopTaq Mastermix (Qiagen), 5 μL DNA template and 0.2 μM of each primer. Reactions for the second round were identical to the first round, but used primers HAEMF and HAEMR2 (Waldenström *et al.* 2004) and 1 μL PCR product from the first round as DNA template. PCR cycling conditions for both rounds of PCR followed Waldenström *et al.* (2004). Positive amplifications, indicating a haemosporidian infection, were sequenced in both directions and run on an Applied Biosystems 3130xl Genetic Analyser at the Griffith University DNA Sequencing Facility (Brisbane, Australia). Parasite sequences were identified to genus level (*Haemoproteus* or *Plasmodium*) by comparison to sequences lodged on GenBank and the avian malaria database, MalAvi (Bensch *et al.* 2009).

RESULTS

We sampled a total of 198 Silvereyes. Of these, 195 were morphologically identified as resident island birds (*Z. l. chlorocephalus*) and three were identified as mainland vagrants (*Z. l. cornwalli*) (Table 1). For resident Silvereyes, nested-PCR revealed a total of 12 infections (6.2% prevalence),

Table 2. Prevalence of infection in island resident and vagrant mainland Silvereyes. Parasite cyt-*b* lineages were identified based on BLAST searches of genetic sequences on GenBank and MalAvi (Bensch *et al.* 2009).

	cyt-*b* lineage			Totals	
	Plasmodium AP70	*Plasmodium* LIN1	*Haemoproteus* ZOSLAT04	**Infected**	**Uninfected**
Island	3	3	6	**12**	**183**
Vagrant	1	0	2	**3**	**0**

six being *Plasmodium* spp. and six *Haemoproteus* spp. (Table 2). All three mainland vagrant Silvereyes were infected, one with *Plasmodium* sp. and two with *Haemoproteus* spp. (Table 2).

DNA sequencing revealed that the infections consisted of three genetic parasite lineages (2 *Plasmodium* spp. and 1 *Haemoproteus* sp.). All three lineages were found in resident island Silvereyes and two were also found in the mainland vagrants (Table 2). The two lineages shared between resident and mainland Silvereyes were previously recorded from the Australian mainland and other Silvereye populations in Vanuatu and New Caledonia (*Plasmodium* AP70, *Haemoproteus* ZOSLAT04; see Beadell *et al.* 2004; Ishtiaq *et al.* 2010; Table 3). The third lineage found in island Silvereyes (*Plasmodium* LIN1; Table 2) has been recovered in a New Zealand Bellbird (*Anthornis melanura;* see Baillie & Brunton 2011) and in a Lewin's honeyeater (*Meliphaga lewinii*) in mainland Australia (NJC unpublished data), but has not been recorded from Silvereyes elsewhere (Table 3).

Table 3. Genbank accession numbers and previous recordings for parasite cyt-*b* lineages identified in island resident and vagrant mainland Silvereyes on Heron Island.

Lineage	GenBank accession #	Regions recorded	Avian hosts recorded	Sources
Plasmodium AP70	AY714203	Australia Vanuatu Myanmar Japan	*Z. lateralis, Acanthiza katherina, Colluricincla megarhyncha, Tanysiptera galatea, Todirhampus sanctus, Acridotheres tristis*	Beadell *et al.* 2004; Ishtiaq *et al.* 2006, 2010; Zamora-Vilchis *et al.* 2012
Plasmodium LIN1	JN415756	Australia New Zealand	*Anthornis melanura, Meliphaga lewinii*	Baillie & Brunton 2011, NJC unpublished data
Haemoproteus ZOSLAT04	JX021550	Australia Vanuatu	*Z. lateralis, Z. flavifrons*	Ishtiaq *et al.* 2010; Zamora-Vilchis *et al.* 2012

DISCUSSION

We report the first evidence of blood parasites in resident Heron Island Silvereyes, thus indicating that resident birds have not entirely escaped blood parasite infection. The sharing of parasite lineages between resident island birds and mainland vagrants suggests that lineages may be regularly introduced from the mainland.

A number of factors may help explain why positive infections were found in this study, but not the previous study of Peirce & Adlard (2004). First, molecular screening protocols may be more efficient at detecting haemosporidian infections than blood smears. Some studies have found that PCR is more reliable than microscopy for detecting avian haemosporidian infections (Durrant *et al.* 2006; Garamszegi 2010). However, skilled investigators using good quality smears should be able to detect a similar infection prevalence when comparing results to PCR screening (Valkiūnas *et al.* 2008). As the previous study on Heron Island birds was carried out by experienced parasitologists using freshly prepared smears (Peirce & Adlard 2004), it is unlikely that infections were missed during microscopy. Rather, the low prevalence found in this study indicates that large sample sizes were needed for accurate determination of whether infections do occur. Indeed, Peirce & Adlard's (2004) sample size of 15 birds is theoretically capable of detecting (at the 99% probability level) a randomly distributed infection only if the parasite population prevalence is ≥26% (Post & Millest 1991). Temporal variation in parasite prevalence may also contribute to the contrasting findings. Birds were sampled in a single year in both the current study and that of Peirce & Adlard (2004), and large variations in the occurrence of vectors, particularly those that depend on freshwater sources for breeding (Marks 1969), is likely to cause temporal variation in prevalence of the disease. Low prevalence in vertebrate hosts may also prevent completion of the parasite life cycle, particularly when vector abundances are also low (Valera *et al.* 2003). Therefore, Heron Island's avian haemosporidian community may be highly unstable and reliant on climatic variables, such as high rainfall and high temperatures, that favour vector establishment (Sehgal *et al.* 2010). Sampling across multiple seasons and years may therefore give a clearer indication of whether the prevalence observed in this study is within a normal range, as well as an indication of whether haemosporidian parasites on Heron Island are influenced by climatic variation.

The differences in parasite prevalence between island residents and

mainland Silvereyes may have important evolutionary implications (Ricklefs 2010). In contrast to the low haemosporidian prevalence found in island residents in this study, prevalence in mainland Silvereyes can reach 70% (NJC unpublished data). Over time, such differences in parasite pressure may lead to different immunological adaptations for mainland and island hosts (Hart 1990; Beadell *et al.* 2007). Indeed, Silvereyes that were introduced to the island of Moorea in French Polynesia within the last 100 years already exhibit a decrease in parasite prevalence, as well as a decreased cell-mediated immune response, when compared to mainland birds (Beadell *et al.* 2007). The differences in parasite pressure observed in this study may therefore provide an important ecological basis to help explain the rapid divergence observed between mainland and island Silvereyes (Clegg *et al.* 2002; Higgins *et al.* 2006; Clegg *et al.* 2008). However, our study addressed two genera of avian blood pathogens, and Silvereyes have been found to exhibit infections with a wide variety of pathogens (Mackerras & Mackerras 1960; Austin *et al.* 1973). Further studies are needed to determine whether differential pathogen prevalence and diversity across mainland and Heron Island Silvereyes is common across a broader range of parasite taxa.

