

and quantified studies are required, for example, of the sort conducted by teams of amateur observers on Square-tailed Kites *Lophoictinia isura* breeding in coastal New South Wales and south-eastern Queensland (Lutter *et al.* 2004 and studies cited therein).

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Breeding Biology and Diet of the Square-tailed Kite on the Mid-north Coast of New South Wales

H. LUTTER¹, M. LUTTER¹, A.B. ROSE² and S.J.S. DEBUS³

¹203 Pacific Drive, Port Macquarie, New South Wales 2444

²Associate, The Australian Museum, 6 College Street, Sydney, New South Wales 2010 (Present address: 61 Boundary Street, Forster, New South Wales 2428)

³Division of Zoology, University of New England, Armidale, New South Wales 2351 (Corresponding author: sdebus@une.edu.au)

Summary

The breeding cycle of a pair of Square-tailed Kites *Lophoictinia isura* was observed for 155 h over 113 days, from nest-building to post-fledging, from late July to early December 2003 at Port Macquarie, northern coastal New South Wales. Both sexes shared incubation and also brought food to the incubating male; the male incubated on at least one night. Incubation lasted an estimated 40 days, and the nesting period 52 days although fledging may have been slightly premature. Parental behaviour during each phase of the cycle, and growth of the nestling, are described. Parental food-delivery rates to the nest increased from 0.1 item/h in the pre-laying phase to 0.3 item/h during incubation and 0.4 item/h in the nesting phase, then dropped to 0.2 item/h in the post-fledging period. By number ($n = 66$), the breeding diet consisted of 76% birds (84% of which were nestlings), 2% lizard, and 23% unidentified though probably nestlings. Inclusion of data from four other pairs monitored in the district, 1997–2002, gave a nesting density of about 13 km between neighbouring pairs or approximately one pair per 170 km², and a fledging rate of 0.7 young per attempt.

Introduction

Over the past decade, the Square-tailed Kite *Lophoictinia isura* has gone from one of Australia's lesser-known raptors (Marchant & Higgins 1993) to one of the better-known in behavioural terms, although recent information has derived entirely from the eastern coast. The most comprehensive and quantified studies are those on one pair over two breeding seasons in south-eastern Queensland (Barnes *et al.* 1999, 2001), and on each of several pairs during a single season in coastal north-eastern New South Wales (Bischoff *et al.* 2000, Griffiths *et al.* 2002, Lutter *et al.* 2003). Aspects requiring better quantification include the duration of the incubation period, and diet in New South Wales (and indeed in most states).

The incubation period at two Kites' nests was estimated as $41 \pm 1-2$ days and >34 days, respectively (Bischoff *et al.* 2000, Barnes *et al.* 2001), hence the need for greater precision. The few quantified studies have found that males take a minor share of daytime incubation, either for short morning stints while the female exercises, or while she feeds on prey brought by the male, and only the female incubates at night (Marchant & Higgins 1993, Barnes *et al.* 1999, 2001). Previous observations have also found that the incubating female is usually or always supplied with food by the male.

This paper describes the breeding biology and diet of a pair of Kites nesting on the mid-north coast of New South Wales, in the suburbs of a coastal city. Particular attention was paid to the duration of the incubation period, roles of male and female in foraging and in daytime and night-time incubation, and quantification of diet throughout the cycle. New or more precise data were obtained on the incubation phase, necessitating amended conclusions on sex roles. This

study also provides new insights into nest-site selection; an estimate of nesting density, foraging range and fledgling productivity; and an update on the pair studied by Lutter *et al.* (2003).

Study area and methods

The nest-site observed in this study was in suburban Port Macquarie (31°26'S, 152°55'E), about 2 km from the central business district. The nest was observed for 155 hours on 113 days from nest-building to post-fledging, 25 July to 30 November 2003, by rotating teams of observers: 25 h/26 days in the nest-building to laying phases; 56 h/33 days in the incubation phase; 60 h/43 days in the nestling phase; and 14 h in the first 11 days post-fledging (HL, ML and volunteers; see Acknowledgements). The observation schedule included an all-day watch (excluding night, but covering dawn and dusk) late in the incubation phase; and occasional dusk or evening checks by spotlight. Observations continued for 7 h/8 days after the fledging was last seen, until its fate was confirmed. Observations were conducted from the ground about 30–40 m from the nest, with the aid of binoculars and telescopes at a viewing angle of about 45°, hence nest contents were not visible. Daily watches were intensified around anticipated laying and hatching dates.

The adult Kites were sexed in the pre-laying phase by copulatory and other behavioural cues. They could not be distinguished morphologically during most of the incubation phase, but from the last week of incubation they were separable by a split in the male's tail, caused by a missing central rectrix; when they perched together he was also seen to be slightly the smaller. Consequently, at times sexing had to be qualified by 'presumed' or 'putative'. Terminology for vocalisations corresponds with that in Marchant & Higgins (1993), Debus (1996) and Barnes *et al.* (1999, 2001).

The ground below the nest was cleared and covered with a 5 × 10 m sheet of shadecloth on 2 August, to facilitate the collection of prey remains and pellets. Ten intact pellets, and fragments of a further four pellets (total 14), were collected along with eight nestling birds dropped from the Kites' nest. Remains were analysed by ABR and SD, by comparison with reference material and a manual (Bemis 1980), and some items were referred to the Australian Museum for further identification. The minimum number of prey individuals was calculated from all sources combined (pellets, remains and direct observations of prey delivered).

