

**Breeding biology, behaviour and foraging ecology of the Black Falcon *Falco subniger* near Tamworth, New South Wales**

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The breeding biology and behaviour of the Black Falcon *Falco subniger* were studied in the Tamworth district (northern inland NSW) through 146 hours of observation over 47 days in 2015 (one pair, pre-laying to early incubation) and 261 hours of observation over 69 days in 2016 (four pairs, pre-laying to fledging, with checks through the post-fledging period). Pellets were collected from under vacated nests. Aerial displays (e.g. agility, V-dives, 'undulatory roll,' 'high winnowing'), nest-site selection and occupation, courtship and mating are described. Adopted stick nests were high in tall or emergent riparian or paddock eucalypts; nearest-neighbour distances averaged 10.25 km (range 9–12 km). Eggs were laid in July, and incubation appeared to take  $34 \pm 1$  days at one nest. Males took a minor share of incubation (1–3% of daylight) and brooding of hatchlings (1%). Interspecific conflict or defence was strongest against corvids in the pre-laying phase, and against Wedge-tailed Eagles *Aquila audax* during the nestling phase. Feeding rates and estimated biomass provision were 0.09–0.26 item/h and ~4–28 g/h at nests that failed during the incubation or hatchling phase, and 0.19 item/h and ~23 g/h to a single nestling that fledged underweight. Nest failure appeared related to cold, wet weather and poor hunting success around hatching time. Breeding productivity was 0.25 young per attempt in 2015–16, and 0.5–0.6 young per attempt for 10 nests since 2004, with up to half of fledglings failing to reach independence. The observed breeding diet was 98% birds and 2% rodents, although insects appeared in pellets. Hunting success on birds was 36% of observed attacks. Demographic and ecological research on this species is required. As the threatened and declining

Black Falcon faces human-related impacts in the sheep-wheat belt, some possible management strategies are suggested (e.g., artificial nests).

## INTRODUCTION

The breeding behaviour and parental time-budgets of the Black Falcon *Falco subniger* have been partly described, with quantification for the second half of the nestling period (Debus *et al.* 2005; Charley *et al.* 2014). Some males share incubation and brooding of downy nestlings, but the relative contribution of the sexes to parental care is unquantified (Debus and Zuccon 2013; Charley *et al.* 2014; Whelan *et al.* 2016). Some aspects of aerial displays, courtship (including supplementary feeding of the female by the male) and mating have been described briefly, with limited data on copulation rates in the pre-laying period (Debus *et al.* 2005; Debus and Tsang 2011; Whelan 2013; Whelan *et al.* 2016). The post-fledging dependence period has also been described (Charley *et al.* 2014; Whelan *et al.* 2016).

The present study attempted to fill remaining gaps on parental behaviour and time-budgets by quantifying pre-laying behaviour and sex-roles during the incubation and early nestling phases. A comparable study has been published on the related Grey Falcon *F. hypoleucos* (Ley and Tynan 2016). The Black Falcon belongs in the heirofalcon ('great' or 'desert' falcon group – Lanner Falcon *F. biarmicus* and relatives), and the Grey Falcon is basal to the heirofalcon/Peregrine Falcon *F. peregrinus* divergence (Fuchs *et al.* 2015).

During our attempt to more completely document the breeding cycle and ecology of the Black Falcon in an agricultural environment, one observed breeding attempt in 2015 failed early in incubation, so we resumed the study in 2016. We include observations from

other territories in the study area where they supplement existing published information, and observations on four pairs in 2016 (albeit a small sample size). Observations presented here are novel for the pre-laying, incubation and early nestling periods, or confirm (in previously unstudied pairs) that certain behaviours are typical for the species.

## METHODS

The study area in the Peel Valley near Tamworth (31°05'S, 150°55'E), in the sheep–wheat belt of northern inland New South Wales, extended to the localities of Warral, Bithramere and Bective (up to ~20 km from Tamworth), as described in previous papers (Debus *et al.* 2005; Debus and Tsang 2011; Debus and Zuccon 2013; Charley *et al.* 2014). In the region, the summer of 2015–16 was notably hot and dry, whereas late winter–early spring of 2016 was cold with extended rainy periods.

The observation protocol was as previously described (i.e., focal-animal sampling from an unconcealed position on the ground outside the falcons' alert distance using telescopes and binoculars, occasionally with digital photography). Initially, observations were conducted from approximately 200 metres away, then gradually moved over the next two weeks to approximately 100 metres away when it was clear that the falcons were not alarmed by non-threatening human presence (e.g., from a car used as a hide). Observation distances, and tree and nest heights, were measured with a range finder after nests were vacated.

In 2015, after monitoring the site since April, SD and GM observed the pair at Warral (Pair/Site 1) for 102.5 hours over 31 days from the first observation date of copulation until the last day the male was present (21 July) (Table 1), until the female abandoned the nest. In

the inferred laying phase and start of incubation, daily watches finished at dusk and started at first light (to determine the female's overnight location). We observed for a further 25 hours over the following 10 days from 22 July, spread fairly evenly through daylight hours (3–6 h per day). When a new male appeared in late August, we observed the nest for 18 hours over six days (28 August to 4 September), spread fairly evenly through daylight hours (2–4.5 h per day), until the falcons were out-competed for the nest (see later) and left the vicinity. The new male was readily distinguished by his much paler cheeks than the original male.

In 2016 SD and AB monitored Site 1 from late April, and the airport site (of Debus *et al.* 2005, hereafter Pair/Site 2) by conducting a fortnightly transect from 14 May (a circuit taking in these two sites and a third – see below, and Figure 1 of Bauer and McDonald in press). When a pair was clearly occupying each site, we commenced timed nest-watches (Table 1). The Pair 1 female was apparently the same individual as in 2015 on plumage, behaviour and other characters, and the male apparently the new one of 2015 with pale cheeks. Conversely, the female was the more pale-cheeked sex of Pair 2 (thus, both pairs were somewhat plumage-dimorphic as well as size-dimorphic, enabling identification of individuals when only the head was visible over the nest rim). We observed Pair 2 for 123.5 hours over 25 days, 17 July to 27 August, from the pre-laying (two days) and laying stages (three days) through incubation (20 days) to nest failure at the point of hatching (Table 1). Incubation was inferred from behavioural cues: early in this phase the female visibly rolled eggs beneath her as she settled.

In early August 2016 we found the nest of a pair at Bithramere (Pair/Site 3: the 'Tamworth' site of Charley *et al.* 2014) during the incubation phase, and observed the nest of

a further pair at Bective (Pair/Site 4) from the downy chick stage in mid-September, as follows.

Nest 3: 68 hours over 13 days, 27 August to 13 September, until nest failure four days after hatching.

Nest 4: 28.33 hours over 11 days, 17 September to 13 October, from the end of Week 2 until fledging (Table 1), with casual observations or weekly checks thereafter until the fledgling could no longer be located.

