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Parental time-budgets and breeding behaviour of the Little Eagle *Hieraaetus morphnoides* in northern New South Wales

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The breeding behaviour and parental time-budgets of a pair of Little Eagles *Hieraaetus morphnoides* were studied throughout 115 hours of observation from nest-building to fledging at Armidale, on the Northern Tablelands of New South Wales, in spring–summer 2009. Supplementary observations were conducted on three other nearby pairs, and the breeding productivity of nine local pairs was monitored. Incubation lasted approximately 38 days (one nest), and one male eaglet fledged at 54 days. Fledgling productivity was 0.56 young per occupied territory in 2009, and 0.63 young per pair per year for 24 pair-years during 2006–2009. Sex-roles, parental time-budgets and nestling growth are described and quantified. Males contributed substantially to nest-building, but little to incubation. In the nestling period for one pair there was a sharp division of labour, with the male supplying all food to the female and young, and the female performing all nest-based parental care. Prey items at the nest (*n* = 24) consisted of immature Rabbit *Orcytolagus cuniculus* (79% by number, ~95% biomass), parrots (13%, ~4%) and ?lizard (4%, ~1%). Adult eagle turnover and mortality appear to have increased, and estimated life expectancy to have decreased, in New England since the 1980s.

INTRODUCTION

Previous efforts to document the complete breeding cycle of the Little Eagle *Hieraaetus morphnoides*, near Armidale on the Northern Tablelands of New South Wales, were thwarted by nest failures or lack of data on the nestling period (Debus *et al.* 2007a; Debus and Ley 2009). The original aim was to try to achieve for Little Eagles what a study on Wedge-tailed Eagles *Aquila audax* had achieved in a single season (Debus *et al.* 2007b), and thus produce a single quantified account of the entire breeding cycle. Such is desirable, because earlier attempts were rather fragmentary or incomplete (Debus 1983, 1984a,b; Bollen 1989, 1991), and the Little Eagle has declined in south-eastern Australia to the point of being listed as *vulnerable* in New South Wales and the Australian Capital Territory (e.g. Debus 2009; Olsen *et al.* 2009). Meanwhile, a study of the species' breeding productivity and diet was conducted in Queensland, where the Eagle was previously unstudied (Fisher 2010). A better understanding of the Little Eagle's biology is a precursor to understanding its decline and formulating management actions, particularly given the 'umbrella' role of raptors in ecosystem and biodiversity conservation (see Sergio *et al.* 2006, 2008).

After the incomplete breeding studies of 2006 and 2008 near Armidale, an active nest of a plumage-dimorphic pair of Little Eagles (dark male, light female) was located in the same area in 2009. This event provided a readily sexed pair for quantification of sex-roles and parental time-budgets. The breeding behaviour of this pair is documented, concentrating on the previously unquantified nestling period, but also testing previous findings on the nest-building and incubation periods where the sexes were sometimes uncertain (cf. Debus *et al.* 2007a; Debus and Ley 2009). The study incorporated ongoing monitoring of nest occupancy and breeding productivity of nine pairs of Little Eagles in the Armidale district.

STUDY AREA AND METHODS

The study area near Armidale was as previously described, and the subject eagle pair was Pair 3 of the 10 mapped pairs surrounding the city (Debus *et al.* 2007a; Debus and Ley 2009, Figure 1). In 2006, the original Pair 3 consisted of light-morph birds, but the possibly ill female disappeared by 2007, leaving the male unpaired through that year. He disappeared in winter 2008, and was replaced by a dark-morph male which remained unpaired through the 2008 breeding season (Debus and Ley 2009). By the start of the 2009 breeding season the dark male had acquired a light-morph mate: clearly a different individual (by plumage details and behaviour) from the 2006 female. This new pair could be sexed by plumage even when one of the members was sitting low in the nest, with only its head visible, and the other was absent. Similarly, the light-morph male of Pair 6 in 2008 was replaced by a dark male in 2009.

The method used was as described previously: i.e. focal-animal sampling during timed observation periods, to calculate time-budgets (% time spent in various activities) by observing the nest with binoculars and telescope from an unconcealed position outside the birds' alert distance (Debus *et al.* 2007a; Debus and Ley 2009). In 2009, the focal pair was observed for 26 hours over 10 days during the pre-laying period, 35 hours over 31 days during incubation, and 55 hours over 51 days (on 5–7 days per week) during the nestling period. Observation sessions were spread almost evenly through two-hour blocks of the day (from 07:00 h), although somewhat biased towards early and late in the day in the pre-laying period (Table 1), and spread evenly through the incubation weeks and each week of the nestling period. In the incubation and nestling periods, watches also alternated equitably between the hourly periods within each two-hour block from 08:00 to 16:00 hours. Nest-watch dates were scheduled to pinpoint laying, hatching and fledging, based on incubation and nestling periods established previously (Debus *et al.* 2007a;

Table 1

Observation schedule (hours of observation) at a Little Eagle nest, in nest-building, incubation and nestling periods (August–December 2009), Armidale (NSW), during each two-hour interval of daylight.

