

# Breeding behaviour and prey of Black Falcons, *Falco subniger*, including food-caching

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## Abstract

*The breeding behaviour and diet of a pair of Black Falcons, Falco subniger, and offspring were studied by 110 hours' observation from incubation to the end of the post-fledging period, and by analysis of pellets, on a wooded floodplain in northern coastal New South Wales in 2013. The sexes shared incubation and feeding of chicks, and delivery of food to the fledglings. Delivered prey was entirely birds in the nestling period (n = 38), and almost half mammals (41%) by number in the post-fledging period (n = 34; rats ~50% of prey biomass in that phase). The adults cached prey, mostly in tree hollows. Parental feeding rates were 0.7 prey item/h (~70 g of prey biomass/h) delivered in the nestling period, and 0.4 item/h (~80 g of prey biomass/h) in the post-fledging period (initially 0.5–0.6 item/h, declining to 0.2/h in the final weeks). Adult behaviour and vocalisations, and growth and development of nestlings and fledglings, are described. The nestling period lasted 42–43 days, and the post-fledging period lasted two months for two surviving juveniles (of four fledged); fledglings died during a storm and from vehicle strike. Supplementary observations of displays, vocalisations, hunting behaviour and prey are provided for a site in northern inland NSW.*

## INTRODUCTION

The Black Falcon, *Falco subniger*, remains poorly known, especially in one of its stronghold states, South Australia (e.g. Debus and Olsen 2011; Debus and Zuccon 2013). Previous attempts to document its life cycle in the sheep–wheat belt mainly covered the pre-laying phase and later

stages of the nestling period, less so the incubation phase, early nestling phase and post-fledging dependence period (Debus *et al.* 2005; Debus and Tsang 2011; Barnes and Debus 2012; Debus and Zuccon 2013). There are few details on aerial courtship manoeuvres between the sexes (e.g. Marchant and Higgins 1993; Whelan 2013a). Food-caching is well known and apparently universal in *Falco* (Cade 1982; Anderson and Squires 1997). Among Australian species, caching has been studied in the Peregrine Falcon, *F. peregrinus* (Sherrod 1983; Cameron and Olsen 1993; Turner, Lawrence and Czechura 1993) and Brown Falcon, *F. berigora* (McDonald 2004), and briefly mentioned for a pair of wintering Black Falcons (Olsen 1994).

Here we describe a breeding event of the Black Falcon in New South Wales (NSW), discovered late in the incubation phase, including novel observations on male incubation, prey, food-caching, and a long post-fledging dependence period. We also describe little-reported aspects of the falcon's pre-breeding and defensive behaviour, vocalisations and hunting behaviour. Now that the Black Falcon is declining in the Murray-Darling Basin, and is state-listed as Vulnerable in Victoria and NSW, comprehensive ecological information is needed in order to manage its habitat requirements, threats and prey base in the agricultural zone (e.g. Debus and Zuccon 2013).

## STUDY AREAS

The active nest studied by DC and HL in northern coastal NSW in 2013 was located ~15 km south of

Lismore (28°49' S, 153°16' E), on the subtropical lower Richmond River floodplain. The habitat was remnant Forest Red Gum, *Eucalyptus tereticornis*, woodland amid agricultural and pastoral (cattle-grazing) fields, with the river and lagoons nearby, sugarcane fields within 1 km, several farm building complexes within 2 km, and a sealed road within 80 m of the nest.

Observations by SD on Black Falcons in northern inland NSW in autumn to spring 2013 were conducted near Tamworth (31°05' S, 150°55' E) in the sheep–wheat belt. Habitat and other context details are provided elsewhere (Debus *et al.* 2005; Debus and Tsang 2011; Debus and Zuccon 2013). However, a hailstorm in autumn 2013 destroyed a focal pair's previous nests of 2010 and 2011–12 and some other corvid-type stick nests in the wider area (including one reportedly used in previous years by unidentified falcons), and no active Black Falcon nest was located in the vicinity of three former territories and nests.

## METHODS

At Lismore, the nest was watched from late in the incubation period (22 July, 10 days before hatching) until the end of the post-fledging period (8 November), in timed observation sessions from an unconcealed position outside the falcons' alert distance (~110 m from the nest). The nest was watched opportunistically at various times of day, for 1–5 hours per day, using binoculars, telescope and digital camera. In the incubation period, the nest was watched for 30 minutes over the midday period (1200–1250 h) on two days. In the nestling period, the nest was watched for one hour on one day early in week 1 (day 2, afternoon), 2.7 hours on one day in week 3 (day 19, midday), and 38.3 hours over 12 days in weeks 4–6 (four afternoons and one morning in weeks 4–5), mostly in week 6 (25.5 hours over seven days; mornings and afternoons). In the post-fledging period, the nest area was watched for ~68 hours on 31 days over eight weeks: intensively in weeks 1–4 (8–16 h/week over 4–6 days/week), less so in weeks 5–8 (2.5–8 h/week over 2–3 days/week). Watches were spread

throughout the day in weeks 1–4, but concentrated on late afternoon to dusk in weeks 5–8, as that was the best time to await the juveniles' arrival. From late in week 3, watches included reconnaissance of the wider area to locate the juveniles, and the nest site was checked a final time for an hour at sunset in week 9 (day 57). The adult falcons and fully grown juveniles were sexed by the females' relatively larger size in this sexually size-dimorphic species (e.g. Debus *et al.* 2005; Debus and Olsen 2011; Debus and Tsang 2011).

Pellets and prey remains (orts) collected under the nest and nearby feeding perch in the post-fledging period (week 1: two pellets; week 7: 10 pellets + ~14 g of broken pellets and three orts) were analysed by SD, using a microscope and reference material from the Zoology Museum, University of England. The calculated minimum number of prey individuals took into account items observed delivered or cached, those additionally found only as orts, and those in pellets only where they added species to the other two categories. Parental delivery rates of prey biomass were estimated from applicable prey weights in raptor dietary studies cited by Marchant and Higgins (1993) or Debus (2012a) and, for comparison, recalculated from prey data in Debus *et al.* (2005) and supporting field notes.

At Tamworth, the search timetable and protocol followed that of Debus and Zuccon (2013). Observations on Black Falcon pairs or individuals encountered were conducted using binoculars or telescope from outside their alert distance, for as long as the bird(s) could be kept in view.

## RESULTS

### Aerial displays

At Tamworth in mid-May a pair of falcons soared together, high over the woodland patch that contained an active Black Falcon nest in previous years. The male briefly stooped with several rapid wing-beats obliquely away from the female (i.e. descending to the side), then rose and made a series of gentle mock stoops or passes over her; she

responded with slight evasive action and lowered feet, then both briefly circled in tandem, the male just above and behind the female. A. Zuccon (pers. comm.) reported that elsewhere in late April 2013 a pair soared high over a previous (2012) nest site, and in similar 'play dives' the male stooped at the female which rolled in response.

### **Territorial defence**

In a probable territorial action at Tamworth in mid-September 2013, a female falcon in flight was approached by a male, which stooped at her; she rolled and thrust her feet upwards, then continued her path on a long, low glide to the horizon while the male soared away in the opposite direction (whence he had come).

Near Lismore, during the nestling period, both adults chased a third Black Falcon (male by relative size) past the nest tree, initially from 400–600 m away. One grappled with the intruder, talons locked, and both spiralled to within 10 m of the ground before they separated and resumed the chase, the male continuing to swoop at the intruder, before the pair returned to the nest tree. A second pair of Black Falcons was known to have a territory 5–6 km away for the previous ~5 years.

