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NESTING BIOLOGY OF THE BANDED GROUND-CUCKOO (*NEOMORPHUS RADIOLOSUS*)

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ABSTRACT.—The Banded Ground-cuckoo (*Neomorphus radiolosus*) is a rare and endangered bird species whose basic biology is poorly known. We provide the first information on nesting biology for the species. We documented two nesting attempts in the Mache-Chindul Ecological Reserve, Esmeraldas Province, northwest Ecuador. Both the first nest, active in March and April 2005, and the second nest, active in May 2005, were in primary rain forest. Both nests were ~5 m above ground in small understory trees (Melastomataceae). A pair of adult Banded Ground-cuckoos attended the first nest and contributed equally to incubation, brooding, and provisioning of a single nestling. The nestling spent 20 days in the nest from hatching to fledging and was fed a wide range of both invertebrates (primarily grasshoppers) and vertebrates (mainly small frogs). The chick fledged successfully. The second nest, also attended by a pair of adults, failed during incubation. We relate our findings to what is known of other ground-cuckoo species and discuss the conservation implications of our results. *Received 23 February 2006. Accepted 3 September 2006.*

Neomorphus ground-cuckoos are relatively large, terrestrial forest birds with large crests, long tails, and iridescent plumage (del Hoyo et al. 1997). The genus includes five species, four of which occur in the Amazon Basin, although one ranges through Central America into Nicaragua (Dickinson 2003). The fifth species, the Banded Ground-cuckoo (*Neomorphus radiolosus*, Cuculidae), is endemic to the Chocó Biogeographical Region, which encompasses 100,000 km^2 of humid rain forest extending from the Pacific coast up the western slope of the Andes in southwestern Panama, western Colombia, and northwestern Ecuador. The region is noted for extremely high levels of diversity and endemism. For example, the Chocó supports 62 endemic bird species, the most of any mainland region in South America (Stattersfield et al. 1998, BirdLife International 2003). The Chocó also contains an outstanding diversity of plants, insects, and terrestrial vertebrates (Dodson and Gentry 1991, Dinerstein et al. 1995, Conservation International 2001). In Ecuador, <4% of the original Chocó forests remain (Sierra 1999), the other 96% having been deforested for timber, agriculture, and settlement by colonists (Conservation International 2001).

The Banded Ground-cuckoo is one of many Chocó endemics whose populations are thought to be in decline due to habitat degradation (BirdLife International 2000, 2004; Ridgely and Greenfield 2001; Greenfield 2002; Renjifo et al. 2002). It is considered ''vulnerable to extinction'' within Ecuador and throughout its range (Greenfield 2002, BirdLife International 2004), which is limited to northwestern Ecuador and western Colombia. The Banded Ground-cuckoo's precarious status is widely attributed to the loss of primary Chocó forests. However, a lack of information has hindered efforts to assess the species' conservation status and requirements (BirdLife International 2000, 2004; Greenfield 2002).

The Banded Ground-cuckoo is one of the rarest and least known birds in Ecuador (BirdLife International 2000, 2004; Greenfield 2002). In recent years, it has been reported from only two localities in northwestern Esmeraldas Province: in 1992 at Alto Tambo and approximately four times since 1996 from Bilsa Biological Station (Hornbuckle 1997, Hornbuckle et al. 1997, Lopez-Lanus et al. 1999, Ridgely and Greenfield 2001). Single individuals, pairs, and small family groups have been seen. Little is known of the species' basic biology or conservation requirements.

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We present the first published report on nesting biology of the Banded Ground-cuckoo, including information on parental care, and discuss the conservation implications of our findings.

METHODS

We conducted our study at the Bilsa Biological Station (79° 45′ W, 0° 22′ N, 330–730 m elevation). Bilsa is a 3,500 ha private reserve owned and operated by Fundación Jatun Sacha within the Mache-Chindul Ecological Reserve in Esmeraldas Province, Ecuador. Bilsa contains a complex mosaic of undisturbed, selectively logged, and regenerating forests that vary in size, isolation, and disturbance. The majority of Bilsa is primary forest but much of the habitat in the surrounding Mache-Chindul Reserve has been degraded. The areas surrounding Bilsa are largely deforested and used for agriculture or pasture; only isolated patches of primary and regenerating forest remain.

