

ARTIFICIAL BIRD NEST PREDATION ALONG A FOREST CONVERSION GRADIENT IN CAMEROON

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Abstract. Land use changes can dramatically impact bird populations: directly through habitat loss, but also indirectly through altered species interactions. In this study, we used 240 artificial ground and bush nests baited with chicken (*Gallus gallus*) eggs for eight days to assess levels of nest predation in an anthropogenic habitat mosaic in the Korup region, western Central Africa. Artificial nests were equally distributed among 24 plots within four distinct habitat types: (1) near-primary forest, (2) secondary forest, (3) agroforestry systems, and (4) annual crops. Similar to other artificial nest predation studies, we found a significantly higher predation rate of ground nests compared to bush nests: nearly one third (34/120, or 28%) of ground nests were plundered, whereas only 12% (14/120) of bush nests experienced predation. There was no effect of habitat type on predation rates of ground nor bush nests and we did not find relationships between vegetation parameters (bush cover and height) and predation rate. From observations of nest remains and animal footprints around depredated nests we roughly categorised animal predators into small- (mammal and reptile) and medium-sized (mammal and monitor lizard) predators. The proportion of cases of predation by medium-sized predators were larger than expected in secondary forest but lower in agroforestry systems and annual crops, while the opposite was the case for small-sized predators. Nest loss from direct human disturbance was recorded especially in agroforestry systems. Overall, human activities such as hunting and snaring of medium-sized mammalian predators as well as landscape context (forest matrix) may have been the primary determinants of the results of this study.

Key words: Central African forest, chicken eggs, conservation, forest conversion, ground nests, shrub nests.

INTRODUCTION

As tropical rainforests are converted into agricultural land, the conservation of biodiversity will depend not only on the maintenance of protected areas but also on the scope for conservation within the agricultural landscape (Harvey *et al.* 2006). However, not much is known of the effects of these changes on tropical bird populations, particularly concerning nest loss. Tropical birds are often reported as suffering higher nest predation rates (Major 1991, Roper 1992, Githiru *et al.* 2005, Pangau-Adam *et al.* 2006) compared with birds in temperate regions (Skutch 1985, Martin 1993a [but see Martin 1993b, 1995, 1996], Rowley & Russell 1995). Many studies in the tropics have indicated higher predation rates in forest edges than forest interiors (Gibbs 1991, Maina & Jackson 2003, Sodhi *et al.* 2003; but see Fraser & Whitehead 2005, Spanhove *et al.* 2009a). It is known that

ground-nesting birds are especially vulnerable to the disturbance and fragmentation of tropical forests (Thiollay 1992, Stouffer & Bierregaard 1995) and that abundance and distribution of understory-dwelling birds is negatively affected by forest disturbance (Waltert 2000, Waltert *et al.* 2005, 2011).

Since tangible nest predation events are hard to observe, one indirect way to determine how well bird species may be reproducing in their habitats is through artificial nest experiments (Gibbs 1991, Major & Kendal 1996, Yahner & Mahan 1996, Wong *et al.* 1998, Matthews *et al.* 1999). These nests are neither defended by adult birds (King *et al.* 1999) nor as well concealed as most natural nests (Berry & Lill 2003) and therefore absolute numbers of predation events from artificial nests may correspond poorly with natural nests (Major & Kendal 1996). While the assumption that temporal and spatial predation patterns of artificial nests are similar to those of natural nests (Andrén 1995, Arango-Vélez & Kattan 1997, van der Haegen *et al.* 2002) has been

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questioned (e.g. Zanette 2002, Mezquida & Marone 2003), the examination of artificial nest predation rates may still be useful in the absence of other information.

Predation rates on artificial nests can be higher (Carlson & Hartman 2001) but also lower (Martin 1987) than on real nests. However, visual predators at least are believed to detect and respond to artificial nests in a manner similar to natural nests (Gibbs 1991, Pangau-Adam *et al.* 2006), and deploying artificial nests may still constitute a valid approach to identifying principal predators and providing a basis on which to develop hypotheses on relative predation patterns between local habitats (Carlson & Hartman 2001). In order to assess effects of habitat on relative levels of nest predation and to develop hypotheses about the principal predators (Andr en 1995, Pangau-Adam *et al.* 2006), we used artificial ground and bush nests in four habitat types along a gradient of forest modification in an agricultural land-use mosaic in the rainforest region of SW Cameroon.