The presence of infections in mainland vagrants suggests that these temporary visitors can act as potential sources for infections, and may therefore influence the stability of Heron Island's avian parasite community. If island populations exist in relative isolation, they may evolve to represent unique faunal communities (Cornuault *et al.* 2012). Vagrant Silvereyes may therefore contribute to the prevention of such insular divergence for haemosporidian parasites on Heron Island by continually introducing mainland lineages. For instance, the two lineages carried by vagrants in this study, *Plasmodium* AP70 and *Haemoproteus* ZOSLAT04, have been recorded previously from Silvereyes on the Australian mainland (Beadell *et al.* 2004 Zamora-Vilchis *et al.* 2012). It is highly likely that these vagrant individuals were infected prior to arrival on the island, rather than contracting the infection there. This is because vagrants typically do not survive on the island for more than a few days to weeks (Kikkawa 1970), and the prepatent period of infection (i.e. the period following transmission when the parasite is not yet found in the blood stream) varies from 11 days to three weeks (Valkiūnas 2005). However, the identification of *Plasmodium* lineage LIN1 in three resident island birds suggests that avian hosts other than Silvereyes may also be carrying parasites to Heron Island. This lineage has only been recorded previously in a Bellbird (*Anthornis melanura*) from New Zealand (Baillie & Brunton 2011) and in a Lewin's Honeyeater (*Meliphaga lewinii*) from

the Australian mainland (NJC unpublished data), and has not been found in Australia's mainland Silvereyes (Beadell *et al.* 2004; Ishtiaq *et al.* 2006; Beadell *et al.* 2007; Zamora-Vilchis *et al.* 2012).

Many other forest-dwelling avian species have been observed as vagrants on Heron Island, including fantails (Rhipiduridae), monarchs (Monarchidae), cuckoos (Cuculidae), pittas (Pittidae), doves (Columbidae) and whistlers (Pachycephalidae) (Kikkawa 1970). The presence of other vagrant species may therefore facilitate the spread of parasites to Heron Island, particularly for *Plasmodium* parasites, which are generally less host-specific than *Haemoproteus* (Bensch *et al.* 2000; Hellgren *et al.* 2009). For lineages such as *Plasmodium* LIN1, migratory birds that feed in New Zealand and use Heron Island as a breeding ground (e.g. Wedge-tailed Shearwaters *Puffinus pacificus* (Hill & Barnes 1989)) may provide opportunities for parasites to colonise new habitats (Mendes *et al.* 2005). Although Peirce & Adlard (2004) did not find evidence of infections in Heron Island's seabirds, blood parasites have been recorded in shearwaters and other seabirds elsewhere (Quillfeldt *et al.* 2011). It may also be possible that *Plasmodium* LIN1 exists in mainland Silvereyes and has thus far escaped detection due to limited sampling. Without more adequate sampling of Australia's bird and vector community, we can only speculate as to how certain lineages colonise the island and infect resident island Silvereyes.

In summary, we report the first evidence of blood parasites in Heron Island's resident Silvereyes. The low overall prevalence in island versus mainland birds may have important evolutionary consequences for the island population. We suggest that mainland Silvereye vagrants and other colonising hosts (both avian and vector) are central to understanding avian parasite community dynamics on Heron Island.

ACKNOWLEDGMENTS

We thank an anonymous reviewer for helpful comments that improved the manuscript. All fieldwork carried out in this study was completed under Queensland Department of Environment and Resouce Management permits WISP08668811 and WITK0866511 and Animal Ethics Approval ENV/23/10/AEC. Field and lab work was supported by Birds Queensland research grants to S. Clegg and N. Clark. We are grateful to the Heron Island Research Station staff for their support during field activities.

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OBSERVATIONS ON THE POST-FLEDGING PERIOD OF THE COLLARED SPARROWHAWK (*ACCIPITER CIRROCEPHALUS*)

C.P. BARNES & S.J.S. DEBUS

ABSTRACT

Observations on the post-fledging period of a brood of Collared Sparrowhawks (*Accipiter cirrocephalus*) were conducted for 64 hrs over 20 days in suburban Bunbaberg, coastal eastern Queensland, from the juveniles' estimated third week post-fledging until they became independent and dispersed (at about 6 weeks after fledging). During this time the juveniles interacted aerially, took food from the parent in flight or caught dropped prey in mid-air, chased various birds (including large species they could not possibly catch), and caught cicadas. The parental food-delivery rate averaged 0.38 item/hr; it declined from 0.43/hr in week 4 and 0.39/hr in week 5, to 0.23/hr in week 6, with two deliveries in the latter stage not collected by a juvenile.

INTRODUCTION

The Collared Sparrowhawk (*Accipiter cirrocephalus*) is little studied in a systematic way, with behavioural descriptions of the breeding cycle and quantified details of its breeding biology and diet at a few sites (Czechura *et al.* 1987; Hollands 1992; Debus *et al.* 1993; Marchant & Higgins 1993; Aumann 2001a,b). Details on the post-fledging period are limited, with previous studies involving one or more fledglings (Debus *et al.* 1993; Marchant & Higgins 1993), and subsequent anecdotal observations involving multiple fledglings (Gosford 2005; Fleming 2009). This paper describes the post-fledging behaviour and development of three sibling Collared Sparrowhawk fledglings from soon after they fledged until they approached independence and could no longer be located, and presents some hitherto unrecorded details on that phase of the cycle. We also describe parental behaviour and food deliveries in that phase.

STUDY AREA AND METHODS

The adult pair of Collared Sparrowhawks built a nest in a small exotic pine plantation (*Pinus* sp.) behind a school and abutting the Bundaberg Botanical Gardens in Bundaberg (24°52'S, 152°21'E), coastal south-east Queensland.

The nest tree stood within a rectangular area of trees 25 × 100 m separating the school and the Botanical Gardens. The core area of observation, by CPB after the juveniles had fledged, was within the Botanical Gardens, bordered by suburbia and the pine plantation and, on the southern side, by a row of trees bordering sports fields.