We trapped an adult Banded Ground-cuckoo (unknown gender) in a mist net on 4 December 2004 and applied three colored leg bands and a lightweight radio as part of a larger study of the species. The radio transmitter (model RI-2C; Holohil Systems, Carp, ON, Canada) was attached to the bird using a backpack style harness made of rubber ligature (Vehrencamp and Halpenny 1981). The 6.0-g radio weighed 1.4% of the bird's total body mass (433 g). We tracked the individual using a Telonics TR4 receiver and a RA-2AK ''H'' antenna until the bird led us to an active nest in March 2005. We suspended radio tracking while the nest was active to minimize disturbance. However, we used the tracking equipment to identify which bird was attending the nest if color bands were not visible, and to obtain qualitative information on movements during the incubation stage.

The radio-equipped bird and at least one other adult without color bands or radio attended the nest. We observed only one unbanded bird plus the radio-equipped individual at the nest at any one time. We believe that only two adults (presumably the male and female) attended this first nest. We used a blind 20 m from the nest to observe the birds using 10× binoculars. We also recorded, and subsequently analyzed, activity using a Sony Hi-8 digital video camera, 6 m from the nest. The birds seemed aware of us but did not appear agitated or nervous. We doubt that our presence strongly affected their behavior. We recorded identity of each adult that visited the nest, arrival and departure times, activity while at the nest, and the type of food fed to the nestling. Additionally, we collected data on egg size and coloration, development of chick plumage and behavior, habitat surrounding the nest site, nest architecture, and postfledging behavior.

The radio-equipped bird led us to a second nest in April 2005 where it was joined by an unbanded individual. We are uncertain if the unbanded bird was the same individual that participated in the first nesting attempt. We mist netted the unbanded adult on 4 May 2005, 30 m from the second nest and attached a 6.0-g Holohil RI-2C radio transmitter (1.6% of the bird's body mass of 365 g) with a backpack style harness (Vehrencamp and Halpenny 1981). Total processing time was 38 min. We used radio-tracking equipment and visual observation to confirm this bird resumed normal incubation behavior on the afternoon of the day it was captured.

We recorded the location of the nests using hand-held Garmin GPS units. No fine-scale satellite imagery is available for Bilsa and no fine-scale maps of habitat types exist for the area. We quantified habitat characteristics within a circular plot of 20-m radius around the nest site. We estimated canopy height and counted the number of trees with a diameter at breast height (dbh) >50 cm and the number of trees in the genus *Cecropia* (Cecropiaceae) within the circular plots. *Cecropia* is a pioneer tree in Bilsa commonly found in disturbed areas, and we used it as an index of previous habitat disturbance. The trees in which the nests were placed and the plants whose leaves were used in the nests were identified by Carlos Cerón Martínez at the Herbario Alfredo Paredes, Universidad Central del Ecuador and by Lorena Carrillo at the Herbario Nacional del Ecuador.

We recorded data for 47 hrs at nest #1 during the incubation stage from 1 through 6 days prior to hatching (n = 6 sessions with an average of 8.0 ± 3.8 hrs per session, range = 3.0–11.5 hrs/session). We recorded data for 113 hrs during the nestling stage of nest #1

with at least one observation period on all but 3 days (n = 17 sessions, average observation period = 4.7 ± 2.2 hrs, range = 2.1–9.5 hrs/session). Data from live observations and video recordings were combined for statistical analyses and are presented as means ± SE. Feeding, brooding, and incubation rates for each of the two adults were not normally distributed (Kolmogorov-Smirnov tests, $P < 0.05$). Thus, we used non-parametric, Mann-Whitney U-tests for pairwise comparisons of parental care by the two adults. All tests were two-tailed and used a significance level of $P = 0.05$ unless otherwise stated. All analyses were conducted using SAS V.8 statistical software.

RESULTS

Nest Site Descriptions.—We documented two Banded Ground-cuckoo nests. Both nests were found by Don Jorge Olivo, the first on 2 March 2005. Nest #1 was ~60 m (elevation) and 120 m (horizontal distance) from a small river on the flank of a large hill that reached ~120 m (elevation) and 600 m (horizontal distance) from the river. The UTM coordinates of the nest were 17N 0643173, 0037755 and the elevation was 540 m.

