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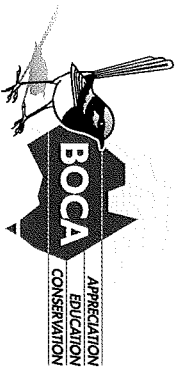
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COVER: Black Falcon nestling, rescued at ~3.5 weeks of age from ground beneath nest, Tamworth, NSW, 9 September 2004.

Photo: Natasha Marshall

Breeding Behaviour and Diet of a Pair of Black Falcons *Falco subniger* in Northern New South Wales

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Summary

The breeding behaviour and diet of a family of Black Falcons *Falco subniger* were studied by 65 hours' observation during the nesting and post-fledging periods, and by analysis of prey remains and pellets, near Tamworth on the North-west Slopes of New South Wales in August–October 2004. By number of prey items ($n = 80$) the Falcons' diet consisted of 55% birds, 41% grasshoppers (Acridoidea) and 4% Rabbits *Oryctolagus cuniculus*, of which Galahs *Cacatua roseicapilla* (11%), pigeons (10%), Common Starlings *Sturnus vulgaris* (10%) and parrots (9%) were frequent prey. By biomass the Falcons' diet consisted of 91% birds, 8% Rabbits, and <1% grasshoppers, of which Galahs (36%), pigeons (23%), parrots (8%) and Starlings (7%) together contributed three-quarters of total biomass from bird prey. The female performed most of the care and guarding of nestlings. The parental feeding rate averaged 0.3 item/h in the nesting period and 0.4 item/h in the first two weeks of the post-fledging dependence period. The post-fledging period lasted at least 21 days. Parental behaviour, displays, vocalisations, hunting behaviour, and juvenile morphology and development are described.

Introduction

The endemic Black Falcon *Falco subniger* of the arid and semi-arid zones is one of the least-studied Australian raptors, and the least-studied Australian falcon, although it is listed as threatened in Victoria (Antos 2003; Fitzsimons 2004) and targeted research to identify its key conservation requirements is considered a priority (Olsen 1998). Since a summary of the limited knowledge on its biology in Marchant & Higgins (1993), there has been a cursory dietary study at one or two nests (Falkenberg *et al.* 2000), and a casual observation suggesting (though not confirming) male participation in incubation (Angus 1992). Otherwise, there have been anecdotal descriptions of hunting behaviour (Olsen 1994); observations of robbery of House Mice *Mus domesticus* from ravens *Corvus* (Hutton 1994); and a few casual records of Falcons capturing, carrying or eating prey (Australian Pratincoles *Stilia isabella*, Crested Pigeons *Oeyphaps lophotes*, Bar-shouldered Dove *Geopelia humeralis*, Galahs *Cacatua roseicapilla*, Cockatiels *Nymphicus hollandicus*, Eastern Rosella *Platycercus eximius*, Budgerigars *Melopsittacus undulatus*, White-fronted Chat *Ephialtina albifrons*, Zebra Finches *Taeniopygia guttata*, Common Starling *Sturnus vulgaris*, grasshoppers Orthoptera: Hutton 1994; Morris & Burton 1994, 1997; Olsen 1994; Read & Badman 1999; van Haeff 1999; Antos 2003; Morris 2003; Stewart & Gynther 2003).

The only detailed study was by Baker-Gabb (1984) on the diet, nesting period and breeding success of one pair of Black Falcons over three years, and the only nest-watch was an observation diary at one nest on part of one day during the

chick phase (Hollands 1984). After two decades the Falcon's parental behaviour is still poorly known, with no quantification of sex roles in each phase of the breeding cycle, and the post-fledging period is essentially unknown. The Falcon's juvenile morphology and age characters are also insufficiently known, with three-year bare parts in juveniles (rather than the pale grey of adults) regarded as the main age criterion (Olsen 1975; Marchant & Higgins 1993). Even the limited information on the Falcon's vocalisations (Marchant & Higgins 1993; Jurisic 1998) is difficult to interpret.

This paper describes the diet and part of the breeding cycle of one pair of Black Falcons in northern inland New South Wales in spring 2004. As the nest was found during the nestling phase, this report is preliminary in anticipation of a more complete study over a full cycle. The aim of the study was partly to determine the Black Falcon's prey and nesting requirements in an agricultural environment. As the Falcon is a top predator in the temperate woodlands and grasslands of the sheep–wheat belt, aspects of its ecology may contribute to the knowledge base needed to conserve the threatened temperate woodlands and their avifauna.

Study area and methods

The Falcons' nest was located near Tamworth (31°05'S, 150°55'E) in late August 2004, by slow driving on minor roads through farmland and searching on foot on wooded watercourses. Teams of observers searched an area ~20 × 40 km over four weekends between late July and late August, using SD's previous sightings and other local records as a guide. The study area is in the Peel Valley, on the North-west Slopes of New South Wales, at 400 m elevation. Tamworth has a mean annual rainfall of about 600 mm with hot summers (mean maximum daily temperature in January c. 30°C; Heatwole *et al.* 2003).

Observations were conducted by rotating teams of observers from a position on the ground at least 70 m from the Falcons' nest, using binoculars and telescopes. The viewing distance was determined by the alert distance of the female, i.e. on the first day when she initially hesitated in feeding her young the observers withdrew to the distance at which she ignored people and started to feed the nestlings. The nest was watched for a total of 45 hours over 15 days in the last 4 weeks of the nestling phase, and 17 hours over 9 days in the first 3 weeks of the post-fledging period, with monitoring for 1.5 h on 1 day in each of weeks 4 and 5 post-fledging. Watches were staggered to cover all parts of the day; the nestling period included two sessions (in nestling weeks 3 and 5) from late afternoon to dusk, overnight on site and continuing from dawn next morning.