Pair 4 was plumage-dimorphic (male with pale cheeks and 'scaled' upperparts). Hatching at Nest 3 was indicated by behavioural cues: the female (for the first time) took prey to the nest rim, tore food and offered small pieces into the nest cup, and also moved eggshell with her bill. The age of the chick in Nest 4 was estimated from a median fledging age of 40 days (from Charley *et al.* 2014; Whelan *et al.* 2016).

Adult vocalisation types (cackle, creaking call and begging whine) and vocal behaviour are described and quantified, with spectrograms, by Debus *et al.* (2017). Agonistic (inter-and intraspecific) encounters were quantified as the number of separate incidents, within which there could be multiple, repeated swooping attacks by one or both members of a pair of Black Falcons until the episode against a particular intruder finished. Further analysis of interspecific interactions is provided by Bauer and M<sup>c</sup>Donald (in press).

Prey species in ors and regurgitated pellets collected from under the active Black Falcon nests were identified as previously described, and biomass of delivered prey was similarly estimated (e.g. Debus *et al.* 2005; Charley *et al.* 2014). Biomass estimates herein are crude, being heavily biased by unidentified, partly eaten items assigned (on relative size) a mass of 50 g or, for small items, 30 g, as seen delivered to the female or young.

## RESULTS

### *Aerial displays: pre-laying period*

The following sequence was observed through the months and weeks preceding egg-laying, among the various pairs.

- (1) Pair re-formation (?): March, within sight of Site 1 (though 4 km away), a high-soaring female Black Falcon stooped to join a low-circling male, they appeared to track each other, interacting, then as the female closely approached the male he dodged away before they separated, hunting alone.
- (2) Male courtship/advertisement: late May, during synchronised soaring by Pair 1 over the nest area, the male performed a power dive and sharp upswing (V-dive) with exaggerated slow-flapping and canting from side to side at the apex, then repeated the performance, before both glided off together.
- (3) High-aerial agility display: early June, during synchronised soaring by a fifth pair (neighbour of Pairs 1 and 2), the female made a jinking manoeuvre (brief twisting dive below the male) before they departed together.
- (4) Unilateral slow-flapping: mid-June, a Black Falcon (sex unknown) flew with bursts of slow flapping, interspersed with slightly anhedral wings in glide, towards Site 3 (~3.5 km away), like a Brown Falcon *Falco berigora* except for the wing attitude in glide.
- (5) Food offering, Pair 1: mid-June, in the female's absence from the nest area, the male arrived with prey then soared high over the nest area, dangling and picking at the small item in his foot as if offering it for collection.

(6) Low-aerial agility display, Pair 1: in late June, as both perched in the nest tree, the female made a low fast flight out and back to her perch. Then, as both left on a low hunting flight, the male rose above the female with exaggerated slow-flapping flight, apparently after having passed low over her.

(7) Female advertisement display: mid-July, the Pair 2 female left her nest-side perch with bursts of rapid, shallow flapping above the plane of the back ('high winnowing'), soaring with wings held in a slight dihedral (Figure 1), as she circled up to join the high-soaring male.

In newly formed Pair 1 (new male), after a lapse of a month in the female's attendance at the nest or tree, the following behaviours were observed a few days after they were first seen reoccupying the site (late August).

(1) Female courtship: as the male appeared soaring higher overhead, the circling female made sudden random changes of direction and short stoops with deep, slow flapping and banking with wings held well forward, then flew rapidly to the nest and peered up at the male (K. Fisher pers. comm.).

(2) Male low-aerial agility display: as an intruding Brown Falcon flew past their territory, the pair arrived and the male flew with exaggerated slow-flapping, canting from side to side as he briefly followed the retreating Brown Falcon, before diving into a tree then flying onto the perched female's back (on the adjacent dead tree) to copulate.

#### *Aerial displays: incubation period*

Several times in the incubation period the Pair 2 female left the nest to perform the 'high winnowing' aerial display, with loud cackling, in the direction of a Wedge-tailed Eagle *Aquila audax* that approached within about 400 metres, and in circuit(s) of the nest site, with

long bouts of creaking calls on the nest or branch, as an intruding female Black Falcon circled over the nest area. The Pair 3 incubating female performed this display flight below a soaring Peregrine Falcon.

### *Nest sites and spacing*

The stick nest of Pair 1 was in the top of a living emergent eucalypt (Table 2). The nest was in one half of the double-trunked tree, and was the vacant (2014) nest of a pair of Australian Ravens *Corvus coronoides*; the other half of the tree contained an older (2013) nest of the ravens, which continued to occupy the area.

The nest of Pair 2 was also built by Australian Ravens (in winter 2015); it was similarly high in the top third of a living, emergent eucalypt. The nest trees of both pairs were located in creekline remnant woodland amid flat to gently undulating agricultural land (cropping and grazing), 80 and 125 metres from public roads, respectively.

The nest of Pair 3 in 2016 was near the base of the dense canopy of a mature remnant eucalypt in sparse paddock woodland, on a low rise upslope from the creek-flat woodland site of 2010 (Debus and Tsang 2011) and 400 metres from roads. Australian Ravens had built and defended (against Black Falcons and Brown Falcons) a nest in this tree in 2013 (SD pers. obs.).

The stick nest of Pair 4 was situated in a Box Mistletoe *Amyema miquelii* in the crown of a eucalypt in an extensive stand of woodland (travelling stock reserve) on a gentle rise from, and contiguous with, the wooded flats of the Peel River, and 117 metres from a minor



backroad. This nest was apparently built by ravens, which had older nests and an active nest in the area.

All four nest sites had emergent or horizontal dead branches in the nest tree and/or surrounding trees, and dead trees within 100 metres, all used by the falcons for perching, mating, prey transfers/consumption and nest-guarding. Nest 2, and part of the tree, were destroyed by a storm in December 2016. The respective limbs supporting Nests 1 and 3 had broken off, and Nest 4 had disintegrated, by July 2017.

Inter-nest distances among all four pairs in 2016 (which appeared to be nearest neighbours to one another) averaged 10.25 kilometres (range 9–12 km). The former nest site of another pair, known to have bred in past years, was also 10.5 kilometres from each of Pair 2 (active nest at the time) and the 2016 nest of Pair 4. All three near-roadside nests were readily visible to the human observer.

### *Nest occupation*

In 2015, Pair 1 occupied the nest site three months before egg-laying (in mid-July): the male initially perching in the nest tree or standing on the nest, and the female joining him in the tree through April–May. The pair frequently occupied the site from mid-May and were seen copulating in the tree from 22 May. From this stage (early June) the male also ‘advertised’ the nest to her, for example: as they arrived together (female with prey or full crop to her perch in the tree), he alighted on the nest and gave creaking calls from it; or (female or both perched in the tree) he flew to the nest and gave creaking calls or sat in it, before copulating at her perch. The female occupied the nest tree and increasingly the nest

from mid-May to early July as laying approached, thus complementing the male's declining attendance of the nest and tree over that period (Table 3).