Results

Nesting density

Plotting the nest-sites of four known pairs in the district (those of Bischoff *et al.* 2000, Griffiths *et al.* 2002 and Lutter *et al.* 2003, and the Port Macquarie nest) gave distances of 14–15 km between neighbouring pairs (mean 14 km, $n = 3$). That these were different pairs is confirmed because some of the nests were simultaneously active in at least some years. In September 2003 a fifth pair of Kites (confirmed by differences in moult pattern) was observed 7–8 km south-west of the Port Macquarie nest, and 14–15 km from the other nearest pair. If all these pairs were nearest neighbours, then an average inter-nest distance of about 13 km translates to a density of one pair per approximately 170 km².

Nest-site selection

A feature of all five nests monitored by HL in the district (i.e. those in Bischoff *et al.* 2000, Griffiths *et al.* 2002, Lutter *et al.* 2003 and at Port Macquarie) was a dead branch 1–2 m long × 5 cm thick that formed part of the horizontal fork on which the nest was built. This projecting branch, easily accessible from the nest, was used by the adult Kites as a perch, and by fledglings at the 'branching' stage. Another feature of these nests was that they were all within 10 m of the forest edge, in each case the opening being a road or track.

Update: 2002 nest

The storm-damaged nest and adopted nest described by Lutter *et al.* (2003) were checked in 2003. The nest-branch, from which the fledgling Kite's natal nest had fallen, had been sawn off with a chainsaw. As this act would have been possible only by the use of a cherry picker, and only that branch had been cut down, it appeared that the branch was removed to prevent the Kites from re-nesting on the highway verge.

The alternative (adopted) nest was occupied by a sitting adult Kite for 15 minutes on 17 September 2003, and on 21 and 22 September an adult circled overhead. In 10 minutes on the latter date it landed twice (for 1 minute) on the nest, then departed. On 23 September the nest was unoccupied and there was no sign of the adult(s), of which there had appeared to be only one; Pied Currawongs *Strepera graculina* foraged unchallenged near the nest-tree. A single Kite was again seen near the nest on 15 October, but the nesting attempt appeared not to proceed. Given that this nest-site also had the typical dead branch projecting from the fork, it was probably an old Square-tailed Kites' nest and not that of another raptor species as previously believed.

Nesting chronology

An adult Kite broke a stick from a dead tree in Port Macquarie on 3 July 2003, and building was confirmed in mid morning of 25 July when a Kite snapped off a leafy branch and deposited it on the partly built nest. At that stage it was uncertain whether two Kites were present. The pair was confirmed on 31 July; laying occurred late in the third week of August; hatching at the end of September; and fledging on 20 November.

Nest-site

The 2003 nest was located in the grounds of historic Roto House, the National Parks & Wildlife Service former headquarters, within Macquarie Nature Reserve (12 ha) and adjacent to the Koala hospital. Both facilities are open to the public every day, the nest-tree being adjacent to a carpark subject to frequent visitor use. A nest was suspected in the vicinity since SD observed a Kite over adjoining suburbia in 1991, and Park staff then advised that a pair was thought to be present. From the behaviour of the pair, a nest was suspected (though not found) in 2002. The 2003 nest was located 28 m above ground, 6 m from the trunk, in a large Blackbutt *Eucalyptus pilularis* (40 m tall, 1.3 m diameter at breast height). The tree was 10 m from a main street, one of Port Macquarie's busiest thoroughfares.

Although the completed nest appeared rather flimsy, it survived gale-force winds at the end of the incubation period when a large branch fell on the observation point. In week 1 of the nestling period it also survived a severe thunderstorm with gale-force winds, torrential rain and hail.

Territorial defence

Through their breeding cycle, the Kites were harassed by other species and sometimes returned the aggression. During the incubation period a returning Kite (presumed male) was attacked by two Torresian Crows *Corvus orru* but became the aggressor, separating the Crows and chasing one out of sight while giving a *chee-chee-chee*... call. Also during incubation, at dawn a Laughing Kookaburra

Dacelo noveguineae landed near the nest and was promptly chased off by the male Kite which had been roosting nearby. Towards hatching, the airborne male was attacked by two Crows but outflew them, while the female yelped from the nest during the attack; the harassment continued intermittently for 20 minutes.

Twice, the airborne male Kite was vigorously attacked by one or two Australian Magpies *Gymnorhina tibicen*; on the first occasion he yelped repeatedly, and on the second he fended them off while calling. Later, he was attacked by two Crows but outflew them on each occasion.

A pair of Brown Goshawks *Accipiter fasciatus* had an active nest about 150 m from the Kites, and fledged two young by early November. No interaction between the two species was observed.

Nest-building

The nest took six weeks to build, from the first week of July to laying in the third week of August. However, addition of material was last seen a week before incubation started. Most observations in the pre-incubation phase were made around midday or in the afternoon, therefore active building times were usually missed. Most building apparently took place in the early morning. The male brought one stick and the female brought one leafy branch between 0900 and 0915 h on one morning; the male brought one leafy branch between 1000 and 1100 h on one morning; and he brought one stick between 1430 and 1530 h on one afternoon (a total of 1.8 material-gathering forays per hour of active building time). Otherwise, during the remaining 23 h of observation time, mostly from late morning to late afternoon, the female was usually perched beside the nest or in an adjacent tree, or was on the nest arranging material. The male was usually absent, but occasionally flew over, alighted on or perched beside the nest. Both were occasionally absent for entire watches of 15 or 30 minutes, mostly in the early building phase (late July). The female was more frequently on the nest as laying approached; on 8 August she was alternately sitting and standing on the nest.

