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# Aspects of the Breeding Cycle of the Little Eagle *Hieraaetus morphnoides*

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**Summary**

The breeding biology and behaviour of the Little Eagle *Hieraaetus morphnoides* were studied throughout 82 hours of observation from the incubation and nestling periods (three nests) to independence of juveniles (n = four families) at Armidale, on the Northern Tablelands of New South Wales, in spring–summer 2008–09. Incubation commenced in September (two clutches), and fledging occurred from mid to late December (four broods). At two nests, incubation (by both parents, but mostly by the female) lasted >35 days and 38–39 days, respectively. At three nests, females performed most of the parental care, but males shared the brooding or feeding of small chicks. The nestling period at three nests lasted 53–54 days, 58 ± 1 days and ~63 days, respectively. Breeding productivity was 0.86 young per occupied territory in 2008, and 0.67 young/pair/year in 15 pair-years 2006–08. The post-fledging dependence period lasted a minimum of 58–64 days (n = 3).

## Introduction

Most aspects of the breeding cycle of the Little Eagle *Hieraaetus morphnoides* have been described in some detail, in terms of adult behaviour, nestling development, quantification of sex-roles, and the duration of the various phases (cf. Marchant & Higgins 1993; Debus *et al.* 2007a). However, there have been few determinations of the nestling and post-fledging periods, little quantification of parental sex-roles in either of these phases, and little information on juvenile development and independence in the post-fledging period. Previous observations on the post-fledging period have been fragmentary (cf. Debus 1984a,b, 1991, 2008; Bollen 1989, 1991).

This paper describes parts of the breeding cycle of four families of Little Eagles in the New England region of New South Wales in spring–summer 2008–09, in order to redress gaps in a previous study (Debus *et al.* 2007a), particularly for the nestling and post-fledging periods. There is still a need for natural-history information on the species, e.g. a full, quantified description of its entire life cycle, as a basis for understanding its ecology and decline in southern Australia (cf. Olsen & Fuentes 2005; Olsen & Osgood 2006; Olsen *et al.* 2008, 2009). We also examine evidence for a possible decline in the Little Eagle population in New England, because atlas sighting data may not match trends in nest-site occupancy and productivity (Olsen & Fuentes 2005).

## Study area and methods

The study area, and observation and analytical methods, at Armidale (30°30′S, 151°40′E) on the Northern Tablelands of NSW, were as previously described (Debus *et al.* 2007a,b). Pairs 1–4 are coded as in the 2006 study of the same pairs of Little Eagles (Debus *et al.* 2007a), and inferences about sex-roles and events in the breeding cycle are also as for that study. An additional pair (Pair 5) was found with a nest in February 2008, and monitored from late in the incubation period in spring 2008. A juvenile of a further pair (Pair 6) was

found by an informant at the fledging stage in 2008 and monitored thereafter. In Pair 6, the male was a light morph and the female a dark morph (i.e. the male and female could be readily distinguished in the field).

Pairs 1 and 2 were observed from the incubation period onwards, until death (Pair 1) or independence (Pair 2) of the juvenile. Pair 4 was monitored opportunistically during the first month of the post-fledging period. The Pair 5 female usually did not tolerate watching from the maximal unobstructed viewing distance (~60 m), so the nest was usually avoided until the late nestling period, then monitored from the fledgling's 'branching' stage until independence. Pair 6 was observed from week 7 of the post-fledging period until independence.

The incubation periods of Pairs 1 and 2 were observed by SD and AJL in rotation for a total of ~9 h over 13 days, mostly in the mornings and almost daily towards the end, to pinpoint hatching dates. Nest-watches were usually of 25–30 minutes (once 90 minutes). The nestling periods of Pairs 1 and 2 (SD) and Pair 5 (AJL) were observed for a total of ~18 h over 17 days, mostly in the mornings, and mostly in the early weeks, declining to checks only (on 15 days by SD, daily in the later stages), to pinpoint fledging dates. Nest-watches were usually of 30 or 60 minutes (occasionally 15–20 or 40–45 minutes).

The post-fledging period was observed by SD, again mostly in the mornings, mainly because juveniles were much easier to locate before or soon after weather permitted soaring, and before they were fed (i.e. still hungry and begging loudly, which also maximised the chance of observing prey deliveries). Attempts were made to monitor at least one fledgling per day, or each of the fledglings about every 3 days (with occasional lapses of a few days), switching from Pair 1 (after that fledgling was found dead) to Pair 6 after the juvenile and nest became known. The post-fledging periods of these four pairs were observed for a total of 55 h over 55 days, in watches usually of ~1 h (sometimes 30 or 90 minutes). During week 6 after fledging, the juvenile of Pair 6 was caught accidentally, in a landholder's fox trap (mesh cage), banded, and released at the nest-site (band supplied by the Australian Bird and Bat Banding Scheme). Because fledging dates were staggered, and the Pair 6 juvenile was the last to fledge, this fledgling was monitored almost daily in its last fortnight of dependence; local landholders also reported on its presence. Observations ceased in the juveniles' natal territories when the birds could not be located on 3–6 days over 2–3 weeks since the last sighting, during searches of 30–60 minutes each, and landholders had not seen the Pair 6 juvenile for a week. Opportunistic checks for the Pair 2 juvenile continued for a further month after it was last seen to be dependent.

The juveniles are identified hereafter by their natal territory (i.e. J1 = offspring of Pair 1, J2 of Pair 2, etc.), as there was only one fledgling per territory. Eaglets were sexed by size at fledging relative to their parents and, in the case of J6, by size in the hand, body weight (1005 g) and required band size (13) ~6 weeks after fledging. Some juveniles were individually recognisable: by a slight notch in the tail-tip (J5), or by the fact that J6 was the only dark-morph juvenile in the study area in 2008–09. J6 was assumed to have fledged around the midpoint between when it was seen still in the nest at the fledging stage (25 December) and the latest local fledging date known for this species (3 January: Debus 1984a), i.e. ~30 December. Observation sessions throughout the Eagles' breeding cycle were essentially opportunistic, rather than systematic.

## Results

### *Eagle population*

The four territories monitored around Armidale in 2006 (Debus *et al.* 2007a) were still occupied in 2008, with the exception that the light-morph male of Pair 3 was replaced sometime between July (when he was last seen) and early October 2008 by a dark-morph male. In 2007 and 2008 the female of Pair 3 was absent, and in 2008 a pair of Brown Goshawks *Accipiter fasciatus* used the Eagles' 2006 nest. In addition, territory 5 (not checked since the 1980s) was confirmed as still occupied, though with a new nest-site on the same hill, and the 'Pine Forest'

male was confirmed as having a mate and nest (= Pair 6), now ~1.5 km east of the forest. His neighbour, the dark-morph male with whom he had territorial disputes in 2006 and which was assumed to be unpaired in 2006, also bred in 2008 (i.e. Pair 7), and there was another pair to the north of Pair 6 (i.e. Pair 8, whose nest was checked in 2006).

The Little Eagle territory neighbouring Pair 4 (in north Imbota Nature Reserve, = former Pair 9) was not re-occupied in 2008, even though Wedge-tailed Eagles *Aquila audax* (which may exclude Little Eagles) did not use their nest in north Imbota in 2007 or 2008 (cf. Debus *et al.* 2007b). The Little Eagle territory between north Imbota and Armidale city (= former Pair 10; only the male present in 2006) was vacant in 2008, since houses had been built on a subdivision (4 × 2-ha blocks), and the pine woodlot adjoining the former nest-site had been logged. The dark male of former territory 10 may have been the dark male that moved into vacant territory 3 (4 km away). Thus, within a semicircle of radius 10 km (i.e. 150 km$^2$) centred on Armidale there were 10 identified potential Little Eagle territories in the mid 2000s (Figure 1), of which two were vacant and one was occupied by a lone male in 2008 (i.e. seven pairs with nests). That is, not all territories may be occupied, or not all of the pairs may breed, in a given year.

The female of Pair 1 was the same female in 2008 as in 2006: in 2008 she still had the same bent secondary feather, which was by then very worn and over 2 years old, having not been shed in the 2007 or 2008 summer/autumn moults (thus also confirming incomplete annual wing-moult in this species). Her mate appeared to be the same well-marked male as in 2006, and Pair 2 also appeared to be the same adults as in 2006, on the basis of their behaviour and routines.

Eight Little Eagles passing through the local (Armidale) wildlife carers' network in the 1990s were mostly road-injured birds: four juvenile males, two juvenile females (one of which had struck a mesh fence) and two adult females. By contrast, only two passed through care in the 2000s (apart from the rescued chick discussed by Debus *et al.* 2007a): an adult female (road-injured), and the accidentally trapped juvenile female from Pair 6. This trend suggests a decline in the number of fledglings being produced, and possibly in the Eagle population.

*Home-range*

The adults of Pair 2 were seen foraging at least 1 km north and west of their nest, and >0.5 km south-east of the nest. The male of Pair 3 was seen foraging 1.8 km south-west of his nest, and at least 0.5 km north of the nest where he would have abutted or overlapped the home-range of Pair 2. The adults of Pair 5 were seen foraging 1.5 km south-east of the nest, and >0.5 km north and west of the nest. The adults of Pair 6 were seen foraging 1.3 km west and north-west of their nest, and (male) 2.3 km south-west of the nest. The dark male of Pair 7 was seen foraging and displaying over an area of ~2.5 × 1 km (~250 ha) that partly overlapped with the hunting range of the Pair 6 male. The male of Pair 8 was seen ~1.3 km south of his nest, interacting with the Pair 6 juvenile where the respective home-ranges abutted.