Nest #1 was in primary Chocó rain forest. It was ~200 m from secondary forest, 600 m from the Bilsa field station, and 250 m from a major walking trail which forms the boundary of the reserve. The nest was 12 m from a trail used once per week by Bilsa volunteers and staff, and occasionally by poachers and their dogs. Chocó rain forest is extremely humid (>3 m of rainfall/year), and the forest surrounding the nest was characterized by an open understory, a closed canopy 25–30 m high, and average visibility of ~20 m. Common trees included *Otoba gordonifolia* (Myristicaceae) and *Gustavia dodsonii* (Lecythidaceae); no *Cecropia* were present. Data from the circular plot surrounding the nest indicated that canopy height was 25 m, and six trees had a dbh >50 cm. These measures are consistent with our data from 100 independent primary forest sites within Bilsa (JK, unpubl. data).

The second nest, discovered on 27 April 2005, was ~150 m south of the first nest on the same hillside (UTM coordinates: 17N 0643622, 0037809; elevation 581 m). It was in primary forest and >100 m from the nearest trail. Data from the circular plot indicated a canopy height of 28 m, two trees with dbh >50 cm, and no *Cecropia*.

Description of the Nests.—Both nests were in the same species of understory tree, *Miconia* sp. (Melastomataceae). Nest #1 was 5.4 m above ground in a 9-m tall tree with a dbh of 7.2 cm. Nest #2 was 3.9 m above ground in a 7.5-m tall tree with a dbh of 6.3 cm. Each nest was positioned close to the trunk in a large crotch formed where one or more branches radiated from the trunk. Nest #1 was built on a 5-cm diameter branch where it left the trunk; Nest #2 was built where two branches of 4 and 5 cm diameter left the trunk. The trunk of the tree with nest #1 was inclined at an angle of 60° from the ground; the adults ran up and down the trunk to access or leave the nest. The trunk of the tree with nest #2 was nearly vertical and to ascend the birds hopped up the lower branches, in effect using them as a ladder. To descend from nest #2, the birds took a few steps from the nest along the branch and glided to the ground.

Both nests were large, open cups of similar shape and size. Nest #1 measured 37 × 25 (length/width) × 13 cm high on the outside, and nest #2 measured 38 × 24 × 15 cm. Both were bulky structures with walls ~6 cm thick. The nests appeared to be made entirely of leaves. We did not see any sticks or moss supporting or anchoring the structure, or lining the inside. We recorded leaves of six species in the nests, the majority of which were from a fern (*Diplazium* sp., Aspleniaceae). Two small bromeliads, one palm, and one unknown species germinated on the wide rim while nest #1 was active and were allowed to grow. We did not record which species germinated on nest #2. Throughout the first nesting effort, the adults brought an average of two new leaves each day (usually *Diplazium* sp.) to build up the lining of the nest, but were not observed removing leaves from the nest.

Incubation Stage and Fate of the Second Nest.—Both nests were discovered in the incubation stage with a single egg. It is possible that both nests had one or more eggs removed by a predator before we found them. However, we consider it more likely the original clutch size for both nests was a single egg. Nest #1 was discovered 13 days prior to hatching; nest

#2 failed during incubation. Both eggs were uniformly cream colored but gradually acquired small brown spots as incubation progressed. The eggs were round rather than oval, with an estimated size of 4.5 × 4.0 × 4.0 cm, based on visual observation.

The two adults tending nest #1 shared incubation duties equally. The radio-equipped bird incubated an average of 3.2 ± 1.9 hrs per observation session, whereas the other bird incubated an average of 3.8 ± 2.5 hrs per observation period. Each adult was observed to remain on the nest until dark (1800 hrs) at least once (three times for the radio-equipped bird and one time for the unbanded bird), suggesting either bird incubated during the night. The egg occasionally went without incubation (max = 3 hrs), but in most cases the birds replaced each other immediately so the egg was uncovered for <30 sec. We did not take detailed data on incubation from the second nest, but we confirmed via radio-tracking that both birds incubated in approximately equal proportions. Qualitative radio-tracking data on movement by the adults indicated the birds traveled >400 m from the nest between incubation bouts (JK, unpubl. data).

The birds on the nest appeared alert but not nervous. We detected no vocalizations or interaction between the adults when they replaced each other on the nest. The birds moved the egg with their bills an average of once per 120 min during observation periods, appearing to change the part of the egg in contact with their abdomen. The birds rounded their backs and extended their wings and tail to completely cover the cup and egg when it rained. Both adults opportunistically caught unidentified flying insects and frequently appeared to pick up small items—which we assume were nest parasites—and eat them during incubation and nestling stages.