Although addition of material was seldom observed, the nest noticeably increased in size through the last week of July and first fortnight of August. From 2 to 8 August, 20 dead sticks, dropped by the Kites, accumulated on the shadecloth beneath the nest. The nest-fork lacked the degree of free access that characterised previous Kites' nests in the district, thus possibly hindering deposition of sticks.

Sunset, evening and early-morning checks revealed that the male and female departed from the nest at dusk for an overnight roost elsewhere, and (once) returned to the nest together, from their night roost, at 0720 h.

On one occasion (4 August) towards sunset, the circling pair descended to the nest, female first with chittering calls by both as the male arrived. The Kites then perched together beside the nest before departing at dusk. Later (9 August), at sunset, they perched beside the nest and preened each other's neck before departing at dusk.

Copulation

Copulation was first observed on 1 August, 19 days before incubation commenced, and last observed on 17 August, three days before incubation commenced. Initial matings did not achieve successful insemination, and later matings were accompanied by calling. Courtship (supplementary) feeding was observed once, two days before incubation commenced. A précis of field-notes follows.



Pair of adult Square-tailed Kites allopreening, Bundaberg, south-eastern Queensland, spring 1999

Plate 19

Photo: C.P. Barnes

1 August: Kites copulating beside nest on the observer's arrival at 1500 h, and continued for a further 70 seconds. Both then perched side by side, 10 cm apart, and the male preened the female's nape for several seconds; they remained together for a further 5 minutes until the watch ceased.

2 August: Female perched beside nest for an hour from 1330 h, then male arrived and they mated for 92 seconds; he discharged a stream of clear seminal fluid (i.e. not white excreta) onto the shadecloth below just before dismounting; then they perched side by side for 10 minutes until the male's departure. Female then moved to the nest and rearranged sticks for 30 minutes, until watch ceased at 1515 h. During the entire time there was much noise from axe and hand saw directly below, as two observers cleared the shadecloth site of litter; yet the Kites seemed unperturbed.

7 August (1200 h): Female perched beside nest, then after 10 minutes moved onto nest as male flew over; he alighted on the nest and they mated after much chittering.

9 August (0930 h): Female eating prey in adjacent tree; male arrived, with chittering by both birds, then they mated for 80 seconds. He departed, she resumed feeding.

12 August (1000–1100 h): Kites mated in adjacent tree, for 90 seconds, and remained perched there.

15 August (1400–1530 h): Kites mated in adjacent tree for >60 seconds; both softly chittering during this act.

17 August (1230 h): Female on nest, male arrived and they mated on the nest.

18 August (1045 h): Female on nest, male arrived and dropped prey in the nest.

Incubation

On 19 August, in mid afternoon, one Kite was perched beside the nest and the other was absent. On 20 August the female was on the nest during three short watches (15 minutes each) through the afternoon to dusk, and remained on the nest overnight. On 21 August she was on the nest at dawn, and through the afternoon she was low in the nest, incubating, until dusk. 20 August was therefore taken as the start of incubation (day 1).

For the first fortnight of incubation, the presumed female was always on the nest, incubating, and the presumed male was usually absent, perched in an adjacent tree, or (once) perched beside the nest at 1630 h before departing. The non-incubating bird did not roost overnight at the male's usual daytime perches near the nest; on one evening the presumed male flew over the nest at dusk but did not roost nearby.

On two days in the first week, the incubating female called repeatedly (the soft *ee-ee...* squeal), apparently food-begging, at the perched male until he departed. The second such incident occurred during a morning watch, but in the mid-afternoon watch the incubating Kite, apparently having fed in the interim, ignored its food-bearing mate as the latter arrived with a small prey item. The hunter then ate the prey in 10 minutes at the nest and perched nearby, while the incubator remained unmoved. On one other occasion the hunter made a quick food-drop to the nest while the other incubated.

During the all-day watch, a fortnight into incubation, male and female shared daytime incubation (20% by the putative male, 80% by the putative female), and each incubated overnight on consecutive nights (Table 1). At this stage the non-incubating bird roosted overnight in the adjacent tree. Over the ensuing 3 weeks a Kite was always incubating during daily nest checks. Changeover was seen on two days, in the early morning and late afternoon, respectively. A food-drop to the incubating Kite was seen on one day, and on another the Kite that was relieved from afternoon incubation soon returned with prey, which both ate at the nest.

By the 40-hour continuous watch, in the last week of incubation (days 35 and 36, Table 2), the male contributed a declining share of daytime incubation (9% and 2% respectively, or 4% over the two days). On day 37 he was refused a share of incubation. At this stage, and perhaps related to hot weather, both adults were keen to incubate and were reluctant to be relieved by the other, although the female usually prevailed and she sat overnight. The male did not roost near the nest.

