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Breeding biology and diet of Banded Kestrels *Falco zoniventris* on Masoala Peninsula, Madagascar

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We studied the breeding biology of the Banded Kestrel (*Falco zoniventris*) in the forest edge habitat of Masoala Peninsula of north-eastern Madagascar from 1997 to 1999. Banded Kestrels begin their breeding season at the end of the wet season during August and the start of the dry season in September. Courtship began during August and September, egg-laying occurred in October and young fledged in December. Three nesting attempts were documented with 10 eggs laid from clutches of three, three and four. Incubation was approximately 29 days (n = 3 clutches). Of 10 eggs laid, 70% hatched and all hatched young fledged. A total of 2.3 young fledged per nesting attempt and overall nest success was 67%. All Banded Kestrel nests were placed inside clusters of epiphytic arboreal plants composed of *Asplenium nidus*, *Phymatodes scolopendria* and *Medinilla* sp. and averaged 18m above the ground. Banded Kestrel diet, derived from 188 prey items, comprised 47% chameleons, 18% other lizards, 31% insects, 3% birds, a frog (0.5%) and a snake (0.5%).

Introduction

Three species of falcons are breeding residents in Madagascar: Peregrine Falcon (*Falco peregrinus*), Madagascar Kestrel (*F. newtoni*) and Banded Kestrel (*F. zoniventris*), the only endemic falcon on the island. Ferguson-Lees and Christie (2001) reported the Banded Kestrel as rare but in reality it is a secretive species with a wide distribution along all the coastal regions of Madagascar, ranging from sea level up to 2 000m (Langrand 1990). This species occupies varied habitat, from forest edge and degraded humid forest in the east to savanna and deciduous dry forest in the west. It is easily separated from the sympatric Madagascar Kestrel by its larger size, yellow eye-ring, streaked and large grey head and lack of the typical falcon moustachial stripe. Females are slightly larger and darker than males (Cade 1982). This species is poorly-known and only two brief studies have been carried out on its nesting biology (Colebrook-Robjent 1973, Thorstrom 1999). To increase our understanding of Banded Kestrel breeding ecology, a two-year field study was conducted from 1997–1998 on three nests and two pairs on the Masoala Peninsula of north-eastern Madagascar (Robenarimangason 1999).

Study area and methods

This study was conducted around Ambanizana village (15°37'S, 49°57'E), situated at the western boundary of Masoala National Park (MNP) in north-east Madagascar. The west coast of the peninsula is covered by an intact lowland rainforest interspersed with secondary forests and slash-and-burn agricultural land consisting of cultivated rice, coffee, vanilla, clove and banana crops in the vicinity of villages. MNP consists of 230 000ha of primary forest with an average canopy height of 25m with some emergent trees (Guillaumet 1984). Altitude ranges from sea level to 1 230m but the study ranged only to 200m asl. The annual average rainfall at Andranobe Field Station, 7km south of the study site, is 6 049mm (Thorstrom *et al*. 1997). The dry season is from October to mid December (Rene de Roland 2000). Mean monthly temperature in January is 32.5°C and in July is 16°C, with an annual average of 25.6°C (Thorstrom *et al*. 1997).

The first field season covered August 1997 to January 1998 and the second season covered August 1998 to January 1999. During August and September, we searched for nesting pairs by following vocalizing and visible adults. Observations were made at least 50m from nests, with X10 binoculars and a zoom-spotting scope. One and two nests were studied during the 1997 and 1998 breeding seasons, respectively.

Nests were observed from the courtship up to the post-fledgling period. Daily nest observations were from 06h00 to 18h00. Prey items were identified during direct prey deliveries to nests, females and young. Nest observations of Banded Kestrels totalled 290.9h during the two breeding seasons. Egg dimensions (length, breadth, mass) were taken by vernier calipers (to 0.01mm) and mass with Pesola spring balance scales (to 0.1g); measures given are means ± SD.

Nests were located and nest tree species were identified when possible. Nest variables measured included height of nest above ground, nest tree height, nest length and width, nest cup and the nest tree 'diameter at the breast height' (DBH) were taken after young had dispersed from their nest area. The distance to the nearest water (freshwater or

ocean) from nest trees was measured either by an Eagle Explorer Global Positioning System (GPS) with a 30m accuracy, or by a 50m tape if the distance was small.

Results

We located one nest in 1997 and two in 1998 for a total of two nesting territories. One of the two nests in 1998 was the same territory and banded pair studied in 1997. Their nests were 150m apart in successive years. Nest observations totalled 76.1h during courtship, 81.1h during incubation, 92.9h during the nestling period and 40.8h during the post-fledgling period.