Observations (all by CPB) were largely incidental, as CPB lives next to the Botanical Gardens and frequently walked there. The nest was first sighted on 29 August 2012, with subsequent casual observations made of nesting behaviour, followed by an observation of incubation/brooding on 5 November. Thereafter, timed field observation sessions, with notes, were supplemented by large series of digital photographs, taken almost daily at various times of day throughout most of the post-fledging dependence period, and consulted later by both authors. Several short video sequences were also obtained of the juveniles eating avian prey supplied by a parent. After a casual observation of a fledgling on 19 December, observations of fledglings totalled ~64 hrs over 20 days, from 24 December 2012 to 13 January 2013, and were made mainly in the mornings (1.5–4.5 hrs during the period 0515–1045 h) and afternoons (1–4.5 hrs; 1400–1900 h), with some observations over midday (0.5–1 hrs; 1120–1330 h).

The Collared Sparrowhawk is one of the most size-dimorphic Australian raptors and, although hatching is asynchronous, juvenile accipiters are adult in body size at fledging, and males grow faster and fledge sooner than the larger females (e.g. see Baker-Gabb 1984; Czechura *et al.* 1987; Marchant & Higgins 1993; Olsen 1995). By ~2 weeks post-fledging (and indeed earlier) they are fully grown (other than primaries and rectrices), and easily sexed by relative body and foot size when with sibling(s) or parent(s).

RESULTS

Nest-site and adult behaviour

The nest was a bulky stick structure ~16 m up in a pine tree, in the terminal branching of the main trunk ~3 m below the canopy. It was first noticed on 29 August 2012 when an adult male and female sparrowhawk were present early in the morning. From undated observations, the male was seen to bring prey to the female very early in the mornings (at first light). Often, the female was given the prey at a transfer perch (a dead tree 15 m from the nest). She typically called as he flew in silently. As the male landed, the female approached with head bowed, edged towards him and took the prey in her talons. On one occasion the female called and flew at the incoming male, taking the prey in an aerial transfer.

After a long lapse in observations, an adult was noted incubating or brooding on 5 November 2012. On the basis of fledgling development (birds inferred to be in their third week from fledging by the fourth week of December: see below), fledging would have occurred in early December, hatching in early November and laying in late September, allowing a month for the nestling period and 5 weeks for incubation (Czechura *et al.* 1987; Debus *et al.* 1993; Marchant & Higgins 1993).

Post-fledging period

Prey deliveries

An adult sparrowhawk made a food drop to the nest, while the juveniles were in the surrounding trees, on the first observation day (19 December) of week 3 of the post-fledging period. A juvenile arrived and ate the prey at the nest. Thereafter, from late in week 3 (20 December), 10 directly witnessed food exchanges were in the form of aerial food-passes to the juveniles, in which the adult arrived high in the air, circling, with the food dangling conspicuously from lowered feet in slow, almost stalling flight as the juvenile(s) flew up to take the prey from the adult's foot, or the adult dropped the prey and the juvenile caught it in flight (Figures 1 and 2). In one case (week 4), the food-bearing male arrived but, in the absence of an intercepting juvenile, landed and plucked the prey, then flew towards the nest and landed, changed perches then flew again before a juvenile saw him and took the prey. The other observed food exchanges (n=12) were partly obscured by trees or distance, but the arriving and/or departing adult was seen and the approaching, begging juvenile was then found near the transfer site with fresh prey which it proceeded to eat.

At the end of week 5 and again early in week 6, the food-bearing male circled (in one case for 3 minutes) but no juveniles appeared. The male then departed (in one case after a brief chase by a Grey Butcherbird (*Cracticus torquatus*)) or was lost to view as he descended. In neither case was he subsequently located in trees in the nest area. Prey was last seen brought to the nest area, but not collected by a juvenile, early in week 6, after a successful delivery on the previous day and the abovementioned non-collection on the afternoon of the last day of week 5. Despite a further 6 hrs of observation on four days from week 6 until early in week 7, no further deliveries were seen. A single juvenile was seen once during this time for 25 minutes before it departed. From the foregoing, it appeared that the adults continued to bring food, albeit at a declining rate (see below), until the juveniles were no longer continuously present or collecting the food.

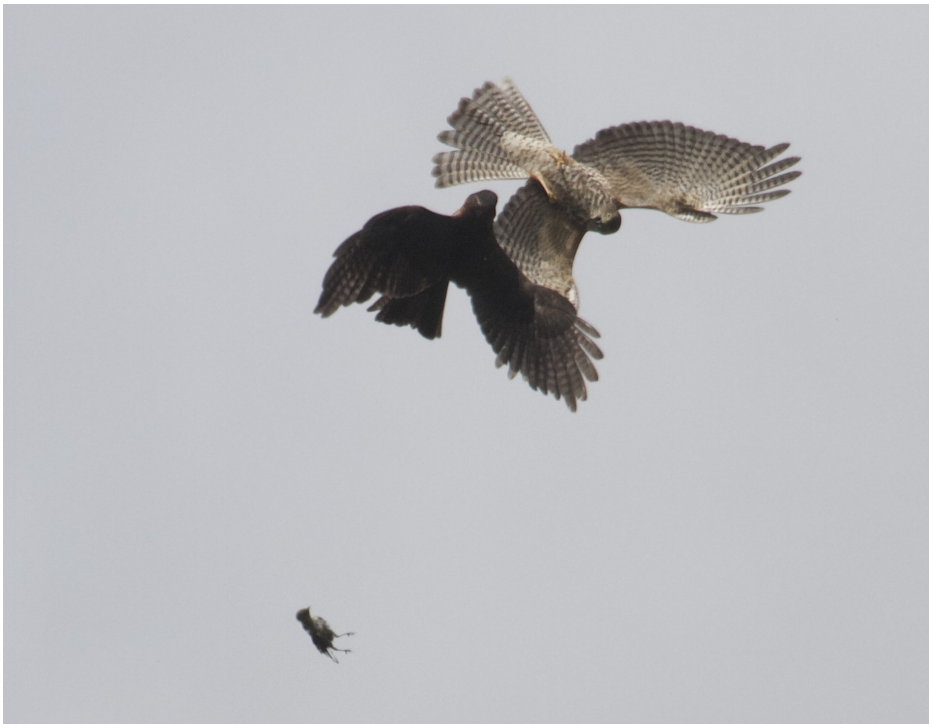

Figure 1. Aerial food drop by adult male (lower) to juvenile (upper) Collared Sparrowhawk. Photo: Chris Barnes.