In the remaining days of incubation, days 38–40, the female was always incubating and the male made several food-drops to the nest, sometimes lingering on or near the nest. On day 38 he tried to effect a changeover, but was refused. On day 39 he stood on the incubating female's back and preened her nape vigorously for 10 minutes, perhaps to initiate a changeover (cf. Table 2), but without response. On day 40 the female ate a provided prey item in 7 minutes, but did not feed young. Hatching was indicated by a behavioural change in both parents: day 38 was the male's last attempt to incubate; from day 40 he made quick food-drops to the nest, typical of the nestling phase, without lingering at the nest; on day 41 the male brought a leafy spray to the nest, and the female changed position frequently in the nest.

To summarise: the male contributed a substantial share of daytime incubation, not only while the female was feeding on provided prey, and he incubated on at

Table 1

Behaviour of adult Square-tailed Kites during all-day watch, early incubation period, Port Macquarie, N.S.W., 2–3 September 2003. A = putative female, B = putative male.

Time (h)	Comments
2 September	
0550	Sunrise; overnight incubator (A) still incubating; B perching in adjacent Tallowwood <i>Eucalyptus microcorys</i> .
0635	B flew to nest and persistently nudged A until A departed 2 min. later, giving a rattling <i>ke-ke-ke...</i> call. B incubated then at 0654 h rearranged egg(s), lining or sticks.
0700	A landed in Tallowwood without prey; tried once unsuccessfully to nudge B, changed perches nine times.
0722	A forcefully ejected B from nest and resumed incubating. B departed on a hunting flight, circling over the tree canopy.
0733	B returned with two small prey items; ate one item on nest rim, perched momentarily nearby, then returned to nest to drop second item, which was promptly eaten by A. B remained nearby.
0808	B left on hunting flight, seen occasionally overhead but did not land.
0915	B arrived on nest with prey, both Kites fed for 4 min.
0925	B departed, returned 2 min. later with green foliage, which it placed in nest.
0930	B perched nearby, departed at 0940 h low over tree canopy.
0940–1630	A incubating; changed position about every half-hour, sometimes rearranging nest-material and possibly turning egg(s), occasionally stretched wings.
1635	After 7-hour absence B returned with prey; dropped it on nest and departed. A ate prey within 1 min.
1640	B returned with another small prey item, dropped it on nest and departed. A ate prey in 3 min.
1650	B returned to nest with another small prey item, both fed side by side; B ate about 80%, A 20% of item.
1655	Incubation change-over: B incubating. A perched beside nest; both yelped several times then relieved. Kite A flew at 1700 h, returned at 1710 h to roost high in canopy of Tallowwood. Both Kites remained in respective positions until dark at 1800 h.
3 September	
0530	Dark; in advancing daylight A still in last night's roosting position in Tallowwood, B incubating.
0620	A flew onto nest and gently but unsuccessfully tried to take over incubation. By 0640 h A gave up and departed, returning at 0710 h without prey; circled for several minutes; departed then returned to nest again at 0725 and 0730 h without prey.
0740	A landed above nest, then effected changeover; B departed on hunting flight.

least one night. The female sometimes foraged, and both sexes brought prey to the nest and shared it with the incubating partner. The nest was always attended until hatching, with egg(s) uncovered only when the incubating parent stood up to feed for several minutes, or momentarily during changeovers. Hatching appeared to occur on 29 September, giving an estimated incubation period of 40 days.

Table 2

Behaviour of adult Square-tailed Kites during continuous 40-hour watch, last week of incubation period, Port Macquarie, N.S.W., 23-25 September 2003. F = female, M = male.

Time (h)	Comments
23 September	
1530	M incubating. At 1535 h F arrived with small prey item, eaten by both Kites. Both called <i>chip-chip-chip</i> ...; no longer giving the chittering calls of courtship phase.
1545	Changeover: F incubated. M circled overhead.
1600	M returned to nest and effected changeover. F reluctantly left and circled overhead.
1610	F returned and insisted on changeover, reluctantly given by M which departed on hunting flight.
1735	M returned, tried to make changeover which was refused by F; for next half-hour M flew around nest-tree and used four different perches.
1810	M departed; not seen again this evening near nest. Unseasonal heatwave this day (39°C).
24 September	
0526	F incubating (overnight). At 0629 h M arrived and tried unsuccessfully to make changeover, circled above then perched nearby.
0638	M landed on nest, but F did not move; M left and circled.
0643	M returned and pushed F out, settled to incubate. 'Forced' changeovers occurred four more times over next half-hour; F prevailed and incubated, at 0715 h M departed in low flight, apparently hunting.
0725	M returned to nest. Two changeovers in next 15 min., but F prevailed and resumed incubating. F forced changeover by pulling sticks and nest-lining from beneath M, and walking across his back several times. F not fed since previous day.
0800	Hot day; F incubating but restless, frequently changing position.
1015	M arrived with small prey item; both appeared to feed together. At 1030 h M perched beside nest.
1050	Changeover: M incubating. F perched beside nest. Reversal at 1100 h: F incubating; M perched in nearby tree then departed at midday.
1330	M reappeared and circled, departed. Incubating F frequently changed position over next hour; temperature 37°C.
1500	M arrived with passerine nest; F extracted and ate two nestlings, then tore it up and lined own nest with it. M perched beside nest, then moved onto nest at 1530 h. At 1600 h M departed; F moving on nest; F incubating to 1810 h (dark).
25 September	
0520	Dawn; F incubating (overnight). At 0540 h (sunrise) M arrived at nest, both gave <i>chip-chip-chip</i> ... call. F did not move, M flew to nearby perch.
0605	M at nest, persistently nudging F for 10 min., but gave up and perched on dead stick projecting from nest-fork.
0620	M at nest. Both preened each other's head and neck energetically for next 15 min.; always initiated by M and responded to by F. At times allopreening almost rough; if an attempt by M to induce changeover, it was unsuccessful.
0635	M returned to dead stick beside nest.
0650	M back at nest, gently but unsuccessfully tried to effect changeover. At 0700 h M flew to treetop branch and sunned; briefly checked nest at 0715 h, but resumed sunning on another high branch.
0730	M departed; F on nest since 1100 h previous day.