<08:00	08:00–10:00	10:00–12:00	12:00–14:00	14:00–16:00	>16:00
Nest-building:					
4	7.5	2	4	3.5	5
Incubation:					
4	6	7	7	6.5	4.5
Nestling:					
8	10	10	9	10	8

Debus and Ley 2009). Observation sessions usually lasted one hour (sometimes 1.5 or 2 h), but two-hour sessions (or two daily watches of 1 h) compensated for the lack of observation on a few days. Supplementary observations were conducted on two other pairs (Pairs 2 and 6), and nest occupancy and breeding productivity of Pairs 1–8 were monitored in 2009. For pairs that did not renew their 2008 nest or whose 2009 nest was not found (Pairs 1, 4 and 5), the territory was checked through the breeding season, and frequently in the post-fledging period to late February/early March for signs of a fledgling. Opportunistic observations were also made at an active nest (plumage-dimorphic pair) at Tamworth 100 kilometres to the south-west.

RESULTS AND DISCUSSION

Nest site

In 2009, the new Pair 3 used the nest site of the old Pair 3, most recently used by Little Eagles in 2006, although it had been vacant in 2007 (when the original male was unpaired) and used by Brown Goshawks *Accipiter fasciatus* in 2008 when the new male eagle was unpaired. Evidently a desirable site quickly claimed by the new eagle pair, it was just below a hilltop, in the lee of the prevailing westerly winds, and the tree (Yellow Box *Eucalyptus melliodora*) and nest branch appeared more stable in windy conditions than did surrounding trees. The new eagles appropriated a pre-existing nest site although neither had been a previous occupant.

The nest tree (described by Debus *et al.* 2007a) was in the rural-residential zone surrounding Armidale city. It was 30 metres from a gravel driveway, on which there was intermittent daily traffic (cars, motorbikes, horse-riding, dog-walking) to or from a house 240 metres away.

The Tamworth nest was approximately 19 metres above ground in a 25-metre Yellow Box, in floodplain grassy woodland of that species and Blakely's Red Gum *E. blakelyi* in the Peel Valley. Historically, Yellow Box, Red Gum and Manna Gum *E. viminalis* have been common nest trees for Little Eagles in New England (Debus 1984a; Debus *et al.* 2007a; Debus and Ley 2009), but they have been selectively removed from the landscape (especially on the more productive soils) to the point where Yellow Box–Red Gum grassy woodland is a state- and nationally listed *endangered ecological community*, and Manna Gum grassy woodland in New England is a state-listed *endangered ecological community*.

Reaction to disturbance

Although initially wary at the nest when approached within 50 metres during the building phase, the new Pair 3 rapidly habituated to routine human activity, and accepted observation from 80 metres. By incubation they did not react to routine human traffic on the driveway, other than initially being watchful. Conversely, the female of Pair 6 did not tolerate being watched from approximately 60 metres (i.e. flushed when approached, so observing that nest was curtailed), and Pair 5 did not use their 2008 nest, possibly a consequence of sensitivity to close observation in 2008 (see Debus and Ley 2009). In 2006, Pair 8 did not reuse their 2005 nest, on a quiet 'bush' block, after a shed was built within approximately 150 metres and occupied by people, and the surrounding land became developed as high-density rural-residential lots (~2.5 ha each). By 2009, the pair had moved to another nest in a larger, more secluded patch several hundred metres towards Pair 6 (which may partly explain the territorial conflict observed in 2008, cf. Debus and Ley 2009).

The Tamworth pair tolerated gradual encroachment of nearby dam construction to the point where, in the nestling phase, the female remained on the nest while earth-moving machinery worked within 100 metres and trucks passed within 20–50 metres. Dam construction had commenced more than 300 metres away in May, before the breeding season, starting with the felling of woodland trees, and had been deliberately staged to approach the nest gradually over many weeks. Earthworks proceeded to approximately 20 metres from the nest, but throughout the nestling period the nest was attended, and the nestling was last seen near fledging age. Nevertheless, in September 2010 the nest was derelict. That is, the eagles did not reuse it in the following year, after chronic intense disturbance and conversion of the adjoining grassy woodland foraging habitat (>6 ha) to a storage dam and other infrastructure.