In 2016, Pair 1 first appeared in the nest tree in late April and the male stood on the nest in mid-May. They were often absent, appearing occasionally through June and early July, until frequenting the nest site and copulating from mid-July, and in late July repeating the behaviour described above for June or a variant thereof (male to branch; female, creaking, to nest). However, after conflict with ravens nesting in the same tree (see below), they were last seen defending the nest and tree and copulating in the tree on 23 July, after which they abandoned the site.

### *Courtship*

Early in the pre-laying weeks at Site 1 in 2015, the pair frequently departed on co-operative hunting flights. Typically, the male left first and the female followed immediately or within a few minutes and readily located him, as they often returned together with a prey item or full crop(s) (crop distension being clearly visible).

In the pre-laying weeks in 2015, courtship (supplementary) feeding took the form of apparent enticement of the female to the nest. For example, in mid-June the male brought prey to the nest, whining softly, and gave it to her, bill to bill, when she joined him there (from her perch in the tree); in late June they arrived together at the nest and he gave her prey there, amid creaking calls, before she took it with whining calls to her perch; in early July this behaviour was repeated, though with frequent female begging (whining) before and after the exchange.

In the pre-laying weeks the female appeared to gorge on the male's kills, being frequently seen with a full crop, feeding on his next delivery while still so engorged, or feeding on his next delivery immediately after having finished the previous one. They also cached surplus food during this phase, and the male sometimes departed on a hunting flight with a full crop.

The female was first seen visiting the nest unelicited (in the male's absence) three weeks before laying: in mid-June for four minutes with creaking calls, leaning into the nest and sitting in it, but thereafter (from early July) at increasing frequency and duration. For example, in early July she spent 8–10+ minutes sitting and shuffling in the nest with soft chittering, clucking or 'ticking' calls, or creaking as the male arrived in the tree, and she frequently whined in long bouts from her perch in the tree. On 3 July she sat in the incubation posture for 45 minutes, and on 6–7 July for up to 1.3 hours (after eating the male's prey), sometimes nibbling or pushing sticks on the rim. The first egg appeared to be laid on 7 July, and from that date the male transferred prey at their perch in the tree. The clutch appeared to have been completed (or nearly so) on 13 July when the female incubated overnight for the first time, although copulation continued for a further five days.

The new male also offered food at the nest: a few days after he arrived (in August) and after synchronised soaring by the pair, he took prey to the nest and held it there for five minutes before eating the prey (initially on the nest, then in the tree) when the female failed to arrive (K. Fisher pers. comm.).

In 2016 in the pre-laying phase at Site 2, both members of the pair shared a large prey item side by side on their feeding perch: as one (apparently the female) held the prey in its foot, both took and ate pieces until the female (with full crop) went to the nest-side branch in the adjacent tree while the male finished the prey.

### *Copulation*

In 2015 mating was observed in late February, at Site 2: after soaring together, the female of the pair landed in a tree, the flying male alighted directly on her back and they copulated with whining calls, within about 200 metres of the subsequently built raven nest. A female Black Falcon was first seen perched beside this nest in early July 2016, and from mid-July the pair was observed occupying the nest.

In 2015 Pair 1 started copulating on their favourite perch (a horizontal dead branch) in the nest tree almost seven weeks before laying. In May–June they were observed to copulate on five days, 0.18 times per hour over 15 days 22 May to 29 June ( $n = 49.5$  h). In July they were observed to copulate 0.24 times per hour (on eight days) over 14 days 2–18 July, almost daily over the inferred laying period to start of full-time incubation (6–13 July) ( $n = 45$  h). During our fairly even observations across two-hour blocks of daylight, including three all-day watches and three half-day watches, the falcons typically mated in early to mid-morning and in mid to late afternoon, rarely in late morning (once, 18 July, after repelling an intruding pair of Black Falcons). Timed copulations increased in duration through June (2–3 sec early,  $n = 2$ ; 4–5 sec in mid to late June,  $n = 2$ ) to the inferred laying phase in early to mid-July (10–11 sec,  $n = 5$ ). The female invited copulation with a head-low bowing posture and creaking calls, and the male typically alighted directly on her back from flight, balancing with flapping

wings. In May, copulation was accompanied by creaking calls or creaking and whining calls together (sex-roles undetermined). In June and July, copulation was accompanied by whining calls by the female, which sometimes gave creaking calls as the male dismounted, and once by creaking calls (July, apparently by the male) as she whined.

In 2016, at the nest re-establishment stage (17–23 July), matings by Pair 1 were accompanied by creaking calls (by the female) or creaking and whining calls together (apparently by the female and male, respectively). They mated three times in 12.75 hours (= 0.24/h). In the week leading up to laying, Pair 2 copulated in the nest tree and adjacent tree twice in 10.75 hours (= 0.19/h). During one post-laying copulation by Pair 2, four days after full-time incubation commenced, the male alighted on the female's back as she was eating his prey on a branch of the nest tree; brief mating ensued with whining then creaking calls apparently by the female.

### *Breeding chronology*

In 2015 the Pair 1 female appeared to lay eggs over the period 7–13 July (consistent with a clutch size of 3–4 and laying on alternate days, e.g. Marchant and Higgins 1993). In 2016 the Pair 2 female appeared to complete laying over the period 23–26 July, and the Pair 3 female appeared to be incubating by 6 August, with hatchling(s) on 10 September. Nest 4 was occupied by 28 July and the juvenile fledged on 14 October; assuming a nestling period of six weeks and incubation period of five weeks (from previously recorded values), hatching occurred in early September and laying in late July.

### *Roosting*

During the inferred laying phase of 2015, the Pair 1 female roosted in a leafy eucalypt canopy within about 50 metres of the nest tree. The male was once seen going to his roost, at dusk, in a different leafy eucalypt (also ~50 m from the nest tree). The day after she abandoned her clutch, on a rainy evening the female was on her favourite perch in the nest tree then at dusk retreated to a more sheltered position against the trunk, in the lee of the wind and rain.

During the incubation phase of 2016, the Pair 2 male sometimes arrived to roost in the nest tree at dusk. Similarly, the Pair 3 male sometimes roosted in the nest tree at dusk, and on one frosty morning he did not rouse and leave to hunt for two hours after sunrise.

#### *Interspecific interactions and defence*

In the pre-laying phase to start of incubation in 2015, most defensive attack bouts (71%) by Pair 1 were directed at other similar-sized raptors that might use a stick nest of raven size or larger (Table 4). Nevertheless, one or both of a pair of Australian Hobbies *Falco longipennis* occasionally visited the falcons' nest or tree, in the falcons' absence, from early May. Also in the falcons' absence, a pair of Spotted Harriers *Circus assimilis* briefly visited the older raven's nest in the other half of the tree until repelled by the pair of ravens, neither event prompting return or defence by the falcons. On one occasion (falcons absent) a raven also perched low in the tree without eliciting a response. However, in 2015 the ravens apparently nested in another tree about 400 metres away, and both repelled the female falcon when she approached it. The female Black Falcon performed most of the 14 defensive attacks

(64%, plus one by both falcons together), including one on a Sulphur-crested Cockatoo *Cacatua galerita* that was on the falcons' nest, pulling out and discarding material.