Figure 2. Aerial food-pass by adult male (upper) to juvenile (lower) Collared Sparrowhawk. Photo: Chris Barnes.

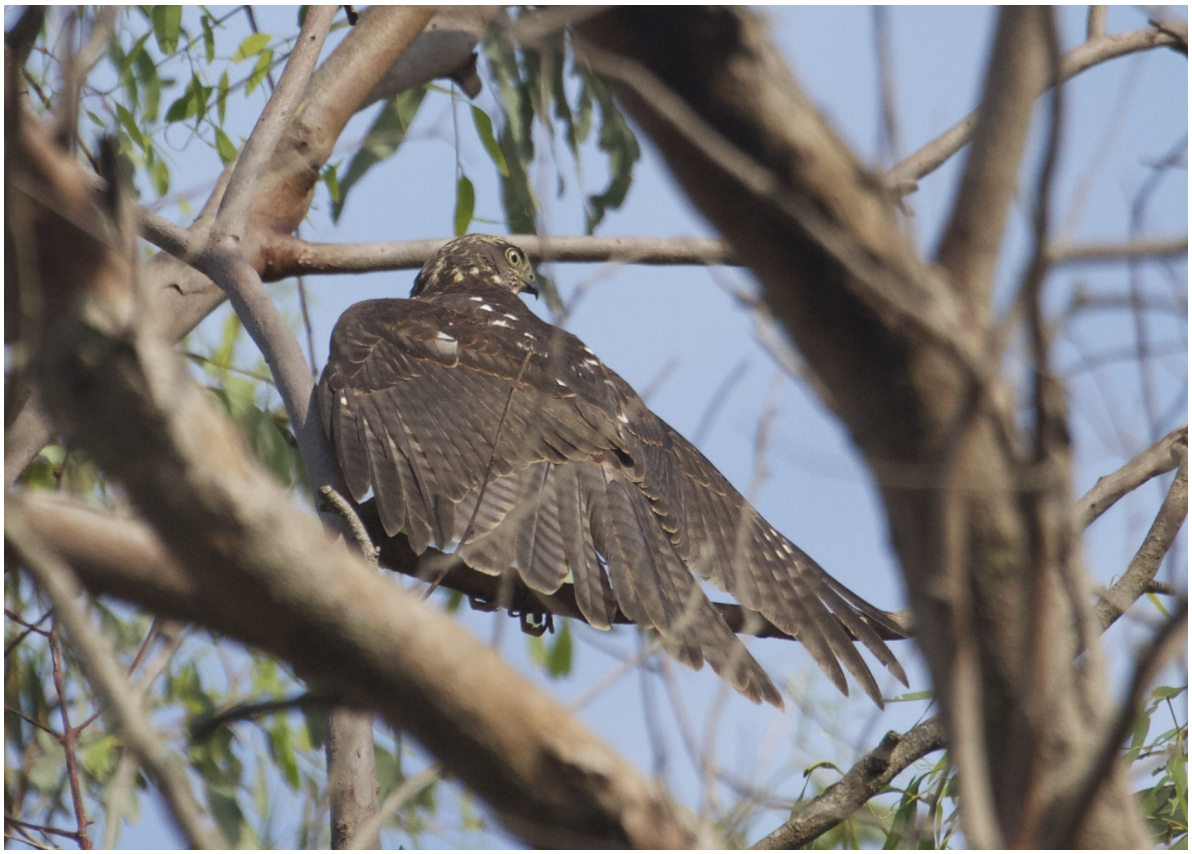

Figure 3. Juvenile Collared Sparrowhawk sunning. Photo: Chris Barnes.

There were 24 parental prey deliveries (two not collected by a juvenile) in 64 hrs of observation (= 0.38/hr) in weeks 3 to 6 of the post-fledging period. The male parent (as determined by size in comparison with the juveniles, and moult pattern) was observed to bring 14 prey items throughout this period, and the female parent (identified by larger size and different moult pattern) three items, late in week 5. In the remaining deliveries, the parental sex could not be determined. However, in two cases during week 4 a juvenile was observed with avian prey only 20 minutes before or after the male had delivered prey to another juvenile, suggesting that both parents may have made deliveries. In two cases the male brought prey again only 34 and 37 minutes after his previous deliveries, and in another the female brought prey again 56 minutes after her previous delivery. The male's deliveries were silent, though visually obvious, but the female called during one delivery.

Prey was delivered in the mornings (13 in 35 hrs = 0.37/hr; 0530–0937 h) and afternoons (11 in 24 hrs = 0.46/hr; 1530–1808 h), but was not observed through the midday period (4.25 hrs), although a juvenile was once seen feeding on prey delivered before ~1130 h. All prey delivered by the adults was avian: mostly plucked or partly plucked small birds/passerines (n=17), sometimes headless or partly eaten; plus more intact Golden-headed Cisticola (*Cisticola exilis*? – tentative identification), juvenile House Sparrow

(*Passer domesticus*?), finch sp. (?, n=2), juvenile Willie Wagtail (*Rhipidura leucophrys*), Silvereye (*Zosterops lateralis*), and juvenile Brown Honeyeater (*Lichmera indistincta*). The prey delivery rate declined from weeks 4 (9 in 21 hrs = 0.43/hr) and 5 (11 in 28 hrs = 0.39/hr) to week 6 (two in 8.75 hrs = 0.23/hr), although observation time also declined in week 6.

Development of young

A juvenile was first seen flying and perched in trees on 19 December, although the precise fledging date was not known. A second juvenile, larger than the other, was first seen on 20 December. These were presumed to be male and female, respectively, on the basis that they would have reached adult body size at least a fortnight prior (see Methods, above). The male fledgling, evidently the younger, still appeared to have incompletely grown rectrices and outer primaries on this date. Both had olive-brown eyes. Therefore, the initial observations (19 and 20 December) are here assigned to week 3 and the remainder (from 24 December, after a lapse in observations) assigned to week 4 onwards, on the basis of age-related fledgling development described by Debus *et al.* (1993). There were three juveniles, consisting of two males and one female, as evidenced by size comparisons during their interactions, although all three were seldom together or in view simultaneously. By this stage (weeks 3–4) the juveniles competently plucked and ate delivered avian prey. In week 3, one juvenile was sunning with outspread wings and tail at 0715 h (Figure 3).