These diverse responses (also Debus *et al.* 2007a; Debus and Ley 2009) suggest that there is much individual variation in the Little Eagle's acceptance of human intrusion. Some birds may habituate to routine or gradually approaching disturbance, but others may not, and sudden novel and major disturbances near nests may not be tolerated by most. Rural-residential expansion has displaced some Armidale pairs, and caused others to shift nest sites (Debus *et al.* 2007a; Debus and Ley 2009; this study), as around Canberra (Olsen *et al.* 2009).

Pre-laying phase

Events leading up to laying in 2009 appeared to be fairly synchronised among the eagle pairs, and followed a sequence from advertising and courtship to nest-building and copulation, then the female mostly sitting in the nest in apparent pre-laying lethargy (Table 2).

In 11.5 hours over seven mornings (07:00–10:00 h) during the building and lining phases, the male of Pair 3 brought

Table 2

Sequence of events in the pre-laying phase of four Little Eagle pairs, August 2009. Pairs 2, 3 and 6 at Armidale, Pair T = Tamworth (see text). M = male, F = female.

Date	Pair	Behaviour
12 Aug	T	Mid–late morning, nest-renovation not yet commenced: F perched on nest branch (of 2008 nest), calling; M perched higher in same tree; both birds soared separately over the nesting territory during the morning.
15 Aug	3	Early morning: no sign of nest-building.
18 Aug	6	Early morning: new (dark) M standing on his predecessor's 2008 nest.
19 Aug	6	M brought two sticks (in bill) in 1 h (08:00–09:00 h), placed them on nest and shaped it by sitting and raking with his foot.
21 Aug	3	Morning, during ~1 h (from ~08:30 h): M and F soared together, in mutual and tandem soaring, during which M once jinked away (in display of agility?) when the pair converged.
22 Aug	3	First observed nest-building (sticks already added to built-up nest by early that morning or on previous day(s)).
22–23 Aug	3	Morning (07:00–09:00 h), apparent peak building days: M brought four sticks in 2 h (= 2/hr), amid calling by F from nest; F bought one item of greenery in 2 h (= 0.5/hr) and arranged nest. Copulation, on branch of tree near nest tree (obscured by foliage), detected once (23/08).
23 Aug	2	Morning (09:50 h): M collected stick in bill from neighbouring tree and placed it on 2008 nest.
26 Aug	2	Morning (09:00–10:00 h): after much calling by both birds near nest, M performed display dive into tree canopy nearby, then brought stick, placed it, shaped nest and moved to rim. After F arrived in nearby tree, they copulated on thick, dead horizontal branch of nest tree with slow squealing notes. M dismounted, soared, performed undulating dives with calling, soared high, then returned over nest area in a fast, shallow glide.
26 Aug	3	When M arrived at nest, sitting F stood up, M jumped on her back in abortive mating attempt.
27 Aug	3	During 3 h (09:00–12:00 h) and 2.5 h (14:30–17:00 h), towards end of lining phase: F mostly sat in incubation posture; M brought item of greenery (late afternoon).
28 Aug	3	F not yet laid; M arranged nest (see text).
29–30 Aug	3	F sitting in incubation posture.

four sticks (= 0.35/hr,) and the female brought two sticks (one dropped/rejected, = 0.17/hr) and two sprigs of green foliage (= 0.17/hr). Both adults broke dead sticks from neighbouring trees by pulling with the bill and flapping. The male shaped the nest (by sitting and raking with his foot) after placing one stick, and the female once sat in the incubation posture after placing a stick. With one exception (greenery in late afternoon: Table 2), no building or lining activity was observed after 09:00 hours (Table 1). During the building and lining phase, the male attended the nest for seven percent of observation time, and the female for 57 percent (*n* = 24 h). The female's attendance increased from mornings only (until 24 August) to much of the day from 25 August onwards, including standing on the nest at sunset on 25 August (i.e. apparently roosting there).

In the last few days before laying (25–30 August), the female progressed from standing on to mostly sitting in the nest, including at sunset, initially defending it and arranging material, or collecting sticks from a neighbouring tree. On 28 August there was a changeover in the early morning (07:00–08:00 h), during which the male sat on the nest for 11 minutes and the female returned with greenery. Later in the day (12:00–14:00 h), the female was off the nest for at least 1.5 hours, preening (appearing to pluck her brood-patch) and eating a prey item delivered by the male. Meanwhile, the male arranged nest material and shaped the nest, sitting briefly in different positions as if testing and adjusting it (suggesting that there were no eggs yet), then perching on the nest branch for at least an hour. Back-dating 38 days from the pipping/hatch date (7–8 October), egg-laying probably occurred on 31 August, on which date the female was incubating (dozing). Alternatively, she may have laid the first of two eggs on 29 August (see Table 2), but only the second egg (laid ~2 days later) hatched.