Neighbouring active nests were 2 km apart (Pairs 2 and 3), and 2.3 km apart (Pairs 6 and 8). The nests of Pairs 3 and 6 were 4 km apart, separated by the nest of Pair 7 (which was not found, but produced a juvenile in 2008). The nests of neighbouring Pairs 4 and 9 had been ~1.9 km apart, in opposite ends of the reserve. The neighbouring nests of former Pairs 9 and 10, and of Pairs 3 and 10, had been 4 km

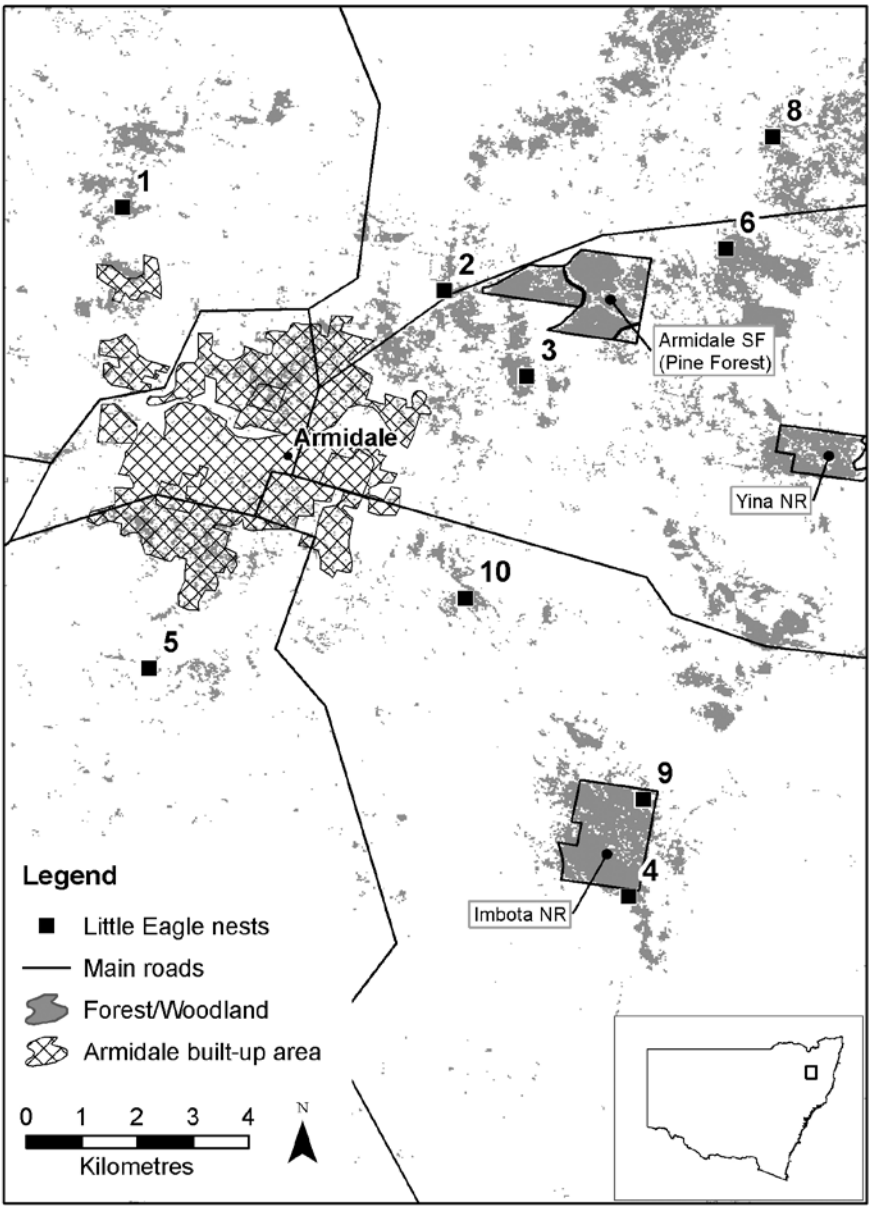



**Figure 1. Map of study area (Armidale, NSW) showing tree cover, locations mentioned in text, and nest-sites of Little Eagle pairs (numbered as in text).**

Map: Martin Dillon

**Juvenile Little Eagle (light morph) in flight**

Plate 13 Photo: David Whelan

**Little Eagle (dark morph) in flight**

Plate 14 Photo: David Whelan

**Wild juvenile Little Eagle (light morph) feeding on road-killed Rabbit against fence**

Plate 15 Photo: David Whelan

apart; and those of presumed neighbours, Pairs 5 and 10, had been 5 km apart. Thus, inter-nest distances ranged between ~2 and 5 km (Figure 1).

*Nest-sites*

Pairs 1 and 2 used the same nest-sites as in 2006 and 2007 (cf. Debus *et al.* 2007a; Debus 2008). Pair 4 used a different nest-site in 2007 and 2008, in contiguous eucalypt woodland on private land ~500 m south-east of the 2006 nest, but not accessible for study. Pairs 5 and 6 also nested in live eucalypts in eucalypt woodland (Table 1): Pair 5 used the same nest as in 2007, and Pair 6 had used the 2008 nest also from 2005 to 2007 (D. Breen pers. comm.).

Combining data in this study (Table 1) with data for 2006 (Debus *et al.* 2007a) gives the following nest-site measurements: tree height 19–25 m (mean 22 m),

**Table 1: Nest-site characteristics of Little Eagle nests at Armidale, NSW, 2008, additional to those studied by Debus *et al.* 2007a: characteristics of nest-tree and position of nest (nest numbers follow the sequence of Debus *et al.* 2007a). For tree species, 1 = Manna Gum *Eucalyptus viminalis*; 2 = Apple Box *E. bridgesiana*; dbh = diameter at breast height; nest height = height of nest above ground.**

| *Pair/nest* | *Tree species* | *Tree height (m)* | *Tree dbh (cm)* | *Nest height (m)* | *Position* |
|---|---|---|---|---|---|
| 5 | 1 | 19 | 36 | 14 | NW slope, flank of minor gully |
| 6 | 2 | 25 | 102 | 17 | SW slope, flank of minor gully |

nest-tree diameter at breast height 36–102 cm (mean 69 cm), and height of nest above ground 14–20 m (mean 15 m; n = 6).

*Breeding chronology*

Pairs 1 and 2 were found incubating on 29 September and 14 September, respectively. Hatching occurred around 2 November and 24 October, respectively, and the single juveniles fledged on 30 December and 16 December, respectively. Pair 5 apparently hatched a chick on 21 October, and it fledged on 23 December. The Pair 6 juvenile was in the nest, at the fledging stage, on 25 December (D. Breen pers. comm.), and thus fledged around the same time as Pair 1 (assumed here to be the same date).

*Reaction to disturbance*

The Pair 2 female usually tolerated observation at the viewing distance accepted in 2006 (140 m, cf. Debus *et al.* 2007a), but in 2008 she occasionally left the nest (flushed?) during the incubation and nestling periods as the observer's vehicle approached the viewing point. On one occasion (week 6 of the nestling period) she appeared reluctant to approach the nest with prey while observers were at the viewing point (so the observers left).

The Pair 5 female usually flushed off the egg(s) or chick when the observer approached within unobstructed viewing distance (~60 m), and gave a squealing alarm call. Even though the male was less wary and sometimes took her place on the nest, observations were usually aborted if she flushed. The secluded nest was ~150 m, ~200 m and ~250 m, respectively, from three occupied rural-residential houses in different directions, but out of direct line of sight.

The nest of Pair 6 was ~140 m from the nearest occupied house/shed complex, which was in direct line of sight of the nest, but over a property boundary, so that the nest was secluded from close human activity.

*Incubation*

At nests 1 and 2, both parents shared daytime incubation. At nest 1, the eggs were covered for 91% of observation time (5 h), the nest was unattended for 8% (for 2–13 min.), and the female was on the nest-branch, beside the nest, for 1%. Where the sexes could be distinguished, the female sat for 77% of observed incubation time (1.9 h), and the male for 23%. The male incubated for one stint of 12 minutes and one for >14 minutes. At nest 2, the eggs were covered for 97% of observation time (4 h), the nest was unattended for 3% (for 1–5 min.), and the female was standing on the nest for <1%. Where the sexes could be distinguished, the female sat for 75% of observed incubation time (1.9 h), and the male for 25%. The male incubated for one stint of 28 minutes, and it was probably the female that incubated for one stint of >90 minutes.

During one stint and changeover at nest 1, the male went to the unattended nest and incubated until the female arrived on the nest-branch, piping softly ('clucking'), and he left before she settled to incubate. During another changeover, the incubating male called (two-note) while peering up, then left apparently to challenge an intruding conspecific; the female, which had been piping and three-note calling in the trees, then arrived on the nest-branch, piping, before settling to incubate. As each adult had a full crop, it appeared that the male had delivered food and relieved the female while she ate. Similarly, on one occasion at nest 2

the male went to the unattended nest and incubated until the female arrived in the nest-tree, piping; as she moved to the nest, he left, then she settled.

At nest 1, incubation from before 29 September to hatching on 2 November ± 1 day gave an incubation period of >35 days. At nest 2, incubation from 14 September to hatching on 23 or 24 October gave a minimum incubation period of 38 or 39 days.