The sexes were initially distinguished by relative size when together, and by the fact that the larger female had a split in her tail caused by a missing central rectrix. When perched, she also had noticeable tail projection beyond her primary-tips, whereas the male's wing-tips almost reached his tail-tip. In flight, compared with the male she also had a slightly greater innerwing/outwing ratio and more noticeable camber in the wings when gliding, whereas the male's shape and flight (apart from the long tail and smaller feet) were reminiscent of the Peregrine Falcon *Falco peregrinus*. In some lights the perched male appeared to have a slightly brighter or more extensive pale throat (which was cream streaked brown in both sexes), but otherwise the sexes were similar in plumage.

Prey remains and pellets were collected from beneath the nest, and from the nest after it blew down. Remains were identified by comparison with a reference collection of bird specimens in the Zoology Museum, University of New England. Pellets ($n = 100$ approximately, some being weathered and fragmented) were analysed by ABR, using a mammal (CSIRO 1970) and reference collection. The minimum number of prey individuals from all sources combined (remains, pellets and observations) was calculated by counting skulls, other skeletal remains and remains or rectrices, including items seen brought to the nest or young.

The nest-tree was not climbed, the base of the tree was visited briefly (to collect food remains) only in the adults' absence, and care was taken to minimise flushing of the adults from the nest area when observers approached or departed from the viewing point. Nest-defence was not incited. The nestlings were aged approximately by back-dating from the fledging date, using a nestling period of 6 weeks (Marchant & Higgins 1993).

Results

Raptor populations

The search produced records of eight other breeding raptors: Black-shouldered Kite *Elanus axillaris*, Whistling Kite *Haliastur sphenurus*, Brown Goshawk *Accipiter fasciatus*, Wedge-tailed Eagle *Aquila audax*, Little Eagle *Hieraaetus morphnoides*, Brown Falcon *Falco bergroni*, Australian Hobby *F. longipennis* and Nankeen Kestrel *F. cenchrusoides*. Of these, all but the Black-shouldered Kite, Kestrel and Brown Falcon were found nesting only in healthy patches of riparian woodland (where some pairs of these three common species also nested). During the search a Black Falcon was seen at 3–6 km (male), 12 km (male), 20 km and 30 km from the subject nest, the first bird probably and the second possibly from the study pair. The other sightings suggest a population (albeit sparse) of Black Falcons in the Peel Valley from Tamworth west to Lake Keepit. There were at least 10 pairs of Brown Falcons in the NW–SW quadrant within 15 km of the Black Falcons' nest, with ~3 km between apparently neighbouring pairs.

Nest-site

The Falcons used an old stick nest, probably of an Australian Raven *Corvus coronoides*, high (~20 m above the ground) under the topmost canopy foliage of an old Yellow Box *Eucalyptus melliodora* ~23 m tall and 143 cm in diameter at breast height (dbh). This emergent tree was the tallest in a stand of creekside grassy box woodland, on a tributary of the Peel floodplain. The nest woodland was the largest and healthiest patch on that watercourse. The nest-tree was near the periphery of the Tamworth airport, an area resembling a semi-arid plain. The surrounding landscape is a gently undulating to flat mosaic of agricultural fields and pasture dotted with paddock trees, and remnant stands of woodland scattered mainly along sections of creek (the banks of which are largely cleared). The Falcons' nest was situated near the boundary between woodland and green crop; the latter was bordered by roadside strips and a paddock of rank grass that supported a dense population of Brown Quail *Coturnix ptiliphora*, with Stubble Quail *C. pectoralis* also present.

The pair had another focal tree, in which they started perching late in the nestling period and roosting in the post-fledging period. This tree was a live Yellow Box 20 m tall and 130 cm dbh, in which there was an old nest of Wedge-tailed Eagles. It was an isolated tree in a grassy paddock grazed by cattle (hereafter called 'eagle tree'), about 800 m from the Falcons' own nest-tree, though within 500 m of riparian woodland. In the post-fledging period the adult and juvenile Falcons used this alternative nest as a feeding platform.

Late in the post-fledging period, a storm damaged the Falcons' nest-support branch and part of the nest collapsed; subsequently the nest fell down. The storm also felled a dead tree used as a feeding-perch near the eagle tree, and the eagle tree, including the support branch for the nest, appeared vulnerable to further storm damage.

The Falcons' nest was 1 km off the end of the busy airport runway, almost beneath the flight-path of landing and departing aircraft up to commercial airline (Dash 8) size, with occasional flights of military and Lear jets. There was also a parallel runway for light aircraft, with frequent landings, circuits and departures over the eagle tree. The adult and nesting or fledgling Falcons ignored the aircraft,

and appeared unperturbed by the noise and traffic. On one occasion the adult pair soared in the airspace between two light aircraft that were flying parallel at different heights.

Breeding chronology

One juvenile Falcon fledged on 24 September, and the second on 27 September. Backdating from the fledging date, using incubation and nesting periods of about 5 weeks and 6 weeks respectively (Marchant & Higgins 1993), hatching would have been in mid August and laying in the second week of July.

Nest-defence

The adult Falcons were seldom observed defending the nest, and generally seemed phlegmatic towards, and tolerant of, other raptors. On one occasion in the nesting period a Brown Goshawk flew past the nest-tree while the female Falcon was perched therein. She took off and followed the hawk silently, tracking it out of the nest area rather than aggressively chasing or attacking it. Meanwhile, the male Falcon (which had been perched unseen in a nearby live tree) flew in and perched in the nest-tree, while the female soared. He had a full crop and may have been reluctant to fly. On other occasions the adults showed no reaction to three Black Kites *Milvus migrans* flying and soaring over the nest area, a Spotted Harrier *Circus assimilis* coursing the adjacent crop paddock, a Brown Goshawk and one or two Little Eagles soaring in the general area, and a Brown Falcon flying past the nest area. However, the male followed the female closely on two occasions as she carried prey to the nest.