Between nesting attempts by Pair 1, during the month the nest was unattended by the falcons, the pair of hobbies claimed the nest, and by the time the falcon pair (new male) attempted to reuse the nest, the pair of hobbies defended strongly and together routed the female falcon when she tried to visit the nest. The falcons then went elsewhere (breeding attempt or success unknown), leaving the hobbies to successfully raise a brood.

From the pre-laying period to the post-fledging period in 2016 (all pairs combined), most defensive attacks on other birds by Black Falcons were directed at Wedge-tailed Eagles (41%) and Australian Ravens (32%), followed by other raptor species (18%) and other bird species (9%;  $n = 44$ ), the last being chased from the nest tree or nearby (Table 4). Females performed most of the defensive attacks (80%), with some jointly by both members of a pair (16%, on ravens and especially eagles), and the balance by the male (5%, on ravens). The hourly rate of attacks on ravens was greatest in the pre-laying (i.e. nest establishment) phase (0.10 attack/h,  $n = 31.5$  h), versus the laying and incubation periods (0.05/h,  $n = 163$  h) and nestling period (0.04/h,  $n = 51.33$  h). The hourly rate of attacks on Wedge-tailed Eagles was greatest in the falcons' nestling period (0.18 attack/h, vs 0.04/h in the laying/incubation period and none in the pre-laying phase). An incubating female falcon also cackled at soaring Wedge-tailed Eagles without leaving her nest or feeding perch, and other females also arrived, sometimes cackling, at their respective nest or guard tree when an eagle flew or soared near the nest with chick(s). One or both members of a falcon pair effectively routed eagles, causing them to retreat, sometimes rolling and parrying the falcons' stoops. In the

post-fledging period, a strongly defending female falcon briefly grappled feet with a flying raven.

In the pre-laying phase, interactions between Pair 1 and ravens took the form of skirmishes over the nest tree, when the ravens built a new nest in the other half of the double-trunked tree. Both ravens together routed the male falcon when he attacked them at their new nest, but the pair of falcons in concert had the ravens retreating (female raven to her new nest where she sat tightly); nevertheless, the falcons abandoned the site when the ravens started incubating in the new nest.

#### *Intraspecific interactions*

In 2015, during the first breeding attempt by Pair 1, there was one observed intrusion by a pair of Black Falcons. The incubating female stood, creaking in long bouts, then left, creaking, to join the male in a long (1 min), weaving and diving chase of the intruding pair through the nest patch and around the nest tree. The female, creaking, and male returned to the nest tree as the intruders retreated; the male then incubated. During the second nesting attempt (new male), the female flew to the nest with a long creaking bout as the male glided past high overhead, followed by an intruding female, until both were out of sight.

Throughout the breeding cycle in 2016, single intruding Black Falcons appeared in the territory of each of the four breeding pairs, at a rate of 0.05 intrusion per hour in the pre-laying phase (Pair 1,  $n = 40.75$  h), 0.03 per hour in the laying/incubation period (Pairs 2 and 3,  $n = 163$  h) and 0.04 in the nestling period (Pairs 3 and 4,  $n = 51.33$  h). Two intrusions at Site 1 (pre-laying period) involved the pair skirmishing aerially with a third falcon, with



chasing, stooping and display flights. Three intrusions by a female falcon at Site 2 involved (a) the breeding female directing a display flight ('high' winnowing and dihedral, as in 'Aerial displays', above) with creaking calls at the high-soaring intruder; (b) the female chasing and attacking the intruder in flight, causing it to fend her off with its feet, followed by a display flight (as above) (Figure 2); and (c) both members of the pair creaking from the nest and branch then soaring, the female performing two curving V-dives then creaking while diving at and fighting (grappling briefly) with the intruder, which whined with a squealing quality while under attack. The female continued chasing and stooping at the intruder until high and distant, pursuing it with slow flapping and canting (the male meanwhile incubating).

Two intrusions at Site 3 involved (a) both falcons chasing the intruder, the female breaking off with creaking calls to return to the nest while the male continued the pursuit; and (b) the male flying below the intruder and cackling, while the incubating female creaked from the nest. Two intrusions at Site 4 in the nestling period involved (a) opportunistic piracy by the intruder after the male had given prey to the breeding female, after which the female chased and grappled with the intruder (to the ground) and the male then chased it, cackling, although the intruder retained the prey; and (b) one of the pair attacking the intruder with creaking calls, attempting to grapple, until all three continued the chase out of sight.

### *Incubation*

In 2015 the Pair 1 female gradually increased her incubation time over the inferred laying period, from stint(s) of 11 minutes on 7 July to 49 minutes on the 9th, 62 and 42 minutes on the 10th, and 35+ minutes on the 11th. She incubated in the mornings (perhaps when laying, as suggested by her behaviour) but not in the afternoons, when she was either

on the nest rim or in the tree. On the 15th she stepped carefully into the nest and visibly shuffled down on eggs. Over the first six days from inferred clutch completion she incubated for 62 percent of percent of daylight observation time ( $n = 21$  h), and was otherwise on the nest rim (17%), in the tree (20%, sometimes feeding on the male's prey) or flying (1%, in absences of ~2 min). Six timed complete stints averaged 47 minutes (range 18–109 min, with others of up to >75 min). The male incubated for one stint of one minute, after the clash with the intruding pair of Black Falcons (see above); his stint was interrupted by chasing a Black Kite *Milvus migrans* that approached the tree, after which he stood on the nest for six minutes. During the laying phase and early incubation he attended the nest tree for 40 percent of daylight observation time ( $n = 45$  h) and stood on the nest for 1 percent (incubating once, as above).

After the intense clash with the intruding pair (see above), the female incubated for only one-third of the remainder of that day (7.5 h) in short stints (2–66 min, mean 18 min,  $n = 8$ ) and spent the afternoon perched on the remains of the male's prey delivery, which she cached at dusk then visited the nest briefly but roosted in a neighbouring tree (as did the male) until it was too dark to see if either went to the nest. Two and three days later the pair appeared to have resumed normal roles, but she then ceased incubating when the male disappeared (presumed dead or injured, although no Black Falcons passed through the local wildlife carer network at the time: S. Pullman pers. comm.). On his first absence day the female retrieved a food scrap from her cache tree and robbed a hobby of prey she saw it catch, and otherwise perched all day in the nest tree (where she roosted that night). Over the next two days she foraged for herself, returning to the nest tree between sorties, until she abandoned the site.