*Nestling period: parental behaviour*

Although data were sketchy, particularly after week 1, at nests 1 and 2 it appeared that daytime parental care and attendance declined, from mostly brooding in week 1 to the female mostly standing on the nest in weeks 2–5 (though sometimes brooding up to week 5 in cool or stormy conditions), to the nest being mostly unattended from week 6 onwards (though the female sometimes stood on the nest or soared over) (Table 2). Parental absences (excluding those possibly observer-induced) ranged from 1–23 minutes in week 1 (n = 2), to 13–34 minutes in week 2 (n = 2), 26 minutes in week 3 (n = 1), >45 minutes in week 4 (n = 1), and >30 minutes in week 6 (n = 1). Parental feeding of chicks, bill to bill, continued until at least week 5 and possibly into week 6 (Table 3). A female sometimes shaded her chick (weeks 1, 2 and 4), usually by standing with her back to the sun so that her shadow fell on the chick, but once (week 1) also by partly spreading her wings. These trends in parental attendance apparently parallelled the growing and feathering chicks' ability to thermoregulate (cf. Table 4).

At nest 2, the male brooded for one stint of 5 minutes in week 1, after delivering prey in the female's absence; when she arrived to feed the chick, the adults touched bills before he left. At nest 5 in week 1, when the female flushed off the nest, the male arrived and fed on prey that was already on the nest, and appeared to feed the chick, before brooding for 20 minutes until the female returned, whereupon he left and she settled.

In week 1, the male of Pair 1 food-called (soft two-note call) in the nest area, then took the prey to the nest, billed the female's nape, then left as she remained brooding; later she removed old prey remains (a stripped hindleg of a Rabbit *Oryctolagus cuniculus*) and dumped them among the trees in the nest-stand, then returned with greenery (at 1010 h). In week 2, the male arrived food-calling (piping) in the trees, dropped prey on the nest (where the female was standing), and left. At nest 2 in week 2, in the female's absence, the male delivered prey to the nest and tore at it for 3 minutes until the female arrived, calling, to feed the chick, and he left. At nest 2 there was fresh greenery on the nest in week 2 (day 12, by 0815 h) and week 4 (day 22).

At nest 1, the only two observed prey deliveries (in weeks 1 and 2) were by the male. At nest 2, the male made two observed prey deliveries (in weeks 1 and 5), and the female made one (in week 6, day 38).

Few data were obtained, but there was some indication that the duration of parental feeding sessions, and the size of the nestlings' meals, increased as the nestling grew (Table 3).

At nest 1 in week 2, towards sunset, the male roosted in a live eucalypt in the nest-stand (within ~50 m of the nest). At nest 2 in week 4, towards sunset, the male roosted on the branch of a live eucalypt next to the nest-tree, while the female remained on the nest.

**Table 2**

**Parental activity at Little Eagle nests, Armidale, NSW, in the nestling period, October–December 2008 (nests 1 and 2 of Debus *et al.* 2007: see text). F = female, M = male parent.**

| *Week* | *Comments* |
|---|---|
| 1 | Nest 1: F brooded for 79% of observation time (total 3.5 h, spread through the day) and stood on the nest for 10%; M stood on the nest for <1%; nest unattended for 11% (in mid/late morning). |
| | Nest 2: M brooded (mid morning) for 13% of observation time (40 min.); F stood on the nest (late morning) for 75%; nest unattended for 13%. |
| 2 | Nest 1: on day 8, during a late-afternoon check, F was brooding; on days 13–14 (late afternoon and mid morning) F stood on the nest for 83% of observation time (75 min.), nest unattended for 17%. |
| | Nest 2: F brooded (day 12, late afternoon) for 1% of observation time (2.5 h), and perched in the nest-tree for 16%; nest unattended for 23%. For the remainder (days 12–13, mid morning), F may have been flushed (and stayed off) for 20%, and may have been perched in the nest-tree, but not visible from the viewing point, for 40%. |
| 3 | Nest 1 (mid morning, day 20): F stood on the nest for 13% of observation time (30 min.); nest unattended for 87%. |
| | Nest 2 (late afternoon, day 17): during a check of 15 minutes, F soared over the nest area. |
| 4 | Nest 1 (late afternoon, day 28): during a check of 15 minutes, F brooded the large, feathering chick during a storm. |
| | Nest 2 (days 22–23): F stood on the nest (late afternoon) for 67% of observation time (135 min.), in one case for >60 minutes with her shadow falling on the chick; nest unattended for 33% (mid morning). |
| 5 | Nest 1: no data. |
| | Nest 2 (day 29): F brooded the large, feathering downy chick (in mid morning) for 60% of observation time (70 min.), and stood on the nest (in late morning) for 28%; M stood on the nest for 4%; nest unattended for 8%. |
| 6 | Nest 1: during a 30-minute watch (day 36, late morning) the nest was unattended; during a check on day 39 (late afternoon) F was standing on the nest, apparently having fed the chick, but left (possibly flushed?)[a]. |
| | Nest 2 (mid morning, day 38): during a 40-minute watch the nest was unattended, but for the final 28 minutes F soared over the nest area with prey in her foot (possibly reluctant to land on the nest while observers present). |
| 7 | Nest 2 (mid morning, days 45 and 49): nest unattended for total observation time (35 min.), but for 15 minutes (day 49) F soared over the nest area. |
| 8 | Nest 2 (mid morning, day 53): check only, nest unattended. |

[a]During checks only in weeks 7–9 (on 5, 3 and 2 days, respectively), across all 2-hr periods of the day, nest 1 was always unattended.

*Nestling period: development of young*

Eaglets were downy for their first 4 weeks, with remiges emerging in week 3 and rectrices in week 4; from week 4, feathers gradually appeared dorsally, then ventrally, then finally on the head (week 6), until by 7 weeks old they were mostly feathered with some down still on the forehead and throat. Down persisted on the underwings until fledging in week 8 or 9, when the primaries and tail were still incompletely grown (Table 4).

**Table 3**

**Parental feeding of Little Eagle nestlings, Armidale, NSW, October–December 2008 (nests 1 and 2 of Debus *et al.* 2007 and nest 5: see text): chicks' meal sizes and morsel consumption rates. All feeding by female parent.**

| *Week/day* | *Nest no.* | *Length of parental feeding bout* | *No. morsels taken by chick* |
|---|---|---|---|
| 1/1 | 2 | >5 min. | No data |
| 2/14 | 1 | 5 min./pause/4 min. (total 9 min.) | 31 pieces in 5 min. (= 6.2 pieces/min.); pause of 13 min.; then 16 pieces in 4 min. (= 4.0 pieces/min.) |
| 3/16 | 5 | >7 min. | No data |
| 5/29 | 2 | 14 min. | ~80 pieces in 14 min. (= 5.7 pieces/min.) |

Eaglets could stand, totter around the nest, flap their wings and defaecate over the nest-rim late in week 2, by which stage they were alert and pecked at objects in the nest. In week 3, one pecked at (and took small pieces from) a food item in the nest. From week 4 they increased in competence, until in week 7 they flapped in the breeze or jumped and flapped between the nest and nest-branch. In week 8, they ventured to branches (i.e. 'branched') in the nest-tree 2–3 days before fledging (Table 4).

At nest 1, hatching on 2 November ± 1 day to fledging on 30 December gave a nestling period of 58 ± 1 days for this female eaglet. At nest 2, hatching on 23 or 24 October to fledging on 16 December gave a nestling period of 53 or 54 days for this male eaglet, but fledging may have been slightly premature during a minor mishap at the 'branching' stage. This juvenile was not seen 'branching', and the structure of the nest mistletoe and surrounding branches could have made the eaglet lose its footing and become airborne accidentally. In support of this interpretation, this fledgling took a few days longer than the others to reach the free-flying and soaring stage (see below and Appendix 1). At nest 5, apparent hatching by 21 October to fledging on 23 December gave a minimum nestling period of 63 days for this male eaglet, which was an adventurous 'brancher' over the preceding 2 days (i.e. from 61 days old: Table 4).

*Fledging*

On its last 3 days at the nest, Juvenile 1 (= J1) was either perched on the nest-branch or (once) lying in the nest. On the morning of its fledging day it was perched in the next tree, ~30 m away, in the absence of its parents. Over its last week before fledging, J2 was either standing or (once) lying on the nest. On the morning of its fledging day it was piping softly in the dense woodland canopy <50 m away, as the female (with full crop) arrived in the nest-tree with prey, perhaps expecting the juvenile to be in the nest. (At this point, searching for the eaglet was aborted, to avoid disturbance, so it was not determined where the food transfer took place). On its last 2 days before fledging, J5 'branched' to 1.5 m, in different directions. On the morning of its fledging day it was in the next tree, ~15 m away, in the absence of its parents. There was no indication that adults used enticement behaviour to encourage their young to fledge; rather, they continued to bring food to the nest over the following days (see below and Appendix 1).