By week 4 the juveniles appeared fully developed and had dull olive-yellow eyes, changing through dull yellow in that week to pale yellow by week 5. From week 4 they interacted aerially, chasing each other and, by week 5, rolling and presenting talons to the chaser (Figures 4 and 5). From week 4, they took food from the parent in flight, either in a foot-to-foot pass or via a swoop to catch it in flight when it was dropped by the parent (Figure 6). Sometimes two juveniles tried to take the same delivered prey item, clashing in the air, and when one caught the falling prey, the other chased its sibling and they fought over the prey (Figure 7). In one case, when a young male had caught the prey, an aerial tussle down through the treetops ensued, in which the young female appeared to wrest the prey from the other's foot and retain it. After food transfers, the food was taken to a perch in the tree canopy, where the juvenile sometimes held it, while calling, for up to 35 minutes before eating. In one case, a waiting Pied Butcherbird (*Cracticus nigrogularis*) caught falling scraps as the juvenile fed. In another instance (week 5), a feeding juvenile was disturbed by an approaching Grey Butcherbird and took the prey to another tree.

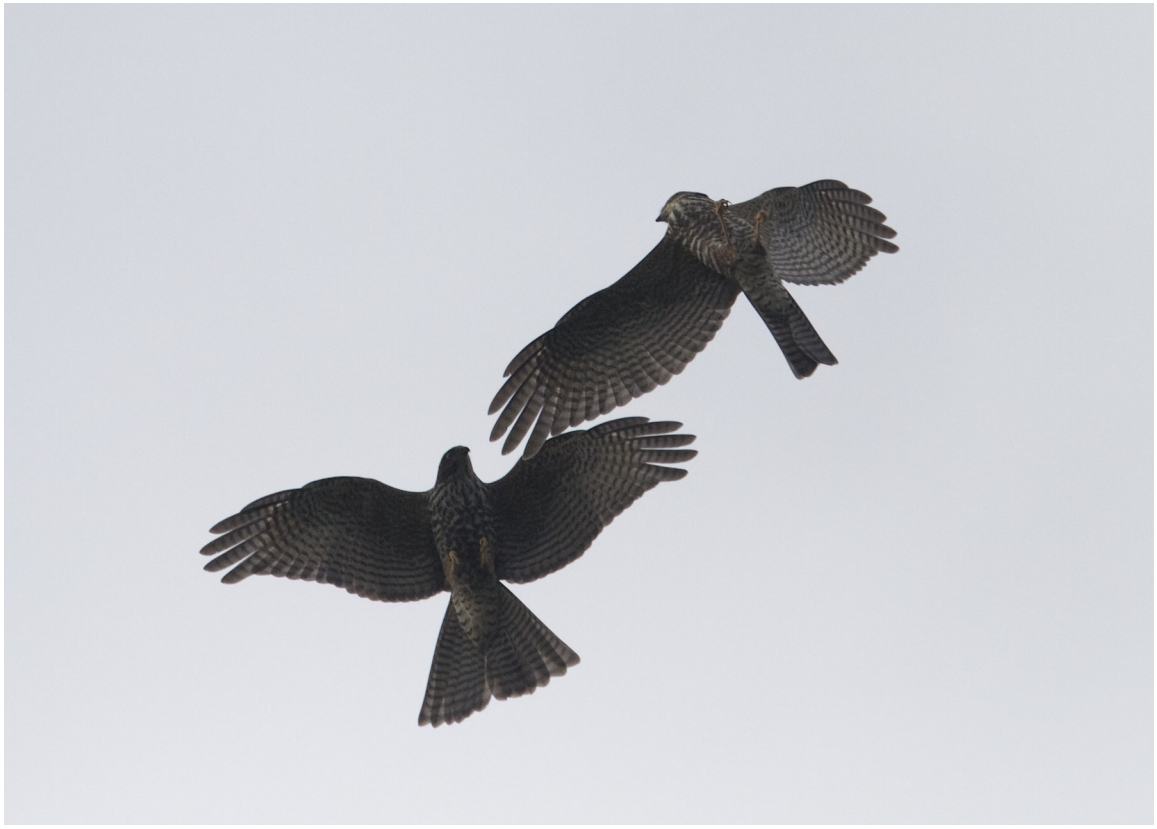

Figure 4. Juvenile Collared Sparrowhawks interacting aerially. Photo: Chris Barnes.

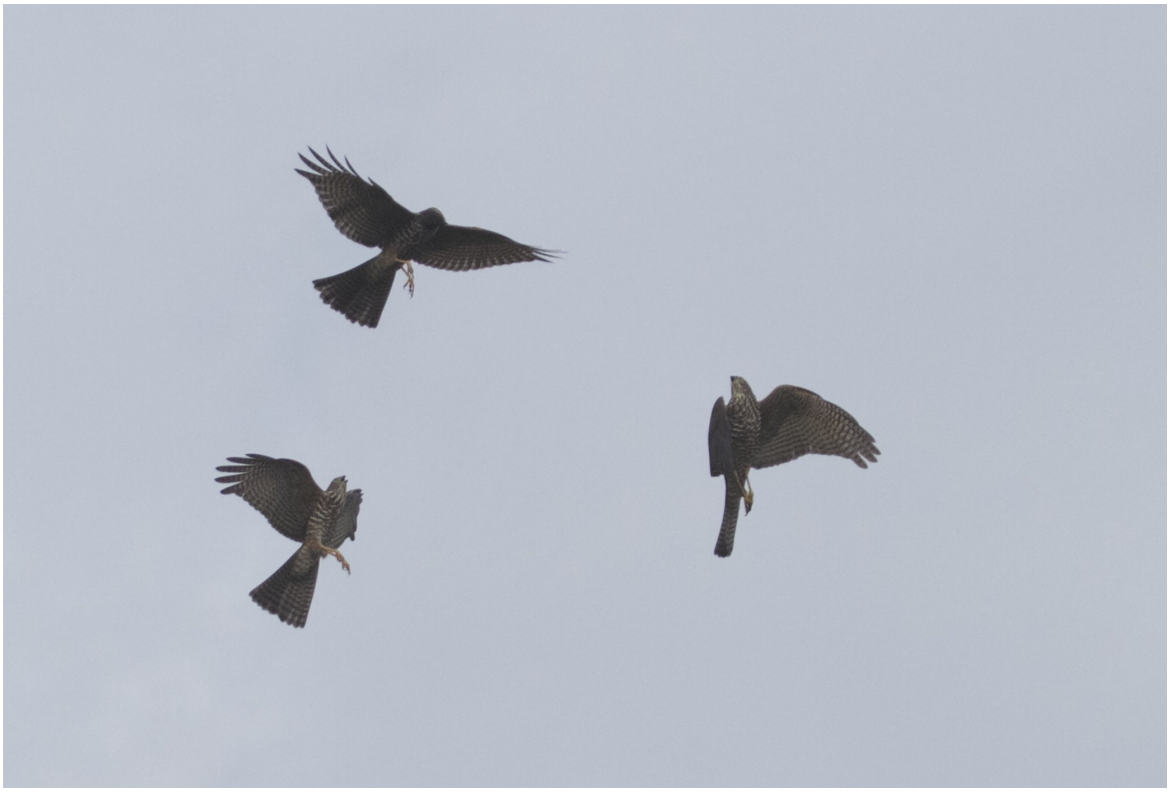

Figure 5. All three juvenile Collared Sparrowhawks interacting. Photo: Chris Barnes.

