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Breeding Behaviour and Diet of the Collared Sparrowhawk *Accipiter cirrhocephalus* in Northern New South Wales

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Summary

A pair of Collared Sparrowhawks *Accipiter cirrhocephalus* and the single young were observed at Armidale on the Northern Tablelands of New South Wales, through the nest-building, incubation, nestling and post-fledging periods (total 200 hours over 73 days, September 1991-January 1992). Behaviour patterns, sex roles, growth and development of young, and voice are described. The diet was entirely small birds until the fledging stage, and thereafter insects (eaten by the fledgling) contributed 5% by number (<1% by biomass) to the total. Birds were <100 g, mostly native passerines; 90% were <25 g and mean weight was 17 g (median 38 g). The female Sparrowhawk took larger prey than the male (mean 50 vs 13 g, 5 and 50 items respectively). Prey delivery rates varied through the cycle, being lowest (0.1-0.2 items/hr) during incubation and end of the post-fledging period, and highest (0.6-0.7 items/hr) in the nestling and early post-fledging periods. The nestling period lasted 31 days, and the post-fledging dependence period lasted at least 39 days.

Introduction

The breeding biology and behaviour of the Collared Sparrowhawk *Accipiter cirrhocephalus* have been described in some detail, though with little quantification (Cupper & Cupper 1981; Hollands 1984, 1992; Metcalf 1982, 1988; Metcalf & Metcalf 1986, 1989; Czechura et al. 1987; Ross et al. 1989; Buchanan 1990; Morcombe 1990). Czechura et al. (1987) quantified the diet for Tasmania and south-eastern Queensland, and listed all other recorded prey species, and Price-Jones (1983) and Metcalf & Metcalf (1986) listed prey species for the Southern Tablelands of New South Wales and suburban Canberra respectively. The Collared Sparrowhawk's calls were rather poorly described until Hollands (1992) provided some details on calls made during the incubation period.

This paper describes the breeding behaviour and diet of a pair of Collared Sparrowhawks near Armidale on the Northern Tablelands of New South Wales, during spring-summer 1991-92. Supplementary observations of behaviour, made mostly within 300 km of Armidale since 1980, are included.

Study area and methods

The nest was in Eastwood State Forest c. 10 km south-east of Armidale (30°30'S, 151°40'E; 1000 m a.s.l.). This is a 250 ha isolated block of open forest, dominated by New England Stringybark *Eucalyptus caliginosa*, Manna Gum *E. viminalis*, Blakely's Red Gum *E. blakelyi*, Apple Box *E. bridgesiana* and Yellow Box *E. melliodora*, with a subcanopy of scattered *Acacia*, and *Cassinia* and other genera in the shrub layer. Further details are given in Ford & Bell (1981).

Observation sessions were essentially opportunistic. As a result, we were unable to apply the rigorous observational regimen recommended by Simmons (1989) for studies of provisioning rates in raptors. During the territory-establishment phase, the nest area was visited casually on three mornings between 16 and 27 September 1991. During the nest-building phase, the nest was observed for 20 hours over ten mornings from 29 September to 18 October, between 0600 and 1100 h (all times given are Eastern Standard Time). It was also visited on four afternoons between 1615 and 1740 h, and watched on one afternoon from 1600 to 1800 h. During the incubation phase, the site was visited once at 1700 h on 1 November, and watched for an hour on two mornings (0600-0800 h, 19-20 November) and two afternoons (1700-1900 h, 23-24 November). During the nestling period, the nest was observed for

a total of 92 hours over 27 days, shared between five observers (23 mornings and 10 afternoons, between 0545 and 1130 h, and 1325 and 1915 h, 25 November-25 December). During the post-fledging dependence period the nest and its environs were observed for 83 hours over 32 days, shared between four observers (32 mornings and 3 afternoons, between 0620 and 1300 h, and 1500 and 1830 h, 26 December-28 January), and checked on a further eight days to 9 February. Observations were made from the ground, near the nest and feeding perch-trees with the aid of binoculars and sometimes a telescope.

Prey items were identified and quantified following Debus et al. (1991). Prey identification was mainly by sight, as few remains or pellets were found under the nest or feeding perches. Few feathers were retrieved from prey being plucked, and many items were brought to the nest area already well plucked and headless. Therefore, some prey items are given as unidentified bird or passerine of an estimated weight. Some sight identifications were tentative and are listed as such.

Results

Nest site and territory

The Sparrowhawks' nest, built by the hawks themselves and apparently new, was 15 m above the ground in a dense mistletoe *Amyema miquellii* at the top of a live Yellow Box. The nest tree was in a drainage line, c. 500 m from surrounding cleared land in two directions (north and west), and 1 km in the other two. It was about equidistant (c. 500 m) from the active nests of two Brown Goshawk *Accipiter fasciatus* pairs, in diagonally opposite corners of the forest patch. The area of Eastwood and surrounding forest is c. 250 ha.

The adult Sparrowhawks had one regular food-transfer perch, an almost horizontal branch on a partly dead tree c. 20 m north-west of the nest. They also used other bare branches within 30 m of the nest for food exchange, but had no regular plucking perches near the nest.

The pair appeared to use most of the 1.7 x 1.2 km forest block, except for an undetermined radius around each Brown Goshawk nest. For instance, in the territory-establishment phase the female ranged 1 km to the eastern boundary and displayed in the centre, 250-500 m east of the nest; the male set off on or returned from hunting flights deep into the forest block, and on all major compass bearings (commonly north-west, and south-west to south-east, but also north and east).

In 1991 the nearest known Sparrowhawk nest was 17 km north-east, in a 40 ha patch of habitat similar to that at Eastwood but with less understorey, and adjoining a larger (c. 250 ha) patch of woodland. This nest was 18 m above ground, also in a mistletoe in a gum *Eucalyptus* sp., and contained two large nestlings on 23 December, which fledged within a few days. In previous years, there was an active Sparrowhawk nest in a 150 ha forest block 8 km north-east of Eastwood, almost equidistant between the two 1991 nests, and one suspected in a >1000 ha forest patch 18 km north-west of Eastwood. This suggests that the Sparrowhawk is dependent on large forested areas, and occurs at much lower density than the Brown Goshawk in the region (c. 1 km between Goshawk nests in suitable habitat: Debus 1985; this study).

Voice

Four main calls were used by the birds at Armidale, and by other displaying and breeding Sparrowhawks observed elsewhere.

(1) A rapid, almost trilled, chittering *ki-ki-ki-ki-ki...* of c. 6 syllables per second, similar to the alarm call of a White-plumed Honeyeater *Lichenostomus penicillatus*. This call is faster than the equivalent Brown Goshawk chattering call. The Leaden Flycatcher *Myiagra rubecula* has a similar twittering call which descends at the end. This call was heard commonly in the pre-laying period, often from soaring Sparrowhawks, and appeared to be an advertisement call. It was given by both sexes, especially the female.

One male gave a hard, unmusical version, an extremely rapid *kek-kek-kek-kek...*, which may be the 'raucous *kkkwark*' described by Metcalf & Metcalf (1986), and the 'screeches' described by Condon (1973).

(2) A soft, mewing *wit...wit...wit...* of one note per second, similar in quality to that of the White-breasted Woodswallow *Artamus leucorhynchus* or subdued mewing calls of the Noisy Miner *Manorina melanocephala*. This call is shorter and less upslurred or shrill than equivalent slow *ee...ee...ee...* Brown Goshawk calls (cf. Aumann 1988). It was heard commonly around the nest in the pre-laying period, given by both sexes but especially the male. This is the 'soft *chip chip chip*' described by Hollands (1992), and presumably the 'persistent, whistling *chew, chew, chew*' described by Metcalf (1982) and Metcalf & Metcalf (1986), and the soft peeping described by Olsen (1981), of a nest-building male. When standing on the nest in the building period, the female sometimes prolonged the notes slightly: *weet...weet...* Sparrowhawks sometimes interspersed the mewing and chittering calls, or uttered slurred mewing or rapid accelerating notes which broke into the chittering call. The male Sparrowhawk uttered the mewing *wit...wit...* as a food call when approaching the nest with prey, but this call was not drawn-out, disyllabic or shrill like that of male food-bearing Brown Goshawks *A.f. fasciatus* or *didimus* (cf. Aumann 1988, 1990). The male Sparrowhawk's mewing call was somewhat higher and thinner than the female's.

(3) A slow, mewing chatter *ee-ee-ee-ee...* of 1.5 syllables per second, uttered by the female on or within a 50 m radius of the nest. It was heard with increasing frequency towards the end of the nest-building period, often in the presence of intruding conspecifics or other birds, and spontaneously by the brooding female early in the nestling period. It appeared to be a territorial call. It was more mellow and less plaintive than equivalent Brown Goshawk slow chattering calls. It is apparently the 'gentle *kee-kee-kee*' described by Metcalf & Metcalf (1986).