Our observations of nest #2 prior to capture of the adult were limited. Following capture, we used radio tracking to monitor incubation patterns. We detected radio signals from both adults coming from nest #2 on 4, 5, and 6 May 2005 but did not approach the nest. On 7 May 2005, we received no radio signal for either adult near the nest; at 1230 hrs, we approached the nest and found it unattended. Closer inspection of the egg revealed a puncture hole ~10 mm in diameter. The puncture was clean, with no fracturing of the shell around the hole. A developing embryo inside the egg was visible through the hole. The inner lining surrounding the embryo had been punctured as well. Neither adult was observed in the nest area following failure of the nest.

TABLE 1. Items fed to a nestling Banded Ground-cuckoo in northwestern Ecuador in 2005.

Food	Category		Subgroup	
	n	%	*n*	%
Vertebrates	12	16.9		
Anurae (frogs)			8	11.3
Anolis sp. lizards			3	4.2
Micrurus sp. coral snake			1	1.4
Invertebrates	39	54.9		
Coleoptera			3	4.2
Lepidoptera			3	4.2
Cicadadae			1	1.4
Orthoptera			23	32.4
Araneae			4	5.6
Unknown arthropods			2	2.8
Oligochatea			3	4.2
Unknown	20	28.2		
Totals			71	100

Nestling Stage and Fate of the First Nest.—The egg in nest #1 hatched between 1800 hrs EST on the evening of 14 March 2005 and 1200 hrs on the following morning, and the chick fledged 20 days later. There was no statistical difference in the rates at which the two adults brooded and fed the nestling. On average, the nestling was brooded 24% of the time by the radio-equipped bird and 33.5% of the time by the unbanded bird (Mann-Whitney $U_{38} = 394$, $P = 0.6$). Similarly, the radio-equipped bird fed the nestling an average of 0.34 ± 0.07 times/hr whereas the other adult fed it an average of 0.25 ± 0.06 times/hr (Mann-Whitney $U_{36} = 631$, $P = 0.4$). Adults brought a range of vertebrate and invertebrate food items (Table 1) and interacted little at the nest. Both birds continued bringing fresh leaves until the chick fledged.

The chick successfully fledged from the nest at 0950 hrs on 4 April 2005. We observed both parents with the fledgling from 4 April through 8 April 2005. Observing the birds was difficult and we limited our observations of post-fledging care. We did note, however, that both adults were present and continued to feed the fledgling, which appeared dependent on its parents for food and protection. We did

not note any begging vocalizations or behavior. We located only the radio-equipped adult, which appeared to be alone, first on 9 April 2005 and then on three subsequent radio-tracking sessions (10, 11, 14 Apr). During the next radio-tracking session (27 Apr) we discovered the radio-equipped bird attending nest #2, which had one egg that was already being incubated. We are uncertain if the fledgling from nest #1 died on 8–9 April, or if the radio-equipped individual left the fledgling in the care of the unbanded adult to start a second nesting attempt with another bird.

Nestling Plumage and Behavior.—The chick's body was covered in white down but its head remained featherless from day 0 (hatching) through day 5. Pin feathers were visible on the chick's head by day 5, and dark feathers were becoming visible beneath the light-colored down on the body. The chick's body was covered equally in down and dark feathers by day 10, a prominent crest was visible on its head, its eyes were open, and it was able to handle and swallow food on its own. The chick was almost entirely covered in dark feathers on day 15 and the skin behind the eye had begun to turn blue. Prior to fledging, it became increasingly active in the nest, eating small insects from within the nest and even catching a flying dipteran with its bill. The chick was entirely covered with a dark plumage similar to that of adults but lacking iridescence when it fledged on day 20, and its crest and the blue skin around its eyes were similar to those of adults. Its beak, however, was noticeably smaller than those of the adults and its tail was less than one-quarter the length of an adult tail.

We did not hear the chick vocalizing while in the nest but it began to snap its bill on day 15. From days 17–20, it did so increasingly when adults were away from the nest (not when they were present). The bill snaps were often answered by bill snaps of adults that were out of our sight but within hearing range.