### **Interspecific interactions**

Near Tamworth, single Black Falcons occasionally swooped at or briefly chased a perched Brown Falcon or flying Australian Raven, *Corvus coronoides* (once each), without displacing or visibly distressing the target, but were more frequently harassed by a Brown Falcon (twice) or raven(s) (four times). Perched Black Falcons seemed distressed by an attacking raven (once in apparent attempted robbery as the falcon ate prey), but in flight a Black Falcon easily evaded two mobbing ravens. A perched Black Falcon eating prey was flushed by a Brown Falcon that briefly continued to swoop, but the Black Falcon retained the prey.

Near Lismore, during the incubation phase, the adult Black Falcons (female on nest, male in nest tree) did not visibly react to an Australian Hobby,

*Falco longipennis*, flying past the tree. During the second half of the nestling phase, the adult falcons (when present in the nest area) usually showed no visible reaction to Torresian Crows, *Corvus orru*, or small to medium-sized raptors flying past or over the nest tree (Pacific Baza, *Aviceda subcristata*; Nankeen Kestrels, *Falco cenchroides*; Australian Hobby), or circling in the general area (Black Kites, *Milvus migrans*). However, the female, after caching prey in a tree, once repeatedly swooped a crow on the nearby road until it left. The female also vigorously climbed, pursued and swooped a high-soaring Wedge-tailed Eagle, *Aquila audax*, >200 m from the nest, and juvenile White-bellied Sea-Eagle, *Haliaeetus leucogaster*, 300 m from the nest, cackling as she did so (and causing the latter eagle to roll and parry with its feet). She also remained perched but cackled and watched, as an adult sea-eagle flew directly high over the nest. Otherwise, from week 5 (day 33) onwards, a Square-tailed Kite, *Lophoictinia isura*, flying over the nest tree, Black Kites and a Whistling Kite, *Haliastur sphenurus*, foraging within 400 m, a Collared Sparrowhawk, *Accipiter cirrocephalus*, soaring 300 m away, two kestrels pausing on the top of the nest tree, and crows inspecting the nest tree, did not cause the absent (and possibly unaware) adults to return and defend the nest and large nestlings.

In the post-fledging period (week 1, day 3), both adult falcons flew ~1 km to swoop a Wedge-tailed Eagle and drive it into a low tree, where it sheltered against the trunk under the canopy. The male continued to dive at the eagle, while the female returned to the top of the nest tree. Later (week 3, day 15), one adult chased a Wedge-tailed Eagle at 300 m from the nest, then both attacked three soaring eagles, calling as they did so, and causing the eagles to dodge or roll as they were driven from the area. In week 3 (day 18) one adult falcon also chased a crow near the falcons' ground cache.

On 28 October a pair of Brown Falcons had a nest with chicks ~two weeks old (i.e. hatched in mid-October) ~400 m from the Black Falcons' nest

(K. Fisher pers. comm.). Allowing five weeks' incubation (Marchant and Higgins 1993), the former's eggs were laid in early September, just before the young Black Falcons fledged (see below), although no conflict between the two falcon species was observed.

### Vocalisations

At Tamworth in mid-July, as a male falcon arrived with a full crop (but no prey) on a dead tree next to the female, he gave a soft chattering trill, barely audible from ~50 m: three trill phrases of three pulses each, one phrase per second. The call was more musical ('chirruping') than the rattle of a Brown Falcon or the guttural rattle (though identical rhythm) of a displaying male Black Falcon (see Debus *et al.* 2005). A perched female Black Falcon startled by an attacking raven gave a brief cackle, deeper than that of a Peregrine Falcon.

At Lismore, the breeding pair gave a variety of calls in various contexts, the calls here categorised according to standard terminology (e.g. Carlier 1995; Leonardi *et al.* 2013):

1. a typical falcon cackle, soft or guttural/grating ('ka-ka...' or 'chuck-chuck...') to very loud and 'churring' according to the level of agitation, e.g. when pursuing an eagle. Usually heard from the female, occasionally from the male, typically around the nest when either arrived (sometimes together) with or without prey, or when the female appeared to be inciting the male to hunt or transfer prey. A repeated 'chuckling' call from the male as he arrived with prey may have been a faster, 'rattle' version (see Debus *et al.* 2005). Single 'chuck' notes were occasionally given by either sex, and a 'yuck' call by the female in apparent alarm before she left to attack an eagle.

2. a wailing call (noted as 'mewing'), given by the female to the male as a food-begging call in the nestling period. Also given by the male when flying around the nest tree during the incubation period (just before he retrieved food from a cache after the female had relieved him), and during

the nestling period as the female fed the chicks on prey collected from him.

3. a 'chip-chip' or 'chick-chick' call, usually given by the male (e.g. to the incubating female after she relieved him), or once during a pause as he fed the large nestlings, but also between the adults when perched in the nest tree during the nestling period, and by the perched female as the male arrived at the roost during the post-fledging period. The female gave a 'cluck-cluck' version, amid bouts of cackling calls, when departing to pursue an eagle; a 'yak-yak' version and cackling when arriving in the nest tree; and a loud, double 'yuk-yuk' or 'chuck-chuck' when perched there, surrounded by begging fledglings. Both also gave 'yuck-yuck' calls when attacking a Wedge-tailed Eagle. At least some of these (specifically noted as double calls, above) were probably the disyllabic 'creaking call' or 'ee-chip' typical of large falcons (see Cade 1982), and known for the Black Falcon (e.g. Debus and Tsang 2011). Observations on Black Falcons elsewhere agree, e.g. noisy around the nest with deep cackles at avian intruders, other chuckles (J. Olsen pers. comm.).

### Nest site and breeding chronology

The nest near Lismore appeared to be the old stick nest of Torresian Crows in a large, dead-topped old-growth Forest Red Gum in woodland of this species in a cattle paddock, on an open floodplain. From a fledging date of 13 September, an estimated hatching date of 1 August (see below) and allowing five weeks for incubation (Marchant and Higgins 1993), egg-laying occurred in late June (i.e. ~six weeks ahead of the neighbouring Brown Falcons).

### Incubation

On 22 July, between 1200 and 1230 h, the female was incubating for 20 minutes while the male perched high in the nest tree, on a dead limb, until the female left the nest and flew out of sight, whereupon the male went to the nest and settled to incubate (shuffling down on eggs) for the remaining 10 minutes of observation. On 31 July, between 1220 and 1250 h, there were two

changeovers of incubation. Initially, the male was incubating for the first nine minutes, arising as the female arrived, and they both landed in the nest tree together for a noisy greeting. The female then incubated for 17 minutes (interrupted once by returning to her original perch for one minute), while the male retrieved and prepared prey from a food cache. He took prey to the nest, then resumed incubation for the remainder (three minutes) while the female perched beside the nest and ate the prey.

### Nestling period

The presence of hatchlings on 2 August was indicated by the female's posture as she settled down onto chicks, sitting high or tall in the nest bowl, with much shuffling. Thus, hatching probably occurred on 1 August (half the interval since the previous observation day, i.e. 31 July, when incubation was still in progress).