(4) A loud, slow mewing *ee...ee...ee...* or *ee-oo...ee-oo...ee-oo...* of one note per second, each note downslurred at the end. This is presumably the 'loud, insistent *kee-yow*' of Condon (1973) and Schodde & Tidemann (1986), and the 'high, descending *swee swee*' of Hollands (1992). It was uttered by the female during the incubation and nestling periods, when seizing food brought by the male and when returning to the nest to relieve him from incubating. It was uttered with increasing frequency and often spontaneously by the female from the second week of the nestling period, and often continued for some minutes after prey delivery, when it may have functioned as a dismissal call. Later in the nestling and early post-fledging periods, the female sometimes uttered it when approaching the nest with food. The same call was used by fully grown but still dependent juveniles, at Eastwood and elsewhere, as a begging call: the 'plaintive *wheea... wheea...* notes' of dependent fledglings described by Marchant (1992). This call was unlike any heard from local Brown Goshawks or described for the southern race *fasciatus* (the loud, slow *ee...ee...ee...* cf. Aumann 1988, which is shrill and upslurred), but may have been similar to one call described by Aumann (1990) for female *didimus*.

The adults at Armidale uttered several other types of call in specific contexts. A threat or mobbing call when attacking potential nest predators was a disyllabic, petulant chatter *kiki-kiki-kiki...* of two *kiki* units per second, sometimes preceded by a rapid *kee-kee-kee-kee...* chatter of two syllables per second, more plaintive than the chatter of the Australian Hobby *Falco longipennis* (cf. Debus et al. 1991). This is the 'scolding *kikikik* or *kekekek...* [or] an accelerated version' of Hollands (1992). During copulation, both sexes uttered a shrill, upslurred and disyllabic or tremulous version of the mewing call: *i-ee...i-ee...i-ee...* or *ee...ee...ee...* of 1.5 *ee* units per second. The adult male uttered a distress chitter (the common accipitrid trilling squeal, a falsetto *i-i-i...*) when

a fledgling seized food from him violently and perhaps grabbed his toe by mistake.

Downy nestlings begged with soft peeping notes, and sometimes called with a more staccato *kik-kik-kik...* (3 syllables per second), apparently in distress. A large, feathered nestling begged with a rapid, piping chatter *ki-ki-ki...* (2 syllables per second), very like the shrill chatter of an adult Brown Goshawk. This was sometimes prolonged into a falsetto, upslurred *ee-ee-ee...* (1.5 syllables per second). At fledging, this juvenile begged with a mellow chatter *ee-ee-ee...* (1.5 syllables per second, like the adult female's slow chatter), sometimes with a falsetto, squeaky quality. Over its first two weeks out of the nest, its call gradually changed to the slow, mewing, downslurred *ee-oo...ee-oo...* call until, by the time it was flying well, it was barely distinguishable from the adult female's begging call. At feeding times, these calls became more excited, rapid and falsetto. At fledging, this juvenile gave a rapid, shrill chatter *ki-ki-ki...* (2.5 syllables per second) in alarm when a Pied Currawong *Strepera graculina* landed next to it, and in its fourth and fifth week a similar threat or alarm call (2 syllables per second, very like the adults) when it chased a Currawong and when a Wedge-tailed Eagle *Aquila audax* sailed low overhead. We did not hear the 'slightly wheezy *whizz*' described by Marchant (1992) for an interacting brood of three fledglings.

Most calls of the Sparrowhawk are noticeably, if subtly, different from those of the Brown Goshawk. Familiarity with the Sparrowhawk enables the calls of the two species to be distinguished readily. Equivalent calls differ in tempo, and many of the Sparrowhawk's calls are more mewing and subdued. At no stage did fledgling Sparrowhawks utter rapid chattering calls like those of fledgling Brown Goshawks; the loud, slow mew of fledgling Sparrowhawks is very distinctive and unlike any call uttered by Brown Goshawks.

Display

Most of the Collared Sparrowhawk's displays have been described elsewhere (Czechura et al. 1987, Metcalf & Metcalf 1989). This species performs a range of typical accipitrine display behaviour, from perching and calling to soaring and calling, slow-flapping 'harrier' flight and undulating or diving aerobatics. These and other displays were performed by breeding Sparrowhawks at Armidale and elsewhere, their contexts described more fully below.

In the undulating display described and illustrated by Czechura et al. (1987, Figure 4, p. 56), the soaring pair gave the rapid chittering call and the perched male gave the mewing *wit... wit...* call (Debus pers. obs.). Early in the breeding cycle, another female soared up for >5 minutes high over her territory, made a long vertical stoop to the tree canopy on a hillside, then soared again.

Territorial defence

The female was first seen on the morning of 16 September 1991, soaring and chittering over her territory, then in slow-flapping flight over the treetops. On the morning of 25 September she perched conspicuously on a dead branch in the sun, chittering and mewing as a Brown Goshawk soared high overhead, then she flew chittering towards the nest site. On the morning of 27 September she was chittering and mewing, and changed perches frequently as a Brown Goshawk soared overhead. She flew with slow-flapping flight over the canopy and perched in the nest gully, finally flying with soft mewing calls to the nest, where she stood for half an hour. The nest was then a scant platform. On the same morning, a yearling male almost in full adult plumage (not her mate) was perched, mewing and chittering 800 m away, with no reaction from the breeding pair. It may not have been visible or audible to them.

From 29 September both sexes were observed building the nest. It was not clear when the male or female first arrived in their territory or started building. The female was a yearling, starting to moult into adult plumage, and there had been no sign of breeding Sparrowhawks in the previous year. The male was an adult. An adult male was seen occasionally in the mid 1980s (H.A. Ford pers. comm.), and a fledgling was seen in January 1988 within 500 m of the nest site (Debus pers. obs.), indicating past occupancy by breeding Sparrowhawks.

The pair was observed to defend the territory against intruding conspecifics twice during the nest-building phase in 1991, and once in the fledgling's first week out of the nest. On the morning of 16 October the male pursued an intruding adult male Sparrowhawk: he left the nest area in slow-flapping flight and stooped at the flying intruder c. 100 m away from the nest. The female stood up on the nest, chittered and settled back in the incubating posture. Both males then soared over the nest site in high circling flight, with jerky slow flapping. The resident male pursued and stooped at the intruder, which dodged each attack. On the morning of 18 October a juvenile (yearling) male Sparrowhawk appeared within 100 m of the nest. The perched female gave the territorial slow chatter, then the intruder landed within 30 m of the nest. The calling female displaced him, and he left. Meanwhile, the adult male had arrived with food, but took no action. He gave the food call from his perch until the female collected the prey. On the morning of 26 November, in the first week of the nestling period, an adult (apparently non-breeding) female Sparrowhawk in fresh plumage made a kill c. 1 km from the nest. No interaction with the breeding pair was seen. On the morning of 1 January, after the male dropped food to his fledgling on the nest and perched nearby, an intruding male Sparrowhawk landed in the nest tree, and the resident male pursued it out of sight.

Elsewhere, during the nest-building phase, two adult female Sparrowhawks were circling about 50 m apart in mid morning, near the presumed mutual boundary of neighbouring territories. One was chittering. It then made a long, slanting glide to the tree canopy c. 500 m away. Other intrasexual encounters by adult Sparrowhawks, in the breeding season, are described elsewhere (Debus 1990).

Throughout the breeding cycle at Armidale, the female was the main defender of the territory. In the nest-building phase, she attacked Pied Currawongs four times, and both sexes together attacked Forest Ravens *Corvus tasmanicus* once, within 50 m of the nest. The female also attacked a Red Wattlebird *Anthochaera carunculata* and Grey Butcherbird *Cracticus torquatus* once each, apparently in aggression rather than attempted predation. The Currawongs were nesting 40 m away, and sometimes initiated or returned the attack. The Sparrowhawks did not react to Brown Goshawks overhead or flying through the trees 50 m away. In the nestling period, both adults attacked Currawongs: the female 11 times, the male once after the female alarm-called from the nest. The female attacked a low-flying Little Eagle *Hieraaetus morphnoides* c. 100 m from the nest, chased an Australian Magpie *Gymnorhina tibicen*, displaced a Black-faced Cuckoo-shrike *Coracina novaehollandiae* from the nest tree, and attacked a Noisy Friarbird *Philemon corniculatus* c. 20-30 m from the nest. In the post-fledging period, she attacked a Little Eagle c. 100 m from the nest, and the male attacked an intruding immature Brown Goshawk c. 200 m from the nest and chased it out of sight. Elsewhere, adult Sparrowhawks were seen harassing a Square-tailed Kite *Lophoictinia isura*, Brown Goshawk and Grey Goshawk *Accipiter novaehollandiae*. The Sparrowhawks attacked in fast flickering flight and shallow stoops, with threat-calling. After interspecific conflicts, particularly against Currawongs, the female often returned with slow-flapping flight and perched conspicuously near the nest.