The present study seems to be the first of its kind in Africa's Guineo-Congolian forest belt. Nest predation has so far been studied mainly in East Africa (artificial nests: Carlson & Hartman 2001, Maina & Jackson 2003, Hanson *et al.* 2007; natural and artificial nests: Githiru *et al.* 2005, Spanhove *et al.* 2009a). Generally, artificial ground nests suffered higher predation pressure than bush nests because of the different predator community, but there is still very limited knowledge on the identities of tropical bird-nest predators overall (Spanhove *et al.* 2009b) and on predation rates in different habitats in particular.

Using previous studies, we hypothesized that (1) overall levels of artificial nest predation in SW Cameroon would be similar to those of other tropical forest regions (e.g. Githiru *et al.* 2005, Pangau-Adam *et al.* 2006); (2) that medium-sized predators would be of increasing importance with increasing habitat modification (e.g. Crooks & Soul e 1999); (3) that predation intensity would increase with increasing habitat modification (e.g. Maina & Jackson 2003, Sodhi *et al.* 2003), and (4) that ground nests would be more heavily depredated than bush nests (e.g. Martin 1987, Pangau-Adam *et al.* 2006), particularly in agroforestry and annual crop systems.

MATERIAL AND METHODS

Study plots. The study was carried out in the NE part of the Korup Support Zone (KSZ), SW Cameroon (Fig. 1). This region, within the Cameroon-Gabon

lowland rainforest, contains exceptionally high biodiversity and a large number of endemics (Stuart *et al.* 1990, Larsen 1997). The study plots were situated along a gradient of human disturbance, where near-primary forest (NF) serves as a reference. They basically differed in their complexity and heterogeneity (Horv ath *et al.* 2001). All plots outside the near-primary forest, i.e. secondary forest (SF), agroforestry systems represented by cocoa/coffee plantations (CF), and annual crops (AC), were located in the vicinity of the forest edge. These habitat types represent the principal components of the landscape structure in the Korup region. Their main characteristics are:

(1) NF: wet evergreen forest with high tree-species richness. Closed canopy averaged 35–45 m in height. The dominant trees were *Oubangia alata* and *Gilbertiodendron demonstrans*; average tree density was 570 trees (minimum 10 cm diameter at breast height) per ha, and mean basal area was 48.7 (± 14.6) m²/ha.

(2) SF: moist evergreen forest which had been cleared for farming along roads about 15 years before the study. These forests had a relatively closed canopy averaging 25–30 m. The dominant trees were oil palm *Elaeis guineensis* and *Musanga cecropioides*; average tree density was 530 trees/ha and basal area 40.0 (± 19.7) m²/ha.

(3) CF: cocoa/coffee plantations shaded by natural forest trees of up to 25 m in height. Apart from cocoa *Theobroma cacao* and coffee *Coffea robusta* trees, oil palm and plum trees *Dacryodes edulis* were dominant; average tree density was 378 trees/ha and basal area 32.7 (± 7.1) m²/ha.

(4) AC: open monoculture of manioc, remnant forest trees, oil palms, no planted shade trees, dead wood, *Chromolaena odorata*, and farmbush thickets; dynamic habitat, due to the short cycles of the cultivated plants and associated human activities; average tree density was 108 trees/ha and basal area 4.9 (± 3.9) m²/ha. See also Waltert *et al.* (2005) and Bobo *et al.* (2006a,b).

For each of the habitat types, six replicate plots were chosen. The avifauna was typical of a lowland rainforest, with more than 184 species restricted to this biome (Fishpool 2000) and 420 species so far recorded in the wider region (Rodewald *et al.* 1994, Bobo *et al.* 2005, 2007).