#### Parental behaviour

On one day early in week 1 (2 August, day 2), during an hour in early afternoon (1435–1535 h), the female fed the chicks for 27 minutes, perched at a food cache (feeding) for 5 minutes, was

absent collecting prey from the male (which accompanied her back to the tree) for four minutes, and otherwise brooded for the balance (24 minutes). The male was absent for 24 minutes, perched in the tree (including at the cache) for 23 minutes, and at the nest for 13 minutes (12 minutes while the female fed the chicks, one minute while she was at the cache). The nest was unattended for five minutes. While the female was feeding at the cache, the male waited there and when she had finished eating, she gave him the remains. There were three chicks, white downy heads just visible, and able to hold their heads up fairly well (i.e. probably hatched on the previous day); the female fed them small pieces of meat. A fourth chick hatched, probably later that day or on the next, but was not discerned until later (next visit, day 19). We could not determine whether the male brooded.

On one day late in week 3 (day 19), in 2.2 hours over midday (1055–1305 h), the female fed the chicks for two minutes, stood on the nest for five minutes and perched in the nest tree for three minutes, but did not brood; she was absent for the balance (2 h, 92%), though she was in the wider

**Table 1. Parental time-budgets of a pair of Black Falcons near Lismore, NSW, in the nestling period, August–September 2013: % observation time (total 38.3 h) spent in each activity. Stand = adult stand on or beside nest; in tree = perched in nest tree; absent = away from nest tree; unattended = neither adult at nest. Numbers in parentheses = n hrs observation in each week. Week 1 = first week after hatching (see text for details of weeks 1 and 3).**

Sex/activity	Week		
	4 (6.3)	5 (6.5)	6 (25.5)
<b>Female</b>			
Stand	1	3	1
Feed chick	1	1	5
In tree	32	4	29
Absent	66	92	65
<b>Male</b>			
Stand	0	1	0
Feed chick	7	1	0
In tree	18	23	9
Absent	75	75	91
Unattended	87	60	90
Both at nest	<1	0	0

**Table 2. Growth and development of nestling Black Falcons near Lismore, NSW, August–September 2013.**

Week	Day	Comments
1	2	Small, white, downy.
3	19	Large, downy (body, wings and head); primary pinfeathers emerged. Chicks filled nest bowl; appeared almost as large as adult male in body size. Standing, being fed in turn.
4	23	Large, downy; primaries lengthening (~10 cm), scapulars emerged. Active, moved around nest. One fed on prey.
	28	Feathers emerging on crown, body and wing coverts (patchy on back, dark collar); primaries and secondaries well developed. Active, ate food scraps. Flapped and stretched wings.
5	30	Face much darker, back mostly feathered, tail ~½ adult length. Milled and pulled at freshly delivered prey; no aggression.
	31	Well feathered on body, back, wings and thighs.
	33	Well feathered, though downy patches on body (crown, chest, sides and vent) and wings, much down under wings. Chicks fed by parent in turn, though one (downiest) missed out.
6	36	Well feathered, little down remaining on body (small patches on neck, flanks and belly); wings appeared nearly full size. Some had more down than others (neck, upper chest and rump); one almost had white collar remaining. One chick walked 0.3 m along nest branch, returned to nest within one minute. Fed on prey dropped in nest, but no fighting.
	37	Little down (armpit, flanks, sides, legs); appeared as large as adult female in body size. Flapped strongly, lifting body off nest, retained grip with feet. Fought over prey, one or two dominant, other submissive (head-low bow).
	38	Fully feathered, almost no down; exercised vigorously. Three fought over prey, one passive. One 'branched' on nest limb for two minutes. Fledging appeared imminent.
	39	One 'branched' repeatedly in and out of nest to 1 m along nest limb. Aggressively crowded and pushed female at feeding time.
	40	Little down remaining (armpit and flanks). Two 'branched', 0.5 and 3 m along nest limb, flapping, then one 5 m from nest. Then hopped/ flapped up vertical branch above nest, flapping but wobbly, returned unsteadily. One tore into whole small prey (duckling) in nest; one took prey from other. Gave adult-like 'chip' call and cackle when Australian Hobby circled over nest tree.
	41	'Branching'; one jumped to perch 0.5 m above nest. One chick appeared larger than others, one submissive (hunched) towards others. Took food from one another, one chick mantled over food.
	42	Aggressive towards female with food, trying to seize it with feet. Two 'branched' above nest.
7	43	Three fledged (fourth fledged two days later); see text.

nest area for almost half of this (52 min., 40%). The male fed the chicks for 18 minutes, perched in the nest tree for 58 minutes (45%, mostly in the female's absence), and was absent for the balance (54 minutes, 42%), though in the wider nest area for most of this (39 minutes, 30%). The nest was unattended for 103 minutes (79%), in periods of up to 42–57 minutes, although either adult was perched elsewhere in the nest tree for about half this time.

By weeks 4–6, the parents only visited the nest to drop prey and feed the chicks, and otherwise perched in the nest tree or were absent (Table 1), although 'absent' included either adult present in the wider nest area, or flying or soaring within view of the nest. The nest was unattended for periods of 8–111 minutes (mean 47 minutes) in week 4, 3–64 minutes (mean 52 minutes) in week 5, and 10–170 minutes (mean 83 minutes) in week 6. In week 5, the male's presence in the nest

tree compensated to some extent for the female's extended absence. The male was not seen to feed the chicks bill to bill after week 5 (day 33), but the female sometimes did so until they fledged. Despite the skew in the observation schedule (see Methods and Table 1), there was a trend of decreasing parental nest attendance (brooding, feeding chicks, perching at the nest or in the nest tree) with chick age. The male was once seen drinking from a pool of water on the road, before arriving to roost.

#### *Development of young*

The nestlings' stages of physical and behavioural maturation are shown in Table 2. At fledging, the juveniles were much darker (being a uniform dark chocolate-brown) than the adults in worn brown plumage, and had buff-edged feathers and a pale-tipped tail; their 'stepped' tails (short outermost rectrices) were evident. They also had a brown cere and blue-grey orbital skin (Figure 1).



Figure 1. Juvenile Black Falcon on fledging day (13/9/13)

Photo: David Charley

Three young fledged on 13 September, giving an estimated nestling period of 42–43 days per chick if (as inferred) hatching occurred on 1–2 August, and the last chick fledged two days later on 15 September. On the morning of the fledging day, three juveniles jumped and fluttered to different branches in the nest tree, then two flew to a tree 40 m away while the third flew to the opposite side of the nest tree. Two (one from the nearby tree) then returned to the nest to be fed. The fourth (youngest) juvenile's first flight was a clumsy, sprawled landing on the outer foliage of a tree where it remained for at least 22 minutes, but all four then returned to the nest.

### Post-fledging period

#### *Parental behaviour*

Owing to the unbalanced watch schedule (biased towards weeks 1–4) and the skew in watch times (biased towards late afternoon/evening in weeks 5–8), there is no discernible pattern to adult nest-tree attendance, other than the female was present more than the male (Table 3). There were four fledglings in week 1 but only two thereafter (see below), thus changing the brood's total food demands and possibly the parents' hunting effort and nest-area attendance. On one morning, local

residents observed both adult falcons on the road, possibly drinking from roadside pools.

In week 1, the adults gave prey to the juvenile(s) at the nest (male parent, on day 3 before the last juvenile had fledged); to a juvenile on a branch of the nest tree (female parent twice, male once) or a dead tree 50 m away (female once, male twice); or the female fed a juvenile piecemeal on a branch of the nest tree (twice). In week 2, the adults initially behaved similarly, giving prey to a juvenile on a branch of the nest tree (female parent twice, male once), or on a fence post (unsexed adult once).