DISCUSSION

It has been known since the 1940s that ground-cuckoos raise their own young and are not brood parasites (Sick 1949). Prior to the present report, only the nest of the Rufous-vented Ground-cuckoo (*N. geoffroyi*) had been described (Roth 1981) but it was unclear whether one or two adults tended the nest. Here we report the Banded Ground-cuckoo provides bi-parental care with both parents contributing equally to incubation, brooding, and provisioning the nestling. This information in combination with the knowledge the species is monomorphic suggests a monogamous mating system (Andersson 1994).

The known nesting biology of Banded and Rufous-vented ground-cuckoos is quite similar. Both species construct bulky, open cup nests at similar heights in understory trees of the genus *Miconia*, although the Rufous-vented Ground-cuckoo nest was slightly lower (2.5 m above the ground) than the two Banded Ground-cuckoo nests we found (3.9 and 5.4 m above the ground). The Rufous-vented Ground-cuckoo nest contained only one egg. We found both Banded Ground-cuckoo nests during incubation stage and cannot be certain of the original clutch size. However, it appears likely the nests we found also had only one egg each. Finally, the account of juvenile plumage in *N. geoffroyi* provided by T. Howell in Haffer (1977) is similar to the data we recorded. We could find no published description of any other *Neomorphus* nest, but Schönwetter (1964, 1988) reports that Rufous-winged Ground-cuckoo (*N. rufipennis*) eggs are 29.2–32.0 × 37.1–41.5 mm, which is slightly smaller than our size estimates for eggs of the Banded Ground-cuckoo.

Both Banded and Rufous-vented ground-cuckoos regularly replenished their nests with fresh green leaves, a trait also recorded in related cuckoos, such as anis (*Crotophaga* spp.) (Roth 1981). A potential explanation for this practice is that chemical compounds in the leaves suppress nest parasites, such as mites (Whimberger 1984). Another possibility is that decomposition of the thick layer of leaves in the nest may provide an additional source of warmth for the egg and chick, as is the case for some reptiles and ground-nesting birds (Seymour and Ackerman 1980).

No detailed data are available on the diets of any *Neomorphus* Ground-cuckoos, but the diets of the phylogenetically related roadrunners (*Geococcyx* spp.) (Dickinson 2003) are well documented and include a breadth of vertebrates and invertebrates (Bent 1940, Baughman 2003). The Banded Ground-cuckoo pair we studied fed the nestling a wide range of

vertebrates and an even wider range of invertebrates (Table 1), which may reflect the composition of the adult diet.

CONSERVATION IMPLICATIONS

The radio-equipped Banded Ground-cuckoo's home range included secondary and altered forest (JK, unpubl. data) but both nests we monitored were built in primary forest. The patch of primary forest with the two nests was surrounded by a complex mosaic of forest types including undisturbed primary forest, selectively logged forests, and 10–15 year-old secondary forest re-growth following intense disturbance. The nests were ~250 m from the edge of the Bilsa Reserve and two major trails ~5 m wide that are heavily traveled by humans and domestic animals including mules, horses, and cattle. At the junction of these two trails, ~350 m from the nests, is a community of four families (La Y-cita), a small store, and a school. Thus, although the habitat immediately surrounding the nests was undisturbed, the area surrounding the patch of primary forest where both nests occurred was far from pristine.

The information on nesting biology presented here highlights the challenges involved with conserving the Banded Ground-cuckoo. One nest failed during the incubation stage and the ultimate fate of the other nesting attempt was uncertain. The species appears to have a small clutch size, perhaps only a single egg. It also may depend on primary rain forest for nest sites, but even when these requirements are met it may be susceptible to more subtle effects of human activities such as hunting, dogs, or edge effects (e.g., Gates and Gysel 1978). The information is scanty, but what little that is known of reproductive biology of other *Neomorphus* spp. raises similar concerns for conservationists. The Scaled Ground-cuckoo (*N. squamiger*) is considered ''near threatened'' with extinction, has a small range and is reported to be sensitive to human disturbance and encroaching human development (BirdLife International 2000, 2004). The Rufous-vented Ground-cuckoo nest reported by Roth (1981) was in secondary forest, had only a single egg, and failed during incubation stage.

The Banded Ground-cuckoo is one of Ecuador's rarest birds and has potential to serve as a flagship species for conservation efforts in the Chocó. It appears that conservation of large tracts of primary Chocó habitat is necessary for conservation of endangered, endemic species such as the Banded Ground-cuckoo.

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