Table 3

Parental behaviour of Square-tailed Kites, nestling period, Port Macquarie, N.S.W., 29 September-19 November 2003. Week = week of nestling period; h = hours of observation time. F = female, M = male. M absence excludes quick food-drops to nest.

Week (h)	Comments
1 (17.5)	F brooded constantly, standing only to feed herself or young for periods of several minutes (once 5 min., once >10 min.). Weather mostly inclement (rain, followed by a storm with wind, torrential rain and hail, then cold rain and wind). As the calmer afternoon of day 6 warmed up, F stood in nest and did much preening and wing-stretching. M usually absent; sometimes perched on dead branch beside nest for 30-60 min., or occasionally in nearby tree.
2 (8)	F mostly brooding (90% of time) or feeding young (5%; 10 min. and c. 5 min.). On day 10 (warm, sunny) F shaded chick (5%; 15 min.), walked around nest rim, stretched and flapped wings. Moved to dead branch beside nest for 5 min. (1% of time). On day 10 F flew off, absent 5 min. (1%). M usually absent, or occasionally perched in nearby tree; not roosting overnight near nest.
3 (10.5)	F standing on nest (not brooding) for entire time, occasionally fed chick which was readily visible from day 19. M usually absent, or perched on dead nest-branch.
4 (5.5)	F always standing on nest. M usually absent, or perched nearby.
5 (7)	F always standing on nest. M usually absent, or flew over or landed nearby.
6 (4.5)	F standing on nest for 17% of time; otherwise absent (83%). F brought one prey item to nest. M absent.
7 (4.75)	F standing on nest for 16% of time, on dead nest-branch for 37%, absent for 47%. F brought one prey item to nest. M absent or (once) on dead nest-branch.
8 (1.75)	F on dead nest-branch for 29% of time, otherwise absent (71%). M absent.

Nestling period

Only the female brooded. Female nest attendance, and proportion of time spent brooding, declined over the nestling phase from constant brooding in week 1, to standing on the nest from week 3, to increasing absences from week 6 (Table 3). Up to week 5 the male sometimes perched nearby, but from week 6 he usually visited only to drop prey; on day 7 he did not roost overnight near the nest. The female made two food-drops: one in week 6 and one in week 7. These behavioural changes matched the single nestling's growth and development (Table 4).

Only the female tore up food for the nestling, except on day 15 when the male brought prey to the nest, plucked it there, and both parents fed the chick bill to bill. Once, the female regurgitated a pellet into the nest. On day 15 she arranged green leaves in the nest.

Fledging

The juvenile fledged at 52 days after hatching, 2 days after first venturing on to the branch beside the nest. After a night of gale-force winds the juvenile was absent from the nest, and remained so all afternoon, although both parents were present and one was feeding in the nest. Towards sunset the female seemed agitated, frequently flying and landing, but finally settled on the nest to roost at dusk. Next morning both adults seemed agitated, visiting the nest and flying around, and appeared not to know where the juvenile was. After three observers

Table 4
Growth of nestling Square-tailed Kite, Port Macquarie, N.S.W., 2003. Week = week of nesting period.

Week	Day	Comments
2	14	Small and downy.
3	15	Completely downy white; sitting up.
	19	Wings pin-feathered; flapped wings.
4	23	Head downy but neck, breast and wings pin-feathered; remex and tail pins burst.
	25	Feathering; but body downy; about half-grown; stood and spread wings.
	28	Feathering advanced.
5	29	Stood up and stretched well-feathered wings; feathered dorsally.
	30	Almost as large as female.
	31	Down on belly and underwings; head-feathers partly grown.
6	38	Feathers growing daily; similar in size to parents.
	39	Fed itself on prey left by parent.
	40	Appeared fully feathered.
8	50	On branch beside nest, flapping wings vigorously.
	51-52	On nest rim, exercising wings; appeared not yet ready to fledge.

searched over 5 hours from dawn, at 1115 h an almost wailing Kite call, *eeep-eeep...*, revealed the juvenile hanging upside down in foliage of the adjacent tree (a Tallowwood *Eucalyptus microcorys*). It then flew around the canopy well, but had difficulty finding the flight-path to the nest. Around midday it finally crashed into the nest, and was still there towards sunset. Given the fledgling's slightly undeveloped state and ineptitude in returning to the nest, it may have been blown out of the nest, although the nest survived intact.

Post-fledging period

Two days after fledging, the juvenile was initially perched in an adjacent tree, with both parents in attendance, then flew and landed competently on the nest. Thereafter, to 10 days post-fledging, the juvenile was either on the nest where it fed, on the dead nest-branch, or in an adjacent tree. On day 5 its wingtips were level with its tail-tip (Plates 20-21). In the first week one or both adults were usually in attendance, in the nest-tree or adjacent tree; on day 7 all three birds roosted 10 m from the nest, in the adjacent tree, overnight. In the second week the adults were absent, except when the female once fed with the juvenile on the nest (day 8) and once sunned with the juvenile on a perch (day 10). The juvenile sunned repeatedly, in bouts of up to 5 minutes. The newly fledged young Kite was frequently harassed in the air by up to four or five Torresian Crows; it seemed to evade injury, but the intensity of attack caused concern for its safety.