The male brought two prey items to the female, at the nest, during the pre-laying phase. She initially took the first one to the nearby trees but returned to eat it on the nest. She ate the other in the trees while the male tended the nest.

Collectively, these observations confirm the sequence of events and behaviours (e.g. advertisement, courtship, copulation, supplementary feeding) in the Little Eagle's pre-laying phase noted or inferred in previous studies, and the substantial role of the male in nest-building (see Debus 1991; Debus *et al.* 2007a; Debus and Ley 2009). The present study shows that copulation may take place on branches near the nest, as well as on the nest rim (as also found by Fisher 2010). This study also revealed that the female may sit in the incubation posture on the days before laying, and the male may even do so briefly, thus requiring caution in interpreting laying dates. Female eagles may sit on the nest for some time before laying, meaning that 'brooding' does not necessarily indicate the presence of eggs (Brown 1976).

During the nest-building phase, the female of Pair 3 chased an Australian Raven *Corvus coronoides* from the nest tree. When an intruding Little Eagle (apparently a yearling light-morph male, with rusty head and distinctive moult pattern) appeared over the territory, the female called at it from the nest, and later the male soared and directed the soaring display posture (Debus 1991) at it. This intruder frequently and persistently reappeared over the territory throughout the incubation and nestling periods, sometimes challenging in the soaring display posture. The sitting female responded with increasing intensity towards it, leaving the nest to soar, call and perform undulating dives, chase it out of the nest area (incubation period), and ultimately (in the nestling period) stoop at it repeatedly, causing it to squeal, roll and parry at each near-miss. In the incubation period the male also swooped at the intruder, with his legs lowered. Defence was most intense within 100 metres of the nest.

Two Little Eagles in aerial conflict. Photo: David Whelan

On one occasion the soaring female made a long stoop at a mobbing Raven flying up towards her. This female was agile and vocal in the air, performing male-like undulations (though without wing-beating), suggesting that Little Eagles seen performing such displays are not always males.

Incubation

The members of Pair 3 shared incubation, the female incubating for 92 percent of observation time (35 h) and the male for four percent. One parent was standing on or beside the nest for two percent (female 2%, male <1%) of observation time. The nest was unattended for three percent of observation time (in periods of 4–12 min, usually <9 min) while the female soared or defended or, on one occasion (week 3), collected a stick which she added to the nest (<0.1 item/h). She incubated for 14 stints of more than one hour, whereas the male's stints averaged 15 minutes (range 5–27 min, $n = 5$), with a sixth (untimed) stint of more than eight minutes. For his shortest stint (5 min), he arrived at the nest without prey, and the relieved female quickly returned, but on all other occasions (>8 min, 10–27 min) he brought prey to the nest and the female took it to the nearby trees to consume, before returning to relieve him. Neither adult was seen to bring greenery during the incubation period.

The female's behaviour was consistent with incubation on 5 and 6 October, e.g. rocking down as if settling on eggs, and sitting low. Pipping may have occurred on 7 October, when the sitting female seemed restless and sometimes roused to preen her belly. Hatching was indicated on 8 October by the presence of stored prey on the nest rim (for the first time), and the female tending a chick beneath her and sitting higher in the brooding position with her dorsal plumage fluffed (see Debus *et al.* 2007a; Debus and Ley 2009).

Pair 3 thus differed from other local pairs previously watched, both in the smaller contribution to incubation by the male (7–11% of time in 2006), and in the changeover routine which was always initiated by the male's visit to the nest, usually with prey. Other local males often delivered prey to the female at a nearby exchange tree before relieving her, or the male relieved the female after she had left the nest (see Debus *et al.* 2007a; Debus and Ley 2009). However, the seemingly larger contribution by males to incubation in 2008 (23–25%) may have been biased by the small sample size, difficulty in distinguishing the sexes (Debus and Ley 2009), and the fact that several of the few watches happened to coincide with prey deliveries and changeovers. Nevertheless, experienced males incubated for stints of sometimes more than 30–50 minutes in 2006 (Debus *et al.* 2007a), suggesting that perhaps some of the minor differences in 2009 were related to Pair 3 being first-time breeders.

Nestling period: parental behaviour

In Pair 3, the female performed all nest-based parental duties, and the male supplied all observed food to the female and young, throughout the nestling period. The female's nest-attendance routine changed through the period, from mostly brooding in the first two weeks, to standing on the nest or nest branch (guarding) during the middle and later weeks, to extended absences in the final weeks (Table 3). However, in week 7 there was a heatwave during which she often stood on the nest for long periods (>1 h) with her shadow falling on the eaglet. She first stood on the nest, preening rather than brooding, on the mild afternoon of day 14, and from week 2 (day 14), and particularly in week 4, some of her 'brooding' in mild weather was really squatting on her tarsi, in the brooding position, while the chick was in front of her body though sometimes in contact (Table 3). Day-brooding was not observed after week 5 (day 32). These trends in maternal attendance apparently paralleled the growing and feathering chick's ability to thermoregulate (cf. Table 5). The female fed the eaglet bill to bill until it fledged.