**Table 4**

**Growth and development of nestling Little Eagles, Armidale, NSW, October–December 2008 (nests 1, 2 and 5 and correspondingly J1, J2 and J5: see text). F = female parent, M = male parent, J = juvenile.**

| *Week* | *Day* | *Comments* |
|---|---|---|
| 1 | 4 | J1: small and downy (rusty-tinged first down), dark eye-rings, cream cere; moving on nest. |
| | 5 | Nest 2: two chicks visible. |
| 2 | 12 | J2 (single surviving chick): downy, white with dark eye-rings; cere and gape creamy yellow. Stood up, tottered and flapped wings; defaecated over nest-rim. Alert, peering, pecked in nest, preened. |
| 3 | 15 | J1: in white second down. |
| | 20 | J1: downy with remex and scapular pins. Active, flapped wings, pecked at prey delivered by M (in F's absence), picked bits of meat from prey with bill. |
| 4 | 22 | J2: downy; wing pins emerged, tips burst (showing as a dark line along wing edge). |
| | 23 | J2: remiges and scapular pins burst, upperwing-covert and tail pins emerged, cere creamy yellow. Flapped wings, walked and stumbled around nest (slow, clumsy steps), pecked at nest contents. |
| | 28 | J1: large and downy, upperwings and scapulars feathering, crown and tail pins burst, cere and gape pale creamy yellow. |
| 5 | 29 | J2: upperwings and scapulars feathering, tail pins burst. |
| 6 | 36 | J1: feathered dorsally; head-feathers emerged, with tufts of down sticking to ends; down on forehead and around throat; cere pale blue-grey, gape creamy yellow. |
| | 38 | J2: feathering; head-feathers emerged, downy forehead. |
| | 39–40 | J1: well feathered, including head; down on throat. |
| 7 | 44 | J1: feathered, including ventrally, but down on throat; wings short. |
| | 46 | J2: feathered dorsally and ventrally, down on chin, tail ~½ full length. |
| | 47 | J1: fully feathered except for down on throat. |
| | 48 | J1: fully feathered except for down on chin and underwings; wings and tail short. Flapped in breeze; jumped and flapped between nest and branch. |
| | 49 | J1: folded wing-tips barely beyond tertials, tail ~¾ full length. |
| | | J2: fully feathered, down on throat, tail well grown, primaries short. |
| 8 | 50–51 | J1: little down on chin. |
| | 53 | J2: fully feathered. |
| | 54 | J2: fledged. |
| | 56 | J1: 'branching' behaviour. |
| 9 | 59 | J1: fledged; wings and tail slightly short. |
| | | J5: fully feathered, appeared ready to fledge. |
| | 62 | J5: 'branching' behaviour to ~1.5 m up tree from nest. Appeared close to adult proportions, feet creamy yellow. |
| | 63 | J5: 'branching' behaviour to ~1.5 m along nest-branch. Tail almost full length; folded wing-tips short and rounded, but extended ~¾ down tail. |
| 10 | 64 | J5: fledged; wings and tail slightly short. |

*Post-fledging period*

In their first week after fledging, juveniles mostly perched in live trees <50 m from the nest, begging. J1 was fed at the nest, and roosted at the nest on some nights (Appendix 1), whereas J2 was never detected back at the nest after it fledged, despite checks in late afternoon and early morning. However, the female initially brought prey to the nest-tree on J2's fledging day (see above). J1 died, of unknown causes, <3 weeks after fledging.

In their second week after fledging, juveniles also perched in the nest area (<50 m from the nest), begging, usually in a live tree though sometimes in a dead tree (Appendix 1). They started to become mobile, in low flights around the treetops, from the end of week 2 or early in week 3, by which time they were approaching adult proportions; the bases of J1's outer primaries were still ensheathed at >7 days after fledging (Appendix 1). One parental food transfer to J5 in week 3 (day 16) was inferred to have been in a tree near the nest-tree. In week 3, juveniles became increasingly mobile, though still in low flapping flight, and ranged to 100 m from the nest (Appendix 1).

In week 4, juveniles started soaring, ranging to >300 m from the nest, and harassing their parents in flight for food. From week 5, they had adult-like aerial abilities, ranging up to ~500 m from the nest; they started practising hunting manoeuvres, making at first tentative and unsuccessful passes or attacks at prey, but making determined attempts from week 7, and investigating carrion from week 6 (Appendix 1). From week 6, juveniles ranged up to ~1 km from the nest and sometimes, by their harassing behaviour, interfered with their parents' foraging. Juveniles begged strongly, and were fed by their parents, until week 9 or 10 (Appendix 1). Thereafter, they appeared to start hunting for themselves, and were seen only intermittently (alone, and not begging) in their natal territories until the last sighting in week 9 (J5, male) or week 11 (J6, female). J2 (male) could not be found in weeks 10 and 11, but was seen twice in or on the edge of the natal home-range in week 13 (Appendix 1).

In weeks 5–9, parental food deliveries were made to the nest-woodland, with food transfers at a perch, even if juveniles tried to intercept food-bearing parents en route to the nest area. From week 7, juveniles sometimes waited on lookout perches towards their parents' hunting grounds, and in week 9 sometimes flew to collect food from a parent away from the nest woodland (Appendix 1). Males made the sole observed prey deliveries to J1 and J4 (in weeks 1 and ~5, respectively); both the male and female made prey deliveries to J2 (one and three observed, respectively: male in week 6, female in weeks 5, 7 and 9). Prey items delivered to juveniles were often the still-furred, gutted hindquarters of partly eaten Rabbit kittens, but in one case the kitten had been completely plucked (female of Pair 2, in week 5).

From about week 4 onwards, when juveniles were likely to harass their parents, the adults appeared to avoid them and the nest area, except when delivering prey. Conversely, when J5 was apparently absent from his natal territory on several days in week 8 (before returning in week 9), his male parent readily hunted again in the vicinity of the nest, unmolested by the juvenile. In week 9, J6 begged to the neighbouring adult male, which responded aggressively (Appendix 1).

J2 (male) was last seen to be dependent, and fed, at 58 days after fledging, and occasionally lingered on the edge of, or returned to, the natal territory until 90 days after fledging. J5 (male) was last seen in the natal territory, apparently independent,

at 60 days after fledging. J6 (female) was last seen to be dependent, and fed, at 64 days after fledging, and last seen in the natal territory (though apparently independent) at 71 days after fledging. The post-fledging dependence period thus lasted at least 58–64 days, with independent juveniles sometimes lingering around or revisiting the natal home-range for up to a further month.

Supplementary data from diverse sources support these observed patterns. The juvenile male of Pair 7 was soaring and begging to his aerially hunting male parent, and practising foraging behaviour (aborted 'parachute' drop at Eastern Rosellas *Platycercus eximius* and Australian Magpies *Cracticus tibicen*, which flushed) in early March 2009, 2.5–3 months after the fledging dates of the other local juveniles. In a previous year (1995), a juvenile female of Pair 2 was slightly injured (rehabilitated and released) while feeding on a road-killed Rabbit in mid January, i.e. within a month of fledging. A juvenile near Canberra, Australian Capital Territory, on 1 January 2009 was nest-bound, doing little practice flapping, but fledged by 3 January; a month later it was patrolling the nest area at much lower height than is usual for adults, and descended on and caught a lizard 20–30 cm long (R. Curnow pers. comm.; confirmed as juvenile Eagle from a photograph). In mid February 2009, i.e. when fledged for probably 1.5–2 months, a juvenile in southern Victoria was still begging incessantly when its parents were nearby, and it fed on a road-killed Rabbit (D. Whelan pers. comm.).

*Juvenile morphology*

Fledglings and advanced nestlings tended to have creamy-yellow cere, gape and feet, or sometimes a pale blue-grey cere (Table 4). The juvenile female from Pair 2 in 1995, a light morph, was in typical plumage, including rufous spots on the lesser upperwing-coverts and dark (fawn), non-contrasting secondary coverts (cf. Debus 1989; Marchant & Higgins 1993); within a month of fledging she had dark-brown eyes, yellow gape, and creamy-yellow cere and feet. J6, a dark morph, resembled light-morph juveniles (except for the underwing pattern and lack of rufous spots on the upperwings), but had heavier black breast-streaking and retained strong ventral rufous colouring until independence; at ~6 weeks after fledging she had dark-brown eyes, a creamy-yellow gape, and pale creamy-grey cere and feet.

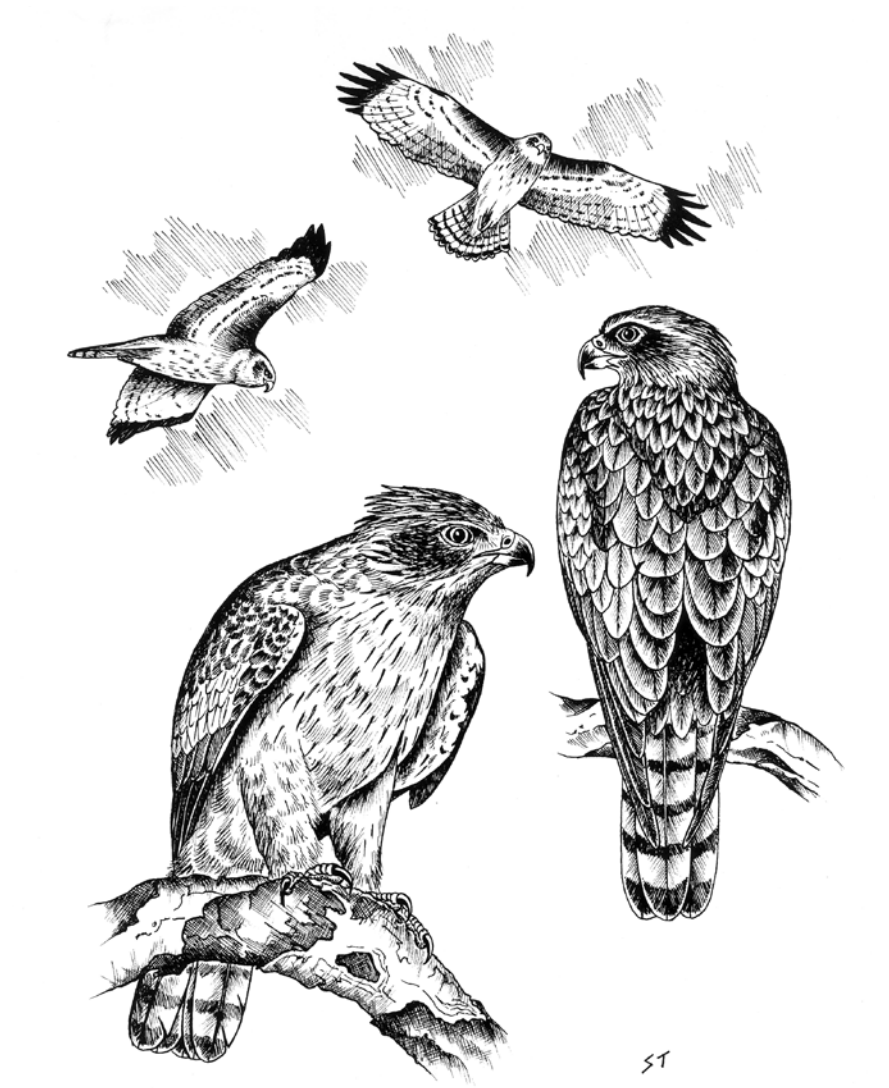
Within 1–2 months after fledging, one juvenile male weighed 655 g, and four juvenile females 865–1090 g (mean 970 g) (source: local rehabilitated birds weighed and banded by SD).