On day 13, an adult brought prey to the nest area and surrendered it to a juvenile after an aerial chase, and the female brought prey to the nest area and, after the juveniles chased her around the nest tree, she fed them piecemeal on the tree. During a tussle for the prey, it was dropped but the female retrieved it from the ground. Early in week 3 the pattern continued, with either parent giving prey to a juvenile on the nest tree, the dead tree, or feeding a juvenile piecemeal on the nest tree (female parent) or dead tree (male parent). From late in week 4, food passes to the juveniles were aerial.

**Table 3. Parental time-budgets of a pair of Black Falcons near Lismore, NSW, in the post-fledging period, September–November 2013: % observation time (total 68.4 h) spent in each activity.**

**In tree = perched in nest tree (includes roosting at sunset/dusk); feed young = feed fledgling(s) bill to bill; absent = away from nest tree. Numbers in parentheses = n hrs observation in each week. Week 1 = first week after fledging (see text for details of week 9); from week 5, watch schedule skewed towards last hour(s) to sunset/dusk roosting time.**

Sex/activity	week							
	1	2	3	4	5	6	7	8
	(15.8)	(10.3)	(13.7)	(8.3)	(8)	(2.6)	(5.6)	(4.1)
<b>Female</b>								
In tree	35	11	34	16	34	30	11	54
Feed young	5	3	<1	0	0	0	0	0
Absent	60	86	66	84	66	70	89	46
<b>Male</b>								
In tree	8	0	22	4	50	14	8	9
Feed young	0	0	<1	0	0	0	0	0
Absent	92	100	78	96	50	86	91	91



Until the end of observations (week 9, day 57), the adult(s) attended the nest tree and roosted there. The adults were often absent through the day (mornings to late afternoons) as the post-fledging period progressed. From week 1, the female's absences were commonly 30–90 minutes (once the entire watch, i.e. >2.5 h), progressing to frequently absent all watch, other than towards dusk (up to >2 h in week 2, >2.5 h in weeks 3 and 4, and >3 h in week 5).

#### *Development of young*

One of the juveniles (the weakest, possibly last fledged) had disappeared, presumed dead, on the morning of day 5 following a severe electrical storm with strong winds and heavy rain overnight, and rain on day 4. It could not be found during a search of the trees and paddock around the nest tree. Another (fledged on day 1) was found freshly road-killed late on day 7, 110 m from the nest (see below). Thereafter, only two of the four (a male and female) survived until independence. At 8–10 days out of the nest, one of these survivors still had incompletely emerged primaries and rectrices (Figure 2).

Behavioural development of the juveniles is shown in Table 4. They rapidly progressed to fast, agile chasing and aerial play-fighting within their first week, although until week 2 (day 10) such flights typically lasted only 1–2 minutes. One possibly made a tentative chase of Scaly-breasted Lorikeets, *Trichoglossus chlorolepidotus*, on day 3. Late in week 1, when chasing each other, one juvenile carried a food scrap from the nest, picked at it in flight then dropped it as the other followed. One juvenile flew low over the road near passing cars, and in week 2 one narrowly avoided a collision by rising over a passing car. The juveniles ranged 600 m from the nest by the end of week 1 to 800 m late in week 2, but were still found within 2 km of the nest towards the end of the study (week 8). From week 3 (day 21), the family group appeared to disperse during the day and became increasingly difficult to locate, although the juveniles still associated and interacted until week 7 (day 46).



**Figure 2. Juvenile Black Falcon 8–10 days after fledging (note short wings and tail)**

**Photo: David Charley**

In week 1 (until day 3, after the fourth had fledged) the juveniles returned to the nest to feed or beg to the adults. Late in week 4 (day 28) a juvenile chased the food-bearing male and rolled to take the prey aerially from his foot. Late in week 7, during an aerial food pass, the prey was dropped in the tussle, but the juvenile dived and caught it in the air. Early in week 4 and again late in week 5, the female and an unsexed adult brought prey to the nest tree, but no juvenile collected it. However, parental food provision continued until at least week 7 (day 48), and the juveniles directed food-begging calls at the adults until at least week 8 (day 52). They appeared to practise hunting behaviour from day 20, harassed large birds from week 4, and accompanied the hunting adult(s) on forays from week 6 (day 37) (Table 4). One juvenile had a full crop when it arrived at the roost in week 8 (day 52), begging to the female parent, but it is not known whether it had caught prey or obtained it from an adult. The juveniles were thus fully dependent until week 3 or 4, and partly dependent until at least week 8.

Except for day 30 when only one juvenile roosted at the nest with the adults, and day 33 when no falcons roosted in the nest tree, the juveniles roosted on or beside the nest with the adult(s) until week 7 (day 43). Thereafter, in week 8, on day 50 one falcon (apparently a juvenile) roosted alone at the nest; on day 52 a single juvenile (female) roosted beside the nest with the adult female; and

**Table 4. Development of fledgling Black Falcons near Lismore, NSW, September–November 2013.**

Week	Day	Comments	
1	1	Three fledged; two flew competently in circuitous flight to 40 m from nest, but landings clumsy (stumbling). Exercised wings (flapping) when perched. Fed competently on prey in nest or on branches.	
	2	Two ranged 150 m from nest, chasing each other. Competent landing (swoop and upward stall to perch).	
	3	Two allopreened; one young followed adult female ~250 m. Young aggressive to female with food. Fourth young fledged.	
	5	One juvenile missing after overnight storm. Others (1 m, 2 f) active, chased one another in low (<2 m above ground), fast, agile flight with twists and turns. One soared, one practised low swoops over grassy paddock. Adult-like cackle calls when not begging.	
	7	One juvenile (f) found road-killed; brood now two, becoming aggressive to each other over food (mantling, gaping, pecking, bill-jousting, upright stance when sparring). Still exercised wings on perches; one ranged 600 m over paddocks.	
	2	8	Fed themselves on carcass at cache. Adult-like creaking and cackle calls when chasing.
		10	Both circled over paddocks to 300 m from nest.
11		Avoided attacking Nankeen Kestrel by roll and half-roll in flight.	
12		One followed female 800 m on hunting flight.	
13		One chased food-bearing male and took prey from him. Juveniles then tussled over prey at perch.	
3	17	Both sat on gravel road; chased low (<1.5 m) above ground, flew across main road out of sight.	
	18	Juveniles initially not located within 600+ m of nest. Both tussled at evening roost by lunging and flapping.	
	20	Both sunned on dead tree 500 m from nest. Swooping and fast direct flight low over grass, possibly hunting. One flew 1 m above grass then pounced in grass; other followed Magpie-lark briefly.	
	21	One flew through trees as if hunting, fast and direct with occasional glides. Roosting juveniles begged when female arrived.	
4	22	Juveniles not located during morning; female brought prey to nest tree but not collected by young.	
	23	One chased Straw-necked Ibis, <i>Threskiornis spinicollis</i> , briefly. Still begged to adult(s).	
	28	Aerial food pass by male to pursuing juvenile in low chase, juvenile rolled to take prey from male's feet.	
5	30	Only one juvenile roosted beside nest with adults.	
	33	In evening, adult (male?) brought and ate prey at nest tree, young did not collect prey or arrive to roost with adults.	
6	37	Both followed hunting adult, harassing ibis, corellas, Galahs, crows gathering to roost.	
	40	Juveniles flew low (<2 m) over grass, swooped and dived over lagoon and paddocks (possibly hunting practice). Joined adult to harass crows and Little Corellas going to roost, chasing and flying at roosting birds.	
7	46	Four falcons (pair and two juveniles) hunted together over lagoons, circling slowly and sideslipping (i.e. maintaining height), searching along the reeds (K. Fisher pers. comm.).	
	48	Aerial food passes by adult(s): (i) prey dropped, but juvenile caught it in air after 5 m dive; (ii) juveniles competed to roll and take prey from male's foot.	

on day 53 three falcons (i.e. at least one juvenile) were present, but only one (unknown age/sex) roosted in the nest tree. The juveniles were not seen during an hour in week 9 (day 57), when one adult brought prey to the nest tree at sunset, ate the food and roosted there alone.