In week 1 the female mostly brooded, or fed the chick or herself, leaving for periods of 2–7 minutes to collect a stick (which she added to the nest) or to discard old prey remains. Her attendance in week 2 was similar, although her absences were longer (4–24 min). In the first two weeks her timed brooding stints averaged 34 minutes (range 30–36 min, $n = 5$), broken by feeding bouts, and in week 4 (day 22) a 'brooding' bout (crouching, chick in front) lasted over an hour. In week 3, her absences lasted 15–56 minutes, and from week 4 she was sometimes absent for at least an hour. During these absences she was usually in the nearby trees (within 100 m) or soaring over the nest area.

The male did not brood or feed the chick. Usually, he was on the nest only long enough to deposit prey ($n = 3$) while the female was present. On one occasion (week 2, day 9) he stood on the nest for three minutes while the female prepared and brought prey he had given to her on an exchange perch; on one occasion (week 3, day 18) he held prey on the nest for three minutes until she arrived; and on another occasion (week 6, day 37) he arrived and stood on the nest for seven minutes while she repelled the intruding Little Eagle.

Fresh greenery was visible on the nest on days 11 (by 09:00 h), 15 (by 07:00 h), 21, 22 (by 08:00 h), 23 (by 07:00 h) and 31. On day 3 the female collected a stick (at 07:20 h); on day 24 she

Table 3

Parental time-budgets of a Little Eagle pair at Armidale, NSW, in the nestling period (October–December 2009): % observation time (rounded, total 55 h) spent in each activity. Stand = adult standing on or beside nest (includes female feeding herself); absent = female away from nest; unattended = neither adult at nest. Number in parentheses = no. of hours observation in each week. Week 1 = first week after hatching; week 8 = short week (fledged after 5 days).

	Week							
Sex:activity	1 (7)	2 (7)	3 (7)	4 (7)	5 (8)	6 (7)	7[b] (7)	8 (5)
Female:								
Brood	83	58[a]	31	22[a]	5[a]			
Stand	5	9	36	25	40	40	86	36
Feed chick	8	25	15	22	29	13	1	5
Absent	5	9	17	30	27	47	13	58
Male:								
Stand		1	1	<1		2		
Unattended	5	8	17	30	30	45	6	58
Both at nest		<1		<1		<1		

[a] On day 14, and from week 4 (day 22), crouching rather than brooding, chick often out in front of female
[b] Heatwave week, in which female spent much time shading the chick

collected greenery (in her bill, at ~10:30 h) and a stick (at ~11:00 h); on day 32 she collected greenery from a neighbouring tree (by pulling with her bill and flapping, at ~11:00 h); and on day 43 she collected a stick (at ~07:40 h). Thus, nest maintenance continued throughout most of the nestling period, usually in the early mornings, at a combined rate (sticks and greenery) of 0.1 item collected and deposited on the nest per hour. The male was not seen to bring nest material during the nestling period.

The female tried to feed the chick on day 1 (the hatching day), but it did not take the offered food. Thereafter, the duration of feeding sessions, and the amount of food taken by the chick increased, at least until week 6, after which growing foliage prevented a clear view of proceedings (Table 4). Until week 5 the female fed the chick almost hourly (i.e. during most watches) on stored or delivered prey, but thereafter feeding sessions declined to three instances in seven one-hour watches (week 6), one in seven watches (week 7) and one in five watches (week 8) (see Table 1). This trend appeared to match the growing chick's crop capacity, so that by the time it was nearly adult size it could gorge on a prey item in a single large meal.

The complete division of labour, with the male not brooding or feeding the chick, contrasted with some earlier studies in which males were reported to brood (Debus *et al.* 2007a; Debus and Ley 2009). A few male Little Eagles do feed chicks bill to bill, although such behaviour is seldom observed or reported (Debus 1984a; Bollen 1989; Debus and Ley 2009).

Nestling period: development of young

The Pair 3 eaglet's growth and development were as previously recorded for the species (Debus and Ley 2009), with this study filling gaps for most of the 'missing' days, particularly in weeks 3–6 (Table 5). The male eaglet (by size) fledged at 54 days old, which is similar to most values given previously for males (see Debus and Ley 2009; Fisher 2010).