Pair formation and courtship period

In 1998 during mid August we recorded the female as the first member of the breeding pair to arrive at the previous year's nesting territory. The female moved from epiphyte to epiphyte and appeared to be searching for a potential nesting site. During this period, the female was very secretive and easily disturbed by human activity. Pair formation was marked by frequent calling by both sexes. Upon the male's arrival he led the female to several possible nest sites. In 1998, the earliest copulation observed was on 28 September and the last was on 14 October, a period of 17 days. We recorded the duration of 27 copulations which averaged 7.7s ± 1.6 (range = 5–10s). The highest copulation frequency occurred from 06h00–08h00 (3/h, n = 24 copulations totaling 189s) and several occurred from 15h00–16h00 (1/h, n = 3 totalling 19s). The frequency of copulations ranged from one to four per day. Males delivered 27 prey items to females during the courtship period.

Nest site characteristics

Nests were placed inside epiphytic plants of *Asplenium nidus*, *Phymatodes scolopendria* and *Medinilla* sp. and located on a forked branch 17.9m ± 8.5 above ground level. Nest trees were 25.3m ± 6.4 in height, and were identified as Voatsikobika (*Carissa serriliflora),* Hintsigny (*Afzelia bijuga*) and Ravintsara (*Ravensara acuminata*). Two nests were placed in forest-edge habitat and one nest was in the centre of Ambanizana village. Nests measured 60.7cm ± 13.8 in length, 50.7cm ± 16.6 in width, and overall nest and cup depths of 67.7cm ± 24.6 and 3.3cm ± 1.4, respectively.

In 1997, one nest was observed and in 1998 two were found. The distance between the 1997 and the 1998 nest was 150m and they were occupied by the same pair, ringed in 1997. The distance between the two new nests in 1998 was 3 500m.

Egg-laying

In 1998, copulations stopped one day before the first egg was laid. Egg-laying occurred during the second and third week of October with the earliest egg laid on 8 October 1998 (n = 3 nests). Recorded clutch sizes were 3, 3 and 4 (average 3.3 ± 0.6) for the three nests. All eggs were laid within an interval of five (n = 1 nest) to six (n = 2 nests) days. Average egg dimensions at one nest were 38.5mm ± 1.1 x 30.5mm ± 0.5 (n = 3 eggs). Average fresh egg mass was 19.7g ± 0.3 (n = 3 eggs). Egg colouration was beige to dirty white with varying brown spots distributed around the egg (n = 1 clutch).

Incubation

Incubation was the primary role of the female while the male provided food and was never observed incubating during the nest observations. During the total observation time the females incubated 77.3% of the time, males 0.4% of the time and the nest was unattended for 22.3%. The incubation period was 28d, 29d and 30d for the three nests. Males were observed delivering 32 prey items during incubation.

Nestling period

During the first week after hatching, female Banded Kestrels brooded and fed the nestlings while the males only provisioned the female with food. In 29.6 observation hours, females brooded young for 56.8% of the time, males 0.1% of the time and the nest was unattended for 43.1% during the first nine days of age of nestlings (Figure 1). When the young were six days old the females began capturing prey and feeding the nestlings (Figure 1). From 10 days of age and onwards, females spent 41% of the observation time in the nest watching and feeding the young and their time decreased to 17.6% after the young were 22 days old. During the third week after hatching, the young were able to feed themselves from prey left at the nest. The young fledged from 26–30 days of age. Males delivered 71 prey items and females 21 prey items during this period. The role of the male was to deliver food to the female and nestlings.

Post-fledgling period and dispersal

The young remained near the nest up to 40 days of age. During this period the adults provided food to the fledged young. The quantity of prey items delivered by the adults decreased after 41 days of age. Males delivered 38 prey items and females delivered 17 prey items during this period. This period was marked by aggressive competition between the young for the delivered food. Prey transfers took place on branches. The more aggressive young received prey first while the fledglings that missed the prey delivery emitted continuous food-begging calls directed towards the adults. Prey-capturing attempts started at 49 days of age and continued until the first young was observed catching its first small chameleon at 52 days of age. At this age, prey deliveries decreased dramatically from the adults. This may have been the stimulus to initiate dispersal by the young. The young were completely independent at 56 days of age.