The adults were not defensive towards humans on the ground in the nest area, except perhaps once when the female passed silently low overhead apparently with her feet slightly lowered, as an observer rescued a distress-calling nesting that had fallen from the nest in week 4. The female had been absent and appeared, from an unknown position away from the nest area, as the chick ran and flapped along the ground with the person in pursuit.

The adult Falcons, perched or soaring, were sometimes swooped (with little effect) by a Black-shouldered Kite that had fledglings about 500 m away from their nest, but not by Nankeen Kestrels that had an active nest about 400 m away. A pair of Australian Hobbies once attacked the female Falcon when she flew within about 200 m of their nest (>500 m from her nest), causing her to divert around their territory. The juvenile Falcons, in their first few days out of the nest, were harassed by a Black-shouldered Kite and a Kestrel.

Vocalisations

The adult Black Falcons uttered two main types of call. Around the nest the female uttered a strident upslurred whining or screaming note, repeated at varying frequency from single notes at 1.5-second intervals to series of notes at one syllable per second (seven notes per bout). In quality it was like a hoarse, powerful version of the 'complaining' note of a Noisy Miner *Manorina melanoccephala*; this is the *walk* call of Baker-Gabb (1989) and Marchant & Higgins (1993), and is apparently the call type shown in Figures 2a and 2b of Jurisevic (1998).

Around the nest and eagle tree, in an excited state, the male uttered a guttural cackle in bursts: one phrase per second, each phrase lasting about half a second

and consisting of three pulses. In quality it resembled the display cackle of a male Brown Falcon though with more even rhythm. This call may be the 'rapidly repeated *gak-gak-gak*...' of Marchant & Higgins (1993: sonagram B, p. 304), and the call type shown in Figures 2c and 2d of Jurisevic (1998). On two occasions the perched male gave a single *gak* note when swooped by a Noisy Miner. On one occasion, when an Australian Magpie *Gymnorhina tibicen* landed 10 m above her in the nest-tree, the female gave a soft chitter and stared at it until it flew off; this may be the 'trill' call of Figure 2e in Jurisevic (1998).

The juvenile begging call was a repeated upslurred whining note at a rate of ~1-1.5 syllables per second, like a subdued version of the adult female's whine. An advanced nesting, rescued from the ground (see p. 171), when handled gave a strident repeated whine like that of the adult female (as in sonagram C of Marchant & Higgins 1993, p. 304), and also hissed when approached. The initial note(s) in a series of such whines, in defence, had a deep, resonant and particularly hoarse quality.

Displays

The male Black Falcon performed several display manoeuvres in the breeding territory late in the nesting period. In week 4 he circled and swooped around the nest. In week 5 after soaring with the female he alighted momentarily (1 second) at the nest, perched briefly (several seconds) in the nest-tree, then flew around the tree, cackling. He then departed with deep, slow wing-beats in exaggerated, laboured flight (like a Brown Falcon). As he joined the soaring female towards the eagle tree, he flew with flickering beats above the plane of the body and with tail tightly furlled (like the Flutter-flight display of a Black-shouldered Kite; Marchant & Higgins 1993), then soared with his wings in a slight dihedral as he gained height. He later perched on the rim of the eagles' nest. Next day he flew rapidly around the Falcons' own nest, cackling, and the female later whined while perched on the eagles' nest. Early in the post-fledging period, at sunset when the pair was roosting in the eagle tree, the male took off and flew, cackling, in a circuit to land again in the tree. All these activities took place when the pair was showing interest in the alternative nest.

Around her own active nest, the female usually flew in rapid winnowing flight with short-amplitude beats below the plane of the body: an apparently intentional signal perhaps of nest or territory ownership. By contrast, when departing on a hunting flight, she flew with deeper, more fluid beats. The female's winnowing flight also contrasted somewhat with the male's often more Peregrine-like flight.

Nesting period: parental behaviour

On the first observation day, the female suddenly arrived at the nest with prey when observers were still below, collecting remains on the ground. She 'froze' on the nest until the observers retreated to the viewing point, then fed the young and remained perched on the rim. If she was perching in the nest-tree as observers approached the viewing point, or when they moved in or departed from the viewing area, she sometimes left. However, she tolerated stationary observers at the viewing distance: she arrived, fed the young, perched apparently resting, left seemingly voluntarily, and later returned, sometimes with prey. The male was less wary, and sometimes perched in the nest-tree or a nearby tree, resting and preening.

Table 1

Parental time-budgets of a pair of Black Falcons, nesting period (weeks 3–6) and post-fledging period (weeks 1–3), Tamworth, NSW, spring 2004; percentage of observation time standing on nest or perched in nest-tree. F = female, M = male, ? = sex unknown.

Week (n obs.)	At nest		In nest-tree	
	F	M	F	M
Nesting period:				
3 (7.75)	27	0	22	0 ^b
4 (7.67)	4	4 ^a	25	13
5 (19.2)	3	0	14 ^c	2 ^c
6 (10)	15	0	4 ^d	18
Post-fledging period:				
1 (7.9)	6	0	0	0
2 (4)	14	0	0	0
3 (4.67)	0	0	0	0

^aThought to be M, but possibly F (i.e. 8% for F, 0 for M?).

^bM perched in tree within 100 m of nest-tree for about 5%.

^cF also perched in tree within 100 m of nest-tree for up to 16%; M and/or F also perched in more distant tree (eagle tree; see text) for up to 10%.