## Hunting and prey

### *Tamworth*

Hunting episodes and prey items are summarised in Table 5 (which gives scientific names). In the case of apparently co-operative hunts by members of a pair (or attempts to initiate such):

1. Two falcons were perched on a dead tree; the female, closely followed by the male, left together on a tandem, fast, contour-hugging flight.
2. The pair of falcons was perched in the same dead tree, the male resting with a full crop. The female twice in five minutes appeared to try to initiate a tandem hunt, by making a flight-intention movement (slowly opening her wings) and leaving, then (i) swinging back around the closest tree and returning to her perch beside the male, and (ii) pausing on a paddock tree ~300 m away and looking back at the male, before departing alone.

In the lizard episode (Table 5), a soaring falcon made a long, shallow dive from 50 m in the air and 100 m away to snatch the lizard from open ground beside a paddock fenceline, without landing. The falcon tried to land on a dead tree, but was displaced by an Australian Raven; the falcon ate the prey in soaring flight. From local habitat and survey data (SD), and its size in the falcon's foot, the lizard was probably a Boulenger's Skink, *Morethia boulengeri*.

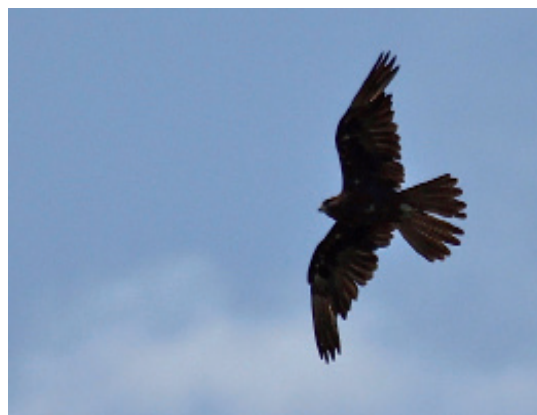
In the co-operative hunt of Musk Lorikeets (Table 5), one falcon waited in the air above, ready to stoop, while the other flew through the trees, flushing the parrots (A. Ashworth pers. comm.). In the starling episode (Table 5), a falcon was hunting a low swirling flock over an open paddock. The falcon made a shallow power-stoop at the tight flock, then a series of direct flying attacks that became shallow stoops at single

starlings that broke away. The targeted starling either dodged the strike at the last moment, or suddenly closed its wings and dropped vertically 2–3 m into the grass as the falcon closed horizontally with it, thus avoiding capture. (See also Ross and Olsen 1988.)

### *Lismore*

Hunting episodes and prey items are summarised in Table 5. The adult female falcon appeared to initiate at least three of seven low, fast tandem hunts: once departing first, closely followed by the male; once together after she wailed and cackled at him; and once when she left alone towards a known prey source (farm buildings), then he followed. She twice also went to join him as he was hunting or circling alone within sight of the nest, in what became a tandem hunt. Some of these co-operative hunts went for at least 700 m, and one resulted in a capture: the pair arrived at a canefield being harvested and alternately stooped repeatedly at an item on the ground, until the male caught a quail and took it to the nest.

The advanced juveniles joined an adult in harassment of roosting birds, and in quartering the margin of a lagoon (Table 4; scientific names of prey in Table 6). On another such occasion, just before sunset, two falcons (at least one adult) came out of the sun through a melee of corellas and other birds, outcome unseen (K. Fisher pers. comm.; Figure 3).



**Figure 3. Parent Black Falcon in heavy moult, post-fledging period, week 7 (28/10/13)**

**Photo: Keith D. Fisher**

The adult falcons' hunting areas included farm buildings <2 km from the nest and several lagoons, the closest of which was <250 m from the nest. Hunting flights occurred at all times of day, from early morning (e.g. when fog lifted) until the last hour of daylight. The male also

repeatedly hawked small bats (Microchiroptera, unsuccessfully) in four short sallies over 10 minutes around his roost tree on one evening at dusk (~30 min. after sunset). The female flew easily and strongly while carrying a seemingly large (partly eaten) Cattle Egret, although at

**Table 5. Observed hunting episodes of adult Black Falcons at Tamworth (May–October) and Lismore (nestling and post-fledging periods, August–November), NSW, 2013.**

**Tandem = male and female of pair co-operating (alternating stoops or direct flying attacks). M = male, F = female. For juveniles associating with hunting parents, see Table 4.**

Search method	Attack type	Target	Outcome
<i>Tamworth</i>			
? (pair)	Tandem	Galahs, <i>Eolophus roseicapillus</i> in paddock tree crown	Fail
M perch-hunt	Stoop to flush prey off ground	Australian Magpie, <i>Gymnorhina tibicen</i>	Fail
Pair perch-hunt	Tandem	Bird sp. in paddock tree crown	Fail
Pair soaring	M opportunistic tail-chase	Passing Feral Pigeon, <i>Columba livia</i>	Fail
Pair fast contour-hugging flight	Tandem?	–	–
F fast contour	–	–	–
High quartering	?	Budgerigar, <i>Melopsittacus undulatus</i>	Success
Quartering	Shallow dive to ground	Small lizard sp. (skink?)	Success
? (pair)	Tandem	Musk Lorikeets, <i>Glossopsitta concinna</i> , in woodland canopy (A. Ashworth pers. comm.)	Fail
?	Direct flying attacks/ stoops	Swirling flock of Common Starlings, <i>Sturnus vulgaris</i>	Fail
?	Tail-chase	Flock of Budgerigars (M. Eden pers. comm.)	?
M quartering	Stoop ×5	Grasshoppers (Orthoptera) flushed by tractor mower	Success ×3, fail ×2
High transect	Stoop	Bird sp.?	Fail
<i>Lismore</i>			
Fast contour ×11 (M ×8, F ×2)	M: (i) flush prey from tree canopy; (ii) tail-chase (other attacks unseen)	M: (i) roosting Galahs and Little Corellas, <i>Cacatua sanguinea</i> ; (ii) flying Grey Teal, <i>Anas gracilis</i>	M: fail/ fail
Pair fast contour ×7	Tandem ×1 (other attacks unobserved)	Brown Quail, <i>Coturnix ypsilophora</i>	Success
M quartering	Dive to ground	?	Fail
F low quartering	–	–	–
F perch-hunt	Flew 250 m, dropped to ground	?	Fail
M perch-hunt	Short sally-strike ×4	Bats (Microchiroptera) at dusk	Fail ×4

~350 g it was ~40% of her body weight (female Black Falcons average 833 g; Debus and Olsen 2011).