Table 1

Frequency of activities at a Collared Sparrowhawk nest during the pre-laying period, Armidale, N.S.W., September-October 1991 (mornings only). M = male, F = female.

Activity	*No. records/hour (n hours of obs.)*
Nest-building period:	
stick deliveries (M)	0.7 (7.5)
stick deliveries (F)	0.9 (7.5)
Nest-lining period:	
stick deliveries (M)	0.1 (12.5)
greenery deliveries (M)	0 (12.5)
stick deliveries (F)	0.4 (12.5)
greenery deliveries (F)	0.6 (12.5)
Copulation	0.4 (13.5)[a]

[a]pre-laying period, from first day on which mating seen

The female of the main study pair once made a threatening or defensive gesture towards a human: early in the nestling period, as she returned to the nest with food, she swooped low and silently over an observer who was standing between her feeding perch and the nest. The female at a nearby territory, with newly fledged young, repeatedly threat-called and swooped at an observer.

Nest building

Both sexes transported material to the nest. In the building phase (watched 29 September-7 October), the male and female contributed an almost equal number of sticks (Table 1). In the lining phase (watched 13-18 October), the female contributed most of the sticks (0.4 vs 0.1/hr) and all the greenery (0.6 sprays/hr). The female collected material from trees by balancing on a dead twig and flapping, or (usually) by pulling with her bill and flapping. Once she collected a stick from the ground. Sticks were usually transported in the bill (sometimes feet), and greenery (eucalypt leaves) was transported in the bill. Both sexes sometimes landed on the nest without material, and both sometimes shuffled around and scratched with their feet in the cup, or arranged material with their bills. There was only one bird on the nest at any time.

Building activity took place in the morning, to about 0900 h. Between 0900 and 1100 h the female perched inactively within 50 m of the nest. On all afternoon checks or watches, the female was perching quietly in a leafy tree within 50 m of the nest and the male was absent. At 1800 h on 13 October the female flew purposefully out of sight (>100 m) through the tree canopy, perhaps to a roost away from the nest.

Both sexes frequently gave the soft, mewing *wit...wit...wit...* when arriving with nest material. The male approached and departed from the nest with shallow, 'winnowing' flight (the 'fluttering beat' of Metcalf & Metcalf 1986). The female departed from the nest in a stealthy glide, steering by twisting and fanning tail movements, to the nearby tree canopy. Between bouts of building, the female perched conspicuously in the sun, on a dead branch in the top of the nest tree or the food-transfer tree, and frequently gave mewing and chittering calls or (towards the laying date) the territorial chatter. The male also often perched in the sun, within 50 m of the nest, in the early mornings.

There was no building activity on 18 October, when laying was imminent (see below). The female sat on the nest in the incubating posture for an hour on the morning of 16 October. On 18 October she sat in the incubating posture for an hour, stood on the nest rim for an hour, then perched and gave the territorial chatter intermittently for half an hour.

Food provisioning

The male provided the female with food throughout the building period, from the first day of systematic observations (29 September). He approached in gliding flight low over the tree canopy, with the prey dangling conspicuously in a lowered foot, and gave the *wit...wit...* food call when within 100 m. On the transfer perch he continued to call, and adopted a special posture: head lowered, with ritualised plucking movements, and tail cocked up at an angle, as he lifted his closed wings with each note (as illustrated in Morcombe 1990). The female took the food from him with soft mewing notes. The male often continued to perch beside the female, in a relaxed attitude and preening, as she ate. The male came and went unnoticed or unheeded by small birds in the vicinity of the nest: there were no alarm calls except once by Black-faced Cuckoo-shrikes on his arrival, and once by a Noisy Friarbird (which harassed him) on his departure. Prey items were either whole and unplucked, or plucked, headless and partly eaten when delivered, in about equal proportions.

Copulation

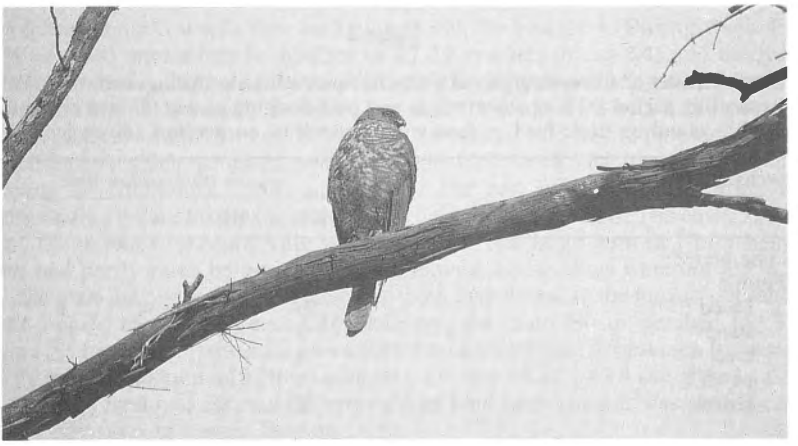
From 6 October the pair often perched side by side. Mounting was observed six times over six mornings 7-18 October in the pre-laying period (0.4/hr: Table 1), always after the male had fed the female, and always on a perch within 30 m of the nest tree. After mounting, the male continued to perch beside his mate. On 7 October, while she was eating, an abortive mounting was followed immediately by copulation. The male flew to the female's back, while the female invited by crouching with tail raised, wings spread and shrill calls. On 17 October there were two abortive mountings: the male gave the shrill call as he tried to alight on the female's back while she was eating, but she resisted with mewing calls, facing him with open bill. On 18 October, with laying imminent, the pair did not copulate in 3.5 hours although the male perched next to the female after feeding her.

Laying

The female's behaviour on 18 October suggested that she was in pre-laying lethargy. From the hatching date (25 November) and a known incubation period of 35 days (Ross et al. 1989), laying commenced around 19-21 October with at least two eggs being laid.

Incubation

On the mornings of 19-20 November and afternoon of 23 November, the female incubated for the entire hour's watch on each day, and the male was absent. On the afternoon of 24 November, at 1745 h, the calling male brought food (a plucked, half-eaten bird). The female immediately flew out to meet him and hungrily snatched it, possibly in the air, while giving the loud begging call. The male immediately flew to the nest and sat in the incubation posture for 12 minutes while the female ate the entire item at a perch c. 20 m away. She returned with 'winnowing' flight and he left with more pronounced 'shivering' flight as she arrived. For the balance of the hour (1700-1800 h), the female was incubating. There were no sounds or behaviour to suggest that hatching had occurred; the behaviour pattern was similar to that described for the incubation period by Morcombe (1990) and Hollands (1992).



Breeding yearling female Collared Sparrowhawk, Eastwood State Forest, Armidale, N.S.W., December 1991: on prey-exchange perch.

Plate 10 Photo: Bob Shepherd

Hatching

On the morning of 25 November the female had prey at the nest, feeding a chick. Soft peeping calls were coming from the nest. From this date the male reverted to the method of prey delivery used before the incubation period, without going to the nest while the female was off. The nest was watched daily to day 5 of the nestling period. On the morning of 27 November (day 3) soft peeping calls seemed to be coming from two chicks simultaneously at feeding times. At least two chicks hatched (two downy heads seen on day 18), from an unknown number of eggs.

Nestling period: parental behaviour

For the first three weeks the male provided all the food, and did not brood. From the fourth week (from day 22) the female also hunted for food, in the afternoons. The male's method of prey delivery was similar to that described above, except that the pair did not perch together after the transfer. The male usually departed in direct flight low over the canopy, but sometimes soared up and glided away. The female became increasingly prompt, vigorous and vocal in claiming the prey, sometimes intercepting the male before he reached the transfer tree and either causing him to stop short at another perch, or seizing it in the air. After transfers, the male left immediately or perched for a variable time, and the female took the food to another perch where she plucked it and sometimes ate a part. She then flew rapidly to the nest in slightly undulating flight, and tore off and fed small pieces to the chick(s). In the first three weeks, whole and mostly feathered prey was delivered to the female about twice as frequently as was plucked and partly eaten prey. In the fourth and fifth weeks, the male brought mostly whole prey, but the female plucked and partly ate her catch before bringing it to the nest. From this stage, the female also took the remains of her large prey away from the nest (usually to the transfer tree) and dropped them, whereas all items supplied by the male were small and completely consumed (except once in week 4 when the female discarded a piece of gut, and once in week 5 when she discarded a bone fragment).

During the first week the female brooded constantly, but thereafter her time spent brooding decreased as her time off the nest increased through the nestling period (Table 2). In the first week she came off the nest only to receive prey from the male, for

Table 2

Parental activities of a breeding pair of Collared Sparrowhawks during each week (W1-W5) of the nestling period (92 h of observation) and post-fledging period (83 h of observation). Stand = stand on nest; feed = feed young; perch = on perches ⟨50 m from nest.