In 2016 incubation was only partial during the laying stage of Pair 2 (consistent with other *Falco*, e.g. Marchant and Higgins 1993), and in both pairs (2 and 3) the male took only a minor share throughout the incubation period (Table 5). The small difference between the sexes' relative contributions in the two pairs (Table 5) appeared to be related to weather: the Pair 2 female left her clutch near hatching after several days of cold wind and rain, when (by her begging) she was also hungry and was often absent, apparently hunting; meanwhile, the male (when present) covered the eggs in her absence, but they ultimately abandoned the clutch. Overall, eggs were uncovered for 7–8 percent of daylight observation time (both pairs, before the Pair 2 female abandoned her eggs), occasionally in periods of up to an hour, though usually 1–14 minutes, commonly 1–6 minutes, unless the female was feeding on the male's prey. Females sometimes interrupted incubation stints with perching on the nest branch, short circuitous flights around the nest tree, or display or defence flights against intruders.

Throughout the incubation period, the Pair 2 female incubated for timed complete stints of 1–146 minutes (mean 47 min,  $n = 53$ ), and the male for stints of 5–123 minutes (mean 34 min, usually 5–16 min,  $n = 7$ ). There were also many occasions on which the female incubated beyond the start or finish of watches (or both), for periods of up to more than an hour or even 2.5 hours.

In the final fortnight of incubation, the Pair 3 female incubated for timed complete stints of 6–200 minutes (mean 64 min,  $n = 9$ ), and the male for one observed stint of seven minutes. There were also several occasions on which the female incubated beyond the start or finish of watches (or both), for periods of up to more than two or even 3.5 hours.

During incubation changeovers, the male typically relieved the female after she had collected his prey (usually in the nest tree or surrounding trees, though once the male brought prey to the nest), and then the returning female (having fed on a nearby branch) simply displaced him from the nest or he left as she approached with cackling. On one early morning at Nest 2, the male went to the nest rim but the female remained incubating and he retreated. Half an hour later he approached and incubated while the female left and perched for an hour elsewhere in the nest patch; he remained as she then returned and perched, whining, on the nest branch for the next hour until she finally displaced him and he left, hunting.

From behavioural cues at Nest 3, inferred incubation on 6 August, incubation on 8 September and hatchling(s) on 10 September gives a minimum incubation period of  $34 \pm 1$  days.

#### *Nestling period: parental behaviour*

The male of Pair 3 performed a minor share of brooding the chicks in their first few days, but from the end of Week 2 through Week 3 of the chick stage only the female of Pair 4 brooded, for a minor proportion of daylight observation time (Table 5). In Week 1 the Pair 3 female brooded for timed complete stints of 6–284 minutes (mean 75 min,  $n = 10$ ), and the male for two observed stints of four and six minutes. There were also several occasions on which the female brooded beyond the start or finish of watches (or both), for periods of up to more than an hour or two. During brooding changeovers, the female collected the male's prey and he brooded until either she brought the prey to the nest and he moved aside into the nest tree, or he rose and defended her against mobbing birds while she fed in the tree. The chick(s) were left unattended for 8 percent of daylight observation time; the female's absences from

the nest were usually short (1–12 min, commonly 1–3 min), but extended to 13–43 minutes when she foraged and/or fed on prey off the nest. She foraged from early in the chick phase: on Day 1 she left for 43 minutes and returned with prey (from the opposite direction to which the male had earlier departed) and fed the chick(s); and on Day 4 the pair hunted cooperatively before she returned with and fed on their captured prey, and on the male's next two deliveries that morning as well, without feeding the chick(s). Nest failure appeared to be related to cold, wet weather in Week 1 and consequently depressed hunting success, when the female was clearly hungry because she fed herself instead of the chick(s).

In the latter half of Week 3 the Pair 4 female brooded for timed complete stints of 8–36 minutes (mean 18 min,  $n = 5$ ) and one stint (on *c.* Day 19) of more than 26 minutes; the final observed stint (on *c.* Day 22) was for 16 minutes in cold, wet weather. In Week 3 the chick was attended for only 14 percent of daylight observation time. Otherwise, from Week 3 onwards the parent(s) if present, usually the female, guarded the chick from nearby perches or by soaring overhead (Table 5). In Weeks 2 to 4 the male delivered prey to the female, which then fed the chick bill to bill; in Week 5 the female stood on the nest while the chick fed itself on prey, and the male carried food towards the nest as if to deliver it in the female's absence. From the end of Week 3 (*c.* Day 21) the female started foraging with the male (though not seen to be successful).

#### *Nestling period: development of young*

On *c.* Day 14 the Nest 4 chick was downy and, during parental feeding, picked at prey in the nest with its bill. On Day 19 it was large and downy with dark feathering around its eyes, and occasionally fed itself during parental feeding. On Days 20–21 its remiges and

rectrices were emerging through its down; it was active, standing but overbalancing; it stretched and flapped its wings, and pecked at nest material in apparent object play. On Days 32–33 (5–6 October) it was mostly feathered, with well-grown primaries and tail, and fed itself on prey in the nest. On Day 40 (13 October) it was fully feathered, had lost its down (except under the wings), and fledging appeared imminent.

### *Fledging*

The Nest 4 juvenile left the nest (on 14 October), but then suffered misadventure. It was found on the ground next morning, unable to fly (Figure 3), and was thin (prominent sternum) and underweight (470 g, cf. mean for male Black Falcons 582 g: Debus and Olsen 2011). It was taken for veterinary assessment; the only signs of illness or injury were minor soft-tissue damage (thickening) on one shoulder, suggesting impact or strain injury. A male on relative size and bill massiveness against its parents, it was metal-banded (band supplied by the ABBBS) and released at the nest site at 593 grams after 10 days in care and recovery of flight.

### *Post-fledging period*

Three and four days post-release, the Site 4 juvenile had adopted a vacant stick nest about 600 metres from its natal nest, and was being defended and fed by its parent(s). A week later it occupied the adults' food-caching tree about 500 metres from its natal nest, sometimes making short flights, and was being fed and guarded (e.g., on one occasion both parents soared up from the cache tree, on another the female flew over, while the juvenile was perched in the tree). It was sometimes seen in that tree up to five weeks post-fledging, when

its band was sometimes visible by telescope (including on the last sighting). In the interim it gained in competence and appeared well fed. It was not located six weeks post-fledging (when its mother defended the nest woodland against a Wedge-tailed Eagle, suggesting it was possibly there somewhere), and neither juvenile nor adults could be located a further week later, suggesting it had become independent or nearly so.

### *Breeding productivity*

One fledgling from three breeding attempts for which the outcome was known gives 0.33 young fledged per pair in 2016. However, without human intervention at Nest 4 the outcome would have been no young raised to independence from those three pairs. There was also no evidence that Pair 1 raised young to fledging from an alternative nest in 2015 or 2016. Success for four known breeding attempts in 2015–16 gives 0.25 young fledged per attempt (albeit a small sample from a limited area).