### *Diet*

The Lismore pair's observed breeding diet (prey deliveries, and other items visible in the nest and caches or found as orts,  $n = 72$  identified) consisted entirely of birds during the incubation and nestling periods, and almost half mammals (41%, rats 38%) by number during the post-fledging period, or 81% birds overall (Table 6, which gives scientific names). No pellets and only three orts were found under the nest during the nestling period, along with fox scats (suggesting that a fox had scavenged most of the evidence). Only one ort was found under the nest early in the post-fledging period, along with two fresh pellets and one ort under a nearby feeding perch (week 1). A sample of pellets ( $n = 10$ , plus fragments) and orts ( $n = 3$ ) found under the nest late in the post-fledging period (day 46) probably represented prey from fledgling weeks 2–7 (Table 6). The pellets measured  $24\text{--}69 \times 15\text{--}23$  mm (mean  $39 \times 19$  mm) and weighed 0.7–3.4 g (mean 1.9 g). All 12 intact pellets (100%) contained mostly feathers (by volume) and traces of other bird remains (bill and bone fragments), five (42%) also contained mammal fur and remains (foot, rat jaw), and three (25%) contained beetle remains. The pellet fragments, representing about seven pellets, contained the same prey profile as the intact pellets (i.e. feathers, fur and beetle). No reptile scales were found in pellets, despite searching. The pellet material contained no vertebrate prey species that were not otherwise observed as delivered or cached prey, or as orts (Table 6).

The cached items in the incubation and nestling periods (Table 6, all before the female started hunting) were probably caught by the male parent. However, the magpie orts (one a fledgling) appeared after the female started hunting, and she delivered one magpie. Otherwise, the male and female falcon took similar prey (Table 6). Rats started appearing in

the diet from late in week 1 of the post-fledging period, but by week 3 the pair had switched almost entirely to rats. At that time there was apparently a glut of rats, possibly exposed during cane-harvesting operations, and many were cached (Table 6). From a crude estimate of prey body weights (from SD's prior raptor studies cited by Marchant and Higgins 1993 or Debus 2012a), rats contributed ~50% of observed vertebrate prey biomass in the post-fledging period. The beetles (three small individuals in the final pellet sample, negligible by biomass) were likely to have been caught by the juvenile falcons. The road-killed juvenile's gut was empty (L. Tsang pers. comm.).

### *Caching*

The falcons had three cache sites in the nest tree (horizontal hollow limbs of various sizes, e.g. an open spout ~20 cm in diameter, below the nest, 6 m above the ground), into which they pushed prey; one on the ground at the base of a Forest Red Gum 50 m from the nest tree; and (in the post-fledging period) a hollow in a dead tree 50 m from the nest. Both sexes retrieved food from the caches: the male either to feed himself or to give food to the female, and the female to feed the chicks during lulls in the male's deliveries. They used the cache sites to store excess fresh prey (e.g. when the female was already feeding the chicks on another item), and to store leftovers after feeding the chicks. Cached avian prey was often, but not restricted to, large species (e.g. Cattle Egrets, Little Corellas), and the adults sometimes moved prey between the ground and tree caches. They continued to use the caches during the post-fledging period, to feed themselves and the fledglings.

### **Feeding rates**

During the nestling period, the adults brought prey to the nest at a combined rate of 30 items in 41.5 hours (0.72 item/h): the male 0.43 item/h (two of these from a cache), the female 0.29 item/h (two of these from a cache, one or two possibly collected from the male away from the nest, as he accompanied her return). These represented ~70 g of prey biomass delivered per hour. The female

**Table 6. Prey of a breeding pair of Black Falcons near Lismore, NSW, incubation to post-fledging period, July–November 2013: n items seen delivered by the adults to the nest or fledglings, or otherwise observed (? = uncertain identification). M = male, F = female; C = observed in or retrieved from cache (probably caught by male); <sup>1</sup> = incubation period; ? = adult falcon unsexed, or item observed in or retrieved from cache, or was an ort in or under the nest; <sup>o</sup> = ort (prey remains); <sup>p</sup> = in pellets; T = total. Care was taken not to double-count items.**

Species	Inc./nestling				Post-fledging				T
	M	F	C	T	M	F	?	T	
Brown Quail, <i>Coturnix ypsilophora</i>	3		1 <sup>1</sup>	4	2			2	6
Maned Duck, <i>Chenonetta jubata</i> duckling					1	1		2	2
Grey Teal, <i>Anas gracilis</i> ?			1 <sup>1</sup>	1					1
Pacific Black Duck, <i>Anas superciliosa</i> duckling			1	1	1	1		2	3
Unidentified duckling		1		1					1
Bar-shouldered Dove, <i>Geopelia humeralis</i>		1		1	1	1		2	3
Crested Pigeon, <i>Ocyphaps lophotes</i>	1	2		3					3
Cattle Egret, <i>Ardea ibis</i>			1	1		1	1	2	3
Purple Swamphen, <i>Porphyrio porphyrio</i>	1			1					1
runner ?									
Masked Lapwing, <i>Vanellus miles</i> ?							1 <sup>o</sup>	1	1
Galah, <i>Eolophus roseicapillus</i>			1 <sup>o</sup>	1					1
Little Corella, <i>Cacatua sanguinea</i>	1		2	3					3
Rainbow Lorikeet, <i>Trichoglossus haematodus</i>							1 <sup>o</sup>	1	1
fledgling									
Scaly-breasted Lorikeet, <i>Trichoglossus chlorolepidotus</i>							1 <sup>o</sup>	1	1
Noisy Miner, <i>Manorina melanocephala</i>	1	1		2					2
Honeyeater sp. (Meliphagidae)		1		1					1
Honeyeater?	1			1					1
Australian Magpie, <i>Gymnorhina tibicen</i>		1	1 <sup>o</sup>	2					2
Magpie fledgling							1 <sup>o</sup>	1	1
Magpie?			1 <sup>o</sup>	1					1
Magpie-lark, <i>Grallina cyanoleuca</i>							1 <sup>o</sup>	1	1
Common Myna, <i>Acridotheres tristis</i>	3	2	1	6			2	2	8
Passerine			1	1			1 <sup>p</sup>	1	2
Medium bird		1		1					1
Small bird	4			4			1 <sup>p</sup>	1	5
Unidentified bird	1	1		2			1	1	3
<b>Total birds</b>				<b>38</b>				<b>20</b>	<b>58</b>
Brown Antechinus, <i>Antechinus stuartii</i> ?					1			1	1
Black Rat, <i>Rattus rattus</i>					2	1	6	9	9
Rat sp.					1	2	1 <sup>o</sup>	4	4
<b>Total mammals</b>								<b>14</b>	<b>14</b>
Beetle (Coleoptera)							3 <sup>p</sup>	3	3
Unidentified							2	2	2
<b>Total</b>				<b>38</b>				<b>39</b>	<b>77</b>

was first seen to bring her own captured prey late in week 4 (day 28), while the male was feeding the chicks. The male took one item to a cache while the female was feeding the chicks. There were several short intervals between departures and next deliveries of avian prey (excluding from caches), e.g. male six intervals of 3–17 minutes (four of 7–9 min.), female one of six minutes. Both adults occasionally arrived (separately) with a full crop but no prey, or (the female, once) also brought the remnant and finished it without going to the nest, showing that they ate additional kills away from the nest.

