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Breeding Biology and Behaviour of the Northern Forest Raven *Corvus tasmanicus boreus*

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Summary

Observations were made of the breeding biology and behaviour of the Northern Forest Raven *Corvus tasmanicus boreus* on the North Coast of New South Wales in spring 1996 and 1997. Both sexes gathered nesting material. The female alone incubated the eggs, and the male fed her at a rate of 0.6–1 delivery/h in different years. Only the female brooded the nestlings; both sexes brought food, although the male provided most of the food. The nestling period lasted between 37 and 43 days, during which the parental feeding rate was 2.0–2.2 deliveries/h in different years. Breeding success was 1.8 fledglings per attempt (n = 6 pair-years). Breeding chronology, parental behaviour, nestling growth and vocalisations are described.

Introduction

The Forest Raven *Corvus tasmanicus* is the least-known Australian corvid. It was recognised and named as a fifth species only recently, and barely included in detailed studies on corvids, in the mainland sheep country, by Rowley (1970). Most of the limited information on its breeding biology concerns the Southern subspecies *C.t. tasmanicus*, and then mostly for Tasmania: small sample sizes for nest-sites, clutches, laying dates and fledging dates (Rowley 1973a; Rowley *et al.* 1973). For the Northern subspecies *C.t. boreus* there have been only casual records of territory size, fledging dates and brood sizes, and incidental observations of both parents feeding nestlings (Rowley *et al.* 1973; Debus 1980, 1983, 1996; Secomb 1997, 2005). Nest-building behaviour and nestling growth are undescribed, parental behaviour and breeding success are unquantified, and the duration of each phase of the breeding cycle is unrecorded.

By comparison, the morphologically and ecologically similar Australian Raven *C. coronoides* is much better known, with breeding chronology more precisely documented and breeding behaviour quantified. For example, the incubation period averages 20 days, the nestling period 43 days, and the post-fledging dependence period about 3 months; only the female incubates, and the male supplies food to the incubating or brooding female (Rowley 1973a). The Forest Raven is assumed to be similar in these respects, although confirmation is required.

This paper describes aspects of the breeding cycle of the Northern Forest Raven on the North Coast of New South Wales, derived from systematic nest-watches and other observations on mainly one pair. Brief notes on parental behaviour of the focal pair, in connection with the birds' use of food-caches, are given elsewhere (Secomb 2005).

Study area and methods

The nesting territory of one pair of Forest Ravens (pair 3 of Secomb 1997) was on the edge of Nambucca State Forest overlooking the settling ponds of the Nambucca Heads sewage-treatment plant (30°38′S, 153°00′E) on the North Coast of New South Wales, approximately

1 km from the beach (Secomb 2005). The nest-site was midslope on a low ridge, in open forest of Blackbutt *Eucalyptus pilularis* with a ground layer of Blady Grass *Imperata cylindrica*; Swamp Mahogany *E. robusta* and Broad-leaved Paperbark *Melaleuca quinquenervia* dominated the gully.

The focal pair of Forest Ravens was known to nest in the same area of forest for several years before the study commenced. This pair was observed for a total of 38.6 hours over 15 days through the breeding cycle in 1996, and 21 hours over 11 days through the breeding cycle in 1997, as follows. Visits were made usually once per week in the afternoon. 1996: 1.6 h/2 days in the building phase; 7 h/3 days in the incubation phase; 24.8 h/8 days in the nestling phase (including one morning); and 5.7 h/2 days in the fledgling phase. 1997: 2.5 h/two days in the building stage, 5.7 h/two mornings in the incubation phase; 12.6 h/6 days in the nestling phase (one morning, five afternoons); and a check on one afternoon in the fledgling phase. Over both years, the nest area was visited a total of 27 times during the breeding cycle. Casual observations were also made, of the focal pair and other pairs in the district, in the building phase in 1990, 1992–93, 1995 and 1998 (5.7 h/3 days); the incubation phase in 1993 and 1998 (3 h/1 day); the nestling phase in 1991–93; and the post-fledging dependence period in 1993–95. For 1996 and 1997, the extreme dates of observation in each phase are given in Table 1.