### *Hunting and prey*

In 2015, early in the pre-laying phase (late April), Pair 1 plus two Australian Hobbies, at least four Nankeen Kestrels *Falco cenchroides* and two Brown Falcons all hawked for swarming flying insects in a thermal column on a warm afternoon. Otherwise, all identified prey items of Pair 1 were avian (Table 6). Similarly, all identified prey items in 2016 were avian (96%) except for one rodent (4%), although a few insects appeared in a minority of pellets during the breeding cycle (Table 6) and, being small, may have been in the stomachs of prey. In 2016, seven intact pellets measured 30.7–39.7 × 15.3–23 millimetres (mean 34.7 × 18.9 mm), and eight pellets weighed 1.3–2.7 grams (mean 2.2 g).

In 2015 and 2016 seventeen attacks on prey (including three cases of kleptoparasitism) were observed (see Figure 4). Almost all observed attacks on prey were shallow, direct flying attacks initiated, apparently opportunistically, from perches in or near the nest tree, at prey on the ground or in the tree canopy (Table 7), although these were biased (and limited) by the observers' nest-watching positions. Five of 14 attacks by breeding adults on avian prey succeeded (36%).

### *Feeding rates*

From the pre-laying phase to early incubation in 2015, the male of Pair 1 delivered or provided (including prey shared or transferred en route to the nest tree in the pre-laying phase) 0.14 prey item per hour, of which one small item (~30 g, pre-lay) was not collected by the female, and he brought an additional item (also pre-lay) that he did not share with her. This rate approximated to a roughly estimated 11 grams per hour of prey biomass provided, to which the female added one kill of her own to approximate 12 grams per hour of observed intake. Excess prey was cached either in a branch fork of the nest tree or in the horizontal hollow limb of a live eucalypt about 50 metres from the nest tree, and was retrieved from both sites.

In the pre-laying period at Nest 2 in 2016, the male's prey-delivery rate to the female was 0.29 item/h (estimated biomass 19 g/h). In the incubation period, his delivery rate was 0.15 item/h (biomass ~9 g/h), to which the female added one observed kill of her own (making ~10 g/h intake). In the incubation period at Nest 3, the male's delivery rate was 0.09 item/h (~4 g/h). In Week 1 of the chick phase the parental delivery rate was 0.26 item/h (~28



g/h), but the female consumed much of it. In Weeks 2–4 of the chick phase at Nest 4, the parental delivery rate was 0.23 item/h (~25 g/h), of which one item was lost to piracy before it could reach the nest (effective rate 0.19 item/h, ~23 g/h). Prey transfers usually took place in the nest tree or neighbouring trees, or sometimes aerially as the male approached the nest site, and in one case the female started plucking the prey in flight en route to the nest tree. Pair 4 had one known cache tree, a large living eucalypt (see ‘Post-fledging period’, above), but the nature of the cache site was not determined.

### *Reaction to disturbance*

Pair 1 did not overtly respond to routine farm activity, road traffic and helicopter flights near the nest tree, although the pre-laying female became alert and flushed when the farmer, pushing logs with a small bulldozer, approached to about 50 metres. Incubating Pair 2 (off the airport runway) did not overtly respond to low overflights by light aircraft, and the grading and gravelling of the nearby road. The female at Nest 3, located farther from regular human activity, flushed off hatchling(s) as the farmer, riding a motorbike down the fenceline, drew level with the nest tree (~200 m away). Pair 4, nesting even farther from regular human activity, flushed from the nest area if approached within about 120 metres by people on foot.

## **DISCUSSION**

### *Displays, courtship and mating*

The Black Falcon’s aerial displays, including diving, exaggerated slow-flapping and canting display flights (by both sexes), are similar to the ‘undulatory roll’ and other aerial

displays of the Gyrfalcon *Falco rusticolus* and Lanner Falcon (both are hierofalcons; see Potapov and Sale 2005; Leonardi 2015; Black Falcon: Debus *et al.* 2005; Debus and Tsang 2011; Whelan 2013; Charley *et al.* 2014; Whelan *et al.* 2016; this study). Aerial displays, courtship (e.g., supplementary feeding) and mating behaviour confirm and expand on previous accounts (Debus *et al.* 2005; Debus and Tsang 2011; Whelan *et al.* 2016), and are similar to those of other hierofalcons and large falcons in general, e.g. Peregrine (allowing for stick nests rather than ledge nests) (cf. Cade 1982; Ferguson-Lees and Christie 2001; Potapov and Sale 2005; Leonardi 2015).

### *Agonistic interactions*

Interspecific conflicts were similar to those described in previous accounts (Charley *et al.* 2014; Whelan *et al.* 2016; see also Bauer and M<sup>c</sup>Donald in press) and appear to be related largely to nest-site selection and competition with other falcons and corvids for nest sites, and defence of nestlings against large raptors (as for other hierofalcons, e.g. Potapov and Sale 2005; Leonardi 2015). Defensive actions were similarly variable in intensity, as for the Grey Falcon (Ley and Tynan 2016). The frequency of intraspecific conflicts suggest a floating population of Black Falcons in the study area, and some competition for breeding territories.

### *Breeding biology and behaviour*

This study reaffirms and extends findings for the study area and elsewhere on the Black Falcon's nest-sites characteristics: tall or emergent eucalypts in lower, flatter parts of the landscape, including lower slopes above riparian zones, and dead trees near the nest tree (e.g. Debus *et al.* 2005; Debus and Olsen 2011; Debus and Tsang 2011; Charley *et al.* 2014;

Whelan *et al.* 2016). Nest trees on lower slopes suggest a broadening of the search criteria for future studies. Inter-nest distances also confirm and extend previous local data (Debus and Tsang 2011), but there is little to compare elsewhere in the sheep–wheat belt. Breeding chronology at Tamworth confirms early breeding (nest occupation in April, laying in mid-winter) in south-eastern Australia (also Charley *et al.* 2014; Whelan *et al.* 2016), perhaps an evolutionary response to nest availability ahead of the corvid breeding season.

This study confirms, although still with limited quantification in the early nestling period, the male's minor role in incubation and brooding, and the decline in maternal nest attendance with chick age, as may be expected and in accordance with the Peregrine, hierofalcons and Grey Falcon (e.g. Turner *et al.* 1993; Potapov and Sale 2005; Leonardi 2015; Ley and Tynan 2016). It also supports an estimated incubation period of 34 days for the Black Falcon (Cupper and Cupper 1980), although this value could bear confirmation, but is similar to that of the Grey Falcon (~34–35 days: Ley and Tynan 2016) and Peregrine (33 days: Marchant and Higgins 1993).

Growth of the Pair 4 chick agrees well with prior data (Charley *et al.* 2014; Whelan *et al.* 2016), and supports its estimated age at fledging and the estimated hatching date. The juvenile's behaviour and development in the post-fledging dependence period were consistent with prior knowledge (Charley *et al.* 2014; Whelan *et al.* 2016), but its progress was influenced by human intervention. After rehabilitation it was successfully reunited with its parents, which resumed feeding and defending it.