The juvenile was last seen alive 10 days after fledging, on 30 November. On 5 December its badly decomposed, maggot-eaten carcass was found 70 m from the nest, indicating death several days earlier (on or about 1 December). The carcass was found by chance, on the ground in thick vegetation, by Park staff



Fledgling Square-tailed Kite, Port Macquarie, N.S.W., 24 November 2003 (day 5 post-fledging)

Plate 20

Photo: H. Lutter



Fledgling Square-tailed Kite stretching, Port Macquarie, N.S.W., 24 November 2003 (day 5 post-fledging)

Plate 21

Photo: H. Lutter

Table 5

Provisioning rates of adult Square-tailed Kites through breeding cycle, Port Macquarie, N.S.W., 2003: number of prey items seen delivered to nest.

Stage	Observation time (h)	No. items	Delivery rate (item/h)
Pre-incubation	25	2	0.1
Incubation	56	18*	0.3
Nesting period	59.5	22	0.4
weeks 1-2	25.5	10	0.4
weeks 3-4	16	6	0.4
weeks 5-6	11.5	2 ^a	0.2
weeks 7-8	6.5	4 ^a	0.6
Post-fledging	14	3	0.2

* One of these by female Kite (in nesting period, delivered in weeks 6 and 7)

during routine grounds maintenance. Meanwhile, since the juvenile's disappearance, one or both adult Kites continued to perch in or quarter the nest area to 22 days post-fledging (final observation day), and visited the nest, but they did not roost overnight near the nest-tree on day 13. The female made a food-drop to the nest on day 22, and the adults allopreened in the adjacent tree on day 21.

From the almost incessant harassment of the fledgling Kite by Torresian Crows whenever it flew, the Crows were suspected as a factor in its death.

Moult

The male Kite lost a central rectrix on 23 September (late incubation period) and a secondary in his left wing on 27 November (post-fledging period); his rectrix was almost regrown on 11 December. The female lost a secondary from her left wing, near the body, on 22 November (post-fledging period) and a primary from her left wing on 4 December. By 9 December she was scruffy and moulting, but the male was still in neat plumage.

Feeding rates

The male's feeding rate to the female in the pre-incubation stage (0.1 item/h) was lower than the parental feeding rate in the incubation period (0.3 item/h) and nesting period (0.4 item/h; Table 5). The feeding rate varied through the nesting period, with a period of apparent food-stress in weeks 5-6 coinciding with the female's increasing absence from the nest and her delivery of a food item in weeks 6 and 7 (Table 3). The feeding rate declined post-fledging (0.2 item/h). The female made a further food-drop to the nest about 10 days after the still-dependent fledgling died late in its second week (0.1 item/h).

Prey deliveries were made throughout the day, from 0630 h to 1725 h. During incubation, the feeding rate was slightly higher in the afternoon (0.4 item/h) than in the morning (0.3 item/h; 28 vs 28 h). Although observation sessions were biased towards mornings in the nesting period (44 vs 16 h), the prey-delivery rate was slightly higher in the afternoon than in the morning (0.4 vs 0.3 item/h).

On an apparently typical day in the incubation period (Table 1), the presumed male made five deliveries: at 0735 h (two items, apparently one in each foot),

0915 h, then a 7-hour absence before three drops in the final 15 minutes to 1650 h. On another day (Table 2), he delivered at 1015 and 1500 h, the second a nest containing two items. On a third morning, he delivered at 0715 and 1030 h. In the nesting period, on one morning he delivered at 0630 and 0835 h, and on another twice between 0930 and 1230 h.

Foraging range

The adult Kites, recognisable by moult pattern, foraged up to 4 km south of their nest, over HL's residence where casual sightings were obtained. If they ranged a similar distance in other directions, they could have used a home-range of approximately 50 km² in the breeding season.

Diet

By number, the Kites' breeding diet consisted of 76% birds (84% of which were nestlings), 2% lizard and 23% unidentified although probably nestling birds (Table 6). Identified species (scientific names given in Table 6) strongly represented in the sample were Spotted Turtle-Dove and Crested Pigeon (total 14%) and honeyeaters (18%). Most remains of large honeyeaters (wattlebirds, Noisy Miner) were of feathered nestlings, close to fledging.

Of the 24 bird nestlings seen brought to the Kites' nest, six were noted as 'small', two as 'sparrow-sized', and one as 'medium-sized' ('large' being of Red Wattlebird size, after Lutter *et al.* 2003). Of the nesting or fledging birds found dropped beneath the Kites' nest, a plucked and partly eaten pigeon or dove (headless, legless) weighed 25 g; a partly plucked and eaten (headless) Crested Shrike-tit 14 g; and an intact cuckoo-shrike (?) 10 g, a Noisy Miner chick 7 g, a plucked whistler (?) 5 g, and three honeyeaters 3-5 g (all after >2 weeks of immersion in alcohol). The lizard was about 20 cm long.