^dF also in eagle tree for 14%.

seemingly unconcerned by stationary observers at the viewing point. He did not leave as an observer arrived, and he also arrived and perched in the nest-tree when people were at the viewing point.

As the nestlings grew, the female spent a declining proportion of time standing on the nest or perched in the nest-tree; from week 5 she tended to perch in trees other than the nest-tree (Table 1). Typically, after feeding the nestlings or delivering prey she stood for a variable time (0–60 minutes) on or beside the nest, then moved to another perch in the nest-tree for varying periods of up to an hour. From week 3 she did not brood the young during the day on dry days or shade them on hot days; no observations were made on rainy days. In week 3 the female left her perch in the nest-tree apparently to roost on the nest at dusk (10 minutes after sunset). She was perched (whining) in the nest-tree at dawn next morning.

The male seldom visited the nest, and he spent a minor proportion of time perched in the nest-tree or other trees in the nesting territory (Table 1). On one occasion in week 4 when the male was thought to visit the nest, he fed the young then immediately flew to another perch in the tree.

In week 3, when not in the nest-tree, the female sometimes soared over the nest area (e.g. once for 3 minutes). From week 5 her absences from the nest area sometimes exceeded 2 hours. Similarly, the male sometimes soared over the nest area in weeks 3 and 4 (once for 20 minutes), but from week 5 he was sometimes absent from the nest area for up to an entire watch (e.g. 2–5 h). In weeks 3 and 4 the female left the nest area to collect prey from the male, sometimes accompanying him up to 1 km away and waiting for his catch. From week 5 she started hunting for prey, capturing and delivering some items to the nestlings.

In week 3 the female always tore up prey and fed the young bill to bill. Feeds commonly took 10–20 minutes, depending on the size and condition of prey items.



Rescued Black Falcon nestling at approximately 3.5 weeks of age, Tamworth, NSW, 9 September 2004

Plate 10

Photo: Natasha Marshall

From late in week 4 she mostly dropped prey for the young to dismember, although early in week 5 she fed part of an item to the younger nestling after the older one had eaten some of it. Items given to the young were sometimes whole if small, though usually plucked and partly eaten.

On cold early mornings in September (about 0°C with frost), the female summed for periods of up to 2 hours by perching high on a bare branch on the north-eastern side of the nest-tree, facing the rising sun with her belly feathers fluffed.

Nesting period: development of young

There were initially three young, but the brood was reduced to two when one fell out of the nest in week 4. On 4 September, at about 3 weeks old when first seen clearly through a telescope, the chicks were partly downy with plumage from most dorsal feather-tracts emerging through the down, and flank feathers starting to appear. At approximately 3.5 weeks they were mostly feathered, but with tufts of down particularly on the head, throat and flanks [Plates 9 (front cover) and 10]. In week 4 they appeared fully feathered, though the younger still had some down on the crown. In week 5 they had no visible down. At fledging they had lost the down, but still had short wings and tail.

In week 3 the young started pecking at prey in the female's foot, while she fed them; the older two took some morsels off the carcass, whereas the smallest received least food from the female and appeared covered by its siblings.

In week 4 one nestling was found alive on the ground below the nest, and was taken into care. Of the remaining two, one pulled at prey in the female's foot but gave up and was fed by her. The smaller appeared more feathered than the larger. At 4 weeks they perched on the nest-rim and flapped their wings; one was dominant and vigorously took food from the female's bill, whereas the other did not compete for food and missed out while its sibling was being fed.

In week 5, at feeding times either nestling (apparently the hungrier) seized the item then mantled, plucked and fed unaided by the female. The other nestling either remained unfed and begged, or there was a tussle over food during which possession changed several times. In the ensuing circuits of the nest it sometimes seemed that one nestling might topple over the rim. At this stage the older one was competent at dismembering prey; they each swallowed a leg or a wing of a shared starling-sized bird, and the younger ate from a whole Rabbit *Oryctolagus cuniculus* kitten, including the head. The nestlings also begged when a Brown Goshawk and an Australian Hobby flew over or past the nest.

In week 6 one nestling picked at an object (possibly playing with old prey remains) in the nest. At this stage, when prey was delivered, one claimed the item and ate while the other begged.

The rescued nestling (week 4, Plates 9–10) initially weighed 495 g and was presumed male; it lost weight in care, ate little, and died 3 weeks later (only 375 g at fledging age). It had an undiagnosed illness that developed into diarrhoea and resulted in emaciation. An autopsy found thick plaque deep in its throat, typical of trounce (trichomoniasis). The specimen has been lodged in the Australian Museum, registration number AM O.71022.

Post-fledging period

One juvenile (J1 = smaller but more advanced, presumed male) fledged on 24 September, and the other (J2 = larger, presumed female) three days later on 27 September. The post-fledging period is thus taken as starting on 27 September (= day 1). Until J2 fledged, J1 mostly perched on bare branches in the nest-tree, sometimes flapping its wings, though it returned to the nest to feed when the adult female dropped prey in the nest.

In weeks 1–2 the adults spent little time at the nest or in the nest-tree (Table 1). The female visited the nest to drop prey, and once fed a juvenile bill to bill. Once each in weeks 1 and 2 she remained standing on the nest for 25–30 minutes while the juvenile ate the prey item. Remains suggested that in weeks 2–3 the juveniles sometimes plucked and ate prey on the ground in the nest area. The juveniles' progress to the end of week 3, after which neither was seen, is described in Table 2. The adult female was also not seen in the nest area after week 3.