In this and previous years (2006–08), offspring of light × light parents were always light morph (*n* = 4 pairs, 8 juveniles); the male offspring of a dark male and light female was light; the female offspring of a dark female and light male was dark; and the male offspring of a dark × dark pair was dark (but initially had white mesoptile down).

Fledging and post-fledging

On its fledging day (= day 1), the eaglet was out of the nest and not located in the nest tree or nearby; the female was standing on the nest, with prey on the rim. She then took the food into the nearby trees, but it was not determined whether she fed the fledgling. On day 3, the fledgling was in the crown of a nearby eucalypt approximately 20 metres from the nest. Its tail was still short (two-thirds to three-quarters grown), as were its wings (folded tips half to two-thirds down its tail), and it had slight down on its chin. Early on day 5 it was in the same tree. Its wings and tail were less than full length (about three-quarters), it still had slight down under its chin/gape, and its feet were creamy yellow. Later that day it was back on the nest, resting with a full crop, with the female standing alongside. That is, food was apparently delivered to the nest, and the fledgling's blood-stained foot suggested that it had fed itself. 'Branching' and post-fledging behaviour was similar to that previously reported for fledgling Little Eagles (Debus and Ley 2009; Fisher 2010).

Two months (64 days) after fledging, the Pair 3 juvenile was flying and soaring well, but still giving begging calls, 500 metres from the nest. About eight weeks after fledging, the Pair 2 juvenile (female) gave begging calls from a tree in the nest patch when an adult flew over. About nine weeks after fledging, the Pair 6 juvenile (male) soared well, ranging up to approximately 1 kilometre from the nest, but gave begging calls as it flew. Juveniles were thus dependent for at least two months after fledging; this period, and their ranging behaviour in the post-fledging period, were similar to previous findings (Debus and Ley 2009).

Feeding rates

In the pre-laying phase, the Pair 3 male brought two prey items to the female in 25 hours of nest watch (= 0.1/h). In the

Table 4

Maternal feeding of Little Eagle nestling, Armidale, NSW, October–December 2009: chick's meal sizes and morsel consumption rates. After week 6, view from observation point increasingly obscured by foliage.

Week/day	Length of feeding bout	No. morsels taken by chick
1/2	~0.5 min	6 (~5 sec between morsels)
1/3	3 min	~10 (= 3.3/min)
1/4	3 min	9 (= 3/min)
1/5	8 min	23 (= 2.9/min)
2/9	11 min	62 (= 5.6/min)
2/10	3 min/pause/>4 min	9 (= 3/min), 21 (= 5.3/min)
2/12	11 min	34 (= 3.1/min)
2/13	13 min	?
3/15	>9 min	16 in 7 min (= 2.3/min)
3/18	23 min	135 (= 5.9/min)
3/21	5 min	24 (4.8/min)
4/24	16 min	59 (= 3.7/min)
4/25	>14 min	15 in 5 min (= 3/min)
4/27	5 min (stored prey)	20 (= 4/min)
	18 min (new prey)	43 (= 2.4/min)
5/29	>11 min	>35 in >11 min (= 3.2/min)
5/31	>12 min (morning)	~3/min
	16 min (midday)	62 (= 3.9/min)
5/32	21 min	60 (= 2.9/min)
5/33	>9 min	>26 in >9 min (= 2.9/min)
5/34	>11 min/pause/13 min	36/pause/38 (= 3.1/min)
6/37	9 min	?
6/42	>25 min/pause/>19 min	>91/pause/>14 (= 3.6, 0.7/min)

incubation phase, he brought five items in 35 hours (= 0.1/h). Collectively, these were distributed through most two-hour blocks of the day (from 07:00 h), with a distinct bias after midday ($n = 5$) and particularly after 16:00 h ($n = 3$). In the nestling period, only five deliveries were observed in 55 hours: in weeks 2, 3, 4 and 6 (= 0.1/h; two between 10:00 h and midday, one in mid-afternoon and two after 16:00 h), but this is an underestimate as some were obviously missed by the observation schedule. For instance, in week 1 there was prey on the nest every day, including new prey by 07:00 and 08:00 h on two days, and on three days there was old prey (dumped by the female) and fresh prey. Similarly, in week 2 there was prey on the nest on five of six days, including an old item that was subsequently dumped. Thus, nest watches did not track increasing day length through October–November, and missed the potential hunting window before 07:00 h when some items were probably delivered. It appeared, from prey on the nest, that there was at least one delivery per day.

The female fed the eaglet in all two-hour observation blocks, often on stored prey but also immediately on delivery of fresh prey. She was not seen to hunt or bring prey to the nest during the nestling period.