Disregarding two pellets that had been flattened, eight intact pellets measured 34-51 × 15-29 mm (mean 37.6 × 19.8 mm). Of the 14 pellets, 11 (79%) contained unidentified nestling feathers; four (29%) contained remains of nesting Turtle-Doves or Crested Pigeons, along with large seeds from their stomachs (wheat and corn, probably provided as birdseed by people), and one (7%) the remains of a nestling Little Wattlebird. Seeds were found in seven pellets (50%) and insect remains in two, these probably in the stomachs of the Kites' prey.

The Kites occasionally brought whole passerine nests, and extracted the nestlings (Table 2). The remains of one Little Wattlebird nestling were with the remains of its nest-cup; fragments of honeyeater and passerine (possibly flycatcher) eggshell were found among remnants of nests. Pieces of white eggshell and nesting, along with nesting remains, suggested that a nesting Turtle-Dove and Crested Pigeon had each been seized with the nest. The adults of these species may have been taken while sitting on their nests.

Adult birds were mostly taken early in the season, in August and early September, presumably before the peak abundance of nestlings. Otherwise, one adult Crested Pigeon was taken in early October. Nestlings were taken throughout the Kites' breeding cycle, although only dove and minor nestlings were recorded in August. The lizard was taken in December.

After the breeding season, in March 2004, in Port Macquarie HL observed one of the adult Kites eating a fully grown juvenile Figbird *Sphetheotheres viridis*.

Table 6
Breeding diet of Square-tailed Kite family, Port Macquarie, N.S.W., pre-laying period to post-fledging period, August–December 2003; N = minimum number of prey individuals from pellets, prey remains, and direct observation.

Prey species	N	%
Remains and pellets:		
Spotted Turtle-Dove <i>Streptopelia chinensis</i> :		
adult	1	1.5
nestling	1	1.5
Dove nestling	2	3
Crested Pigeon <i>Ocyphaps lophotes</i> :		
adult	1	1.5
nestling	2	3
Spotted Turtle-Dove/Crested Pigeon nestling	2	3
Red Wattlebird <i>Anthochaera canaliculata</i> nestling	1	1.5
Little Wattlebird <i>Anthochaera chrysoptera</i> nestling	3	4.5
Noisy Miner <i>Manorina melanoccephala</i> nestling	2	3
Honeyeater sp. nestling	3	4.5
Crested Shrike-tit <i>Falcunculus frontatus</i> fledgling	1	1.5
Whistler <i>Pachycephala</i> sp. (?) nestling	1	1.5
Cuckoo-shrike <i>Coracina</i> sp. (?) nestling	1	1.5
Observations:		
Lewin's Honeyeater <i>Meliphaga lewinii</i> (?)	1	1.5
Yellow-faced Honeyeater <i>Lichenostomus chrysops</i>	1	1.5
White-naped Honeyeater <i>Meliphrephus lunatus</i>	1	1.5
Sparrow-sized bird	1	1.5
Small bird	1	1.5
Nestling passerine	2	3
Nestling bird	22	33
Lizard	1	1.5
Unidentified	15	23
Total	66	100

Fledging productivity

Fledging results are available for seven nesting attempts by four pairs of Kites in the district, 1997–2003 (nests 1 and 2 of Bischoff *et al.* 2000 and Lutter *et al.* 2003; that of Griffiths *et al.* 2002; and this study). Five young from seven nesting attempts gives 0.7 young fledged per attempt, and 1.3 young per successful nest ($B/1 \times 3$, $B/2 \times 1$).

Discussion

The nest at Port Macquarie, in a large living Blackbutt, was typical for the district, though with somewhat poorer flight access, compared with those studied by Bischoff *et al.* (2000), Griffiths *et al.* (2002) and Lutter *et al.* (2003). A previously unremarked, but apparently common, feature of Kites' nests is the presence of a

dead branch projecting from the nest-fork. As well as being used frequently by the adults as a readily accessible nest-side perch, it appears to have a role in the safe 'branching' of new fledglings. Such a branch, clear of obstructing foliage, may be advantageous for this long-winged species. Proximity to the forest edge may also assist access, and siting of nests near roads or tracks may be a predictable feature.

Most aspects of the biology of the Kites at Port Macquarie were similar to those reported in other studies. For instance, the laying date was within the range reported for the general latitude and for the district (Marchant & Higgins 1993, Bischoff *et al.* 2000), although about 2–3 weeks earlier than for local nests observed by Griffiths *et al.* (2002) and Lutter *et al.* (2003). An incubation period of 40 days is in close agreement with that of Bischoff *et al.* (2000), and longer than the inconclusive estimate of Barnes *et al.* (2001). It is also similar to incubation periods (about 40 days) of the other 'old endemic' Australian raptors — the Black-breasted Buzzard *Hamirostra melanosternon* and Red Goshawk *Erythrorhynchus ruficeps* — but longer than those of the milvine kites *Milvus* and *Haliaeetus* (31–35 days; Marchant & Higgins 1993). The nestling period was slightly shorter than reported in other studies (55–60 days; Marchant & Higgins 1993; Barnes *et al.* 1999, 2001), but fledging may have been weather-induced and about 2 days premature.

The roles of the sexes during incubation were mostly as previously reported, but with notable exceptions in behaviour as compared with previous studies (Marchant & Higgins 1993; Barnes *et al.* 1999, 2001). The male took a greater role in incubation than previously reported, including overnight sitting reported herein for the first time. This difference may be individual variation, although sex roles in nocturnal incubation are seldom studied in diurnal raptors. Males sometimes incubate overnight in some other raptor species (Newton 1979).