The nest was viewed from about 100 m away, with the aid of 10 × 50 binoculars and often a 25× telescope, from the crest of a ridge. Observations were sometimes conducted from within a vehicle, though mostly from beside the vehicle. Sometimes, when not vocal, the Forest Ravens were difficult to locate and monitor. The adults were sexed according to parental roles of Australian Ravens at the nest, and the fact that only female Forest Ravens (as in other Australian *Corvus* spp.) have a brood-patch and are therefore likely to be the sole incubator and brooder (Rowley 1973a; Rowley *et al.* 1973). The approximate dates of egg-laying and hatching were calculated using the incubation period of 20 days, and stages of nestling growth, of the Australian Raven (from Rowley 1973a).

Results

Local corvid populations

The nearest known pairs of Forest Ravens were at the Deep Creek estuary 2 km to the north of the focal pair, and the Nambucca River estuary 2.5 km to the south. The nearest Torresian Crow *Corvus orru* pairs were in urban areas of Nambucca Heads 1.5 km south, Hyland Park 1.5 km north, and agricultural areas 3 km to the west. Along the coastal parts of this region of New South Wales, Forest Ravens occupy a narrow wooded strip of State Forest and Crown land, whereas Torresian Crows occupy coastal towns and agricultural land west of the wooded strip (further details in Secomb 1997).

Groups of Torresian Crows passed through the focal Forest Raven territory, and even over the nest, without any reaction by the Ravens. However, there was some conflict with the neighbouring pair of Crows to the west. At times the Ravens replied to the Crows' calling in the distance, and on occasions one of the Crows flew over or near the Ravens' nest, sometimes with an aerial wing-flicking display, to which the Ravens responded with two or three calling bouts. At times Forest Ravens, believed to be non-resident, were heard calling to the south; when the focal male Raven replied, they became quiet. A pair of Forest Ravens at Hungry Head, 10 km north of the study site, was regularly in conflict with the neighbouring pair of Torresian Crows at that location.

Breeding chronology

Pooling all years, nest-building by Forest Ravens was observed between mid June and mid August; incubation between the end of July and late August; nestlings between late August and early October; fledglings between early and late October; and dependent (begging) juveniles between mid November and mid December,

Table 1

Breeding chronology (day/month) of Forest Raven pairs at Nambucca Heads, NSW. For 1996 and 1997, dates refer to period of nest-watches in each phase (duration of phase not implied).

Year	*Stage*				
	Build	*Eggs*	*Nestling(s)*	*Fledgling(s)*	*Juvenile(s)*
1990	18.8				
1991			28.9		
1992	15.7	3.8	16.9	21.10	
1993	5.7	23.8	20.9		11–25.12[a]
1994					21.11
1995	30.7				19.11
1996	11–29.7	8–21.8	29.8–3.10	10–24.10	
1997	27.7–2.8	16–24.8	7.9–2.10	9.10	4.1.98
1998	13.6–15.7	30.7			

[a]Dependent (begging) on 11.12

with young accompanying parents in the natal territory until early January (i.e. about 3 months post-fledging: Table 1). One adult of the focal pair had commenced moulting wing-feathers in mid October, in week 1 of the post-fledging period, although the other had not by late October (week 3). One adult of a neighbouring pair was in primary moult (P1–3) in late October. However, another neighbouring pair was not moulting wing-feathers at that time, nor in early December when the pair had a dependent juvenile.

Nests

All Forest Raven nests found were in large eucalypts. At the study site the 1996 nest was 36 m above ground in a 38-m Blackbutt, in an upright four-pronged fork with a layer of foliage a metre above it. This nest was re-used in 1997. The 1998 nest was in a three-pronged fork high in a Blackbutt.

In 1991 the nest was 23 m above ground in a 25-m Swamp Mahogany. A new nest was built 0.5 m above this nest in 1992. The 1993 nest was in a large Blackbutt, on a large upright branch where several smaller branches formed a prong. This nest, about 50 cm deep and 40 cm wide, was just below a layer of foliage covering an area of 2 × 3 m. The 1990–93 nests were within about 50 m of the 1996–97 nests.

Nest-building

Nest-building by Forest Ravens occurred throughout July, the earliest observed activity being 13 June and the latest 18 August (Table 1). Members of the pair kept close company for much of the time both in and out of the nest area, and when together they often gave soft calls. From limited observations, all nest-material was sourced among the trees. Both sexes collected nest-material, but it was unclear whether both were involved in the early stages of nest-construction. At the lining stage when fibrous material was collected, both birds were on the nest at the same time. They took turns at rotating in the nest and pushing the base

of the cup with their feet, while the other waited on the rim.