Sex/activity	*% observation time*				
	W1	*W2*	*W3*	*W4*	*W5*
Nestling period:					
Female					
brood	89	79	34	6	0
stand	3	4	1	11	3
feed	8	7	6	7	3
perch	1	11	59	54	83
absent	0	0	0	22	10
Male					
perch	30	5	1	2	3
Post-fledging period:					
Female					
stand	2	0	0	0	0
feed	3	0	0	0	0
perch	67	40	10	0	0
absent	26	60	90	100	100
Male					
perch	20	4	7	1	⟨1

periods of 1-3 minutes while she plucked it and called (the slow, mewing begging/dismissal call). The chicks' meals lasted 5-15 minutes (commonly 10-15 minutes) depending on prey size. The male often perched after prey delivery, for 10-75 minutes (commonly 10-20 minutes). Food provision at this stage was in excess of requirements, as the female did not collect two items: the male deposited one on the nest after calling and plucking for 35 minutes, and he ate the other after 4 minutes. In both cases the female and chicks had been fed earlier that morning.

In the second week the female brooded constantly to day 10, but from day 11 she spent increasing periods (7-30 minutes) perched in the sun on the transfer tree between morning prey deliveries. On one stint off the nest she collected greenery. She promptly and noisily snatched all prey items delivered, and spent 2-17 minutes (commonly 4-8 minutes) calling, plucking and eating before taking the food to the nest. The chicks' meals lasted 3-13 minutes (commonly 5-9 minutes). The male left immediately or perched for 2-15 minutes (commonly 2-10 minutes).

In the third week, the female brooded intermittently in stints of 42-75 minutes, but spent periods of 7-128 minutes (commonly 15-60 minutes) perched within 30 m of the nest. She spent 1-7 minutes calling and plucking before taking prey to the nest. The chicks' meals lasted 7-31 minutes. The male left immediately or perched for 1-5 minutes after delivery. When he flew in to perch near the nest tree after he delivered food to her, the female gave dismissal calls while feeding the nestlings.

There were two chicks on day 22, but only one was seen thereafter. Food was apparently in short supply in week 3, as the male's prey delivery rate was lowest at that stage (Table 4). The second chick apparently perished early in the fourth week

(when it was about 3 weeks old, assuming it was the younger). During week 4 the female brooded intermittently in stints of 27-29 minutes to day 24, and thereafter did not brood during the day except once (day 28) for 4 minutes during rain. However, from day 24 she occasionally stood on the nest for long stints of 85-120 minutes. She often perched within 50 m of the nest tree for periods of 5-137 minutes (commonly 30-120 minutes) which increased towards the end of the week. She spent 4-21 minutes, increasing to commonly 10-20 minutes by the end of the week, calling and plucking/eating before taking the male's prey deliveries to the nest. The chick's meals lasted 2-23 minutes, exceptionally 66 minutes for one large item (a Noisy Miner) caught, and partly eaten beforehand, by the female. Some items were not fed to the chick: the male ate one and left with another (both uncollected in the female's absence), and the female ate three items. After delivery, the male left or perched for 2-17 minutes. From day 22, the female was sometimes absent from the nest area for periods of 12-90 minutes (commonly 20-60 minutes). On day 24 at 1745 h she glided quietly away over the treetops, and had not returned an hour later when it was getting dark. She may have roosted away from the nest.

In the fifth week, the female stood on the nest for one bout of 18 minutes, but usually perched within 50 m of the nest tree for periods of 21-132 minutes (commonly 30-90 minutes). She was absent from the area for periods of 22-37 minutes. She spent 6-16 minutes calling and plucking before taking the male's food deliveries to the nest. From day 29 she took the male's prey c. 50 m from the nest to pluck/eat before returning to feed the nestling. The chick's meals lasted 2-7 minutes. The male left or perched for 2-9 minutes after delivery.

Nestling period: development of young

In the first two weeks, little could be determined except that the chicks begged with soft peeping notes and took small pieces of food from the female's bill. Sometimes they uttered more strident, staccato notes apparently when squabbling, hungry or otherwise in distress. On days 13 and 14 a creamy-white downy chick was seen moving on the nest.

In the third week, the young milled around on the nest on day 16 when the female arrived without food. On day 18 two creamy-brown, downy heads were visible. The chicks were very active and appeared close to being capable of feeding themselves, as they snatched at the prey while the female pulled it apart. On day 20 they were grabbing food from the female's bill.

On day 22 (week 4) one chick stood and flapped its wings. Its primaries were well grown, and its wings were long, with down on the leading edges and underneath. It was still mostly downy (white), with short, dark tail feathers and dark flight feathers with pale edges; there were some dark wing coverts showing, and perhaps some dark feathers on the back. Its tail feathers were more than pins: a single row of dark rectrices, with the tips out of their sheaths. The cere, lores and area around the eyes were bare and pale grey, and the eyes were dark grey. It appeared to lift its tail and defecate over the nest rim. On day 24 the single chick was well feathered and large, with a creamy, downy head. It stood up intermittently and stretched its wings, and later stood on the nest rim and flapped them. When fed it pecked at the prey, and pieces offered by the female seemed larger than on previous watches. On day 23 it uttered a mellow, piping chatter as described earlier, and on day 27 it begged with a call similar to that of the adult female. On day 26 it was standing on the nest rim, and seemed close to fledging. On day 27 it pecked at prey in the female's talons as soon as she arrived.

On day 29 (week 5), the nestling stood on the nest rim and flapped its wings. Its head was downy, and its body was blotchy with feathers and down. The quills of flight and tail feathers were still ensheathed. It fed itself on whole birds deposited by the male. On day 30 it clambered on sticks (mistletoe) adjoining the nest rim, and flapped its wings.

Fledging

Only one young, a female, fledged on 26 December. Assuming it was the first hatched, the nestling period had lasted 31 days. On the morning of 25 December (day 31) it was clambering about in the branches of the mistletoe containing the nest, and jumping and flapping between the nest and a supporting branch. In the afternoon it moved out along the main eucalypt branch supporting the nest. Early on the morning of 26 December it was in a fork about 1 m below the point where the nest branch joined a main vertical branch. The female was calling and holding prey c. 50 m north-west of the nest. The fledgling suddenly flew, flapping franctically, about 10 m south to the leafy canopy of the neighbouring stringybark, where it balanced precariously as the leaves and branchlets bent under its weight. The female flew to the transfer tree and then to the nest, with the food, and started eating. After 7 minutes the fledgling flew back to the outside of a different mistletoe in the nest tree, then after another 5 minutes it flew to the nest mistletoe, clambered down to the nest and was fed.

Post-fledging period: parental behaviour

The male supplied most of the fledgling's food throughout its period of dependence, and during the first two weeks his deliveries followed the usual pattern of gliding in over the trees, dangling the food and calling. The female supplied some items (plucked and headless/partly eaten) in the first two weeks. In the first week, items supplied by the male were more frequently whole and feathered or partly feathered than plucked and headless (2:1). These were mostly delivered to the female which then fed the young at the nest; two (whole) items were given directly to the fledgling at the nest. From the second week, the male's food items (delivered directly to the young) were usually whole and feathered (7:1). Some transfers to the female were aerial. In the only one clearly seen, the male paused momentarily in the airspace between tree crowns and adopted the tail-up posture as he dropped the prey; the approaching female rolled and caught it.

In the first week, the female often perched on the transfer tree for periods of 42-192 minutes (commonly 60-180 minutes). She was absent from the nest area for periods of 61-104 minutes, sometimes precipitated by the fledgling's approach to her perch when she did not have prey. When she collected food from the male she took it c. 100 m away from the nest, calling, to pluck/eat before returning to the nest (except on day 5 when she ate all of one item). She waited until the fledgling returned to the nest, then fed it on small pieces (until day 5). Such meals lasted 4-25 minutes, depending on prey size. In the female's absence, the male delivered prey to the fledgling at the nest. He deposited prey only when the fledgling was on the nest. On the first such delivery, he went to the nest and left again with the prey twice before the fledgling finally arrived there and took it on his third attempt. When feeding itself (from day 2), the fledgling's meals lasted 4-10 minutes depending on prey size and condition. After delivery, the male left or perched for 3-72 minutes (commonly 10-60 minutes, longer in the female's absence). On day 2 the male left his perch hurriedly as the female was returning from an absence; as she arrived without prey, she stooped briefly at him.

In the second week, the female perched on the transfer tree for periods of 41-120

Fledgling Collared Sparrowhawk, Eastwood State Forest, Armidale, N.S.W., January 1992. Nest is just out of picture, in mistletoe.