Feeding rates in the incubation and nestling periods were similar to previous findings (0.1 item/h: Debus *et al.* 2007a; Debus and Ley 2009). The seemingly lower rate in the nestling period (0.1 vs 0.2–0.3 item/h) was probably inaccurate, but Pair 3 in 2009 nevertheless had surplus prey for the chick in its first weeks at least. The sharp division of labour, in prey provision by the sexes, also contrasts somewhat with that noted for Pair 2 in 2008 (cf. Debus and Ley 2009).

Prey and hunting

Observed prey items ($n = 7$) delivered to the female in the pre-laying and incubation phases usually consisted of the hindquarters of small or kitten Rabbits *Orcytolagus cuniculus* (once, a headless rabbit kitten). As a minimum, fresh items delivered to or observed on the nest in the nestling period ($n = 17$, not double-counting old items) were the rear half or hindquarters of small rabbits (12), probable Eastern Rosella *Platycercus eximius* (two), probable parrot (one), probable lizard (one), and one unidentified item. Thus, rabbit contributed 79 percent of prey items by number ($n = 24$), followed by birds (13%) and lizard (4%). Rabbits (probably 200–500 g) would have contributed even more by biomass (~95%), compared with parrots (~100 g, ~4%) and lizard (probably a small dragon, 50–100 g; ~1%). These results, from observations only, are very similar to previous local results for the Little Eagle from orts (remains), pellets and observations combined. They thus support the calculation of the minimum number of prey individuals from all these sources, though not double-counting orts and pellets nor assuming that one pellet equals one prey item (see Debus *et al.* 2007a; Debus and Ley 2009; Olsen *et al.* 2010a).

Observations of successful hunting strikes by Little Eagles are rare (cf. Debus *et al.* 2007a; Debus and Ley 2009). At the start of the pre-laying phase in 2009 (15 August), the Pair 6 female was soaring in hunting mode in late morning (~11:00 h). She made a stealthy slow descent, in stages, towards a rabbit warren, keeping tree crowns and ultimately a tree stump between herself and a rabbit sitting at the entrance to a burrow. She made a sudden steep drop from behind the stump, taking the rabbit by surprise, standing on it and clutching it for several minutes

Table 5

Growth and development of nestling Little Eagle, Armidale, NSW, October–December 2009.

Week	Day	Comments
2	11	In first down, dark eye-rings; moved around nest with aid of wings; flapped wings (unsteadily)
	12	Backed to nest rim, defaecated over rim
3	16	Down thicker, dark eye-rings still evident; cere and gape cream; tips of primary pins visible; preened, stood briefly (unsteadily)
	18	Pecked at prey left by male, before female arrived
	20	In second down; primary pins newly emerged (not yet burst)
	21	Primary pins burst
4	23	Fully in second down; scapular pins, upperwing-covert pins, remex pins emerged (not yet burst)
	24	Remex and scapular pins burst; rectrix pins emerged
	26	Upperwing pins burst, tail pins burst
	28	Upperwings feathering (more brown than down); half-jumped and flapped
5	31	Upperwings almost feathered (little down); head pins burst, breast pins burst
	33	Wings feathered; head, breast and flank feathers emerging; cere creamy yellow
	34	Feathering; nape, throat, underwings, most of underparts downy; gape yellow
	35	Breast feathers sprouting
6	36	Head nearly feathered
	37	Head feathered
	39	Almost fully feathered dorsally; cheeks, throat downy
	42	Tail almost half-grown
7	43	Almost fully feathered; throat, underwings downy
	44	Feathered; chin/throat downy
	45	Large (near adult size); folded primary tips just beyond tertials; tail about half-grown; throat, forehead downy; stood on nest rim, jumped into nest with wings open
	46	Feathered except downy forehead and throat; little down on underwings; jumped and flapped from nest to rim and back
	47	Throat, forehead downy; jumped and flapped
	48	Throat, forehead downy; 'branching' behaviour (flapped, jumped from rim to rim, stepped onto nest branch, jumped back to nest)
	49	Down on throat, little/none on forehead and underwings
8	50	Down on chin
	51	Little down on chin; folded primary tips still barely beyond tertials, tail short (≥ half-grown); 'branching' behaviour to dense (shady) foliage of nest mistletoe
	53	Little down remaining; folded primary tips short (but beyond tertials), tail ~two-thirds grown; 'branching', flapping on branch
	54	Slight down on chin; wings still short (tips about halfway down tail); cere creamy grey, gape creamy yellow
	55	Fledged

before carrying it away and eating it. This event appeared to be a well-practised manoeuvre of an experienced hunter.