Black Falcon productivity and recruitment are low in the study area (Debus 2015b), compared with productivity for this species elsewhere, and for other Australian falcons (cf.

Debus 2012a; Charley *et al.* 2014; Whelan *et al.* 2016). Combining our 2016 data gives a total of only four successful nests out of 10 monitored attempts (40%) since 2004, from which only five or six young fledged (0.5–0.6 per attempt) and at least one juvenile, perhaps up to three, failed to reach independence. Without rescue, the 2016 fledgling would also have failed to reach independence.

### *Foraging ecology*

The Black Falcon's breeding diet (mostly birds) at Tamworth in 2015–16 was similar to that in previous years, and to that elsewhere in agricultural landscapes of south-eastern Australia (cf. Debus *et al.* 2005; Debus and Olsen 2011; Debus and Tsang 2011; Charley *et al.* 2014; Whelan *et al.* 2016), but contrasts with the higher proportion of mammals taken in arid and tropical Australia (Marchant and Higgins 1993; Corbett *et al.* 2014). Pellet size and mass were within the previously recorded range (cf. Debus *et al.* 2005; Charley *et al.* 2014; Corbett *et al.* 2014; Whelan *et al.* 2016). Collectively, the various samples potentially provide diagnostic criteria for Black Falcon pellets versus those of some other raptors; further systematic collections may provide an index of food intake when calibrated by feeding trials on captive birds.

Hunting behaviour was consistent with previous observations on the falcon's search and attack methods, allowing for the nest-site focus of the observers (cf. Debus *et al.* 2005; Debus and Tsang 2011; Debus 2012b; Debus and Zuccon 2013; Charley *et al.* 2014). Combining our 2015–16 data with a larger sample (Debus 2015a; Whelan *et al.* 2016) gives a hunting success rate of seven of 35 attacks on birds (20%) and nine of 37 attacks on vertebrates (24%), but includes falcons of unknown age and social status. Weather-affected

feeding rates and biomass provision at the hatching stage and for a single nestling were lower than for older nestlings and larger broods, respectively, in other studies (cf. Debus *et al.* 2005; Charley *et al.* 2014), and may have been implicated in nest failure at Site 3 and the poor condition of the fledgling at Site 4 (cf. Brown Falcon and Peregrine Falcon: McDonald *et al.* 2004; Robinson *et al.* 2017). The use of caching appears related to food supply and hunting success (cf. the high rate of caching, and the abundant prey and large brood size in the study by Charley *et al.* 2014), but deserves investigation.

### *Conclusions*

The breeding biology and behaviour and foraging ecology of the Black Falcon are now well known in general terms, although the incubation period and parental time-budgets in the early nestling period could bear confirmation. Diet composition, feeding rates and biomass provision deserve investigation in relation to prey abundance, and further data are required on hunting success. The falcon's reactions to human activities suggest that, although some pairs habituate to routine farming and other practices, those nesting in secluded woodland may be warier and adversely affected by sudden novel, major disturbances. Future research could usefully focus on population aspects, e.g. long-term monitoring of breeding density, nest occupation and breeding success, and to home range, habitat use, dispersal and movements, using banding, colour-banding and telemetry.

The Black Falcon is now listed as *vulnerable* in New South Wales. Its main problems in the sheep-wheat belt appear to be loss of tall eucalypts in degraded riparian zones and sparsely treed paddocks; loss of nest sites to storms and abundant, competing corvids; and collisions with vehicles and human infrastructure (Zuccon 2014; Debus 2014, 2015b; this

study). All these factors appear to be contributing to its low breeding productivity and recruitment, so part of a recovery strategy might include provision of artificial nest sites, and hack-release of captive-bred offspring from unreleasable injured falcons that are currently euthanased (Debus 2015b). These topics at least deserve discussion and a review of government policy. Some aspects of habitat management in the agricultural zone, and competition with a thriving Peregrine Falcon population, may also be relevant (cf. Lanner Falcon: Sarà 2014; Sarà *et al.* 2016).

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Figure captions:

**Figure 1.** *Pair 2 female Black Falcon performing 'high winnowing' display with dihedral towards intruding raptor, incubation period.*

Photo: Keith D. Fisher

**Figure 2.** *Pair 2 female Black Falcon fighting with intruding Black Falcon, incubation period.*

Photo: Keith D. Fisher



**Figure 3.** *Site 4 fledgling Black Falcon on its fledging/rescue day (see text); nest tree in left background.*

Photo: Alice Bauer

**Figure 4.** *One of the Tamworth Black Falcons hunting feral Rock Doves, May 2016.*

Photo: Michael Perkins.

**Table 1**

Observation schedule (hours of observation) at Black Falcon nests, Tamworth (NSW), during each two-hour interval of daylight: pre-laying phase to egg-laying or early incubation period (Nest 1, May–July 2015); laying and incubation period (Nest 2, July–August 2016); incubation and hatchling stage (Nest 3, August–September 2016); and nestling stage (Nest 4, September–October 2016, see text for locations).

<08:00	08:00–10:00	10:00–12:00	12:00–14:00	14:00–16:00	>16:00
<b>Nest 1:</b>					
11.5	19.5	18.5	18	20	17
<b>Nest 2:</b>					
9.75	14.5	20.67	30.58	27.5	20.5
<b>Nest 3:</b>					
8.75	11.25	9	15.5	13.5	10
<b>Nest 4:</b>					
4.5	3.75	4	7	5.75	3.83

**Table 2**

Nest-site characteristics of four Black Falcon pairs, Tamworth district (NSW), 2016. For tree species, YB = Yellow Box *Eucalyptus melliodora*; WB = White Box *E. albens*; GB = Western Grey Box *E. microcarpa*. For position in landscape, 'creek' = creekline or creek flat; 'No' = lower slope. 'Dead trees' = dead trees/dead branches in vicinity of nest, used by falcons.

Nest #	Tree sp.	Tree ht (m)	Tree dbh (cm)	Nest ht (m)	Creek	Dead tree(s)
1	YB	30	167	28	Yes	Yes
2	YB	27	81	23	Yes	Yes
3	WB	24	123	19	No	Yes
4	GB	23	60	20	No	Yes

**Table 3**

Occupation of Black Falcon nest and (separately) the nest tree (% daylight observation time), pre-laying phase (May–July 2015), Tamworth (NSW, Site 1). First half of pre-laying period = 22 May–19 June ( $n = 10$  observation days); second half = 20 June–6 July ( $n = 8$  observation days; start of laying inferred to be 7 July). Hours of observation in parentheses.