Late in week 4 the adult male, having fed, was perched on the nest-branch of the eagle tree. He retrieved the remains of a Galah from the nest-rim, then circled high over the tree; at first the prey hung conspicuously in his foot. Soaring higher, he moved the prey between bill and feet several times in an apparent demonstration that he had food for collection: a display reinforced by his distinctive silhouette with bulging crop and lump of prey under his tail. He soared up until lost from view. By this stage the juveniles had disappeared, and the display may have been directed at the female. Conversely, when adults carried food to the nestlings it was often tucked up under the tail, so that it was difficult to see until delivered.

Table 2 Progress of juvenile Black Falcons, Tamworth, NSW, spring 2004. Week, day = stage of post-fledging period. J1 = first fledged, J2 = second; M = adult male, F = adult female. Eagle tree = tree containing eagles' old nest 800 m from Falcons' nest.

Week	Day	Comments
1	2	Juveniles perched on bare branches in nest-tree; appeared clumsy.
	4	Juveniles in nest-tree; milled in the air around arriving F as she dropped prey; ate at nest (one claimed prey, other waited then picked at remains).
	6	J2 ate prey on log on ground under live tree 100 m north of nest, then both juveniles waited on dead tree 200 m north of nest. Both flew to intercept food-bearing M in the air as he approached; J1 took food aerially and flew to eat on dead tree in paddock 600 m from nest, while J2 returned to focal dead tree. As F arrived with more prey, J2 flew to nest and claimed prey; mantled then ate (finished Rabbit Kitten in 20 min.).
	7	Both juveniles perched on focal dead tree in late afternoon; at dusk (15 min. after sunset) roosted on nest. Flew well with continuous, shallow wing-beats; appeared broad-winged and short-tailed.
2	11	One juvenile accompanied adult pair 3–4 km from nest. Thereafter, only one juvenile (J2) seen in nest area.
	13	J2 perched on nest-branch of eagle tree; still appeared slightly clumsy on perch, tail slightly shorter than adults.
	14	F holding prey in eagle tree for 40 min., then started feeding; J2 then arrived beside F and begged; F dropped prey in eagles' nest, where J2 fed. M brought prey to F in eagle tree; both adults ate. When J2 begged from eagles' nest, F took item to nest and fed J2 bill to bill.
3	16	M eating prey on ground below eagle tree; J2 and F perched in tree. J2 flew to ground apparently to feed, but scuffle ensued in which M seemed to rebuff J2 with flapping wings. J2 returned to eagle tree and perched beside F; at sunset M flew up to tree (separate branch) where all three roosted at dusk. J2 appeared adult in proportion.
	19	J2 and F perched in eagle tree. J2 flew around nest woodland then returned to perch (apparently with insect in its foot) and begged; F moved to eagles' nest but as J2 approached she departed, apparently shunning J2. J2 left eagles' nest and circled surrounding paddocks, mostly flying within 2 m of ground. Last sighting of F in nest area.
	21	Towards sunset J2 arrived in eagle tree alone, from c. 2 km away. Flew to nest woodland, swooped and briefly chased Maggie en route; at dusk roosted on bare branch in own nest-tree. No sign of adults. Last sighting of J2: now adult-like and competent, appeared large and long-tailed, with tail-tip slightly beyond wing-tips at rest.

Late in week 5 there was no sign of the Falcons, until the adult male arrived to roost in their original nest-tree 10 minutes after sunset. Fresh prey remains and pellets suggested that one or more of the Falcons had been roosting in the tree in the preceding week or two.

To summarise: the juvenile(s) were dependent on parental feeding until the end of week 2 post-fledging; one remained in the natal territory until at least the end of week 3, by which time it was not seen to be fed, and the adults then avoided it. At that stage it appeared capable of catching prey. Late in week 4 it could not be found in the nest area.

Description of juveniles

In week 4 the nestlings had a dark-brown cere, light blue-grey gape flanges, brown eyes, pale-blue orbital skin, and light olive-grey feet (Plates 9–10). At fledging age the bare parts of the rescued juvenile were similar, except that the cere had developed a slight blue-grey tinge around the nostrils. The two wild fledglings were similar to the captive juvenile in these respects. All three had narrow rufous fringes to the dorsal plumage. Compared with the adults, the fledglings were more uniformly dark (sooty) with less contrasting ear-coverts and dorsal 'scaling', and had a prominent pale tip to the tail. The adults had a larger pale area around the base of the bill (caused by the pale cere), paler and more noticeable ear-coverts, more prominent pale throat, and paler feet (all of which contrasted more with the rest of the plumage); they also had more prominent pale 'scaling' on the upperparts, and lacked pale tips to their worn tail-feathers.

In week 3 of the post-fledging period, compared with the adults, the juvenile was darker (including the cheeks) with a clearly pale-tipped tail, and feather perfect (unlike the worn and moulting adults). It had less pale area on the face (cere) and chin, less noticeable dorsal 'scaling', and no visible barring under the wings and tail. Like the adults it had a 'stepped' tail, with a slightly shorter outermost rectrix on each side.

A newly fledged juvenile Black Falcon at a nest studied by Falkenberg *et al.* (2000), in inland South Australia, had extensive pale markings on the head, in the form of buff forehead and cheeks (SID pers. obs.). This condition has not previously been noted in juveniles (Marchant & Higgins 1993).

Two recent specimens in the Australian Museum, from northern inland New South Wales, shed further light on age characters. A juvenile male (AM O.70108; weight 456 g), obtained in early March had a dark-grey cere, pale-grey legs, and the pale tail-tip rather narrow and worn. A juvenile female (AM O.65488) obtained in late April had a dark grey-brown cere, pale-grey legs with a bluish cast, and a worn tail-tip (bare-part colours as described on tags). Both had indistinct pale dorsal scaling (less evident on the female) and basal mottling on their outer primaries; the female also had slight pale fringing on her ventral plumage and pale tips to her undertail-coverts. These data suggest that the bare parts start to change colour several months into the first year, by which time the pale tail-tip is wearing off and the rufous dorsal fringing is fading, and that some juveniles have pale markings under the wings and tail (like adults).