In 1990 both sexes of one pair were observed 10–20 m above the ground breaking dead sticks, up to 50 cm long and 1 cm in diameter, off trees (mostly Pink Bloodwood *Corymbia intermedia* and Tallowwood *Eucalyptus microcorys*), 50–100 m from the nest. In other years a Forest Raven broke sticks off a Paperbark and carried them to the nest, and collected bark from the trunk of a Swamp Mahogany. In 1997 the pair built on the 1996 nest, adding fresh sticks.

In 1990 a soft moaning call was heard from the nest, but it was not possible to see whether one or both birds placed sticks in the nest. The presumed male flew to a large dead tree and gave a short territorial call, while the female continued building the nest which at that stage was a large mass of sticks. In 1993 a Forest Raven was calling, strongly at times and with a stick in its bill, from a treetop.

In July 1996 at the study site, both Forest Ravens returned from the beach foraging area without calling. As they preened together, one (presumed female) sidled up beside its mate in bodily contact. The female (?) then departed, returning 11 minutes later with a dead leafy twig, and spent 4 minutes at the nest. Meanwhile, the other Raven had flown to a treetop on the forest edge, but then joined its mate at the nest where some soft, long deep calls were made. Both then flew off. For newly built nests, in 1996 the building phase lasted at least 18 days and in 1998 it lasted at least 32 days (Table 1). In 1998, at the lining stage, each member of the pair spent 1–5 minutes (mean 3 min., n = 9 observed bouts in total) forming the nest-cup.

Although allopreening was not observed in the prelaying period, on one occasion in the nestling period when the adults were perched together it appeared that one tried to preen the other around the neck. In the building phase in 1998, both birds flew to the nest and one (which had a large piece of food) fed the other when they arrived. The feeder (presumed male) then spent 2 minutes forming the nest while its mate waited on the rim; when the former departed, the latter (presumed female) then spent 4 minutes forming the nest.

At the study site in July 1992, at 1030 h, a Forest Raven flew to a nest that was used in the previous season. When approached by the observer, it flew with a stick to another nest, used in 1989, where it arranged sticks in possible decoy behaviour. A second Raven approached with a stick, but went towards the initial (1991) nest.

No territorial defence against raptors or Torresian Crows was observed during the building phase, although a Whistling Kite *Haliastur sphenurus* circled in the nest area and passed 6 m above the nest unchallenged. The only response by a Forest Raven working on the nest was to cease all movement while the Kite was within 100 m.

Territorial defence

During the egg and nestling phases the adult Forest Ravens defended their territory against intruders, the intensity and distance from the nest depending on the species involved. Potential threats were challenged by calling or chasing. Challenge was more likely if a potential threat was close to the nest, 45% of 29 challenges being within 50 m of it. Large raptors circling, in foraging behaviour, were targetted.

White-bellied Sea-Eagles *Haliaeetus leucogaster* were chased if they approached

within 300 m, and warning calls were given if the Sea-Eagles were within 600 m. Medium-sized raptors such as the Pacific Baza *Aviceda subcristata*, Whistling Kite, Brahminy Kite *Haliastur indus* and Little Eagle *Hieraaetus morphnoides* were usually chased if they were within 100 m, although this distance was sometimes relaxed to 30 m for action other than warning calls. No action was taken against an Osprey *Pandion haliaetus* at 50 m, a Collared Sparrowhawk *Accipiter cirrhocephalus* at 10 and 70 m from the nest, or a Square-tailed Kite *Lophoictinia isura* at 400 m although Torresian Crows were harassing it. In 1993 the Forest Ravens showed no concern towards a pair of Sparrowhawks building a nest 100 m from the Ravens' nest. When chasing a Little Eagle and a Whistling Kite, the female Raven flew with reduced-amplitude flight and strong calling with short, quick notes, but no returning-home calling or triumph ceremony was observed.

Other Forest Ravens elicited defensive calling if they approached within 600 m; no closer intrusions were seen. Neighbouring pairs of Torresian Crows usually elicited defensive calling if they were within 600 m, and Crows were chased (if detected) when they approached within 50 m of the nest, although there were three instances where no action was taken at 150–200 m. Most (81%) intrusions by Crows were of small transient groups that passed through unchallenged.