Plate 11 Photo: Bob Shepherd

minutes. She was absent for periods of 25-240 minutes, often for entire 2-4 hour observation sessions from day 12. She delivered one item at the nest on day 8, and on a perch on day 13. The male delivered virtually all items directly to the juvenile, except for one (on day 11) delivered to the female. He delivered items to the nest up to day 13 if the juvenile was on it, but transferred some items to the juvenile at a perch from day 9. From day 11, some of his deliveries to the juvenile were aerial. On the first occasion, he left his perch and flew slowly as the juvenile arrived and followed him; the juvenile then snatched the prey from his feet. The juvenile fed itself, meals lasting 4-20 minutes. The male left or perched for 1-21 minutes (often 5-10 minutes) after delivery.

From the third week the female parent was entirely absent from the nest area, except for one morning (day 17) when she perched in the transfer tree for two hours. In the third and fourth weeks, about a third of the male's deliveries were aerial. From day 17 he arrived silently and stealthily through the tree canopy, without giving the food call, and waited quietly on a perch with his prey. He sometimes plucked or changed perches, until the juvenile saw him or called and the two were able to locate each other. On day 20 he retreated from one attempted transfer and apparently departed with the prey, or it was lost, after a second unsuccessful attempt. The juvenile's meals lasted 5-30 minutes (commonly 10-15 minutes). After delivery, the male left or perched for 2-55 minutes (longer in the female's absence) in the third week, declining to 1-3 minutes in the fourth week when he was mostly absent. In the fifth week the male was virtually absent except when delivering prey. On one occasion (before the juvenile had been fed) he was flushed from a tree in the nest area, where he had been perching quietly without prey for an unknown period.

Post-fledging period: development of young

At fledging the juvenile was fully feathered with down remaining on its forehead. Its wing tips were short and rounded and its tail appeared about half adult length. Its eyes were dark, and its legs and feet were dull yellow. Its eyes were dark brown on day 11 and light brown on day 17 of the post-fledging period. Its cere was creamy yellow, and its eye-rings yellow, on day 11. Its wings appeared to reach adult proportions by day 18 (i.e. at about 48 days old). Its tail was estimated as about two-

Table 3

Estimated maximum distances from nest at which a juvenile Collared Sparrowhawk was seen on given days during the post-fledging period, based on daily visits to the site. Day 1 = day of first flight from nest tree (26.12.91).

Day post-fledging	*Distance (m)*
1-3	10
4-8	30
9-15	80
16-25	100
26	>200
27	300
33	500

thirds adult length on day 8, three-quarters on day 17 and full length by day 24 (i.e. by about 54 days old). Its tail appeared rounded until day 20, and until day 24 when tightly furled. On days 24-25 it appeared square or notched, with sharp corners, when partly spread, but it was not until day 26 that its tail appeared fully square and adult in proportion, sleek with presumably hardened shafts, and slightly flared at the tip when loosely closed. On day 33 its eyes had changed to dull yellow. Throughout the period, it was very vocal and until day 39 (when last seen) it frequently gave the loud begging call.

In its first week the fledgling ranged up to 30 m from the nest (Table 3), in low tree-to-tree flights of up to 10 m. It returned readily to the nest to receive food there. Its first flights were direct flapping. On day 4 it flew strongly and competently, and anticipated food at the nest by flying there ahead of adult arrival. On day 7 it flew in wheeling and jinking flight, in a rapid half-circle with continuous flapping between trees.

In its second week the fledgling ranged 50 m from the nest on day 9 to 80 m on day 12. On day 9 it flew in direct, slow flap-and-glide to land in a competent and controlled manner, and steered around trees in a circuitous flap-and-glide. It collected food from the male at a perch by flying to him when he arrived. It dropped one item and retrieved it from the ground, spreading its wings protectively ('mantling') before taking it to a perch. It balanced on the perch, mantling, but had difficulty plucking and holding the item as it ate. On day 10 it started taking food to the nest to eat it. On day 11 it took prey from the male in flight by following him and snatching the food from his talons, and thereafter some transfers were aerial. On day 12 it chased small passerines in a flapping and wheeling, flat circle between trees. Its flight was agile, with gliding, and competent. After feeding, it cleaned its bill by stropping both sides on its perch. On day 13 it received food from the male at the nest, then flew to displace him from a perch, and returned to the nest to eat. It stumbled and appeared clumsy when landing. Its flights ranged up to 50 m. On day 14 it was adept, without clumsiness, when it ate food at a perch. When it dropped prey during a transfer it returned to the spot and searched on the ground.

In its third week the juvenile ranged up to 100 m from the nest, from day 16 which was the last day of prey transfer at the nest. From day 17 it ranged widely around the nest in the early mornings and returned to the nest area during mid morning to await the male. Prey deliveries took place in trees c. 30-50 m south of the nest. On day 17 the juvenile 'crashed' into foliage near a small bird. It consumed all of a 10 g passerine provided by the male. On day 18 it swooped low to the ground and back up, followed a piece of dislodged bark down in a swoop, then harassed a Pied

Currawong by swooping and chasing it. On day 19 it wheeled over the tree canopy, and flew >100 m. It again returned and displaced the perched male after a prey transfer. On day 20 it unsuccessfully chased and swooped at flying insects, and at Leaden Flycatchers that were mobbing it.

In its fourth week, the juvenile was ranging 200-300 m from the nest by days 26-27. On day 23 it again displaced the male after a prey delivery. It removed and discarded the bill sheath of a stout-billed European Goldfinch *Carduelis carduelis* before eating the prey. It dropped food during a transfer, and searched for it by walking around on the ground for 6 minutes until it was found. On days 25-27 it persistently chased Pied Currawongs, Noisy Friarbirds and Leaden Flycatchers. It wheeled and glided around the treetops, and made a long flight of >200 m. Until day 26 it still used the nest as a feeding platform, and sometimes rested there. On day 28 it expanded its flight radius in all directions from the nest. It sallied for a fluttering leaf or insect, seized it in flight, then dropped it at a perch. By this stage it was eating beetles, but no captures were seen.

In its fifth week, the juvenile snatched insects (?) and leaves from the canopy foliage, carried them to a perch, and picked at the leaves and dropped them. It also picked at leaves on the ground. On day 31 it ranged 500 m from the nest. On day 34 it still returned to the nest area during mid morning and begged, and was given food on that day. It appeared to be fully dependent until five weeks post-fledging, when systematic observations ceased. In its sixth week it was in the nest area on days 37-39, and was eating unidentified prey on day 39. Thereafter it was not found in the nest area during checks on days 40-46.

At the other nest 17 km away in 1991, development of the young followed a similar pattern. Two young fledged between 23 December and 6 January. On 6 January one fledgling had difficulty balancing while it ate prey (a small unidentified bird) at a perch; a Pied Currawong was within 1.5 m and tried to rob it. On 13 January one fledgling had food, and on 20 January both fledglings had food in the nest area. On 27 January one was 300-500 m from the nest, and had pale eyes.

Feeding rates

The male's hourly feeding rate varied throughout the cycle (Table 4). It was apparently lowest (although our sample size was small) in the incubation period, presumably when the family's nutritional demands were least. His provisioning rate increased in the second week of the nestling period, apparently in response to increased demand: the female appeared to communicate her needs by not collecting food when she or the chicks were sated, or by aggressively seizing food and giving dismissal calls, and ultimately by chasing him from the nest area (to induce him to hunt?). The low feeding rate in week 3 may have reflected a food shortage, possibly causing the demise of the second nestling early in week 4. From week 4 onwards the female supplemented the male's provisioning rate by more than her hourly rate would suggest, because she brought much larger prey (Table 5).

The adults' combined feeding rate in the post-fledging period declined after the female left, but the male continued regular food provision into the fifth week when the delivery rate declined. The juvenile communicated its needs to the male by seizing food aggressively, giving dismissal calls and by chasing the male from the area after deliveries.

In the pre-laying period most observed deliveries occurred early in the mornings (earliest 0610 h, latest 0940 h), but on one afternoon visit the female had just eaten at 1710 h. In the incubation period, the only observed delivery was at 1745 h. In

Table 4

Parental feeding rates at a Collared Sparrowhawk nest during different stages of the breeding cycle. h = no. hours observation; n = no. prey deliveries; M = male; F = female

Stage	*h*	*n*	*deliveries/hr obs.*		
			M	*F*	*Total*
Pre-incubation	20.0	8	0.4	0	0.4
Incubation	4.3	1	0.2	0	0.2
Nestling:					
Week 1	11.75	5	0.4	0	0.4
2	25.75	16	0.6	0	0.6
3	11.75	4	0.3	0	0.3
4	32.75	18	0.4	0.1	0.5
5	10.3	5	0.4	0.1	0.5
Post-fledging:					
Week 1	20.25	12	0.5	0.1	0.6
2	19.0	12	0.6	0.1	0.7
3	20.5	9	0.4	0	0.4
4	15.5	8	0.5	0	0.5
5	7.25	1	0.1	0	0.1

the nestling period, deliveries occurred from before 0545 h to 1121 h (male only), and from 1522 h to 1811 h (both sexes). Hunting appeared to occur throughout much of the day, with a lull in the hottest part from midday to 1500 h. From the fourth week of the nestling period the female hunted in the afternoons, perhaps when the male's morning provisions were insufficient.