The female Kite occasionally foraged and brought prey back to the nest to share with the incubating male, behaviour not previously reported in this species. Such behaviour may be individual variation, or may have gone undetected in some previous studies because the sexes can be difficult to distinguish, and observers might assume a clear division of labour (male as hunter, female as incubator). Similar behaviour, of the sexes alternating parental roles almost equally, and feeding each other, has been recorded in one pair of Black-breasted Buzzards (Marchant & Higgins 1993), although another pair of that species showed the usual division of labour in raptors (Angus 1992).

Parental roles during the nestling period were generally as previously reported for this species, although males occasionally brood chicks but rarely feed them bill to bill (Marchant & Higgins 1993; Barnes *et al.* 1999, 2001; Griffiths *et al.* 2002; Lutter *et al.* 2003). The female at Port Macquarie may have foraged during the nestling period, and earlier in that phase than usually reported, if the male had difficulty finding sufficient prey in weeks 6–7. Growth and development of the nestling at Port Macquarie confirm and enlarge on previous information (in Barnes *et al.* 1999, Griffiths *et al.* 2002), and corroborate the estimated hatching date.

Nest-building, courtship, copulatory, and other pre-incubation behaviour and vocalisations were similar to those previously reported for this species, with this study adding descriptive detail and perhaps some examples of individual variation, as compared with data in Marchant & Higgins (1993), Debus (1996) and Barnes *et al.* (2001). The close pair-bond, tolerant intra-pair relations and degree of sharing of nesting duties are unusual in raptors, though a feature also of the related Black-breasted Buzzard (Marchant & Higgins 1993). Johnstone & Storr (1998) place

the two species in the same genus (*Hamirostra*).

Several other studies have reported short post-fledging periods of about a week (Barnes *et al.* 1999, Griffiths *et al.* 2002); the fate of the fledgling Kite at Port Macquarie suggests that those other Kite fledglings also died soon after fledging. Events at Port Macquarie suggest that, in subtropical coastal areas supporting important Kite populations, and particularly in suburban areas, large numbers of Torresian Crows (by their predation or harassment) may be a significant negative factor in the survival of young Kites.

Fledgling productivity was similar to that farther north in New South Wales for one pair over five seasons (0.8 young per attempt: Brown *et al.* 2000). Similar results were also obtained for the wider mid-north coast region: 11 pairs fledged a maximum of one young per successful nest, with some failures; success for one pair over 7 years was 0.7 fledgling per attempt (Kavanagh *et al.* 2001).

Parental prey-delivery rates were generally similar to those reported elsewhere, including a higher rate in the afternoon than in the morning (Barnes *et al.* 1999, 2001; Lutter *et al.* 2003). The rate was slightly higher in the incubation period than previously reported (0.3 vs 0.2 item/h), perhaps because the female brought prey to the incubating male.

The breeding diet of the Kites in Port Macquarie was similar to that of other pairs on the subtropical eastern coast, including the clear dependence on nesting birds and the habit of taking whole nests with their contents (Barnes *et al.* 1999, 2001; Brown *et al.* 2000; Griffiths *et al.* 2002; Lutter *et al.* 2003). No eggs were confirmed as eaten at Port Macquarie, eggshell beneath the Kites' nest being most likely the remains of hatched eggs brought with nests and nestlings. Prey remains and pellets were biased towards larger prey species, although observations suggested that most prey items taken were small, including some unfeathered nestlings that would leave no remains.

It appears that, in the 'green' suburbs of subtropical coastal cities, the Kites prey heavily on some of the most abundant birds such as introduced doves, Crested Pigeons and large honeyeaters (wattlebirds, miners). The pigeons, doves and miners also have long breeding seasons and multiple broods (our pers. obs.). Adult Turtle-Doves and Crested Pigeons, at about 150 g and 200 g respectively (Higgins & Davies 1996), are the largest avian prey recorded for the Kite, though defenceless when compared with parrots of <150 g that are rarely taken.

Estimated breeding density in the study area was similar to that for the Gratton area (Debus 1996), where three pairs were on average 11 km from each other, or one pair to about 120 km². Inferred foraging range of the Port Macquarie pair was similar to that observed for one pair on one day north of Gratton (50 km²: Debus 1992). Available data suggest low densities and large home-ranges.

This project demonstrates that ongoing observation of well-studied species, particularly of new pairs or sites, can produce new information. Nevertheless, all phases of the breeding cycle of the Square-tailed Kite have now been intensively watched, including the entire cycle for some pairs, and further research might profitably switch to population monitoring such as breeding density and fledgling productivity, or recruitment of colour-banded nestlings. The dietary sample for New South Wales remains less than for Queensland, and diet in other states is unquantified. Research on the Kite's biology is needed in south-western Australia,

where the Kite is readily accessible to Perth ornithologists (e.g. Johnstone & Storr 1998) but is essentially unstudied.

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Postscript

The adult Kites were observed in Port Macquarie through winter 2004 (HL), and rebuilt the partly collapsed nest. Incubation commenced on 24 August. The nest looked flimsy and insecure, and on 2 October it blew down during a storm. The nest contained a broken egg and a dead chick at hatching age, 39 days after incubation started. The chick has been lodged with the Australian Museum. ■