In the post-fledging period until week 7, the adults brought prey to the juveniles in the nest area at a combined rate of 27 items in 68.4 hours (0.39 item/h): the male 0.19 item/h (three of these from a cache, all in week 3), the female 0.13 item/h (two of these from a cache, in weeks 3–4), and five by an unsexed adult (0.07 item/h). These represented ~80 g of prey biomass delivered per hour. The combined rate was 0.51 item/h in week 1 (brood of four), 0.58/h in week 2 (after brood reduction) and 0.51/h in week 3, declining to 0.36/h in week 4 and 0.19/h in weeks 5–7 combined (no witnessed deliveries in week 6; total observation time given in Table 3). The female was last confirmed to deliver prey in week 4, and there were no observed deliveries in week 8 (although the juveniles could have obtained prey from the adults away from the nest area in weeks 5–8). In week 3 the male once departed and returned with a fresh rat in two minutes. In weeks 3 (day 18) and 5 (day 32) the female arrived at the roost with a full crop, i.e. had fed away from the nest without bringing the prey, and in week 4 (day 26) she ate prey from a cache without sharing it with the juveniles that had also arrived to roost.

### Roosting

Near Tamworth, from early July to early August a probably male Black Falcon was seen three times going to roost in the canopy of a live paddock eucalypt in the same stand of trees in a drainage line, around 1730 h. Each time, the falcon flew in

at low level, more than 10 minutes after sunset. On one of these, the falcon had gone by sunrise the next morning.

Near Lismore, during the second half of the nestling period, the female roosted at dusk on the nest branch, beside the nest (week 5, day 31 and week 6, days 38 and 40), and the male roosted away from the nest tree. However, on one evening in week 5 (day 30) when the female had not returned at dusk, the male roosted beside the nest. Throughout the post-fledging period, both adults roosted either on a branch beside the nest (female) or in the nest tree within a few metres of the nest (male), as did the juvenile(s), up to at least week 8 (day 52).

### Reaction to disturbance

The focal pair of falcons at Tamworth had a favourite prominent perch (a dead tree) overhanging a rural sealed road. They remained perched, usually showing no visible reaction to passing vehicles of all sizes, but the female was once briefly startled by a truck gearing down directly below her. This female, and some other Black Falcons, readily perched on dead trees in or near (within ~50 m) farmstead backyards.

The Lismore nest was ~80 m from a busy main road with many car and truck movements, to which the adult falcons showed no visible reaction. Nor did the adults or fledglings visibly react to the observers, sometimes flying low over the parked vehicle as if inspecting us; once a juvenile landed in a tree 15 m away to eat a rat. There was a fire 300 m from the nest during the chick phase, but the falcons showed no reaction, other than watching the fire, as dense smoke enveloped the nest tree (without causing chick death).

### Juvenile specimens

A known-age juvenile male reference specimen, road-killed near Tamworth (Debus and Zuccon 2013), is now registered as Australian Museum O.74636 (L. Tsang pers. comm.). The road-killed fledgling from the Lismore nest was a female, weighed 730 grams (possibly dehydrated: see

Schoenjahn 2011), and is also now registered in the AM, O.74912 (L. Tsang pers. comm.). At six days out of the nest, its primaries and rectrices were not fully emerged, their bases still ensheathed ('blood quills').

## DISCUSSION

### Displays and vocalisations

The aerial courtship displays supplement descriptions of high aerial male-female interactions (e.g. in Marchant and Higgins 1993), and the pre-laying and nest-selection behaviour described by Debus and Tsang (2011). Some of the male hunting behaviour at Tamworth in May (e.g. magpie episode, Table 5) may have been in display to the female. As in solitary aerial displays (Whelan 2013a), the male's manoeuvres during courtship appear to be demonstrations of speed and agility. The Black Falcon's aerial courtship manoeuvres are similar to those of other 'great falcons', subgenus *Hierofalco* (see Cade 1982; Ferguson-Lees and Christie 2001).

The Black Falcon's greeting trill may be similar to the trill illustrated for this species by Jurisevic (1998, Figure 2e). It is difficult to match our other call descriptions to Jurisevic's spectrograms, but the various cackles may match his Figure 2a,b. The Black Falcon's varied vocal repertoire is evidently similar to that of the Lanner Falcon, *Falco biarmicus*, and other 'great' falcons (e.g. Ferguson-Lees and Christie 2001). The Black Falcon's frequent and sometimes loud vocalising around the nest contrasts with prior perceptions (e.g. Marchant and Higgins 1993) that it is silent or subdued, at least away from the nest (although nest defence against humans is silent, e.g. Olsen and Olsen 1980). The male's frequent vocalising accords well with the pair's high fledging success, and contrasts with a male's infrequent vocalising at a nest with lower success (Debus *et al.* 2005). However, statistical correlation of male vocal signalling with breeding success (Leonardi *et al.* 2013) awaits proper investigation among multiple pairs.

### Territorial defence

The intraspecific territorial interactions enlarge on previous information (e.g. in Marchant and Higgins 1993), and illustrate typical falcon aerial agonistic behaviour. Interspecific nest defence, and tolerance of most other raptors, accord with prior experience (e.g. Debus *et al.* 2005; Debus and Zuccon 2013), and suggest that nesting Black Falcons are mainly concerned with large eagles or conspecifics unless other species intrude too closely. Initiation of breeding (nest selection, laying) more than two months ahead of Brown Falcons may have minimised conflict with them over nest sites.

The Black Falcon, like other 'great' falcons, appears prone to interspecific conflict with corvids over stick nests, e.g. the Gyrfalcon, *Falco rusticolus*, and the Northern Raven, *Corvus corax* (Potapov and Sale 2005). Similarly, it appears to usually lose such contests with large corvids, which may be a factor in its decline in the sheep-wheat belt in the face of increasing, superabundant ravens and apparently increasingly severe storms which destroy stick nests (Debus and Tsang 2011; Debus and Zuccon 2013; SD pers. obs.). There may be a case for experimenting with artificial stick nests, high in tall trees in low, flat (e.g. riparian) parts of the agricultural landscape, for Black Falcons.

### Breeding biology

As elsewhere, the Black Falcons at Lismore were early breeders (see Debus *et al.* 2005; Debus and Tsang 2011; Debus and Zuccon 2013). Our brief observations establish that at least some male Black Falcons share incubation while the female is absent or eating the male's catch, although further details and quantification of male and female roles are required. Shared incubation is common in *Falco* generally (e.g. Cade 1982).

Previous Black Falcon nestling periods were 38–42 days (Baker-Gabb 1984), i.e. ~6 weeks, as at Lismore. Marchant and Higgins (1993, '42–49 days') misquoted Cupper and Cupper (1981), who estimated 'between 6 and 7 weeks' (p. 88)



and '42 days' (p. 92), i.e. 49 days is too long. In the equivalent Peregrine Falcon it is 38–45 days (Marchant and Higgins 1993). As previously (Debus *et al.* 2005), advanced nestlings could feed themselves on delivered prey (*contra* Cupper and Cupper 1981).