*Breeding productivity*

Pair 2 had two chicks visible on day 5 of the nestling period, but thereafter only one chick was seen. All three nests monitored throughout the cycle (Pairs 1, 2 and 5) fledged a single juvenile, and Pairs 4, 6 and 7 also had a single juvenile during the post-fledging period (i.e. one young per successful brood). Pair 3 (lone male) made no nesting attempt. Productivity was thus six young from seven occupied territories (0.86 young/pair) in 2008. Taking into account productivity in 2006 (one young from four attempts: Debus *et al.* 2007a) and 2007 (three young from four attempts: Debus 2008), productivity in the Armidale area was 0.67 young/pair/year over 15 pair-years 2006–08.

*Feeding rates*

Only one prey delivery to the incubating female was seen in 9 h (pooled for




**Little Eagle**

Plate 16 Sketch: Steve Tredinnick

Pairs 1 and 2) in the incubation period (0.1 item/h). Pooling the few data for Pairs 1 and 2, five prey deliveries were observed in the nestling period in 18 h, or 0.3 item/h. Pooling data for Pairs 1, 2, 5 and 6 in the post-fledging period, and including one inferred delivery to J5, eight deliveries were detected in 55 h or 0.1 item/h while juveniles were still dependent.

*Diet and hunting*

Prey items seen delivered to nests or juveniles included small Rabbit ×2, starling-

sized native passerine, plucked bird and unidentified item (Pair 1); Rabbit kitten ×2, probable Rabbit ×3 and unidentified item (Pair 2); and probable Rabbit (Pair 6). Australian Wood Duck *Chenonetta jubata* pluckings were found under nest 2, and three Common Bluetongue *Tiliqua scincoides* skulls, and a pellet containing Bluetongue scales and Rabbit fur, were found under nest 5. (The female of Pair 5 was also seen carrying a Rabbit kitten in February 2008.) Breeding diet thus consisted mostly of Rabbits, with some birds and a few lizards.

In addition to the observations of adults hunting and juveniles practising what appeared to be typical hunting manoeuvres for this species (Appendix 1), the adult male of Pair 5 was seen hunting on two mornings in the post-fledging period: (1) from high quartering flight he made (i) a sudden vertical stoop, with closed wings, into the woodland canopy, flushing Eastern Rosellas (which escaped), then (ii) after kiting he made a long vertical stoop but aborted at treetop height; (2) after high quartering and kiting he made a steeply angled dive towards the ground (outcome unseen). Collectively, all the observations herein and those of Debus *et al.* (2007a) suggest that most foraging is done in flight (soaring and high-quartering), and attacks are variously stoops at avian prey, or dive attacks or drop attacks (sometimes in stages) at prey on the ground, and often preceded by, or interspersed with, kiting before launching the final strike.

## Discussion

### *Breeding biology and behaviour*

The Eagle foraging ranges in this study were limited to distances at which known individuals were seen travelling and returning, from observation points within view of their nest-sites. They are, therefore, underestimates of total home-range, which would need to be determined by individual marking and/or radio-tracking (e.g. Olsen & Osgood 2006). The similar Booted Eagle *Hieraaetus pennatus*, which occurs at over twice the density (inter-nest distances of only ~1 km) in probably more productive habitat, forages up to >10 km from the nest in home-ranges of up to >200 km$^2$ (Martínez *et al.* 2007). There is increasing evidence of long-term fidelity of individual Little Eagles to nest-sites and breeding territories (Debus 1984b, 1991; Debus *et al.* 2007a; this study), although confirmation is required from banding and individual marking.

Although some nesting Little Eagles are tolerant of the proximity of houses, there is much individual variation. Some are shy, using nests concealed from human view by the woodland canopy, and flushing off eggs or chicks (thus placing them at risk) if approached by humans (this study; Debus *et al.* 2007a). Some females that were disturbed by humans, and flushed off (successful) nests several times in 2006, used a different nest in 2007–08 (Debus 2008; this study). Urban development also affects the Little Eagle's foraging habitat as well as nest-sites (e.g. Olsen & Fuentes 2005; Olsen & Osgood 2006).

Data in this study confirm that Little Eagles nest in all common local *Eucalyptus* species, and apparently prefer large trees on slopes with a southerly component (cf. Debus 1984a; Debus *et al.* 2007a). Nest-site measurements at Armidale fall within known nest-site parameters (cf. Marchant & Higgins 1993).

Egg-laying dates were consistent with previous data for south-eastern Australia (cf. Marchant & Higgins 1993; Olsen 1995; Debus *et al.* 2007a). An incubation period of 38–39 days also supports previous values of ~36, 36–40 and 37–39 days (Debus

1984a; Bollen 1991; Debus *et al.* 2007a). Similarly, nestling periods of 53–63 days support and enlarge on previous values of 55 days, ~59 days, 54–60 days, and ~60–67 days (Baker-Gabb 1984; Debus 1984a; Bollen 1991; Marchant & Higgins 1993), and a case of premature (human-induced) fledging of two siblings at 52–56 days (Cupper & Cupper 1981).

Data on sex-roles in the incubation and nestling periods support previous findings (Debus *et al.* 2007a) on male sharing of incubation and brooding, and provide further evidence that males sometimes feed chicks (cf. Debus 1984b; Bollen 1989). From limited data (this study; Debus 1984b; Debus *et al.* 2007a), it appears that nestling meal sizes and duration increase with age, but confirmation is required. Limited data on the decline in parental care and nest attendance through the nestling period, as eaglets grow, support previous fragmentary data and assumptions (Debus 1984a,b; Bollen 1989; Debus *et al.* 2007a), but the definitive study of parental time-budgets remains to be conducted.

Fledgling productivity was variable in 2006–08: greater in 2007 and 2008 than in the poor year of 2006 (cf. Debus *et al.* 2007a). Overall, in the 2000s, it has averaged lower than in the 1980s to early 1990s (0.67 vs 1.0 young/pair/year, cf. Debus 1991).

Parental feeding rates in 2008 were similar to those of 2006 for the incubation period (0.1 item/h in both years) and nestling period (0.3 item/h cf. 0.2–0.3 item/h), and to those from 1980 for the post-fledging period (0.1 item/h in both years:Debus 1991; Debus *et al.* 2007a). It appears from limited observations that the food-delivery rate to juveniles may be lower than in the nestling period. However, confirmation is required, and it remains to be determined whether the feeding rate declines through the post-fledging period. Feeding rates in the incubation and nestling periods were similar to those recorded for Armidale in the 1980s (0.1 item/h and 0.2 item/h, respectively: Debus 1991), but lower than for the nestling period where the diet included a higher proportion of small birds (0.4–0.6 item/h: Bollen 1989, 1991).

*Juvenile development and independence*

Observations on nestling growth, development and morphology confirm and enlarge on previous reports (cf. Debus 1984a,b, 1991; Marchant & Higgins 1993). This study also confirms that juveniles fledge as either morph (dark or light), and that within each morph juveniles are 'redder' than adults (*contra* Hollands 2003). Data from the present study suggest that the rescued eaglet in 2006 (Debus *et al.* 2007a) may indeed have had somewhat retarded growth, as suspected, before it died of an undiagnosed illness or developmental impairment.

Synthesising the limited data from this study and others (Debus 1984a,b; Bollen 1989,1991; Debus *et al.* 2007a; Debus 2008), it appears that, in their first week or so after fledging, juvenile Little Eagles at least sometimes return to, roost on and are fed at the nest. For their first fortnight they mostly perch in the tree-canopy in the nest area, and the parents deliver food to them on perches in the nest-patch. Thereafter, when their flight-feathers are fully grown and they appear adult in proportions, juveniles make low tree-to-tree flights and start soaring low over the tree-canopy, until by their first month they can soar well in an adult-like manner and range several hundred metres from the nest. From this stage they start following their parents, practising hunting behaviour, and (mainly females) start investigating carrion such as road-kill, although parents still transfer food on a perch in the nest-patch. In their second month, they range >1 km from the

nest, sometimes wait on lookout perches for food-bearing parents between the nest and hunting grounds, and sometimes collect food from a parent away from the nest area. They may start catching, or trying to catch, prey, and the smaller and more agile males may hawk flying insects. Finally, by the end of their second month when parental feeding ceases, they range >1.5 km and start venturing away from their natal territory for perhaps several days at a time, though they may return intermittently over at least a further month. Around the time juvenile Little Eagles approached independence in New England, prey animals such as juvenile or immature Common Bluetongues and dragon lizards (*Amphibolurus* and *Pogona*) were fairly common, and sluggish on cool mornings or evenings; adult lizards also basked conspicuously on roads (SD pers. obs.).