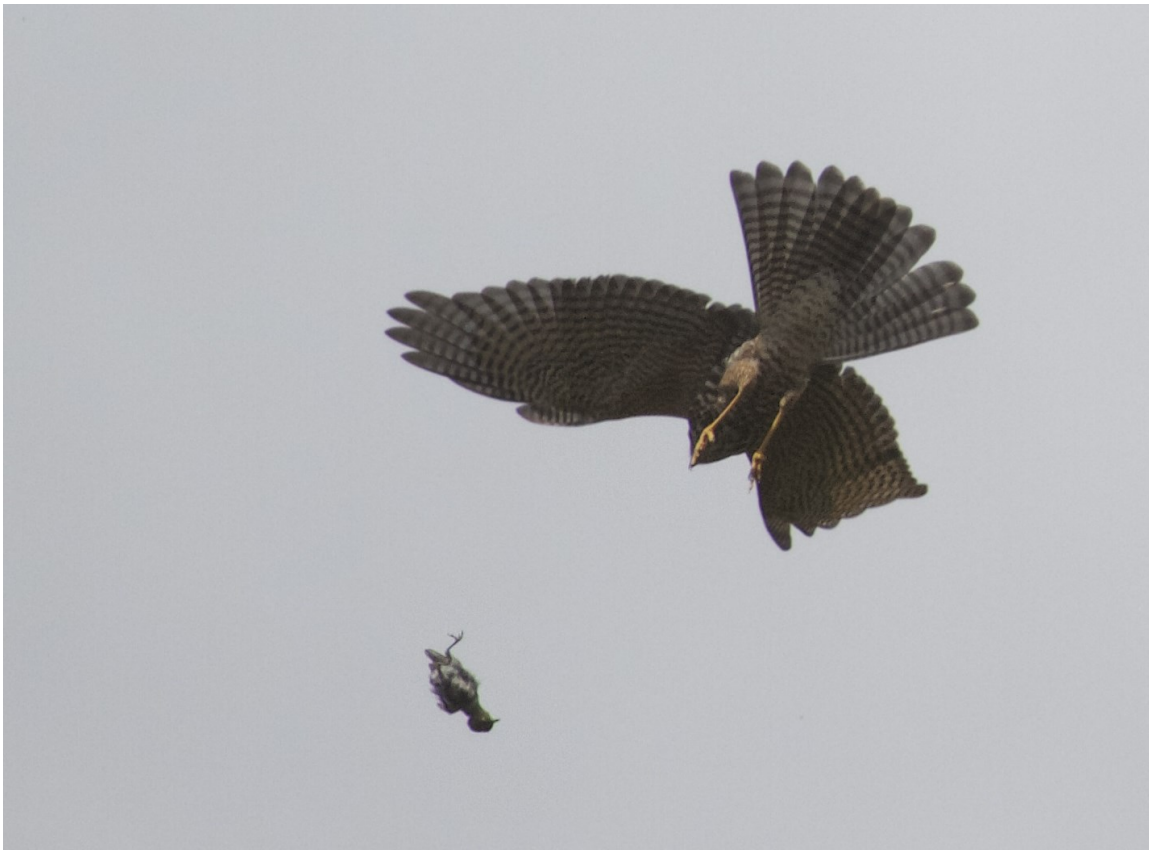

Figure 6. Juvenile Collared Sparrowhawk catching prey dropped by parent. Photo: Chris Barnes.

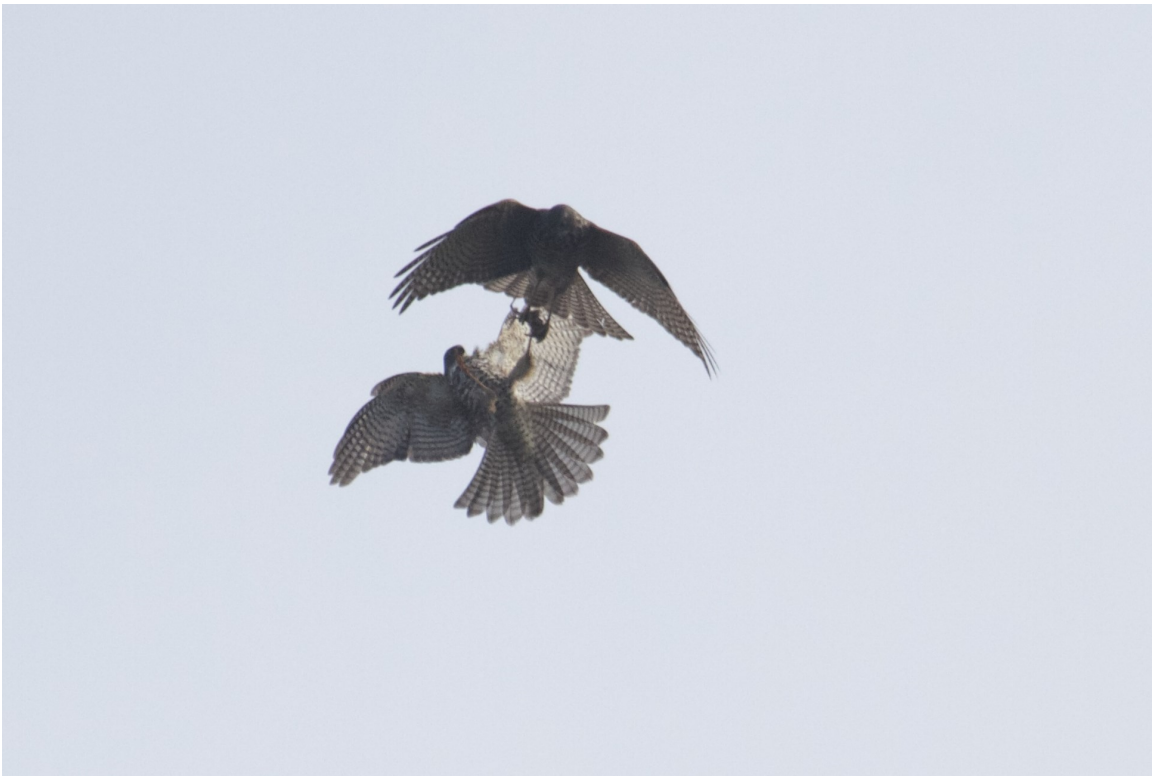

Figure 7. Juvenile Collared Sparrowhawks tussling over prey. Photo: Chris Barnes.