Diet and hunting behaviour

During the two study seasons, 1997 and 1998, 188 prey items were identified during nest and foraging observations. Recorded prey items were 1.6% birds, 67% reptiles, 0.5% amphibians and 30.9% insects. Reptiles were composed of 47.3% (89) chameleons (*Furcifer* and *Calumma* spp.), 16% (30) day geckos (*Phelsuma* spp.), 3.2% (6) leaf-tailed geckos (*Uroplatus* sp.), and 0.5% (1) frog, and 58 insects, mainly katydids and preying mantids. Lizards made up 96.9% of the 130 vertebrate prey in the diet of Banded Kestrels during this study. On a biomass basis, birds were composed of 0.8%, lizards 94.8%, frogs 0.4% and insects 4.0%. Chameleons (86%) made up the most important prey item in terms of biomass in the Banded Kestrel's diet. Banded Kestrels hunted by scanning an area thoroughly

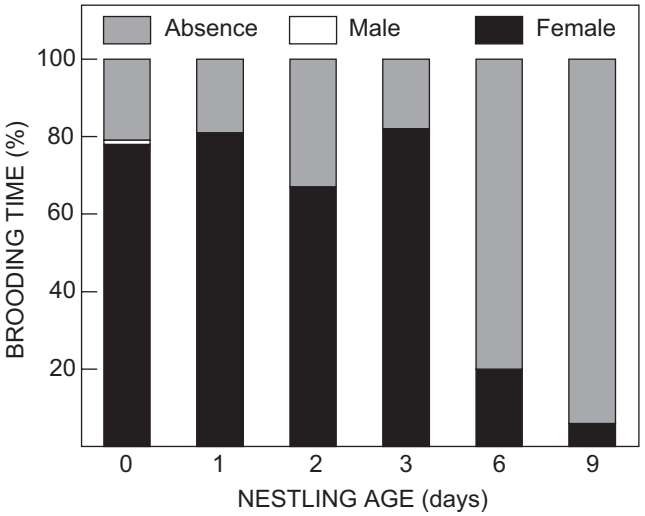

Figure 1: Brooding time of Banded Kestrels (*Falco zoniventris*) during the first nine days of nestling age from the 1997 and 1998 breeding seasons on Masoala Peninsula, Madagascar (n = 3 nests)

from a raised perch, and moving on to another area. When prey was spotted they flew directly at prey, grasping it with their feet.

Reproductive success

In the three documented nesting attempts containing 10 eggs, seven eggs (70%) hatched and all of the hatched young fledged (Table 1). Productivity from the three nesting attempts was 2.3 young/pair with two of the three nests fledging all their eggs and young. Nest success would have been greater if it were not for human persecution of the adult male during the incubation period observed at the nest in Ambanizana.

Discussion

In spite of its widespread distribution in Madagascar, the Banded Kestrel is a poorly-known endemic species with little known about its nesting habits and ecological requirements. The only ecological knowledge for this species comes from a brief study by Colebrook-Robjent (1973), who described courtship and nest-search behaviour near Marojejy, a study by Thorstrom (1999) reporting on behaviour and diet during the nestling period, and a possible foraging association with Sickle-billed Vangas (*Falculea palliata*) observed in the west central coastal region (Tingay and Gilbert 2000).

In this study, all observed Banded Kestrel nests were placed inside epiphytic plants, confirming the observations of Thorstrom (1999) and Colebrook-Robjent (1973). This nest placement differs from that of the common and sympatric Madagascar Kestrel, which uses tree cavities in the Masoala Peninsula (Robenarimangason 1999) and elsewhere in Madagascar nests in holes in buildings and on cliffs (Langrand 1990). Two nest trees were located in secondary forest and the other was a tree situated in the centre of Ambanizana village. From these documented nests, we suspected that the choice of a nest site depends more on the location of the epiphytes on the tree than the habitat type, tree species or nest height.

The distance between the two nests in 1998 (3 500m) was much greater than for the smaller sympatric Madagascar Kestrel (675 ± 386.2, n = 4) (Robenarimangason 1999) in the same study area, and the Seychelles Kestrel *F. araea* (448m ± 536[m?], n = 33) (Watson 1981). This greater distance between neighbouring nests suggests Banded Kestrels utilise a larger area and live at a lower density than does the Madagascar Kestrel and other kestrel species. The inter-nest distance reflects the population size within a given area (Newton *et al*. 1977).

Like many raptors, the courtship period was marked by frequent calling, courtship feedings (prey deliveries from male to female) and mating. The number of copulations per day observed during this study for Banded Kestrels was low when compared to the rate of European Kestrels with 7–8 copulations/day (Masman *et al*. 1988), 10 copulations/hour in American Kestrels (Palmer 1988) and 8/day in the Madagascar Harrier Hawk (Thorstrom and La Marca 2000).