Smaller birds such as an Eastern Rosella *Platycercus eximius* and Noisy Friarbirds *Philemon corniculatus* were chased from around the nest-site (<10 m) and, rarely, at up to 50 m (one Friarbird).

Incubation

In 1996 the eggs were laid on approximately 6–7 August and hatched on approximately 26–27 August (assuming an incubation period of approximately 20 days). The same applied in 1997, in the same nest as used in 1996. In other years the start dates were similar, e.g. first seen incubating on 3 August 1992 and 30 July 1998 (Table 1).

In 1996 the female was on the nest for 89% of observation time (7 h), in the nest area for a further 8%, and absent for 3%. Her incubation stints ranged from 21 to 155 minutes (mean 62 min., n = 6), and her absences 1–7 minutes (mean 5 min., n = 7). Two longer absences (11 and 12 min.) occurred when she chased a Little Eagle and a Whistling Kite respectively on the one day. The male did not stay at the nest, but he spent at least 44% of observation time in the nest area and the remainder away from the nest. He spent 4–95 minutes (mean 49 min., n = 7) in the nest area, usually within 200 m and often on the forest edge 30 m away; he sometimes foraged (e.g. once for 48 minutes in the tree-canopy close to the nest). His absences ranged from 5 to 37 minutes (mean 21 min., n = 5).

In 1997 the female was on the nest for 98% of observation time (5.7 h), and in the nest area for the remaining 2%. Her incubation stints ranged from 83 to 155 minutes (mean 68 min.), and her absences 1–4 minutes. The male spent 80% of observation time in the nest area and the remaining 20% away from the nest. In 1998 the female was on the nest for the entire 3-hour watch on one day; the male was in the nest area for 88% of time (continuously for 165 min.) and absent for the remaining 12%.

When the female left the nest, commonly after food delivery by the male, he remained close to the nest. Conversely, in the male's absence the female occasionally left the nest to defend the territory against intruding birds of various

Table 2

Growth of nestling Forest Ravens, Nambucca Heads, NSW, 1996 and 1997. One brood in each year; data for both years combined.

Approximate age (days)	*Remarks*
11–13	Head naked; eyes closed?
16–17	Eyes open; head black.
22–24	Feathers emerging on head; burst primaries visible; tail c. 2 cm.
29–31	Large, well feathered; stretching wings; active on nest.
36–37	Very active: stretching wings; preening; standing on nest edge.

species.

The male usually fed the female at the nest, or he took food to a nearby cache where she joined him. The male was observed to feed the incubating female four times in 7 h in 1996 (0.6/h), five times in 5.7 h in 1997 (0.9/h), and three times in 3 h in 1998 (1/h). In 1996 the feeding schedule was apparently interrupted by the need to evict a Little Eagle and a Whistling Kite during one observation session. On one morning in 1997 the female was first fed 20 minutes after sunrise. Three times during the latter part of the incubation period, after being fed by the male, the female flew to the male and preened herself; twice she tried to sidle up in bodily contact.

During the incubation phase territorial calls were heard only occasionally from the male, usually in the treetops. Most calls were related to warning or repelling of intruders. On one morning there was no Forest Raven chorus, although the first Raven calls were heard 26 minutes before sunrise. Soft calls were also given sparingly.

Nestling period

In both years (1996 and 1997) the young fledged between 3 and 10 October, giving a nestling period of between 37 and 43 days. The nestings' growth stages are summarised in Table 2. Up to week 5 of the nestling period, both adults sometimes ate the nestlings' faecal sacs; they also removed some in week 5, but not in week 6. In week 6, when a Whistling Kite chased by Australian Magpies *Gymnorhina tibicen* flew past within 70 m of the nest, the adult Ravens did not react but the nestlings crouched low in the nest. The nestlings were heard begging in weeks 1 and 2. In weeks 5 and 6 they were active, standing on the nest-rim in week 6 when the adults were nearby, but were usually inactive when the adults called urgently or if potential predators were present.