	May–June (30 h)	June–July (28 h)
<b>Male:</b>		
Nest tree	19	10
Nest	5	1
<b>Female:</b>		
Nest tree	35	28
Nest	2	9

**Table 4**

Responses of breeding Black Falcons to other bird species intruding in the breeding territory or nest tree (within ~400 m): defensive attack bouts by Falcons (*n*), and instances of intrusion eliciting no defensive attacks (= Nil), falcons' pre-laying phase to start of incubation (Pair 1, 2015) and pre-laying phase to post-fledging period (all pairs combined, 2016). The non-raptors were all in or within 50 m of the nest tree.

Species	2015		2016	
	<i>n</i>	Nil	<i>n</i>	Nil
Black Kite <i>Milvus migrans</i>	3 <sup>A</sup>	2	1	4
Whistling Kite <i>Haliastur sphenurus</i>	1	2	2 <sup>A</sup>	1
Brown Goshawk <i>Accipiter fasciatus</i>		2	2	3
Spotted Harrier <i>Circus assimilis</i>	1	3		1
Swamp Harrier <i>Circus approximans</i>				1
Wedge-tailed Eagle <i>Aquila audax</i>			18	7 <sup>B</sup>
Little Eagle <i>Hieraaetus morphnoides</i>		2	1	1
Nankeen Kestrel <i>Falco cenchroides</i>	1	2		2
Australian Hobby <i>Falco longipennis</i>	2 <sup>A</sup>	2		7
Brown Falcon <i>Falco berigora</i>	2	1		7
Peregrine Falcon <i>Falco peregrinus</i>		2	2	
Little Corella <i>Cacatua sanguinea</i>			1	
Sulphur-crested Cockatoo <i>Cacatua galerita</i>	2		1	
Red-rumped Parrot <i>Psephotus haematonotus</i>	1			
Laughing Kookaburra <i>Dacelo novaeguineae</i>			1	
Noisy Miner <i>Manorina melanocephala</i>	1			
Australian Magpie <i>Gymnorhina tibicen</i>			1	1
Australian Raven <i>Corvus coronoides</i>		2	14	8
Total observed attacks	14		44	

<sup>A</sup>one attack on each of these species was kleptoparasitism

<sup>B</sup>three of these were soaring high, and three cases were juvenile eagles flying past (in two cases chased by ravens and magpies): all in the falcons' incubation period or (once) at the hatching stage.

**Table 5**

Parental time-budgets of breeding Black Falcons, Tamworth (NSW), 2016: laying and incubation periods of Pairs 2 and 3, hatchling stage of Pair 3, and downy chick stage (weeks 2–3) of the nestling period of Pair 4 (see text): % daylight observation time spent in various activities (*n* observation hours in parentheses).

Gender/stage	Incubate/ brood	Stand on nest	Perch in nest tree	Defend
<b>Pair 2, laying</b> (10.25 h):				
Female	22	7	56	0
Male	1	1	8	0
<b>Pair 2, incubation</b> (107.75 h):				
Female	77 <sup>A</sup>	<1	11	1
Male	5 <sup>A</sup>	0	5	<1
<b>Pair 3, incubation</b> (45 h):				
Female	92	<1	3	<1
Male	<1	0	12	<1
<b>Pair 3, brooding</b> (23 h):				
Female	86	5 <sup>B</sup>	5	0
Male	1	0	16	<1
<b>Pair 4, brooding</b> (18.08 h):				
Female	8	6	17 <sup>C</sup>	3
Male	0	0	7 <sup>C</sup>	3

<sup>A</sup>89% and 3% (of 92.75 h) before female abandoned the eggs near hatching (see text)

<sup>B</sup>includes feeding chick(s)

<sup>C</sup>includes guard trees next to nest tree

**Table 6**

Identified prey items of Black Falcons, Tamworth (NSW), Pair 1 in 2015 and all four pairs combined in 2016: *n* by direct observation and occurrence in pellets (*n* = 13).

Prey species	<i>n</i> obs.	<i>n</i> obs.	In <i>n</i> pellets
	2015	2016	2016
Stubble Quail <i>Coturnix pectoralis</i>		1	
Rock Dove <i>Columba livia</i>	1		
Crested Pigeon <i>Ocyphaps lophotes</i>	1		
Probable Crested Pigeon	3		
Galah <i>Eolophus roseicapilla</i>	1	1	2
Probable Galah		1	
Cockatiel <i>Nymphicus hollandicus</i>	1		
Eastern Rosella <i>Platycercus eximius</i>		2	1
Red-rumped Parrot <i>Psephotus haematonotus</i>	2	1	
Noisy Miner <i>Manorina melanocephala</i>		1	
Australian Magpie <i>Gymnorhina tibicen</i>		1	
Magpie-lark <i>Grallina cyanoleuca</i>		2	1
Common Starling <i>Sturnus vulgaris</i>	3	6	8
Probable starling	1	1	
Common Myna <i>Acridotheres tristis</i>		1	
Passerine sp.	2	1	
Bird sp.	2	5	3
Black Rat <i>Rattus rattus</i>		1	
Insects			3
Total	17	25	

**Table 7**

Hunting episodes of breeding Black Falcons, Tamworth (NSW) 2015–16, pre-laying phase to nestling period as applicable (see Table 1), all pairs combined. M = male falcon, F = female. Scientific names in Tables 4 and 6.

Target	Attack type	Outcome
Rock Doves	M, F co-operative alternating stoops at milling flock	Fail
Red-rumped Parrot in tree	F direct flying attack around tree canopy, flushed parrot	Success
Common Starlings on ground	M direct flying attack	Fail
Bird sp. on ground	F direct flying attack	Fail
Bird sp. in tree	M direct flying attack	Fail
Starling on ground	M direct flying attack	Success
Starlings on ground	M direct flying attack	Fail
Black Kite	M kleptoparasitism	Success, but rejected food (road carrion?)
Australian Hobby	F kleptoparasitism of starling: hobby caught starling near falcon's nest tree, F immediately chased hobby and snatched prey from it in flight	Success
Whistling Kite	M, F joint kleptoparasitism of Eastern Rosella (road kill?)	Success
Starling flock on ground	F direct flying attack	Fail
Starling on ground	F direct flying attack	Success
Unknown	M flushing dives around trees and ground	Fail
Australian Magpie	M, F co-operative prolonged chase	Success
Starling on fence	M direct flying attack	Success
Australian Magpie	M, F co-operative attempts (alternating swoops) to flush incubating bird	Fail (magpie remained on nest)
Starling flock on ground	M, F co-operative alternating stoops at fleeing flock	Fail





**Figure 1.** *Pair 2 female Black Falcon performing 'high winnowing' display with dihedral towards intruding raptor, incubation period.*

Photo: Keith D. Fisher



**Figure 2.** *Pair 2 female Black Falcon fighting with intruding Black Falcon, incubation period.*

Photo: Keith D. Fisher



**Figure 3.** *Site 4 fledgling Black Falcon on its fledging/rescue day (see text); nest tree in left background.*

Photo: Alice Bauer



**Figure 4.** *One of the Tamworth Black Falcons hunting Rock Doves, May 2016.*

Photo: Michael Perkins