Data collection. Data were collected from January to April 2006, between the mid dry season and the

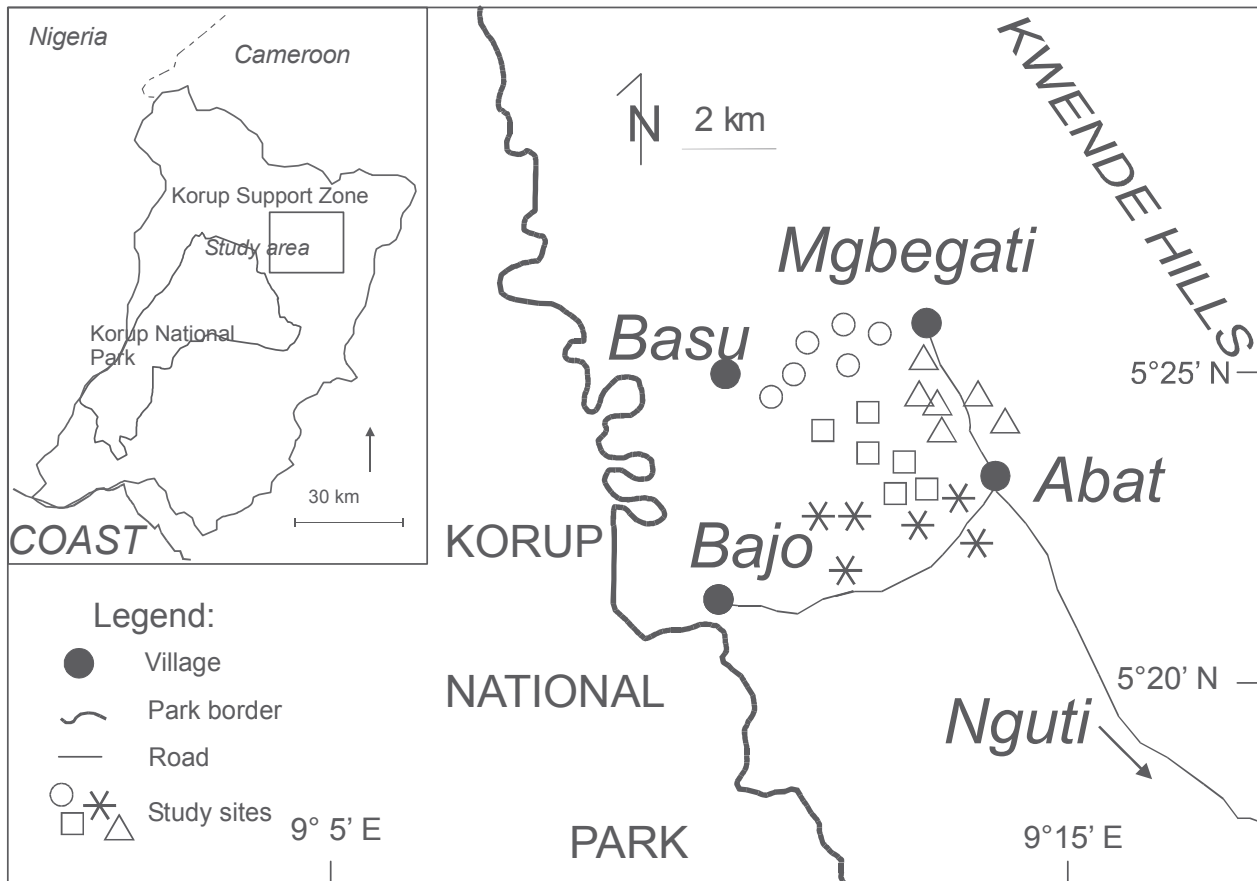


FIG. 1. Location of the study area and study plots in Cameroon. The landscape was completely forested at the time of the study, with near-primary forest representing the main landscape matrix, and only the immediate surroundings of villages were composed of a mosaic of secondary forest, agroforestry systems, and annual crop fields.

beginning of the rainy season, i.e. presumably before the beginning of the breeding season for most songbirds.