Possible re-nesting

Apart from the behaviour described above under Displays and Post-fledging period (week 4), and in Table 2, the adults showed other behaviour suggesting interest in another breeding attempt in 2004. In week 5 of the nestling period, after the display-flight described, one adult landed on the eagles' nest as the other left it for a perch in the eagle tree. Thereafter, they frequently perched on the nest-branch of the eagle tree and sometimes on the eagles' nest, e.g. male on the branch, with female on the nest. On one such occasion (week 1 of the post-fledging period), the female had been out of sight below the rim then climbed out to perch on the branch beside the male. However, by week 3 post-fledging the female had lost interest in the eagles' nest and a check in mid December revealed no breeding activity in the Falcons' territory. At that stage, after their original nest had fallen down, the male (with full crop) was observed to roost in the eagle tree an hour before sunset, but the female was absent.

Table 3

Parental feeding rates of Black Falcons, Tannworth, NSW, spring 2004, during nestling period (weeks 3–6) and post-fledging period (weeks 1–3).

Week	Hours obs.	N prey items	Delivery/h
Nestling period:			
3	7.75	3	0.4
4	7.67	3	0.4
5	19.2	5	0.3
6	10	3	0.3
Total	44.6	14	0.3
Post-fledging period:			
1	7.9	3	0.4
2	4	2	0.5
Subtotal	11.9	5	0.4
3	4.67	0	0
Total	16.6	5	0.3

Feeding rates

The parental feeding rate in the nestling period declined after week 4 (Table 3), but this trend may have been related to the reduction in brood size (and hence nestlings' food demands) in week 4. In the first two weeks of the post-fledging period, the feeding rate was similar to pre-fledging levels. There were no deliveries observed in week 3 post-fledging, despite similar observer effort to that in week 2 (Table 3), suggesting that in week 3 parental food-provisioning was curtailed.

It appeared that until week 3 of the nestling period the male supplied the prey, although the female collected it from him away from the nest and took it to the nestlings. From week 4, the female brought some items that she apparently caught. In the post-fledging period both parents supplied prey approximately equally: two items each, and one other where the sex of the parent was undetermined.

Prey deliveries were observed between 0615 and 1340 h, commonly between 0800 and 1100 h. Although there were afternoon observation sessions on 10 days between 1400 h and dusk (total 13 h), no prey deliveries were observed at these times. In the afternoons the adults, if present, perched in trees.

Diet

Thirty-three intact pellets measured 19–55 × 13–27 mm (mean 37 × 20 mm). By number the Falcons' diet consisted of 55% birds, 41% insects and 4% mammals, among which Galahs (11%), pigeons (10%), Common Starlings (10%) and parrots (9%) were frequent (Table 4). Birds occurred in 84% of 83 pellets, insects in 14%, and Rabbit in 2%. Bird species most frequent in pellets were Starling (36%), Galah (28%) and pigeons (13%). Eleven pellets, collected early in the study under the male's perch in the nest-tree, consisted only of grasshopper remains: up to five individuals per pellet.

By biomass the Falcons' diet consisted of 91% birds, 8% mammals and <1%

Table 4

Diet of a family of Black Falcons, Tamworth, NSW, nesting and post-fledging period late August to October 2004: minimum number of prey individuals (n) from observations, prey remains (skulls, feathers), pellets and pellet debris (< 100 pellets); contribution by each prey species calculated as percentage by number and by biomass. Prey weights from Marchant & Higgins (1993) and other literature, or estimated from literature.
* = Introduced species, ^E = estimated weight.

Prey species	Weight (g)	n (%)	Biomass (%)
*Rabbit <i>Oryctolagus cuniculus</i> (kitten) ^E	250	3 (4)	750 (8)
Stubble Quail <i>Corumix pectoralis</i>	102	2	204
*Domestic Chicken <i>Gallus gallus</i> (juvenile) ^E	200	1	200
Australian Wood Duck <i>Chenonetta jubata</i> (duckling) ^E	150 ^a	2	300
Banded Lapwing <i>Vanellus tricolor</i>	184	1	184
Masked Lapwing <i>Vanellus miles</i>	360	2	720
*Rock Dove <i>Columba livia</i>	308	3	924
Crested Pigeon <i>Ocyphaps lophotes</i>	205	5	1025
Galah <i>Cacatua roseicapilla</i>	335	9 ^b	3015
Cockatiel <i>Nymphicus hollandicus</i>	95	3	285
Eastern Rosella <i>Platyercus extrinus</i>	110	2	220
Red-rumped Parrot <i>Psepholus haematonotus</i>	62	2	124
Pallid Cuckoo <i>Cuculus pallidus</i>	86	1	86
Noisy Miner <i>Manorina melanoleuca</i>	52	1	52
Magpie-lark <i>Grallina cyanoleuca</i>	90	1	90
Australian Magpie <i>Gymnorhina tibicen</i>	329	1	329
*Common Starling <i>Sturnus vulgaris</i>	75	8 ^c	600
Total birds		44 (55)	8358 (91)
Yellow-winged Grasshopper <i>Gastrancistrus muscivorus</i>	1	.30	30
Spur-throated Locust <i>Austriactis gutulosa</i>	1	2	2
Grasshopper sp. (Acrididae)	1	1	1
Total insects^E		33 (41)	33 (<1)
Total		80 (100)	9141 (100)

^aOne downy runner ≤100 g, one feathering runner ≥200 g

^bFour juveniles

^cOne juvenile

insects, of which Galahs (36%), pigeons (23%), parrots (8%) and Starlings (7%) collectively contributed three-quarters of the biomass from bird prey (Table 4). Many of the birds taken were adults, including the Magpie, although the last four Galahs taken (from mid October onwards) were fledglings.