The brief observations of parental behaviour in the chicks' first week accord with those of Hollands (1984) for downy chicks. Based on his photographs, and comparison with known-age Peregrine Falcon chicks (in Olsen 1995, p. 157) and Black Falcon chicks (in Cupper and Cupper 1981, p. 90), Hollands' Black Falcon chicks were about two weeks old. Available data (including Debus *et al.* 2005; Debus and Zuccon 2013) suggest that up to ~two weeks old, chicks are mostly brooded and fed by the female. Otherwise, parental behaviour and development of older nestlings agree well with the study of Debus *et al.* (2005) and, overall, aspects of the Black Falcon's breeding cycle resemble those of the Peregrine Falcon (see Marchant and Higgins 1993; Turner *et al.* 1993; Olsen 1995). However, quantification of the Black Falcon's full breeding cycle (sex roles, parental time-budgets) from pre-laying to independence remains to be done.

The juveniles' morphological characters at fledging age agree with recent studies (Debus *et al.* 2005; Debus and Zuccon 2013). The post-fledging dependence period at Lismore was long (two months, cf. three weeks recorded by Debus *et al.* 2005), but is as expected for juveniles of large bird-eating falcons, which presumably take many weeks if not months to hone bird-catching skills (e.g. Peregrine Falcon: Marchant and Higgins 1993; Turner *et al.* 1993). The fate of two fledglings at Lismore (a) suggests that the juveniles in a prior study (Debus *et al.* 2005), which disappeared early, may have perished before independence; and (b) reinforces the role of human hazards in Black Falcon mortality (see Debus and Olsen 2011; Debus and Zuccon 2013). The behavioural development of fledglings resembled that described by Debus *et al.* (2005) and Barnes and Debus (2012) for comparable

stages, and was generally similar to that described for the Peregrine Falcon (see Turner *et al.* 1993). Further study of this aspect will require radio- or satellite telemetry.

## **Foraging and prey**

### *Hunting behaviour*

The hunting observations at Tamworth and Lismore (Debus *et al.* 2005; Debus and Tsang 2011; Debus 2012b; Debus and Zuccon 2013; this study), together with recent anecdotal reports elsewhere (Debus 2013; Gemmell 2013; Whelan 2013b), confirm that Black Falcons search for prey by perch-hunting, fast contour hunting, high quartering, or soaring and prospecting, and attack in a direct flying attack, stoop (at aerial prey), tail-chase, or dive to the ground, and that co-operative hunting of avian prey by the male and female of a pair is common. Co-operative hunting flights appear to be frequently initiated by the female. For video examples of hunting behaviour, including tandem hunts, see D. Gemmell's website <[www.raptorcapture.com](http://www.raptorcapture.com)>.

### *Prey*

The prey items at Tamworth are consistent with previous data from there and elsewhere in southern Australia, i.e. mainly birds (Marchant and Higgins 1993; Debus *et al.* 2005; Debus and Olsen 2011; Debus and Tsang 2011; Debus and Zuccon 2013). However, there are few previous records of reptiles as prey. One early claim cited by Marchant and Higgins (1993) is doubtfully referable to the Black Falcon (given likely confusion with the Brown Falcon); the other (a lizard: Hollands 1984, p. 140) was overlooked. Small lizards may be taken frequently, at least in the inland, but would not appear in pellets other than as tiny scales among fur, feathers or insect fragments.

The diet of the breeding pair at Lismore is noteworthy for its frequency of Common Mynas, more the fare of agile raptors near cover than of fast falcons of open habitats (cf. Australian Hobby and Peregrine: Olsen 1994; Olsen *et al.* 2008). Much the same applies to the terrestrial mammals,

requiring agility near the ground during fast, low-level attacks. In such a comparison with the Peregrine, the Black Falcon parallels the Lanner Falcon (e.g., see discussion by Debus and Olsen 2011).

Dietary flexibility, in response to seasonal or geographical availability of prey classes, is well known in the Black Falcon (e.g. Marchant and Higgins 1993). However, the switch from birds to mammals within the one breeding event (at Lismore) seems noteworthy. In its ready alternation between birds and abundant mammals, and inclusion of bats, reptiles and insects, the Black Falcon resembles the Lanner Falcon and the Laggard Falcon, *Falco jugger* (see Ferguson-Lees and Christie 2001).

#### *Feeding rates*

The parental feeding rate was higher at Lismore than at Tamworth, both in the nestling period (0.7 vs 0.3 item/h; 70 vs 50 g of prey biomass/h) and, week for week, in the post-fledging period (0.5–0.6 vs 0.3 item/h; 80 vs 70 g of prey biomass/h in weeks 1–3) (cf. Debus *et al.* 2005). Although the difference in the nestling period may relate to brood size (four vs three then two), brood size was equal post-fledging, so the difference may relate to greater food supply at Lismore (especially given the use of caching; see below). In both studies, the increased biomass delivered in the post-fledging period reflected the increase in mammal captures (rats/rabbit kittens) and, at Tamworth, the capture of fledgling Galahs.

#### *Caching*

The Black Falcons at Lismore used tree hollows as cache sites, unlike a pre-breeding pair that was said to cache excess prey in the 'wall' (presumably the earth bank) of a farm dam (unsourced in Olsen 1995, p. 101). At Lismore, caching probably enabled the falcons to take advantage of abundant and easily caught prey in a high-rainfall zone, may have acted as a buffer against wet weather (when hunting might be difficult), and may have facilitated the successful brood of four fledglings by ensuring a constant

food supply to the chicks (e.g., see Cade 1982; Sherrod 1983; Cameron and Olsen 1993; Olsen 1995; McDonald 2004). Caching was not recorded at the nest studied by Debus *et al.* (2005), from which only two young fledged after a third chick (underweight and sick) fell from the nest.

#### **Implications for research and conservation**

The endemic Black Falcon is arguably of greater conservation concern than the cosmopolitan Peregrine Falcon. The latter is not threatened in any Australian State, is increasing, and is adapting to nesting on city buildings and other human infrastructure (e.g. Debus 2012a). Conversely, the Black Falcon is limited to pre-built stick nests in trees (Debus and Olsen 2011; Olsen 2014), and is of concern in the Murray-Darling Basin; two occupied nests in central Victoria, one in northern Victoria, and one in southern inland NSW (the only ones known to be monitored) all failed in 2013 (D. Gemmill, A. Zuccon pers. comm.).

There is little published on the biology or ecology of the Black Falcon in South Australia (Fraser 1985; Falkenberg, Hurley and Stevenson 2000; Debus and Olsen 2011). It has not been the focus of a detailed ecological and population study there or elsewhere in the sheep-wheat belt, although a Black Falcon breeding population is readily accessible from Adelaide (e.g. Debus and Olsen 2011).

In particular, the role of human hazards and unnatural mortality (e.g. vehicle strike, especially in the post-fledging months), and of corvids in nest-site availability, deserve investigation (see Debus and Olsen 2011; Debus and Tsang 2011; Debus and Zuccon 2013).

In contrast with dark Brown Falcons, the Black Falcon is more like a long-tailed, all-dark Peregrine Falcon in flight style and habits, and indeed the Black Falcon's genetic, morphological and ecological counterpart, the Lanner Falcon, has been extensively compared with the Peregrine in ecology, morphology and aerodynamics (e.g.

see studies cited by Debus and Olsen 2011). A similar comparison between Black and Peregrine Falcons in Australia would greatly enhance understanding of the Black Falcon's biology (e.g. see Olsen 1994, Debus and Olsen 2011 for preliminary remarks), with satellite telemetry also needed to understand its complex ecology and elucidate its movements (both daily and seasonal).

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