From week 4 the juveniles chased or harassed other birds: Pacific Black Duck (*Anas superciliosa*), Australasian Darter (*Anhinga novaehollandiae*), Eastern Great Egret (*Ardea modesta*), Cattle Egret (*Ardea ibis*), Nankeen Kestrel (*Falco cenchroides*), Laughing Kookaburra (*Dacelo novaeguineae*), Pied Butcherbird, Australian Magpie (*Cracticus tibicen*), Torresian Crow (*Corvus orru*), Spotted Dove (*Streptopelia chinensis*), Pale-headed Rosella (*Platycercus adscitus*), probable Brown Honeyeater, Noisy Miner (*Manorina melanocephala*), Blue-faced Honeyeater (*Entomyzon cyanotis*), Magpie-lark (*Grallina cyanoleuca*) and Welcome Swallow (*Hirundo neoxena*). Only the last seven of these species are of a size or an inoffensiveness to be potential prey, even for a female sparrowhawk (e.g. Czechura *et al.* 1987; Debus *et al.* 1993). On three days in week 4, a juvenile male caught and ate (at a perch) cicadas, in one case four sequentially, by making short, direct rapid flights to pick them off branches with his feet. The dominant local species was the Clanger or Clear-wing (*Psaltoda claripennis*), but at least two other species of similar size were present.

In week 5, the juvenile female picked a long strip of bark from a tree, took it (in the feet) towards the nest via another perch but dropped the material en route, then landed on the nest and spent 4 minutes intermittently dipping her head into the nest, in apparently incipient or practice nest-building behaviour. Also in week 5, a juvenile appeared to rain-bathe by flying to an exposed perch and half-spreading its wings and tail in the rain. The roost site of one juvenile in week 5 was within heavy vegetation cover, where it remained quiet and hidden until observations ceased at 1900 h, when almost dark.

On one day at the end of week 5 (day 35), and on one of two days early in week 6 (day 37) on which the male parent brought food, the juvenile(s) did not arrive to claim the prey. A single juvenile (but no other sparrowhawk) was present, sometimes calling, for 25 minutes on one of the three other observation days (day 38) in week 6. No sparrowhawks were subsequently detected in the nest area to the middle of week 7 (day 45), when observations ceased. Thus, it appeared that the juveniles became independent by week 7. By that stage they were not seen to catch birds, although chases of passing passerines in weeks 4–5 had appeared determined. In sibling interactions with each other and during parental food-passes the juveniles were fast, agile and competent flyers, suggesting that by week 7 they were capable of catching birds.

DISCUSSION

The Collared Sparrowhawk's willingness to nest in exotic trees in suburban settings is known, and the pair's inferred laying date at Bundaberg is consistent with previous information for south-eastern Australia (e.g. Marchant & Higgins 1993). The prey-delivery behaviour of the adult sparrowhawks in the post-fledging period was similar to that previously described (e.g. Debus *et al.* 1993; Marchant & Higgins 1993; Fleming 2009), although low-level aerial prey transfers to juveniles, with the juvenile following the parent, were not observed in the present study. This difference may relate to the already advanced age of the juveniles when observations commenced at Bundaberg. Parental prey-delivery rates at approximately equivalent stages in the post-fledging period were similar to those recorded by Debus *et al.* (1993), including a decline in the week leading up to independence. The dropping of prey in mid-air by the adult male, although (perhaps incidentally) giving the juveniles practice at catching prey in flight, may have been to avoid potentially injurious contact with aggressive juveniles (especially the larger female), rather than deliberate 'training'. As in the other comparable study (Debus *et al.* 1993), most parental food deliveries to advanced juveniles were made by the male.

Prey species at Bundaberg are consistent with previous information, particularly for south-eastern Queensland, and support the view that the Collared Sparrowhawk specialises on small passerines (Czechura *et al.* 1987; Debus *et al.* 1993; Marchant & Higgins 1993; Aumann 2001b). As elsewhere, the juveniles at Bundaberg chased or harassed large birds that they could not possibly catch or subdue, supporting the view (e.g. Czechura *et al.* 1987) that claims in the literature of supposedly large prey involve either harassment or pursuit practice (not genuine attempted predation), or observers misidentifying larger raptor species (e.g. Brown Goshawk *Accipiter fasciatus* and perhaps others) as sparrowhawks. Cicadas at Bundaberg may have helped to sustain the young male sparrowhawks between parental food deliveries, especially on the occasions when they lost delivered prey to robbery by the young female.

Age estimation of the juveniles at Bundaberg is only approximate, as fledging was not witnessed. However, behavioural development was similar to that described by Debus *et al.* (1993) and Gosford (2005) for inferred similar ages, with the proviso that in the case observed by Debus *et al.* there was only a single fledgling and hence no sibling interaction for comparison. Again, with the proviso that age comparisons are approximate, the fledglings

at Bundaberg appeared to reach independence at a similar age or maturity to that observed by Debus *et al.* (1993). Gosford (2005) inferred that the juveniles he observed were catching birds, but on the basis of their begging calls it is likely that those juveniles obtained some of their avian prey from the adult(s) unseen, at least in the early stages. Sunning and rain-bathing have not been recorded previously for the Collared Sparrowhawk, nor incipient nest-building behaviour by a recently fledged, dependent juvenile (Marchant & Higgins 1993).