Many of the smaller avian prey species had accumulated in remains and pellets before week 4 of the nesting period, at a time when the male was likely to have been doing the hunting. In week 3, and from week 4 onwards when both sexes were hunting, the male brought Crested Pigeons, a Galah, a small bird, a starling-sized bird and an unidentified bird (most of these transferred to the female), and the female brought two ducklings, a Rabbit kitten, a Galah and a quail (the last possibly collected from the male). Also from week 4, larger avian prey such as Masked Lapwings and a Magpie appeared in fresh remains. In the post-fledging period the male brought a small prey item (possibly bird) and a Rabbit kitten, and ate two Galahs, and the female brought a Galah and a Rabbit kitten. These observations suggest that the male may take many birds in flight, and the female may tend to take more terrestrial prey.

The crop and stomach of a juvenile female Black Falcon from inland New

South Wales (AM O.65488), in grassland in autumn, contained the remains of a button-quail *Turnix* and four Budgerigars (per data sheet).

Hunting behaviour

In early August (incubation period) a male Black Falcon, possibly the subject male, unsuccessfully attacked a flock of Common Starlings in farmland 6 km from the nest. He made a near-vertical stoop at the airborne flock, which had formed a tight ball, then he swung up and soared away. In week 3 of the nesting period the presumed male of the pair took a Crested Pigeon in a backyard on the outer suburban fringe of Tamworth, 4 km from the nest. The attacking Falcon flushed the Pigeon into collision with a fence, the prey fell to the ground, and the Falcon seized it and carried it towards the nest (N. Marshall pers. comm.).

In week 3 of the nesting period, the female whined in an apparent food-transfer, then carried partly eaten prey 1 km to the nest, with the male following just above and behind her. An hour later the male was perched in the nest-tree and the female whined from the nest then from a perch near him; he soared up from the nest-tree and made a long glide 2 km towards scattered trees on the edge of riparian woodland. He made a long, slanting stoop into the open woodland, scattering Magpie-larks *Grallina cyanoleuca* which spiralled up from the ground. Meanwhile, the female had followed well behind and as he stooped she closed and waited in the air above. As the male emerged from treetop height, unsuccessful, she returned to the nest area. Also in week 3, when the male arrived circling over the nest the female left and they flew off together, apparently hunting, >1 km away. Twenty minutes later she returned with prey. Later that morning she brought a plucked, partly eaten item to the nestlings, while the male also returned and perched with a full crop. In week 6 the pair soared away together, an hour later the female brought a plucked, partly eaten prey item to the nest, closely followed by the male which circled the nest-tree then perched. All these observations suggest co-operative hunting, or the female following the male to collect his catch, and the male then guarding the food-bearing female back to the nest.

In week 5, soon after sunrise in the male's absence, the female flew out of binocular range (2 km), in apparent foraging flight, and 20 minutes later brought a whole duckling to the nestlings. Two hours later she repeated this behaviour, to perhaps 3 km away, and returned in 40 minutes with another whole duckling.

In week 5 of the nesting period, when the pair soared high over the nest area, the male appeared to hawk aerial insects briefly. Later in week 5 the male, alone, soared high and hawked aerial insects before being lost from view.

Moult

The female had moulted a central rectrix by 28 August (end of week 2 of the nesting period), which was half regrown by 3 October (1 week post-fledging) and had a narrow pale tip. Sometime late in the breeding cycle she moulted a central secondary (later retrieved with the fallen nest). The male dropped a central secondary on 12 October (week 3 post-fledging), but to the end of observations (late October–mid December) his tail became increasingly ragged and worn without yet moulting.

Discussion

The results of this study confirm and extend previous knowledge of the Black

Falcon's parental behaviour in the nestling period, although details remain to be obtained for the incubation and early nestling periods. Researcher activity (e.g. handling chicks) may depress the female's hunting time, by increasing her guarding/defence time (Olsen & Tucker 2003), but in our study this effect seemed unlikely. Details of the Falcon's courtship and prelaying behaviour (Hollands 1984; Baker-Gabb 1989) remain sketchy and anecdotal, and further information is desirable.

The Black Falcon's vocalisations appear to fit the general vocabulary and call types of other large falcons (as described by Marchant & Higgins 1993, Jurisvic 1998 and Ferguson-Lees & Christie 2001). Like other falcons it utters a cackle, a whine, a maternal *chup* call, and an *ee-hip* type of creaking or squeaky call in courtship (cf. Buckingham & Jackson 1985; descriptions and sonagram A in Marchant & Higgins 1993 p. 303; sonagrams in Jurisvic 1998, and description in Morcombe 2000). Nest-defence, without calling, is consistent with previous information (Olsen & Olsen 1980; Marchant & Higgins 1993).

This study confirms and extends knowledge of juvenile morphology, age criteria and field characters of the Black Falcon (Olsen 1975; Marchant & Higgins 1993). However, the cere of advanced nestlings and fledglings was dark brown (almost concolorous with the head-feathers) with only a hint of blue-grey around the nostrils, not wholly blue-grey or pale blue-grey (*contra* Marchant & Higgins 1993). It appears that the cere is dark grey-brown to dark grey for several months of the first year, until at least the first autumn.