In the post-fledging period, the female also hunted in the mornings. Observed prey deliveries took place between 0640 h and 1125 h, and 1612-1655 h, with a tendency for morning deliveries to become later from week 4.

Rain, wind and fog appeared to depress the male's provisioning rate (reflecting lack of hunting success?) to some extent, but his delivery rate was variable even on successive mornings of similar (fine) weather. On mornings of multiple deliveries, the interval between his visits ranged from 5 to 249 minutes (commonly 40-70 minutes). On three occasions he left immediately after delivering food and was back in 5, 6 and 10 minutes, respectively, with the next item.

All prey items were transported in the feet. The female and juvenile seized the male's prey with their feet. When taking his captures to the nest, the female often transferred them to her bill on take-off but back to her feet in flight.

Diet

The Sparrowhawks' breeding diet, until the juvenile was approaching independence, consisted entirely of small birds (Table 5). Only three birds captured were obviously juveniles, although fully grown: a Grey Fantail *Rhipidura fuliginosa*, Yellow-rumped Thornbill *Acanthiza chrysorrhoa* and Spotted Pardalote *Pardalotus punctatus*. Many were adults, or at least free-flying, rather than fledglings. The maximum prey weight was about 70 g, and 90% of items were estimated to be less than 25 g. Mean avian prey weight was 17 g, and median weight 38 g. All observed prey items were brought to the nest or fledgling; the male occasionally, and the female frequently, fed from items delivered to the young.

Birds taken were mostly common species of the local woodland tree and shrub

canopy (Ford & Bell 1981). A wide range of passerines was taken, with Spotted Pardalotes and Striated Pardalotes *Pardalotus striatus* the most common prey. A few ground or understorey species were taken, and the aerial species (Welcome Swallow *Hirundo neoxena* and Fairy Martin *Cecropis ariel*) may have been caught as they gathered mud or hawked insects low over a dam in the forest.

Five pellets, measuring 24 x 12 to 31 x 12 mm, were found under the nest in the fourth week of the post-fledging period (but not before, despite frequent checks). This was when the juvenile was still using the nest as a feeding and resting platform, but after the female had disappeared. They each contained feathers and bone fragments of small birds, and beetle fragments (5 beetles; 5% by number and <1% by biomass). Apart from the beetles, the pellets added only one prey item to the total (Red-rumped Parrot *Psephotus haematonotus*). A dead Gould's Wattled Bat *Chalinolobus gouldii* (14 g: Strahan 1983) was found under one of the fledgling's feeding/prey-transfer trees, and may have been dropped by the Sparrowhawks. The fledgling occasionally dropped (or caused the male to drop), and failed to retrieve, prey items during transfers.

At the other nest near Armidale in 1991-92 the only observed prey item, eaten by a fledgling Sparrowhawk, was a Crested Pigeon *Ocyphaps lophotes* (mean weight c. 200 g, larger than any item at the Eastwood nest). A pair of Sparrowhawks nested at Eastwood again in summer 1992-93: the male was seen clutching an unidentified small bird, and the female was seen plucking a Yellow-rumped Thornbill and holding a freshly caught (unplucked) juvenile Fan-tailed Cuckoo *Cuculus pyrrhophanus* (c. 50 g). One of the adult Sparrowhawks also caught what appeared to be a fledgling Noisy Friarbird, under intense mobbing by a pair of Friarbirds (J. Ford pers. comm.).

Impact on the local bird community

For the purpose of calculations, we assume a daily food requirement of 23% of body weight per day for small, active accipiters in warm weather (from Brown & Amadon 1968). The juvenile's intake was probably similar to that of an adult female, on average, over its nestling and post-fledging period (less when a downy chick, more when a large, growing and feathering nestling). Mean body weights for male and female (125 g, 242 g: Baker-Gabb 1984) give a consumption of 3.48 and 6.72 kg wet weight for male and female over the four months (120 days) of the breeding cycle, and 3.36 kg for the juvenile's first two months. A mean prey weight of 17 g equates with about 800 birds in four months. Prey delivery rates at different stages of the cycle (Table 4) give a similar answer. Assuming 12 hours of daylight (hunting time) in the pre-incubation month, and 13 hours of daylight in the remaining months, the hourly delivery rates for pre-incubation (30 days), incubation (35 days), nestling period (31 days) and post-fledging period (first 35 days) give 629 birds delivered to the female and juvenile. Adding 20% for the male's requirements gives 755 birds in four months. Both methods give 6-7 birds taken per day.

Eastwood State Forest and the surrounding woodland cover about 300 ha. If all birds were taken from this area, about 0.02 birds/ha would be taken daily, or 2.6 birds/ha through the season as a whole. Densities of all birds at Eastwood State Forest were estimated as 23.6/ha in 1978, 21.5/ha in 1979 (Ford & Bell 1981), 9.7/ha in 1981 (Ford et al. 1985), and 11.5/ha in 1990 and 1991 (H.A. Ford unpublished). For birds in the size range taken by Sparrowhawks (<100 g), densities were 8-9/ha in 1990/91. Thus Sparrowhawks could have taken up to 30% of the small birds from this patch of woodland. This would be an overestimate as there would be recruitment from breeding, although 1991 was one of poor breeding success, and a turnover of migratory and wandering birds. In addition, the Sparrowhawks could have hunted outside this patch. The White-eared Honeyeater *Lichenostomus leucotis* taken by the

Table 5

Diet and prey partitioning between the sexes at a Collared Sparrowhawk nest, October 1991-January 1992, Armidale, N.S.W. M = male, F= female, ? = sex unknown. For male, e (early) = to end of week 3 of nestling period, before female started hunting; l (late) = later in nestling/post-fledging periods after female started hunting. All prey weights averages from local specimens (Ford & Bell 1981; local banding data).

Prey species	*Prey mass (g)*	*n captured by*				*Total*
		Me	*Ml*	*F*	*?*	
Red-rumped Parrot						
Psephotus haematonotus	65				1	1
Shining Bronze-Cuckoo						
Chrysococcyx lucidus	23		1			1
Welcome Swallow						
Hirundo neoxena	12	1				1
Fairy Martin						
Cecropis ariel	10	1				1
Rufous Whistler						
Pachycephala rufiventris	26		1		1	2
Grey Shrike-thrush ?						
Colluricincla harmonica	64			1		1
Leaden Flycatcher						
Myiagra rubecula	14		1			1
Grey Fantail						
Rhipidura fuliginosa	8		2			2
Superb Fairy-wren						
Malurus cyaneus	9		1			1
Fairy-wren ?	9		2			2
Speckled Warbler						
Sericornis sagittatus	13		1			1
White-throated Gerygone						
Gerygone olivacea	10		1			1
Buff-rumped Thornbill						
Acanthiza reguloides	8	1	3			4
Yellow-rumped Thornbill						
Acanthiza chrysorrhoa	9	2	1			3
Striated Thornbill						
Acanthiza lineata	7	1	2			3
Thornbill sp.	8	1	1			2
Varied Sittella ?						
Daphoenositta chrysoptera	16		1			1
White-throated Treecreeper						
Climacteris leucophaea	24	2	1			3
Noisy Miner						
Manorina melanocephala	68			1		1
White-eared Honeyeater						
Lichenostomus leucotis	27		1			1
Fuscous Honeyeater						
Lichenostomus fuscus	18		2		1	3
Brown-headed Honeyeater ?						
Melithreptus brevirostris	15	1	1			2
White-naped Honeyeater						
Melithreptus lunatus	15		1			1
Spotted Pardalote						
Pardalotus punctatus	8	3	1			4
Striated Pardalote						
Pardalotus striatus	12	5	6			11

Table 5 continued

Prey species	*Prey mass (g)*	*n captured by*				*Total*
		Me	*Ml*	*F*	*?*	
Silvereye						
Zosterops lateralis	10	1	1			2
European Goldfinch						
Carduelis carduelis	14		1			1
Diamond Firetail						
Emblema guttata	19		1			1
Thornbill/fairy-wren	8		3			3
Thornbill/pardalote	10	2	3			5
10 g passerine	10	1	2			3
20 g bird	20	7	8	1		16
50 g bird	50			2	2	4
Small bird			4			4
Unidentified (small bird?)		2	4	1		7
Unidentified			1			1
Beetles (Coleoptera) (eaten by juvenile)	2					5
Total		31	59	6	5	106

male was probably caught farther away, as this species has not been recorded at Eastwood for over 10 years (H.A. Ford pers. comm.). With these important provisos the calculations do indicate the potential impact of raptors in highly fragmented habitat, especially on species with small populations (although rare species are probably seldom taken).