These results contrast with the view that juvenile Little Eagles may become independent 'quite quickly' (Hollands 2003). Rather, they are dependent on parental feeding for ~2 months after fledging, which finding supports previous inferences of dependence for at least 2 months (Marchant & Higgins 1993; Debus *et al.* 2007a).

So far as can be determined, the Little Eagle's post-fledging period, independence and dispersal phase may be similar to those of the Booted Eagle and Bonelli's Eagle *Aquila fasciata* (cf. Balbontín & Ferrer 2005, 2009; Cadahía *et al.* 2007, 2008), but this assumption requires confirmation by radiotelemetry. One Booted Eagle juvenile was dependent for at least 64 days after fledging (Ferguson-Lees & Christie 2001).

Aspects of the Little Eagle's post-fledging period appear to contrast with that of the Wedge-tailed Eagle (cf. Debus *et al.* 2007b). Unlike the larger species, Little Eagle families did not associate as close trios of parents and offspring; there was no evidence of adult Little Eagles hunting together or co-operatively, nor of juveniles accompanying hunting adults. Rather, juvenile Little Eagles harassed their parents for food and interfered with their foraging, and adults appeared to be solitary, avoiding dependent juveniles except when delivering prey to them. These differences may be related to differing predatory habits: in comparison with Wedge-tailed Eagles, Little Eagles appear to specialise more on active prey of a size they can carry, seldom eat carrion, and members of a pair appear not to share kills away from the nest.

There was no evidence that parent Little Eagles drove off their offspring at the end of the dependence phase, or acted aggressively towards them, although the male parent of J2 performed a territorial display when the now-independent J2 reappeared, after absences, in the natal territory at ~3 months since fledging. Claims of eagles driving away offspring may be based on misinterpretation of juveniles harassing parents for food, or being warned off when they stray into a neighbouring territory, as observed in this study.

*Diet and hunting*

The incidental dietary items observed in this study are a subset of those previously recorded in the district (cf. Debus 1984a, 1991, 2006a,b, 2008; Debus *et al.* 2007a), and indeed in south-eastern Australia generally (cf. Marchant & Higgins 1993). Further studies of breeding diet in little-studied regions (e.g. Western Australia and the tropics) would be valuable, as would studies of non-breeding diet (cf. Moleón *et al.* 2007, 2009).

The hunting episodes observed in this study are consistent with previous

information (cf. Marchant & Higgins 1993; Aumann 2001; Debus 2006b; Olsen *et al.* 2006; Debus *et al.* 2007a). Little Eagles appear to do much foraging in flight, as suggested by Hollands (2003), and (especially breeding males) perform some Booted Eagle-type attack behaviour (cf. Ferguson-Lees & Christie 2001), e.g. swift stoops or dives.

*Eagle population*

The Little Eagle population around Armidale in the mid 2000s was about the same as in the 1980s and 1990s, i.e. ~10 known pairs within a radius of 10 km of Armidale (Debus 1984a, 1991), although by the late 2000s this had declined to eight known territories, seven of which were occupied by a pair with an active nest. Inter-nest distances and density were similar in the 2000s to the 1980s, i.e. 2–5 km between neighbouring nests and one breeding pair to 1500–1600 ha (cf. Debus 1984a). However, the number of Little Eagles passing through the wildlife carer network has declined substantially. Together with declining fledgling productivity, these trends suggest a declining population, although less so than for more southern parts of NSW to date (cf. Olsen & Fuentes 2005; Olsen & Osgood 2006; Debus *et al.* 2007a; Olsen *et al.* 2008, 2009). Furthermore, cases of apparent illness in a chick and an adult female (Debus *et al.* 2007a), and the premature death of fledgling J1 (anomalous at that age), suggest that there are potential problems for the local Little Eagle population (perhaps pesticides or other chemicals in the food chain, as suspected elsewhere: Olsen & Osgood 2006).

Atlas data showed a decline in the Little Eagle's reporting rate over 20 years: 14% nationally, with >20% decline across the Murray–Darling Basin and eastern sheep–wheat belt, and 39% in NSW, although there was no significant decline detected in the New England Tableland bioregion (Barrett *et al.* 2003, 2007). Surveys of nests found an 80–90% decline in the number of breeding pairs around Canberra, ACT, over the last 15 years, a trend not reflected in local atlas data (Olsen & Fuentes 2005; Olsen *et al.* 2009). Subsequent analysis of NSW atlas data found a 50% decline in the Eagle's reporting rate in south-eastern NSW over the past 30 years (B. Curtis in Canberra Ornithologists Group 2008). Where atlas sighting data and surveys of breeding pairs conflict, monitoring of nests more reliably indicates raptor population trends (Sergio *et al.* 2008; Olsen *et al.* 2009). In the case of the Little Eagle, objective survey data provided a case for listing as Vulnerable in the Australian Capital Territory (Olsen *et al.* 2008).

*Conclusions*

The Little Eagle's breeding biology and behaviour are similar to those of other small aquiline eagles, particularly the Booted Eagle and other *Hieraaetus* species (i.e. Booted, Wahlberg's *H. wahlbergi* and Ayres' Eagles *H. ayresii*, cf. Brown 1976; Cramp & Simmons 1980; Brown *et al.* 1982; del Hoyo *et al.* 1994; Ferguson-Lees & Christie 2001). The Little Eagle's general biology, as a composite picture from several partial studies, is now fairly well known. However, the present study was incomplete, particularly for the Little Eagle's nestling period. It remains to conduct a complete, quantified observational study throughout the breeding cycle, from nest-building to independence of juveniles, on plumage-dimorphic (i.e. readily sexed) pairs of Little Eagles, and to obtain more complete data on parental feeding rates in the post-fledging period, as for the Wedge-tailed Eagle (cf. Debus *et al.* 2007b).

Limited evidence suggests that Little Eagle numbers and breeding success may be starting to decline in New England, and that this decline may be related to habitat loss, and in particular urban and rural-residential expansion around inland cities, and competition from Wedge-tailed Eagles for increasingly scarce breeding habitat and nest-sites (Debus 1991; Debus *et al.* 2007a; this study). The apparent decline in the Little Eagle's population extends the decline elsewhere in south-eastern Australia, which is attributed to the same factors (e.g. Olsen & Fuentes 2005; Olsen & Osgood 2006; Olsen *et al.* 2008, 2009). It may continue and worsen, given the scale of ongoing clearing of native vegetation in NSW and thus consequences for the Eagle's native prey base, breeding habitat and nest-site availability (cf. Johnson *et al.* 2007; Olsen 2008). Hence, long-term monitoring of territory occupancy, breeding density and productivity, and adult turnover are required.

Recent studies on Booted and Bonelli's Eagles provide potential models for the studies required on the Little Eagle, to shed light on its decline and guide its conservation (cf. Mateo *et al.* 2003; Pagán *et al.* 2004; Bosch *et al.* 2005; López-López *et al.* 2006, 2007; Martínez *et al.* 2006, 2007, 2008; Martínez-López *et al.* 2007, 2008; Casado *et al.* 2008; and related studies cited by Debus *et al.* 2007a). An increasing issue of concern overseas is whether human-induced mortality of breeding adult eagles (e.g. through pesticides, electrocutions, or collisions with windfarms and other infrastructure) may act against the genetic fitness of the species, and so accelerate population declines (Balbontín *et al.* 2005).

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**References**

Aumann, T. (2001), 'Habitat use, temporal activity patterns and foraging behaviour of raptors in the south-west of the Northern Territory, Australia', *Wildlife Research* **28**, 365–378.

Baker-Gabb, D.J. (1984), 'The breeding ecology of twelve species of diurnal raptor in north-western Victoria', *Australian Wildlife Research* **11**, 145–160.

Balbontín, J. & Ferrer, M. (2005), 'Factors affecting the length of the post-fledging period in the Bonelli's Eagle *Hieraaetus fasciatus*', *Ardea* **93**, 189–198.

Balbontín, J. & Ferrer, M. (2009), 'Movements of juvenile Bonelli's Eagle *Hieraaetus fasciatus* during dispersal', *Bird Study* **56**, 89–95.

Balbontín, J., Penteriani, V. & Ferrer, M. (2005), 'Humans act against the natural process of breeder selection: A modern sickness for animal populations?', *Biodiversity & Conservation* **14**, 179–186.

Barrett, G., Silcocks, A., Barry, S., Cunningham, R. & Poulter, R. (2003), *The New Atlas of Australian Birds*, RAOU, Melbourne.

Barrett, G.W., Silcocks, A.F., Cunningham, R., Oliver, D.L., Weston, M.A. & Baker, J. (2007), 'Comparison of atlas data to determine the conservation status of bird species in New South Wales, with an emphasis on woodland-dependent species', *Australian Zoologist* **34**, 37–77.