In each study plot, five experimental subplots were selected, lying *ca.* 30 m apart. A subplot consisted of one ground and one bush nest set up *ca.* 15 m from each other and marked with red tape tied nearby. To further facilitate relocation, ground nests were placed near the buttresses of trees (Wong *et al.* 1998, Pangau-Adam *et al.* 2006) to simulate nest sites of ground-nesting forest birds such as rails Rallidae, francolins *Francolinus spp.* and pittas *Pitta spp.* (Coates *et al.* 1997). Bush nests were deployed between 1 and 2 m above the ground in bushes or in forked branches of trees, imitating the nest type of understory flycatchers (e.g. *Terpsiphone rufiventer*). As nest appearance and site of placement could strongly influence predator perceptions (Berry & Lill 2003), the percentage of bush cover for each bush nest was estimated (Sieving 1992). We also measured the height of bushes carrying the nests.

Nests were made of wire baskets, 12 ± 2 cm diameter by 4 cm depth and 10 ± 2 cm diameter by 5 cm depth respectively for ground and bush nests, lined on the inside and outside with dry vegetation (leaves and grasses) so that no part of the nest could be seen through the grass cladding and it looked as close to natural as possible (Berry & Lill 2003). A total of 240 (120 ground and 120 bush) nests were deployed. Because of the lack of availability of quail eggs, we used two small chicken eggs (35-40 x 25-30 mm) which were placed in each nest. It is to be expected that predators react differently to chicken eggs than to quail eggs (Haskell 1995, Hanson *et al.* 2007; but see Berry & Lill 2003), limiting the possibilities of comparing our study with others but allowing for a comparison across habitats (see also Rangen *et al.* 2000 who used plasticine eggs versus finch eggs). Nests and eggs were placed outside for one week before use to reduce any artificial odor. Nests were deployed at the same time for the same habitat type, before shifting to another habitat. During the setting

up and controls, all nests, eggs and surroundings were touched using gloves and boots to minimize human scent (Laurance *et al.* 1993). After deploying nests and eggs, leaves were carefully removed from the litter layer so as to facilitate detection of animal prints around nests. Nests were controlled twice, after three and after eight days, and counted as preyed upon if one or both eggs were missing, eaten, or obviously cracked. As an attempt to identify the group of predator species, animal footprints were studied around plundered nests and eggshells were checked 5 m around nests with the help of local hunters. Considering the fact that identification of predators from nest and egg remains is problematic (Larivière 1999), we limited categorization of potential predators to (1) small-sized predators (squirrels, rats, bushbabies, snakes, and small lizards); (2) medium-sized predators (mongooses, civets, genets, monitor lizard); (3) humans, and (4) other sources of nest loss (wind or fallen timber). Such a categorization may roughly be valid since larger predators tend to remove eggs as

a whole, often leaving footprints which are relatively easily recognized by experienced field staff, while smaller ones may not be able to do so, leaving egg shells in or near the nest. A variety of birds (i.e. cuckoos) in the study area may also prey on chicken eggs and may belong to either category (small or medium), since sizes of African forest cuckoos are very variable. In contrast to other studies carried out in Africa (e.g. Carlson & Hartman 2001), corvids (e.g. Pied Crow *Corvus albus*) were not present in the study area at the time of the study (Waltert *et al.* 2005).

Data analysis. Predation intensities were estimated as the number of artificial nests preyed upon after eight days at each study plot; the intensity of egg predation was not evaluated, as two eggs in the same nest were probably not preyed on independently (Pangau-Adam *et al.* 2006), but we evaluated predator identities as frequencies of separate predation events because, as we discovered after two checks (the 1st on