Breeding productivity and population turnover

Pairs 2, 3, 6 and 8, and another known pair (last checked in 2005) several kilometres south-east of Pair 6, all raised a single fledgling in 2009 (from an undetermined number of eggs or hatchlings). The male of Pair 1 was unpaired in 2009; his mate had not been seen since their fledgling died of unknown causes in January 2009 (see Debus and Ley 2009). Pairs 4 and 5 failed in 2009 (Pair 5 did not use their 2008 nest), and another known pair several kilometres west of Pair 1 also failed. Thus, productivity was five young raised from nine territories (0.56 young per pair). Incorporating data from 2006–2008 (Debus and Ley 2009), productivity of the Little Eagle around Armidale was 15 young over 24 pair-years to 2009 (0.63 young/pair/year). This figure, although better than the 'bad' year of 2006, is still below that for the 1980s and early 1990s in New England (1.0 young/pair/year: Debus 1991). However, it is similar to that in the arid zone in recent years (cf. Aumann 2001; Fisher 2010).

Following the disappearance of Pair 9 in 2005 (not replaced by 2009), the vacation of Territory 10 (by the lone male) in 2007/08, the disappearance of the Pair 3 female in 2006/07 (Debus and Ley 2009) and the male in 2008 (replaced by new Pair 3 in 2008–09), the female of Pair 1 disappeared in 2009 and the light-morph male of Pair 6 in 2006–08 was replaced by a dark male in 2009. One member of a known pair west of Pair 1 was found dead in mid-2009 (N. Christian pers. comm.); the survivor had a new mate by the breeding season, but they did not breed. Conversely, Pair 2 appeared to be the same individuals in 2006–2009, and the pair south-east of Pair 6 consisted of a dark male and light female in 2005 and 2009. Even allowing for the Territory 10 lone dark male (immature in 2006) possibly becoming the new Pair 3 adult male, a conservatively estimated loss of seven adults over three years (assuming absence = death), out of 23 birds in 12 territories, equates to a turnover of 30 percent or an annual adult mortality of 10 percent. This is twice the annual mortality estimated for the 1980s (4–5%: Debus 1991), and concomitantly halves the calculated mean life expectancy (9.5 vs 19.5 years, cf. Debus 1991). This trend suggests a developing environmental problem for Little Eagles in New England, mirroring that in the ACT: possibly secondary poisoning from pindone and other toxins used to kill rabbits or other agricultural pests (see Olsen *et al.* 2009, 2010b). For instance, one could speculate that the Pair 1 female fed part of a poisoned rabbit to her fledgling, then both died.

CONCLUSIONS

This study confirms and expands on the findings of previous studies, with some new data from a different pair. The minor differences from previous studies, mainly relating to the parental division of labour, may represent individual variation or the conservative behaviour of a new, inexperienced pair breeding together for the first time. This study agrees with previous reports in most other respects concerning Little Eagle parental behaviour, sex-roles, time-budgets and prey. The various cumulative small samples, collectively, give a composite picture of what is probably typical for the species, in behavioural terms. However, this study (like the previous ones) was only a 'snapshot' in nature. Taken together, the findings at Armidale during 2006–09 are similar to the breeding biology and behaviour of the closely related Booted Eagle *Hieraaetus pennatus* (cf. Cramp and Simmons 1980; del Hoyo *et al.* 1994; Ferguson-Lees and Christie 2001).

Pair 3 provided an even greater contrast with the Wedge-tailed Eagle, in terms of parental sex-roles, than did the other Little Eagle pairs in 2006–2008 (cf. Debus *et al.* 2007a,b). Thus, behavioural and other differences support the continued recognition of the two genera (*Aquila* and *Hieraeetus*), although internationally they tend now to be combined (e.g. Gjershaug *et al.* 2009).

This study shows that repeated studies can produce new findings, particularly if they concentrate on gaps in knowledge. One such remaining gap for the Little Eagle is parental feeding rates through the post-fledging period. Nevertheless, spare-time, unfunded observational studies on individual pairs of Little Eagles have probably now reached the limit of their usefulness. It is time for a change in tack to the sorts of rigorous time-budgeting studies that funded or postgraduate research on multiple pairs could achieve, and to ecological research including telemetric studies of home-range and habitat use (e.g. Debus 2009; Olsen *et al.* 2009).

The apparent trends in Little Eagle breeding productivity and life expectancy in New England are a forewarning of a possible regional spread of the population decline already evident in southern New South Wales and the Australian Capital Territory (e.g. Debus and Ley 2009; Olsen *et al.* 2009). Surveys of nest occupancy and breeding productivity provide a more reliable yardstick against which to assess trends in bird atlas reporting rates, hence the need for long-term monitoring of these aspects in sample areas (e.g. Olsen *et al.* 2009). The causes of territory desertions and anomalous eagle deaths also require investigation (e.g. Olsen *et al.* 2010b).

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