Bollen, C. (1989), 'Notes on Little Eagles breeding on the Southern Tablelands of New South Wales', *Australian Bird Watcher* **13**, 65–66.
Bollen, C (1991), 'Further notes on the Little Eagle breeding on the Southern Tablelands of New South Wales', *Australian Bird Watcher* **14**, 110–111.
Bosch, J., Borrás, A. & Freixas, J. (2005), 'Nesting habitat selection of Booted Eagle *Hieraaetus pennatus* in central Catalonia', *Ardeola* **52**, 225–233.
Brown, L.H. (1976), *Eagles of the World*, David & Charles, London.
Brown, L.H., Urban, E.K. & Newman, K. (Eds) (1982), *The Birds of Africa*, vol. 1, Academic Press, London.
Cadahía, L., Urios, V., López-López, P. & Negro, J.J. (2008), 'Estimating the onset of dispersal in endangered Bonelli's Eagles *Hieraaetus fasciatus* tracked by satellite telemetry: A comparison between methods', *Ibis* **150**, 416–420.
Cadahía, L., Urios, V. & Negro, J.J. (2007), 'Bonelli's Eagle *Hieraaetus fasciatus* juvenile dispersal: Hourly and daily movements tracked by GPS', *Bird Study* **54**, 271–274.
Canberra Ornithologists Group (2008), 'Nomination of a Vulnerable species to the ACT Flora and Fauna Committee—Little Eagle', *Canberra Bird Notes* **33**, 84–95.
Casado, E., Suárez-Seone, S., Lamelin, J. & Ferrer, M. (2008), 'The regulation of brood reduction in Booted Eagles *Hieraaetus pennatus* through habitat heterogeneity', *Ibis* **150**, 788–798.
Cramp, S. & Simmons, K.E.L. (Eds) (1980), *The Birds of the Western Palaearctic*, vol. 2, Oxford University Press, Oxford, UK.
Cupper, J. & Cupper, L. (1981), *Hawks in Focus*, Jaclin, Mildura, Vic.
Debus, S.J.S. (1984a), 'Biology of the Little Eagle on the Northern Tablelands of New South Wales', *Emu* **84**, 87–92.
Debus, S.J.S. (1984b), 'Further notes on nesting Little Eagles', *Australian Bird Watcher* **10**, 196–201.
Debus, S.J.S. (1989), 'Plumages and moult of the Little Eagle *Hieraaetus morphnoides*', *Australian Bird Watcher* **13**, 103–113.
Debus, S.J.S. (1991), 'Further notes on territory, breeding and plumage of the Little Eagle', *Australian Birds* **25**, 1–10.
Debus, S. (2006a), 'Wedge-tailed Eagle robs Little Eagle', *Boobook* **24**, 43.
Debus, S. (2006b), 'Avian food items of Little Eagle', *Boobook* **24**, 44.
Debus, S. (2008), 'Little Eagles in New England, NSW', *Boobook* **26**, 7.
Debus, S.J.S., Hatfield, T.S., Ley, A.J. & Rose, A.B. (2007a), 'Breeding biology and diet of the Little Eagle *Hieraaetus morphnoides* in the New England region of New South Wales', *Australian Field Ornithology* **24,** 137–157.
Debus, S.J.S., Hatfield, T.S., Ley, A.J. & Rose, A.B. (2007b), 'Breeding biology and diet of the Wedge-tailed Eagle *Aquila audax* in the New England region of New South Wales', *Australian Field Ornithology* **24**, 93–120.
del Hoyo, J., Elliott, A. & Sargatal, J. (Eds) (1994), *Handbook of the Birds of the World*, vol. 2, Lynx, Barcelona.
Ferguson-Lees, J. & Christie, D.A. (2001), *Raptors of the World*, Helm, London.
Hollands, D. (2003), *Eagles, Hawks and Falcons of Australia*, 2nd edn, Bloomings Books, Melbourne.
Johnson, C., Cogger, H., Dickman, C. & Ford, H. (2007), Impacts of Land Clearing: The Impacts of Approved Clearing of Native Vegetation on Australian Wildlife in New South Wales, WWF-Australia report, WWF-Australia, Sydney.
López-López, P., García-Ripollés, C., Aquilar, J.M., García-López, F. & Verdejo, J. (2006), 'Modelling breeding habitat preferences of Bonelli's Eagle (*Hieraaetus fasciatus*) in relation to topography, disturbance, climate and land use at different spatial scales', *Journal of Ornithology* **147**, 97–106.
López-López, P., García-Ripollés, C. & Urios, V. (2007), 'Population size, breeding performance and territory quality of Bonelli's Eagle *Hieraaetus fasciatus* in central Spain', *Bird Study* **54**, 335–342.
Marchant, S. & Higgins, P.J. (Eds) (1993), *Handbook of Australian, New Zealand and Antarctic Birds*, vol. 2, Oxford University Press, Melbourne.
Martínez, J.A., Calvo, J.F., Martínez, J.E., Zuberogoitia, I., Zabala, J. & Redpath, S.M. (2008), 'Breeding performance, age effects and territory occupancy in a Bonelli's Eagle *Hieraaetus fasciatus* population', *Ibis* **150**, 223–233.
Martínez, J.E, Pagán, I., Palazon, J.A. & Calvo, J.F. (2007), 'Habitat use of Booted Eagle (*Hieraaetus pennatus*) in a special protection area: Implications for conservation', *Biodiversity & Conservation* **16**, 3481–3488.

Martínez, J.E, Pagán, I. & Calvo, J.F. (2006), 'Interannual variations of reproductive parameters in a Booted Eagle (*Hieraaetus pennatus*) population: The influence of density and laying date', *Journal of Ornithology* **147**, 612–617.
Martínez-López, E., Marcia-Mojica, P., Calvo, J.F., Wright, J., Shore, R.F., Romero, D. & García-Fernández, A.J. (2007), 'Organochlorine residues in Booted Eagle (*Hieraaetus pennatus*) and Goshawk (*Accipiter gentilis*) eggs from southeastern Spain', *Environmental Toxicology & Chemistry* **26**, 2373–2378.
Martínez-López, E., Romero, D., Marcia-Mojica, P., Martínez, J.E., Calvo, J.F. & García-Fernández, A.J. (2008), 'Changes in blood pesticide levels in Booted Eagles (*Hieraaetus pennatus*) associated with agricultural land practices', *Ecotoxicology & Environmental Safety* **72**, 45–50.
Mateo, R., Taggart, M. & Meharg, H.A. (2003), 'Lead and arsenic in bones of birds of prey from Spain', *Environmental Pollution* **126**, 107–114.
Moleón, M., Bautista, J., Sánchez-Zapata, J.A & Gil-Sánchez, J.M. (2009), 'Diet of non-breeding Bonelli's Eagles *Hieraaetus fasciatus* at settlement areas of southern Spain', *Bird Study* **56,** 142–146.
Moleón, M., Gil-Sánchez, J.M., Real, J., Sánchez-Zapata, J.A., Bautista, J. & Sánchez-Clemot, J.F. (2007), 'Non-breeding feeding ecology of territorial Bonelli's Eagles *Hieraaetus fasciatus* in the Iberian Peninsula', *Ardeola* **54**, 135–143.
Olsen, J. & Fuentes, E. (2005), 'Collapse in numbers of breeding Little Eagles in the Australian Capital Territory', *Canberra Bird Notes* **30**, 141–145.
Olsen, J. & Osgood, M. (2006), 'Numbers of breeding Little Eagles in the Australian Capital Territory in 2006', *Canberra Bird Notes* **31**, 178–182.
Olsen, J., Fuentes, E., Rose, A.B. & Trost, S. (2006), 'Food and hunting of eight breeding raptors near Canberra, 1990–1994', *Australian Field Ornithology* **23**, 77–95.
Olsen, J., Osgood, M., Maconachie, M. & Dabb, G. (2008), 'Numbers of breeding Little Eagles *Hieraaetus morphnoides* in the Australian Capital Territory in 2007', *Canberra Bird Notes* **33**, 77–80.
Olsen, J., Osgood, M., Maconachie, M., Dabb, G. & Butterfield, M. (2009), 'Numbers of breeding Little Eagles *Hieraaetus morphnoides* in the Australian Capital Territory in 2008', *Canberra Bird Notes* **34**, 81–85.
Olsen, P. (1995), *Australian Birds of Prey*, New South Wales University Press, Sydney.
Olsen, P. (Ed.) (2008), 'The state of Australia's birds 2008', supplement to *Wingspan* **18**(4).
Pagán, I., Martínez, J.E., Carrete, M. & Calvo, J.F. (2004), 'Nest occupancy patterns of Booted Eagles *Hieraaetus pennatus* in southeastern Spain', pp. 645–652 in Chancellor, R.D. & Meyburg, B.-U. (Eds), *Raptors Worldwide*, World Working Group on Birds of Prey & Owls, Berlin, and BirdLife Hungary, Budapest.
Sergio, F., Newton, I. & Marchesi, L. (2008), 'Top predators and biodiversity: Much debate, few data', *Journal of Applied Ecology* **45**, 992–999.