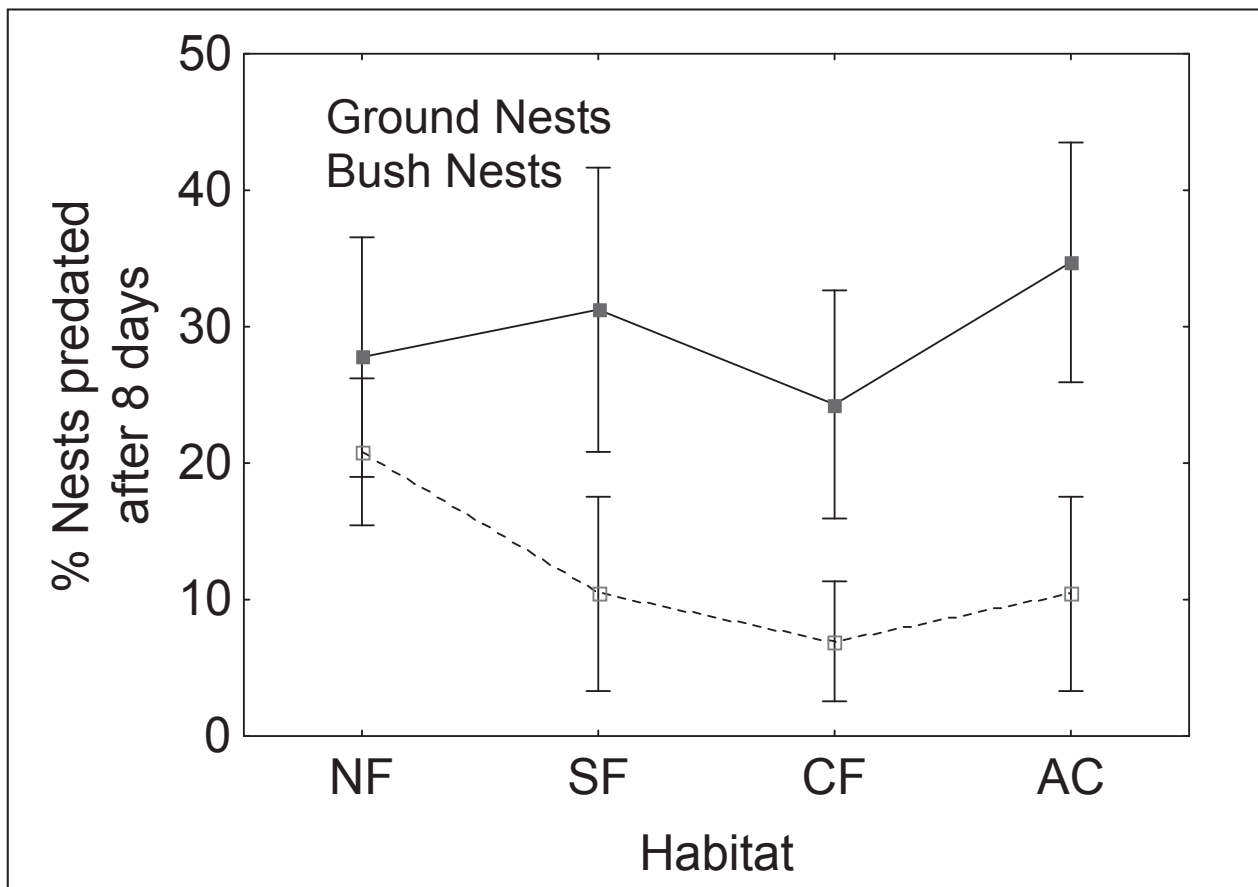


FIG. 2. Percentage of artificial ground (solid) and bush nests (open squares) preyed on after eight days of exposure in different habitats (mean \pm SE). NF: Near-primary forest; SF: Secondary forest; CF: Agroforestry systems; AC: Annual crops.

the 3rd day and the 2nd on the 8th day), some nests were indeed predated twice. We undertook a logistic regression, with predation (0 or 1) as binary dependent variable, and days (0, 3, or 8 days after instalment) as continuous independent variable, and habitat and nest type as grouping variables. A chi-square test was used to determine if the frequency of predator groups differed between habitats. Spearman rank correlation coefficients r_s were also calculated to describe relationships between the overall intensity of predation of artificial bush and ground nests and the percentage vegetation cover and height, tree density and basal area (with and without cocoa/coffee trees), as well as understory plant density. All statistical analyses were performed using STATISTICA 6.0 (StatSoft 2001).