Given that the Collared Sparrowhawk is fairly common and breeds in 'green' suburbs, there is ample scope for further study. As the species is now reasonably well known with respect to behavioural aspects of the breeding cycle, further studies might address long-term breeding densities and reproductive success in sample areas, and detailed dietary studies in urban areas. The fate of dispersing, newly independent juveniles, and assessment of home-range size and habitat use by adult sparrowhawks, would require study by banding, colour-banding and radio-tracking. Another area for study is window strikes, and harassment by overabundant species such as Pied Currawongs (*Strepera graculina*) and corvids (e.g. Marchant & Higgins 1993), as it is not clear how the urban sparrowhawk population copes with these impacts.

ACKNOWLEDGMENTS

We thank Dr Tom Aumann, William Riddell, Dane Panetta and Denise Elias for helpful comments on a draft.

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The Sunbird (2014) 44(1): 24–25

DUST BATHING BEHAVIOUR IN A YOUNG MALE AUSTRALIAN BRUSH-TURKEY (*ALECTURA LATHAMI)*

ELLIOT LEACH

Whilst birding at Oxley Creek Common on 31 July 2013, I encountered a young male Australian Brush-turkey (*Alectura lathami*). When I first came across the bird, he was vigorously scratching at the ground, as this species is prone to do. What captured my attention was his subsequent behaviour. He lay down in the spot that he had been scratching at and, using his right wing, scooped up the loose soil that had been disturbed and flung it onto his back. He sat on the ground for a little while, in the full sun, and then began digging again. I watched him for around 20 minutes, during which time the depression in the soil was enlarged to such an extent that when he lay in it, two thirds of his body was below ground level. While observed, he frequently used both wings to 'splash' dust, scraped from the sides and the bottom of the depression by turning motions, over his back (Figure 1). He would then rest in the sun for up to a minute before shaking the dust from

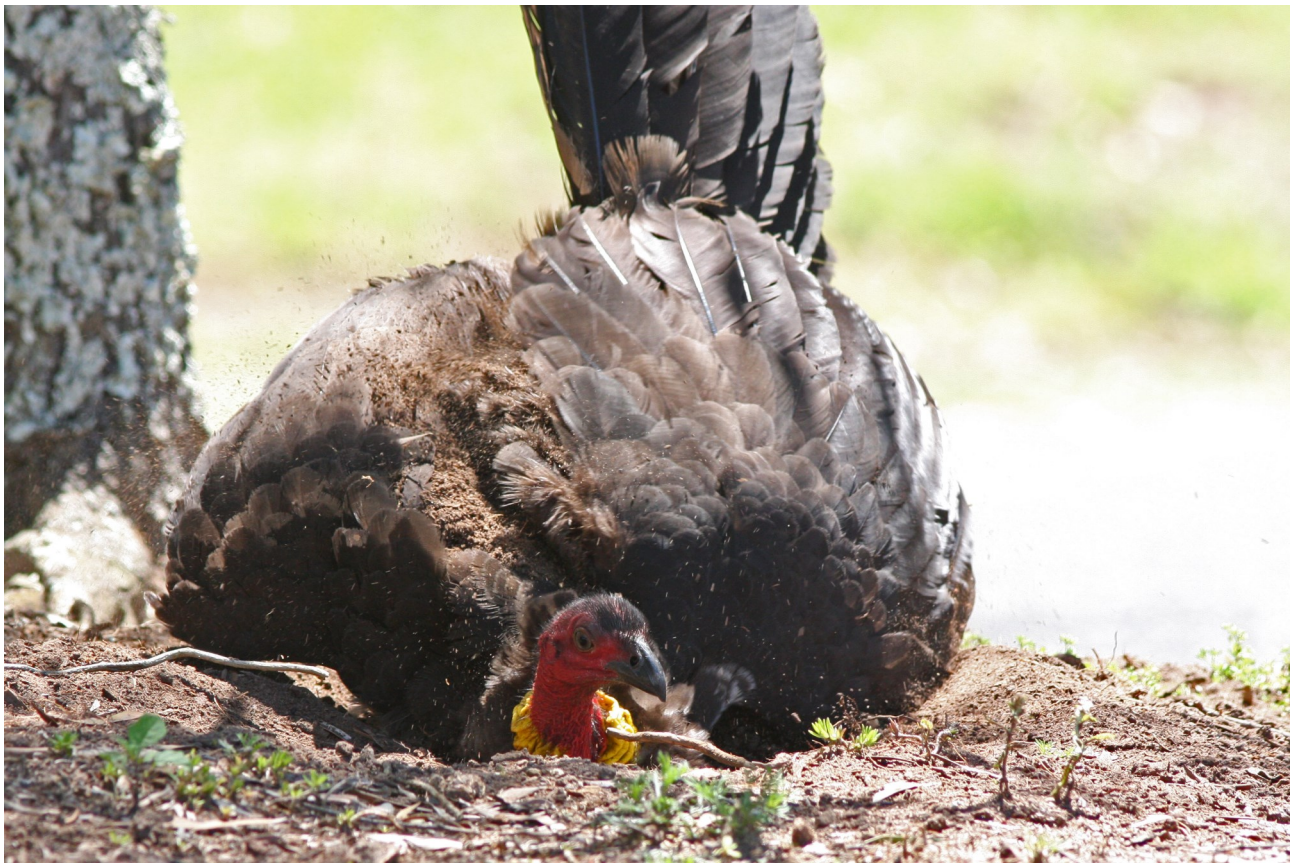

Figure 1. A dust bathing Australian Brush-turkey. Photo: Jill & Ian Brown.

his plumage and beginning again. He persisted in this behaviour even as people walking by passed within 5 m. Eventually, he seemed to have had enough, and left the area. I checked for the presence of ants where he had been sitting, as I presumed he had been anting (McAtee 1938), but none was found. I then concluded that the bird had simply been dust bathing.

In the HANZAB entry for this species (Marchant & Higgins 1993), dust bathing is briefly mentioned, and the description is based on behavioural observations made by Dow (1988). As far as I am aware, no other records of this behaviour exist in the literature. My observations suggest that the behaviour observed by Dow (1988) was not that of an atypical group of birds.

It has been suggested that dust bathing occurs as part of routine feather maintenance, in both brush-turkies (Dow 1988) and other species (e.g. Raikow 1968; Hein 1970). In addition to its role in feather maintenance, dust bathing may serve another purpose: as a pleasurable or relaxing experience. This certainly seemed to be the case for the brush-turkey that I observed.

ACKNOWLEDGMENTS

I would like to thank an anonymous reviewer and Dane Panetta, whose comments improved an earlier version of this note. Thanks also go to Jill Brown, who provided helpful comments as well as an excellent photograph.

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