In 1996 the female's time spent brooding or otherwise on the nest declined through the nestling phase (Table 3). In week 1 she brooded in stints of 22–35 minutes (mean 29 min., n = 3), with spells off the nest of usually 12–16 minutes, though with one absence of 26 minutes when chasing a Sea-Eagle for the second time that day (mean 17 min., n = 4). In weeks 2 and 3 she spent periods of 2–71 minutes on the nest (mean 30 and 6 min. respectively), and 1–87 minutes off the nest (week 3: on 2–12 min., mean 6, n = 4; off 8–87 min., mean 17, n = 5). In weeks 2 and 3 her time standing on the nest-rim, rather than brooding, increased from 13% to 66% of nest-attendance time, respectively. In week 2 she stood on the nest-rim on a calm morning, but brooded in windy weather. In week 3 she

Table 3

Time-budgets of adult Forest Ravens at Nambucca Heads, NSW, during the nestling period: % observation time spent in parental activities. Observation time for each week (h) in parentheses. Week = stage of nestling period; F = female, M = male.

Week (h obs.)	*F on nest*	*F in nest area*	*F absent*	*M in nest area*
1996:				
1–2 (12.8)	72	19	9	36
3–4 (3.8)	11	42	47	21
5–6 (5.0)	0	67	33	46
1997:				
2 (2.5)	88	2	10	75
4 (1.8)	51	25	24	44
5 (4.7)	49	16	35	39
6 (3)	2	68	30	34

spent 30 minutes at the nest in hot weather when the nest was in the sun, but left in the cooler afternoon. The male ceased feeding the brooding female by week 3, and from week 4 the female visited the nest only to feed the young. From week 4 the male fed the young directly, rather than passing food via the female.

In 1997 the pattern was similar, although the female's close attendance of the nest persisted longer into the nestling period (Table 3). She still spent long periods at the nest during weeks 4 and 5 (week 4: on 4–18 min., mean 14, n = 4; off 9–15 min., mean 12, n = 3; week 5: on 14–28 min., mean 22, n = 4; off 8–32 min., mean 20, n = 3). At the start of a watch in week 6 she was sitting on the nest, sheltering the large nestling from an approaching storm, but was flushed off by a close lightning strike and clap of thunder. During moderate rain that lasted for 7 minutes, she did not return. The male ceased feeding the female by week 5, later than in 1996.

The male usually visited the nest only to feed the female or young. Nevertheless, he spent much of the observation time in the nest area throughout the nestling phase, more so in 1997 than 1996 (Table 3). When the female was not on the nest at least one of the adults remained close to the nest, spending periods of 5–56 minutes in the nest area. In the female's absence the male guarded the nest, and when she returned he departed; compared with the incubation period, he moved around more and much farther afield.

In the nestling phase of both years, up to week 5 the female often probed vigorously in the base of the nest, rearranging the sticks. At times the male also remained briefly after a feeding visit, and performed the same probing actions.

The male fed the female at a rate of 0.9 visit/h in weeks 1–2 in 1996 (n = 12.8 h), and 0.8/h in week 2 (n = 2.5 h) and 0.5/h in week 4 (n = 1.8 h) in 1997. Three of 11 feeds in 1996, and all three in 1997, were away from the nest (usually at a cache).

Parental feeding rates

Parental feeding visits to nestlings averaged 2.0/h in 1996 and 2.2/h in 1997 (Table 4). During the first fortnight of the nestling stage, the male provided most of the food either directly to the nest or by depositing food at the cache. At that

Table 4

Parental feeding rates (no. feeding visits/h) to nestling Forest Ravens, Nambucca Heads, NSW. Observation time for each week (h) in parentheses. Week = stage of nestling period; M = male, F = female, ? = sex unknown.

Week (h obs.)	*M*	*F*	*?*	*Total*
1996:				
1–2 (12.8)	1.1	0.9		2.0
3–4 (3.8)	1.4	1.4	0.3	3.0
5–6 (5.0)			1.0	1.0
Mean (21.6)				2.0
1997:				
2 (2.5)	2.4	1.2		3.6
4 (1.8)	1.1	2.2		3.3
5 (4.7)	0.2		1.7	1.9
6 (3)			0.7	0.7
Mean (12)				2.2

stage, when the male brought food to the nest he passed it to the female which either then fed it to the young or ate it. At times she stood on the nest-rim, allowing the male to feed the young directly. From week 3 onwards, when the sexes could not always be distinguished, male and female appeared to make approximately equal contributions to feeding the young. When the male brought food to a cache, both ate there and both took food to the nest. Nest-watches were strongly skewed towards afternoons; limited data suggest that feeding rates may have been higher (by 75%) in the mornings. There appeared to be a peak of feeding visits between 0600 and 0800 h, and 1600 and 1700 h. In weeks 1–2 the female twice left the nest after sunset, remaining off for 5 and 19 minutes, and returned without food 21–22 minutes after sunset.