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## Appendix 1

**Behaviour of juvenile Little Eagles in the post-fledging period, Armidale, NSW, December 2008–March 2009 (single juveniles J1, J2, J4, J5 and J6 from respective nests 1,2, 4, 5 and 6: see text). F = female parent, M = male parent. J2 and J5 were male, J1 and J6 female (J6 assumed to have fledged on same date as J1: see text).**

| *Week* | *Day* | *Comments* |
|---|---|---|
| 1 | 1 | J1: perched in next (live) tree ~30 m from nest-tree. |
| | | J2: perched in woodland canopy <50 m from nest-tree; F food delivery to nest-tree in late morning (further details not obtained). |
| | | J5: perched in next (live) tree ~15 m from nest-tree. |
| | 4 | J1: perched on nest-branch in late afternoon (roosted there?). |

**Appendix 1** continued

| *Week* | *Day* | *Comments* |
|---|---|---|
| 1 | 5 | J1: perched in mid canopy ~20 m from nest, well below nest height; M prey delivery to nest (late morning), F arrived at nest-branch then nest, M left; J1 returned to nest in stages by short scrambling flights, meanwhile F started to bill prey; J1 reached nest, claimed prey and mantled, F left, J1 fed from prey (clumsy at first, overbalancing when tearing prey on nest, then feeding successfully). In late afternoon, J1 perched in trees near nest (i.e. not at nest). |
| | 6 | J1: lay on nest in late afternoon for >1 h (roosted there?). |
| 2 | 8 | J1: perched in top of nest-tree, balancing on outer-canopy foliage, in late afternoon. Last sighting of J1 alive. |
| | 9 | J1: not detected in nest area in late afternoon (though M on roost-tree). Weathered remains subsequently found (10 days later, after lapse in observations) included outer primaries with bases still in sheath; approximate date of death (midpoint between J1 alive and remains found) = day 14 ± 5 days. |
| | 13 | J5: appeared approximately adult in proportions. |
| | 14 | J5: flew in flapping circuit low over tree-canopy around nest, then perched on dead tree, flapped wings. |
| 3 | 19 | J2: mobile in nest area, low flapping flight tree to tree within 100 m of nest; had difficulty balancing on high thin branch in wind; tumbled off, but landed competently on lower solid branch. Appeared adult in proportions. |
| 4 | 25 | J5: soared low over and around treetops around nest (within ~50 m); appeared practised, adult in proportions; wind-soared well, landed between flights, descending with retracted wings to perch. |
| | 27 | J5: soared in circles, landed competently on branch in live treetop, spiralled to >5 × treetop height, like adult; stooped to lose height, landed in tree ~100 m from nest. |
| | 28 | J5: soared up in circles, thermalling expertly in still air. Followed soaring parent (F?) to ~300 m from nest; then soared (begging) with M >300 m from nest, made passes at M with feet down, but M jinked away (not carrying prey). |
| ? | ? | J4: ~1 month after fledging, soared high, begging, ~300 m from nest as M approached in long shallow glide with prey in foot; M stooped to nest-woodland, J4 followed in stoop; food transfer at perch in nest-woodland. |
| 5 | 29 | J5: soared high, practised 'parachute' drop (aborted before reaching ground); soared very high, tracked Brown Falcon *Falco berigora* that was soaring lower, made mild stoops towards it (Falcon retreated); soared to ~400 m from nest, practised long fast glides, kiting, 'parachute' drops, stoop. Essentially adult-like aerial ability, but no attacks on prey seen. |
| | 32 | J5: soared, made pass at Galahs *Eolophus roseicapillus* on dead treetop (veered off when they flushed); practised swooping around and between tree-crowns. |
| | 33 | J2: F? prey delivery to nest-woodland (not to nest) in mid morning; J2 ate food on live tree-limb <50 m from nest. J2 subsequently flew to ~300 m from nest, returned wind-soaring and circling unsteadily, clumsy landing on dead treetop in wind. Then soared, circling to 2–3 × treetop height, landed on outer canopy, balancing; soared again, landed, then soared. Final landing competent, by descending among treetops with wings retracted, into wind (after earlier, heavier landings), i.e. noticeably improved with practice. |

**Appendix 1** continued

| *Week* | *Day* | *Comments* |
|---|---|---|
| 5 | 33 | J5: soared, made full 'parachute' drop almost to ground (aborted); ranged ~500 m from nest. |
| | 34 | J2: soared low over hilltop trees of nest-woodland. |
| | 35 | J2: soared low over hill trees to ~150 m from nest, then circled to 2–3 × treetop height, stooped to former height, then circled again 200–300 m from nest for >4 min., to >4 × treetop height. |
| | | J5: soared, paused over and almost stooped at Torresian Crow *Corvus orru* on or near ground; soared very high in adult-like manner, made sudden brief stoop; tracked Brown Goshawk; made long fast glide to soar with and stoop at distant soaring parent (which avoided contact); soared also with high-soaring, intruding (i.e. not parent) dark Little Eagle; swooped at one of pair of high-soaring Goshawks (~1000 m altitude). |
| 6 | 37 | J2: soared, ranging ~400 m from nest. |
| | | J5: perched in nest area, peering intently at activity of small birds; soared high; Wedge-tailed Eagle glided high over, F attacked it with squealing alarm call; J5 followed high-soaring F. |
| | 38 | J6: entered fox-trap (mesh cage) for bait; banded and released at nest-site on day 40. Primaries and rectrices fully grown and hard-penned. |
| | 39 | J2: perched beside prominent stick nest (used by Australian Ravens *Corvus coronoides* in 2006) ~200 m from own nest. Then soared and begged over where F had stooped (unsuccessfully) into trees, then soared up to beg to high-soaring M, which left, but J2 soared very high and tracked M to ~800 m from nest. J2 returned in long fast glide, stooped at soaring F with feet down (F squealed, parried and left); J2 stooped to lower level, soared again, tracked F to ~1 km from nest before returning. In late morning, M prey delivery (with two- and three-note calls) to nest-woodland; J2 collected prey and fed competently on stout lower limb of live woodland tree <100 m from nest. |
| | 42 | J2: soared, swooped at hunting adult (M?), interfering with his descent at sighted prey. M was in a drop attack from ~5 × treetop height (or ~100 m?), J2 swooped faster to intercept, causing M to dodge; J2 tracked M during resumption of kiting and dropping until M dived and did not reappear. J2 resumed soaring and begging, practised 'parachute' drop; showed adult-like aerial ability. |
| 7 | 43 | J5: soared high, made long angled dive (unsuccessful) at Australian Magpies, which scattered with alarm calls. |
| | 44 | J2: soared high, made failed attack at prey ('parachute' drop with wings retracted, feet down, then final short dive at Australian Magpie on ground; Magpie flushed, J2 soared again). F food delivery (in late morning) to nest woodland >200 m from nest; soaring J2 made long shallow stoop into trees to collect prey. |
| | | J6: soared up to beg from high-soaring F; then soared with and begged to M over his hunting grounds 1.3 km from nest. M landed and perch-hunted from live tree over Rabbit-infested area; J6 waited on dead tree, begging, ~150 m from M. |
| | 46 | J2: soared; practised kiting, long glide, height loss by short stoop, then long shallow stoop. Soared very high, made stoops at high-soaring F (which evaded). Rufous on belly now fading. |
| | 49 | J2: soared, kiting, hawked aerial insect. |

**Appendix 1** continued

| *Week* | *Day* | *Comments* |
|---|---|---|
| 8 | 52 | J6: perched in prominent tree, begging, between nest area and parents' hunting grounds; soared well, ranging ~800 m from nest; landed competently within live tree-canopy. |
| | 56 | J2: soared, begged to and stooped at M ~800 m from nest. |
| 9 | 59 | J2: soared ~1 km from nest, practised hunting manoeuvres (kiting, 'parachute' drop); not begging from aerially hunting M. F appeared in flight ~1 km from nest with prey (mid morning); J2 followed F, begging and harassing her, back to nest-woodland, prey transfer in trees ~300 m from nest. |
| | 61 | J5: soared alone, apparently hunting, ranging up to 1.5 km W and N of nest; hawked aerial insect three times in 15 min.; no begging or interacting with parents seen, appeared independent; rufous on belly faded (whitening). Last sighting of J5. |
| | | J6: soared in hunting mode (kiting, stoop which became 'parachute' drop then final drop attack to ground with wings retracted, alulae projecting, legs down; unsuccessful). Soared again, begging to distant soaring F. |
| | 63 | J6: soared, wide-ranging (to 1.3 km from nest); circled with neighbouring M (not M parent, on respective moult patterns) in neighbour's home-range ~1 km from J6's nest. Neighbour M soared in display posture, made 'warning' dive or pass at J6; J6 continued to circle and beg, neighbour M stooped and struck at J6, which tumbled briefly, shook herself in flight, then glided swiftly back to perch in own nest-woodland, begging. |
| 10 | 65 | J6: perched prominently between nest and parents' hunting grounds, begging, in early morning. Parent gave food-call (piping) from ridge 1.3 km away, J6 flew directly, begging, towards parent; food transfer, J6 carried prey to separate perch. |
| | 66 | J6: seen and heard (begging) around nest-woodland (B. & L. McCann pers. comm.). |
| | 69 | J6: soared high over nest area, not begging; made sudden long (several seconds) vertical stoop with closed wings, then pulled out to soar above treetops in hunting mode, descended among treetops (did not re-emerge). |
| 11 | 72 | J6: soared high in hunting mode (not begging); kiting, stooping, kiting again, then 'parachute' drop into woodland (did not re-emerge). Last sighting of J6. |
| 13 | 86 | J2: alone on edge of natal home-range (rural residential/suburban interface) ~1 km from nest. |
| | 91 | J2: glided back over nest hill, from excursion away from natal territory; M, soaring higher, displayed and called territorially. Last sighting of J2. |

**Footnote**: The rescued eaglet previously discussed (Debus *et al.* 2007a) is now registered in the Australian Museum as specimen AM O.72565, confirmed as female. ■