Prey partitioning

There was clear prey partitioning between the sexes, in terms of avian prey sizes taken by male and female Sparrowhawks, although the sample size for the female was small (Table 5). The male's prey averaged 13 g to the third week of the nestling period, before the female started hunting. Mean prey weight after the female started hunting, from the fourth week of the nestling period, was 19 g. However, this was biased heavily by the male's 50 prey items (which still averaged 13 g), compared with the female's five recorded items which averaged 50 g. The mean weight of species represented in prey remains from the late nestling and post-fledging periods was 42 g (n=5). Most of the items concerned were probably captured by the female, because the male's maximum recorded prey weight was 27 g and virtually no remains were discarded from his deliveries.

There was some prey partitioning between the two sympatric accipiters at Eastwood, although data for the Brown Goshawk are few and casual. Prey items noticed around Brown Goshawk nests at Eastwood since 1984 have been two Rabbit *Oryctolagus cuniculus* kittens (c. 200-400 g), a Painted Button-quail *Turnix varia* (c. 100 g), a honeyeater and a fledgling Pied Currawong. Other Brown Goshawk prey records for non-urban areas around Armidale in the breeding season, some from nests, include four Rabbit kittens, a Eurasian Coot *Fulica atra* (c. 500 g), two small native passerines and a lizard. The Brown Goshawk's diet is thus much more diverse, and includes much larger items.

Other raptors commonly seen around Eastwood or in adjoining open country were the Little Eagle, Australian Hobby and Australian Kestrel *Falco cenchroides*, but their

local breeding diets overlap little with that of the Sparrowhawk (cf. Debus 1984, Debus et al. 1991, Paull 1991). Brown *Falco berigora* and Peregrine Falcons *F. peregrinus* were seen occasionally, but there are no local diet data for these; overlap with the Sparrowhawk is likely to be slight.

Hunting behaviour

The adult Sparrowhawks seldom hunted in the vicinity of the nest, therefore few observations of hunting behaviour were obtained. On one occasion in the nestling period (week 1), the male flew silently around in the trees within 50 m of the nest: he flew in a circuit back near his original perch, in what looked like stealthy, short-stay perch hunting with low, tree-to-tree undulating flight. He then left (his actual departure undetected), and returned within 45 minutes with prey already partly plucked and headless. In a previous year a male was seen around the dam in the forest on two occasions, flying in undulating mode between the trees around the water's edge (H.A. Ford pers. comm.).

In week 5 of the nestling period, after she had resumed hunting, the female attacked a Noisy Friarbird in what may have been territorial defence rather than attempted predation. However, it illustrated how she might tackle large passerines of the size she was catching. From her perch in the transfer tree, she made a direct flying attack on the Friarbird (initially in a tree 10-20 m away) and pursued it for 40 m, in what became a twisting and diving tail-chase among the trees; it did not end in capture. In week 1 of the post-fledging period, the female left the transfer tree and made a direct flying attack on a small bird in the tree canopy c. 50 m away. It became a rapid tail-chase between tree crowns for a further 50 m, and she was lost to view; she did not return within half an hour.

Other observations of hunting behaviour in northern New South Wales 1980-1992 have been as follows. The outcome is stated if known.

Search behaviour:

1. Many (unquantified, c. 10) cases of Sparrowhawks being flushed from dense foliage cover, where they were perching quietly (apparently hunting rather than loafing, i.e. no crop distension indicating a recent meal).
2. Concealed perch hunting in a leafy eucalypt, changing perches by low, undulating 'cuckoo' flight (x2).
3. Unconcealed perch hunting, by an adult female on a suburban fence, in an area where exotic passerines were common.
4. Fast, flickering contour flight through a forest canopy (male x1).
5. Fast, downhill gliding transect through a woodland canopy (female x1).
6. Quartering coastal *Banksia* scrub (x1).
7. Flying rapidly over/through coastal dune scrub (x2).
8. Slow flap and glide low between well-spaced shrubs, with flight action like that of a Pacific Baza *Aviceda subcristata* (not display, as the bird, a female, was searching intently).
9. Low, direct undulating flight at rooftop height by adult male: once through urban area for 50-100 m (fine afternoon), then in thick fog in early morning, through well-treed caravan park for >50 m.
10. Direct flap-and-glide at treetop height for c. 100 m across an urban park, then perch in the centre of a pine tree for c. 5 minutes, scanning the area before leaving (adult female).

Attack behaviour:

1. A stealthy glide attack by an adult male, below a forest canopy, at thornbills in the understorey (unsuccessful).
2. A glide low over shrubs, followed by a stoop among the shrubs.
3. A stoop (unsuccessful) among suburban street trees.
4. A dive into coastal scrub, from direct flight.
5. A long, slanting glide attack across a river, then a twirling tail-chase around bank vegetation (outcome unseen).
6. A tail-chase, by a juvenile female, after a Spotted Turtle-Dove *Streptopelia chinensis* (unsuccessful).

7. Suburbia, at sunset: fast contour hunting at rooftop height over a playing field, then a direct flying attack into an ornamental cypress at full speed, where Common Starlings *Sturnus vulgaris* were gathering to roost; the Starlings flushed, banked and circled (juvenile female; outcome unseen).
8. Adult male: twisting dive and tail-chase after small passerines, down through the tree canopy in which he was perched (outcome unseen).
9. Adult male perch hunting low (2-3 m) in a thick suburban tree; flew c. 30 m across a road in undulating fashion ('cuckoo flight') to a higher perch (10 m) in another leafy tree; then made an unsuccessful dive attack on a House Sparrow *Passer domesticus* on the branch of a low (2 m) shrub, followed by low, fast flight away between houses and shrubs.

These observations and our subjective impressions, together with observations by Hobcroft (1992), suggest that the Collared Sparrowhawk's most frequently used search method is short-stay, concealed perch hunting, interspersed with low tree-to-tree flight, often in undulating mode. Fast contour hunting and other aerial methods are commonly seen, but may be recorded out of proportion to their true importance. The Sparrowhawk's common attack methods appear to be stealthy glide attacks and direct flying attacks that often develop into short tail-chases when prey is surprised at close range.

Adult plumage, moult and comfort behaviour

The breeding female at Eastwood was mostly in juvenile plumage on 25 September 1991. On 17 October, in the immediate pre-laying period, she moulted her left innermost primary. On 24 November, during the incubation period, she was acquiring adult plumage with new (slate-grey) secondary coverts and much grey on her mantle; she was moulting her middle primaries. On 2 December, in week 1 of the nestling period, she had much grey on the wings and mantle. On 3 December she shed an outer primary. On 16 December her primaries, secondaries and coverts were a mixture of old and new feathers, with new primaries appearing symmetrically in the descendent mode. During December the adult barring started from each side on her breast, and on 23 December it was continuous across her throat and upper breast. At this stage she had shed her two central rectrices, and the replacements were just emerging. On 26-28 December she shed a left and right secondary, and her soft parts seemed to be getting brighter yellow. On 5 January her dorsum was nearly solid grey, with scattered brown feathers, but she still had the brown juvenile head.

Until 26 January the male showed no sign of wing or tail moult, but during January his dorsal plumage started to appear slightly worn. His irides and eye-rings were a brilliant, intense yellow, more so than the female's, as noted in another adult pair (Hollands 1992). A feature of the adult male, and other adult, non-moulting Sparrowhawks, was a series of pale dorsal spots which can be hidden or displayed at will when the birds are perching conspicuously. These are formed by pale bases of the scapular feathers: in relaxed mode, with feathers fluffed, these are visible. However, when the feathers are sleeked the spots are overlain by neighbouring feathers. The fully grown juvenile also displayed these spots.

After feeding, the female cleaned her bill by stropping each side rapidly several times on her perch, and cleaned her toes by nibbling them with her bill. She often preened during her morning stints off the nest during the nestling period, in the sun on the transfer tree.

Pair bond, post-breeding dispersal and territory re-occupation

Relations between male and female Sparrowhawk were amicable during the pre-laying period, when they often perched together. From the incubation period, the female became increasingly dominant over, and aggressive towards, the male. By

the late nestling period, they had become virtually estranged. Prey transfers became violent: the female sometimes caused the prey to be dropped, or the male dropped items just before she arrived. She then swooped and retrieved them from the ground or (in aerial transfers) caught them before they reached the ground. During the post-fledging period the pair bond appeared to break down, and the female's attachment to the nest site declined until she left the area, leaving the male to continue feeding the dependent fledgling. She was not seen after 11 January, but the male continued to visit the nest area until 28 January. During autumn and winter, adult Sparrowhawks (particularly females) appear in Armidale, and can be seen in the same places over a period of weeks. For instance, in 1992 a moulting adult female was seen in the city on 4 March. This suggests some local post-breeding dispersal to winter home-ranges. Juvenile Sparrowhawks also appear in Armidale in autumn; the first one seen in 1991 was on 13 April (Debus pers. obs.).