To the male's feeding visits in Table 4 must be added his visits to feed the female, as a reflection of his total foraging effort for the family. In weeks 1–2 in 1996 his total delivery rate was therefore 2 visits/h; in week 2 and 4 in 1997 the rate was 3.2 and 1.7 visits/h respectively.

Only the male took food to the caches, which were used mostly in the early mornings or late afternoons. For example, on a morning in week 2 the cache supplied two of the initial feeds to the nestlings, and early on a morning in week 5 both adults retrieved food after they had spent 30 minutes defending the area against Torresian Crows. Use of caches decreased from week 3; food was still retrieved occasionally in weeks 5–6, although food was not seen to be taken to caches at that stage. At times the Forest Ravens inspected the cache, but no food was retrieved.

Small items of food were obtained around the settling ponds, but the male brought large items of food from the beach to the caches. When returning from the beach, he often went to water to dunk the food or wash his bill. Only food that could be concealed in the bill was taken to the nest, though a bulge in the throat was occasionally visible. At times when feeding the young, the adult's throat action indicated expulsion of food from the gular pouch, and moisture could be seen dripping from the bill.

Fledglings

The newly fledged young of 1996 and 1997 were usually hiding in dense sapling regrowth, with an adult Forest Raven always close by. In 1996 the parental feeding rate to the fledgling was 0.5 delivery/h (n = 5.5 h). A man with two dogs elicited warning calls from the adult Ravens when these intruders approached the fledglings at 100 m; the calls increased in intensity as they approached to 50 m, then ceased. Warning calls were also directed at the observer, and a Brahminy Kite elicited parental warning calls at 200 m.

At the end of the nestling period in 1997, after the parents evicted a Sea-Eagle, both called for 7 minutes from the sapling thicket as if trying to entice the nestling to fledge and follow them to cover.

Dependent juveniles often accompanied the adults to the beach foraging area. The 1996 juvenile was last seen near the beach on 16 March 1997. In other years, 1991–95, juveniles were last seen in the natal territory in December (once), January (three times) and February (once). The post-fledging dependence period thus lasted about 3 months, with juveniles in the natal territory for up to 4 and (exceptionally) 5 months.

Breeding success

In both study years (1996, 1997) there were initially two nestlings, but one was lost in about week 4 in 1996 and about week 3 in 1997, resulting in a single fledgling in each year. In other years the Forest Ravens reared three fledglings in 1992 and presumably in 1993 (when three large nestlings were seen), two in 1994 and one in 1995. This gives a total of 11 young in six pair-years for which the outcome was known, or 1.8 fledged per successful brood and per attempt.

Vocalisations

The focal pair gave many variations on the typical deep territorial cawing call. Of all the Australian corvids, the Forest Raven's calls seem the most varied and richest. The adult Forest Ravens gave series of 1–7 notes, short or long, usually 2–4 syllables per phrase but commonly up to 5–6; for longer notes the terminal one or two syllables were at times drawn-out. In extended calling bouts the series could consist of several short notes followed by or interspersed with longer notes. Vowel sounds were usually *ah* or *oh*, but also *er*, *eh* or *uh*, and could be used interchangeably within a calling sequence. During the breeding cycle the male gave most of the loud calls, often from exposed positions such as treetops. On one occasion when both adults were calling, the male's calls were slightly deeper than those of the female.

Types of call recognised were as follows.

Contact call: Soft to medium strength, apparently to indicate the caller's location, and typically given as one bird left the nest area to forage after being on guard duty; volume appeared to vary with distance to the mate. This departure call also appeared to be directed at an advanced nestling (week 6), as the mate was not in the area. Soft calls were often given when the adults were together, including when allopreening, by the female when begging food from the male, and by the male when bringing food to her. Contact calls were heard many times during the building stage, especially when both adults were at the nest, irregularly during the incubation and early nestling stages, and occasionally during the late nestling stage.