Egg colouration was beige to pale white with brown spots, the same as described by Thorstrom (1999). For European Kestrels, egg colouration ranges from pure white with brown spots to a fairly uniform, deep chocolate brown (Village 1990). Cade (1982) stated that *Falco* species generally require 28–30 days of incubation. Like the similar-sized Seychelles Kestrel (Watson 1981) and American Kestrel (Balgooyen 1976), the Banded Kestrel had a similar incubation period of around 29 days.

Only female Banded Kestrels incubated while males food-provisioned females during incubation and the nestling period. This lack of male incubation is not surprising for raptors in general (Newton 1979), and it has also been observed for the Madagascar Kestrel (Robenarimangason 1999), although male Peregrine Falcons (*F. peregrinus*) in Madagascar has been observed incubating nearly 30% of nesting observation time (Razafimanjato 2001).

Banded Kestrels hatched towards the end of the dry season. After the two-week nestling period, the adult females spent less time at the nests, as the nutritional demands of the nestlings increased, and began searching for food to supplement the male's provisioning. From one week to a few days before first flight (fledging) Banded Kestrel young began to feed themselves from food brought by parents. The smaller sympatric Madagascar Kestrel fledged at 23–24 days whereas the Banded Kestrel young made first flights four days to one week later (Robenarimangason 1999). At one nest, the smaller (suspected male) nestling fledged four days prior to the larger (assumed female) young. The shorter fledging period of the male is typical of raptors where the male nestlings develop faster than the females (Newton 1979).

During this post-fledgling period, there was a decrease in prey deliveries by the adults, possibly forcing the young to disperse from their natal areas (Moreno 1984, Edwards 1985, Rene de Roland 2000). The young were able to catch their own prey at 52 days of age and became independent quickly after this age. Young Banded Kestrels dispersed from their nesting territory at 56 days of age, taking longer than Madagascar Kestrels that dispersed at 44–45 days (Robenarimangason 1999).

Table 1: Reproductive success of Banded Kestrels *Falco zoniventris* during two breeding seasons, 1997 and 1998, on Masoala Peninsula, Madagascar

Year	Number breeding attempts	Number of eggs	Mean clutch size	Number eggs hatched	Number of young fledged (%)	Fledglings/breeding attempts	Nest success (n) (%)
1997	1	4	4	4	4 (100)	4 (4/1)	100 (1/1)
1998	2	6	3	3	3 (100)	1.5 (3/2)	50 (1/2)
Total	3	10	3.3	7	7 (100)	2.3 (7/3)	67 (2/3)

Almost 50% of the identified prey in this study was chameleons, and chameleons were also reported by earlier observers (Rand 1936, Colebrook-Robjent 1973, Thorstrom 1999) as the major portion of Banded Kestrel diet. Chameleons are likely to be more available, or more vulnerable to detection, by this large-eyed kestrel, or may have denser populations in the partially-open and forest edge habitat. In October and November, chameleons are known to lay their eggs on the ground, making them susceptible to predators (J Rabearivony pers. obs.) at a time when the kestrels breed. Despite the sympatric Madagascar Kestrels also being lizard specialists in Masoala, they preyed predominantly (94%) on terrestrial plated lizards (*Zonosaurus* spp.) rather than chameleons (Robenarimangason 1999).

In comparison to the sympatric Madagascar Kestrel in Masoala, Banded Kestrels laid smaller clutches (3.3 *vs* 4.0, n = 6 clutches) but fledged more young per nesting attempt (2.3 *vs* 1.2, n = 7 fledglings) and had higher nest success (67% *vs* 50%, n = 6 nesting attempts). This productivity difference between the two sympatric kestrels arose from the more frequent nest failures, due to weather and predation of the Madagascar Kestrel. Due to the human persecution of the male from the Ambanizana nest site in 1998, the lone female continued incubating the eggs while simultaneously foraging for herself. We believe the gradual increase in the female's hunger and lack of nest protection caused the eggs to fail. This illustrates the difficulty many raptor species in Madagascar, and globally, experience when attempting to nest in the vicinity of humans.

We suggest that future researchers gather information on the natural history and ecology of this endemic kestrel in western and southern Madagascar, where epiphytes are few or non-existant, and where the forest habitat and prey base differ, for comparison with our observations on Banded Kestrels in eastern Madagascar. We believe it is important to assess the population size and influence of human disturbance (direct disturbance and slash-and-burn agriculture) on productivity in other areas, in order to establish an IUCN categorisation of this species in Madagascar.

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