In spring 1992 an adult pair of Sparrowhawks bred again in Eastwood State Forest. Without marked birds, it was impossible to determine whether they were the same individuals as in 1991. They nested c. 500 m north-east of the now abandoned 1991 site, using a freshly built nest of the same construction and similarly in a mistletoe near the top of a tall Yellow Box. The 1992 nest tree was the one used by a pair of Brown Goshawks in 1991, and there was also a newly built but abandoned Goshawk nest in that tree: in 1992 the Goshawks did not breed in the vicinity of the Sparrowhawks' active nest. The Sparrowhawks were seen several times in November-December, including prey transfers near the nest, and from 11 to 22 December the female was brooding; there were tufts of down around the nest rim, suggesting large downy chicks. A single (apparently female) young subsequently fledged (its distinctive begging mew first heard 24 January 1993), and it was still begging and using the nest on 30 January (casual observations only; none in the first three weeks of January). On 2 February the female collected prey from the male, deposited it on the nest and retreated while the fledgling flew to the nest and fed itself. This suggests that fledging was later, and/or the female stayed in the territory longer, than in the previous season. The begging juvenile was seen or heard near the nest until 13 March: a longer dependence period (7-8 weeks) than in 1992.

Field identification

Familiarity with the Collared Sparrowhawk revealed several subtle differences from the Brown Goshawk, mainly in voice (as noted above) but also in behaviour and mannerisms. The adults were much more confiding than Brown Goshawks, and tolerated a close approach by humans. In direct flight, the Sparrowhawk's wing action often seems more fluid and 'bouncy', at times reminiscent of the flight of an Australian King-Parrot *Alisterus scapularis*. Overhead in soaring flight, there are subtle differences in relative head and neck projection (longer in Goshawk), and in wing shape (primaries more turned-back in Sparrowhawk, accentuating the more curved trailing edge).

The pale dorsal spots may be a useful field character (and species identity signal) in non-moulting Sparrowhawks, but it is difficult to observe a Brown Goshawk in relaxed mode to see if it reveals pale bases to the scapulars. Our field experience, and a check of museum specimens, suggest that non-moulting adult Brown Goshawks do not display pale dorsal spots in the field. An obvious trap for inexperienced observers is tail shape in dependent fledgling Sparrowhawks: the tail is rounded until the rectrices are fully grown. Tail shape in fledgling Brown Goshawks is similar to that of newly fledged Sparrowhawks.

Discussion

The Sparrowhawks' behaviour throughout the breeding cycle was similar to that described in previous accounts of the nest-building, nestling and post-fledging periods (Cupper & Cupper 1981; Metcalf 1982; Metcalf & Metcalf 1986, 1989; Buchanan 1990; Marchant 1992). Hollands (1992) has filled gaps in knowledge of the incubation period, which we were unable to study in detail. Aspects of the Sparrowhawk's breeding biology at Armidale (e.g. nestling period and development of young) were also similar to previous accounts.

The post-fledging dependence period at Armidale lasted longer than most previous authors have stated for this species. This may have been partly because there were few flying insects and fledgling passerines on which the juvenile could practise and sustain itself, owing to the drought and the poor and late passerine breeding season (unpubl. data). However, the behaviour of juveniles in previous studies could have created a false impression that they had departed: the bird at Armidale sometimes ranged out of earshot (particularly in the early mornings) and returned later in the morning. It also perched quietly for long periods and we sometimes took up to an hour to locate it in the nest area. Stated post-fledging periods of 2-3 weeks may be too short, because flight and tail feathers are not fully developed within two weeks, and because a bird specialist may need a long period in which to develop bird-catching skills. A post-fledging dependence period of five weeks is similar to the duration recorded for some other small and medium-sized *Accipiter* species such as the Northern Sparrowhawk *A. nisus*, although shorter periods of 2-3 weeks are sometimes given (cf. Newton 1979, 1986).

The behaviour of the adult Sparrowhawks may have been slightly affected by the proximity of observers. During the nest-building and incubation periods, the adults ignored a single observer sitting quietly on the ground 30 m from the nest, or walking around under their perches or nest. During the nestling period the food-bearing male sometimes landed on a different tree if an observer was beneath the transfer tree, and the female sometimes appeared agitated and changed perches if an observer approached to see the prey she had collected. The adults also appeared more wary if more than one person was present, and sometimes flew off or ate prey rather than taking it to the nest. A prompt retreat rectified the situation, but it is possible that observer presence slightly inflated the percentage observation time that the female spent off the nest when collecting food from the male. In general, the Sparrowhawks were tolerant of an observer, and were so cryptic and unobtrusive that they were often undetected unless they called, flew or perched conspicuously, or unless one knew exactly where to look for a bird at a concealed perch.

The diet of the Sparrowhawks at Armidale was consistent with previous information. Many of the prey species or their equivalent congenerics have been recorded previously in the hawk's diet, and it is clearly a specialist on forest and woodland passerines; the composition at Armidale was similar to the breeding diet in Tasmania (Czechura et al. 1987). The size range of birds taken (mostly <100 g, not more than 200 g) was also as expected, and no attempts on species >200 g were seen. Feeding rates and times were similar to previous, limited data (in Metcalf 1982).

Prey partitioning between the Collared Sparrowhawk and Brown Goshawk was as expected (cf. Czechura et al. 1987). There was also some prey and habitat partitioning between the Sparrowhawk and the Australian Hobby, another local raptor of similar size that specialises on small birds (cf. Debus et al. 1991). Although the Hobby sometimes appears over Eastwood, around Armidale it hunts in open and urban areas, and takes many exotic passerines. Breeding Sparrowhawks seem more restricted

to native forest and woodland and native passerines, although non-breeding or wintering individuals prey on exotic birds in the city. The apparently low breeding density of the Sparrowhawk around Armidale, and the remarkably high visitation rate by intruding birds of a seemingly scarce species, suggest that suitable breeding habitat is at a premium and that there is competition for breeding territories. The Sparrowhawk's density may be low because the larger (and more dominant?) Brown Goshawk may be advantaged by habitat fragmentation, or because there are few flocks of small birds in open country. In Canberra, where the Hobby and Sparrowhawk coexist, the latter also breeds in suburbia and preys mainly on exotic birds (especially House Sparrows; Metcalf & Metcalf 1986). Canberra has many green belts and parks with dense woodlots and plantings of native and other trees, and wooded hills around the city. Sparrowhawks might be encouraged to live and breed in Armidale, and prey on exotic birds, if many more woodlots and shelter belts of native trees were created throughout the city.

Our observations enable clarification of some aspects of the Sparrowhawk's behaviour. Czechura et al. (1987) suggested that the 'cuckoo' style of direct flight may be a shallow undulating display, and they interpreted the 'fluttering beat' of Metcalf & Metcalf (1986) as possibly the 'cuckoo' flight. It is now clear that the 'fluttering beat' refers to the winnowing or 'shivering' flight of the male in the vicinity of the nest, which may be an appeasement display in the female's presence (the female being much larger, dominant and aggressive). It is also clear that the 'cuckoo' flight is not a shallow undulating display, but a style of direct flight used when the Sparrowhawk is changing hunting perches. It may serve to disguise the identity and intentions of a hunting hawk, as it resembles the flight of a cuckoo, cuckoo-shrike *Coracina* sp. or rosella *Platycercus* sp. It seems to be used particularly by male Sparrowhawks (similar in size to those species), but females also appear to have a 'deceptive' style of hunting flight. Although Sparrowhawks use a slow-flapping 'harrier' flight in display with conspecifics, a female has also been seen using a slow, rhythmic flapping style when clearly searching from shrub to shrub across open ground. It now seems likely that the female 'patrolling her territory' with slow flight (case 1 of Displays, Czechura et al. 1987, p. 55) was actually hunting: she flew a direct course low over the tree canopy and out of sight, with no conspecifics present (Debus pers. obs.). These 'cuckoo' and slow-flapping flights are unlike the usual and recognisable accipiter style, and may enable a close approach to unsuspecting prey.

In most aspects of its breeding biology and behaviour, the Collared Sparrowhawk resembles other sparrowhawks, particularly the well-studied Northern Sparrowhawk (cf. Newton 1986). The moult pattern of the pair at Armidale was also typical, with the female moulting while tied to the nest and inactive, and the male not moulting until he was released from hunting for his family (Newton 1986). The Collared Sparrowhawk is now reasonably well known in behavioural terms. Future studies might concentrate profitably on nest density, home-range size, breeding success, hunting behaviour and quantitative diet data in different parts of its range, especially in more continuous natural habitat. Where possible, observational studies on breeding raptors should adopt the procedure recommended by Simmons (1989).

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