Territorial call: Moderate to strong though variable phrases, given in series in usually short bouts (rarely lasting 3 minutes). First heard 22 and 26 minutes before sunrise, on two mornings.

Defence call: Alert or warning calls, e.g. when potential predators were sighted, were strong calls often shorter and slightly higher-pitched than normal territorial calls. When leaving a perch in pursuit of an intruder, calls had an urgent quality. Sometimes the female performed reduced-amplitude flight with this call as she left the nest to engage a large raptor. Calls were given also as the sole defence action, or after an intruder departed or was evicted; such bouts, of many notes in a series, were long (7–17 minutes) and had the rich quality of territorial calls. When with a fledgling, on the approach of the observer, an adult gave soft deep croaks. When disturbed by the observer, the neighbouring pair of adults (which had a dependent juvenile) flew to a treetop and gave single nasal notes similar to the bleat of a sheep. Once, when the observer approached a fledgling closely, the calling parent's body was horizontal with tail depressed; twice when the observer approached a fledgling, and once after evicting a Sea-Eagle (late nestling period), the call resembled a bleating lamb.

Creaky call: A call resembling a creaky door was heard, from both sexes: by the female (a deep 'frog' call) at the end of a calling bout after evicting a raptor; by the male when departing from guard duty and while at a cache (both when the female was nearby); and when he visited the nest to feed young in the female's absence.

Juvenile begging call: A constant short *ah*, higher-pitched than normal adult calls.

On three occasions, all in the nestling period, the adults gave a duetting sequence of alternating notes. On the first occasion, both had just fed the nestlings and flown to separate perches; over the next 30 seconds they in turn gave single *oh* notes. After evicting two Torresian Crows, the Forest Ravens perched near each other and alternately gave single *oh* notes that changed to *ah* notes as the duet progressed. After one adult ate at a cache, both gave *ah* calls with a nasal quality resembling the bleat of a young lamb, at times in duet.

On one occasion in January when two Forest Ravens were flying towards the beach, one gave two long notes with the wings drooped below the horizontal plane.

Discussion

Through the breeding cycle, the male Forest Raven provided most of the food to the female and young, whereas the female performed the nest duties related to incubation, brooding and care or guarding of the young. The inter-year difference in parental time-budgets and feeding rates (Tables 3, 4) suggests that food may have been more abundant in 1997 than in 1996, enabling the male to provide most of the food and more guarding until later in the cycle, and the female to stay on the nest for longer and later into the nestling phase, in 1997.

The results of this study confirm and enlarge on the previous limited data for the Forest Raven (both subspecies combined), for instance on the breeding season in New South Wales, although the precise length of the incubation, nestling and post-fledging periods remains to be determined. The results of this study are also similar to results obtained for the Australian Raven (Rowley 1973a; Rowley *et al.* 1973). The Forest Raven's nest-building behaviour, and duration of the building phase, are similar to those of the Australian Raven; the incubation, nestling and

post-fledging periods appear to be very similar in the two species; and parental time-budgets in each phase, nestling growth and breeding success are also similar. In this study, the focal pair's prelaying behaviour suggests that allopreening occurs in courtship in the Forest Raven, as in other Australian corvids (Debus 1996).

The focal pair of Forest Ravens at Nambucca Heads appeared to live in an area of low corvid density; absence of, or large distances between, neighbours may reduce the need for territorial calls. Forest Ravens appeared able to distinguish resident, territorial Torresian Crows from transient Crows. On the coast, as on the tablelands (Debus 1996), there was interspecific conflict over territories.

The Forest Raven's call types, and vocal behaviour, appeared generally similar to those of the Australian Raven as described by Rowley (1973b). Reaction to intruders, both intra- and interspecific, is similar in the two species, which appear to have equivalent major predators of their young (Sea-Eagle for coastal Forest Ravens, Wedge-tailed Eagle *Aquila audax* for Australian Ravens). Coastal Forest Ravens performed little in the way of specific flight behaviour (e.g. triumph ceremonies) on return from repelling an intruder, and called mostly after they had landed. This aspect may be typical of the Forest Raven, but requires confirmation on the tablelands where conflict may be more prevalent in the presence of possibly higher corvid densities, involving three or four species, and the presence of Wedge-tailed Eagles.

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