From the photographic sequence of known-age nestling Peregrine Falcons in Olsen (1995), at equivalent age the Black Falcon nestlings had less bulky down than Peregrine chicks (e.g. at c. 3 weeks they resembled 4-week-old Peregrines). From the morphology (e.g. bare-part colours) of the juveniles in this study, the age-classes assigned to the Black Falcon photographs on pp. 91–92 of Olsen *et al.* (1993) require correction. The 'adult female' on p. 92 is clearly a fledgling, as revealed by its dark cere and eye-ring, rufous dorsal fringing, short wings and tail, and flecks of down on its forehead (and possibly above its cere). The 'adult' on p. 91 is probably a juvenile, as suggested by its blue eye-ring and dark cere with blue-grey tinge around the nostrils (and by its approachability). Contrary to previous opinion (Marchant & Higgins 1993), this study found the dorsal 'scaling' to be more obvious in adults than in juveniles, therefore this character may be variable within age-classes. This study found the 'stepped' tail not to be an age character. Of the trio of Black Falcon photographs in Hollands (1984) not assigned age-classes, the bird in flight (top) is apparently an adult (from the extensive pale base to the bill); the bird at carrion with a Whistling Kite and raven (middle) is a juvenile (from the dark cere and blue eye-ring); and the perched bird (bottom) is an adult (from the pale cere and eye-ring).

The juvenile in this study remained in the nest area longer than the 'c. 1 week' previously reported, and the post-fledging period lasted longer than the 'at least 2 weeks', from incomplete observations, previously reported (Marchant & Higgins 1993). Although the better-known bird-eating falcons require a long post-fledging period of several weeks or more in which to develop their hunting skills (Olsen 1995), 3 weeks for the Black Falcon is similar to that of the more generalist Kestrel and Brown Falcon (Marchant & Higgins 1993). The post-fledging period may also vary with seasonal conditions. The present study is incomplete on this aspect; the difficulty is to continue monitoring juveniles as they approach independence, and further observations are required.

Hollands (1984) found a nestling Black Falcon dead near fledging age, and a

newly fledged juvenile was also found dead near one of the nests studied by Falkenberg *et al.* (2000) (SD pers. obs.). In the present study, the rescued nestling may have fallen from the nest because it was weakened by disease, and would certainly have died in the wild. Black Falcons may contract tracheitis by eating feral Rock Doves *Columba livia*, which carry this disease (Olsen 1990).

Beruldsen (1980, 2004) claimed that the Black Falcon 'may nest twice during extended abundant seasons', although there are no supporting data and the species was pronounced single-brooded on the available evidence (Marchant & Higgins 1993). Unlikely in a large falcon, double-brooding is perhaps possible in light of the indicative behaviour observed in this study; further investigation and documentation are desirable.

Observations in this study, including a suggestion of co-operative hunting by members of the pair, support previous conclusions on the Black Falcon's hunting behaviour and response of flocking prey species (Ross & Olsen 1988; Marchant & Higgins 1993). Parental feeding effort to nestling falcons is adjusted to brood size, and declines with brood reduction (Olsen & Tucker 2003).

The diet of the Falcons in this study was similar to that recorded by Baker-Gabb (1984), though fewer Rabbits were taken. Both studies, and other prey records cited herein, reveal the Falcon to be heavily dependent on birds in the sheep-wheat belt. It appears to take flocking birds that feed on the ground, of the most readily available species. This study also raises the possibility of some prey partitioning by the sexes, though with much overlap. As adult Black Falcons are clearly accomplished hunters of flying birds, we speculate that individuals seen feeding on carrion are probably juveniles still acquiring hunting skills.

In the sheep-wheat belt the Black Falcon appears adaptable to the 'cereal steppe' landscape, a diet of bird species (including introduced ones) that are abundant in farmland, and to human activity. However, for breeding it requires riparian woodland patches with old, emergent trees containing stick nests built by other species. Although it will use stick nests in power pylons (Marchant & Higgins 1993), these are localised and powerlines have a negative impact on the Falcon (collision accidents: Birks 1998). Many of the Falcon's important prey species, e.g. Galahs and other parrots, require tree-cavities for breeding. In this study, the highest abundance and diversity of nesting raptors (and other birds) was on timbered drainage lines. These woodland remnants are important not only for raptor nesting sites, but also for maintenance of avian prey populations. Given the degraded condition of riparian zones in rural Australia, and the cumulative loss of old trees from the landscape, the future of the Falcon and other significant fauna in the agricultural belt may be uncertain unless remedial action is taken. Olsen (1994) documented loss of breeding pairs of Black Falcons in South Australia when their riparian nest-trees were destroyed.

The Black Falcons in this study were inconspicuous, making it likely that the species is overlooked in the sheep-wheat belt. They perched on dead branches in large live trees, below or within the foliage canopy, where their posture on short legs made them look deceptively small (if they were visible at all), in contrast with Brown Falcons that perch conspicuously on long legs in exposed positions. The Black Falcons also often soared at great heights, or flew low (at horizon level from the viewer's perspective), and ranged out of sight from the nest. They can thus 'disappear' in a vast landscape. Nevertheless, aspects of their nest-sites and nesting habitat may enable them to be located predictably.

As an endemic Australian species the Black Falcon deserves further detailed study to elucidate its basic biology, elements of which remain to be determined. Such ought to be readily feasible, given the proximity of breeding pairs to capital and regional cities in south-eastern Australia (Bakers *et al.* 1984; Barrett *et al.* 2003), and the likelihood of populations in the sheep-wheat belt. For instance, the Falcon seems fairly common in the western Darling Downs of southern Queensland (SD pers. obs.) and in the Riverina of New South Wales (P McDonald pers. comm.). As the densest populations are in remote arid areas that present logistical problems, a useful approach might be to conduct observational studies on any pairs that present opportunities in accessible areas.

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