RESULTS

Effects of habitat and nest type. A total of 48 (20%) out of 240 nests were preyed upon within the 8-day study period. Nearly one-third (34/120) of nests placed on the ground were plundered, whereas only 12% (14/120) of those placed in bushes suffered predation (Table 1). While nest type significantly affected predation rate, with ground nests suffering higher rates (Logistic regression: $df = 1$, Wald-stat = 15.95, $P < 0.001$), neither habitat ($df = 3$, Wald-stat = 1.001, $P = 0.801$), nor habitat*nest type did ($df = 3$, Wald-stat = 4.88, $P = 0.181$). Of course nest predation was also dependent on time [days after instalment] ($df = 1$, Wald-stat = 40.97, $P < 0.001$).

Identification of predator groups. In 72 cases, egg loss or damage were assigned to different predator groups.

TABLE 1. Number and proportions of artificial ground (total $n = 120$) and bush nests (total $n = 120$) predated in different habitats after eight days of exposure. NF: Near-primary Forest; SF: Secondary Forest; CF: Agroforestry systems; AC: Annual crops.

Habitat	Ground nests	Bush nests	Total
NF	8 (27%)	6 (20%)	14
SF	9 (30%)	3 (10%)	12
CF	7 (23%)	2 (7%)	9
AC	10 (33%)	3 (10%)	13
Totals	34 (28%)	14 (12%)	48

From the observations made around the nest (presence/absence of footprints and shells, marks on shells; see methods), small-sized predators were identified in 34 cases (47%), medium-sized predators in 26 cases (36%), human activities were reported as being responsible in 8 cases (11%), and other causes in 4 cases (6%). Most predation signs were from ground nests (52 cases or 72%), only 20 (28%) were from bush nests. The frequencies of small- and medium-sized predator records did not differ significantly between ground and bush nests (chi-square test, $\chi^2 = 0.564$, $P = 0.453$, $FG = 1$). However, medium-sized predators were more frequent than expected in secondary forest, while they were much less frequent than expected in agroforestry systems and annual crops (chi-square test, $\chi^2 = 15.10$, $P = 0.002$, $FG = 3$; Table 2). All losses caused by humans were either in agroforestry systems (7) or annual crops (1) (Table 2).

TABLE 2: Distribution of predator/nest loss categories (Medium: medium-sized predators; Small: small-sized predators, Humans, Other: wind/fallen timber) between habitat and nest types. NF: Near-primary Forest; SF: Secondary Forest; CF: Agroforestry systems; AC: Annual crops.

		NF	SF	CF	AC	Total
Ground Nests	Medium	4	10	0	7	21
	Small	6	4	7	8	25
	Humans	0	0	5	0	5
	Other	0	1	0	0	1
Bush Nests	Medium	4	1	0	0	5
	Small	5	2	1	1	9
	Humans	0	0	2	1	3
	Other	0	0	0	3	3

Correlations between predation rates and vegetation parameters. There were no significant correlations between any of the vegetation parameters and any of the nest predation rates, neither for ground nor bush nest types separately, nor for both nest types combined (in all 35 cases, r_s between [-0.22, 0.27], $P > 0.05$), although the percentage cover of bushes was significantly different between habitat types (Kruskall-Wallis test, $H_{3,24} = 11.694$, $P = 0.009$): bush cover (in %) was highest in near-primary forest (mean \pm SD, 75.12 ± 2.04), lower in secondary forest (39.12 ± 5.04 , $P < 0.001$) and agroforestry systems (44 ± 19.25 , $P = 0.001$), and lowest in annual crops (33.5 ± 12.96 , $P < 0.001$), where the difference to near-primary forest was significant (multiple comparison of mean ranks: $P = 0.007$). Bush nest height did not differ significantly between habitat types (Kruskall-Wallis test, $H_{3,24} = 2.985$, $P = 0.394$).

DISCUSSION

Overall predation rates. In this study we deployed chicken (*Gallus gallus*) eggs, which are relatively larger than the quail (*Coturnix japonicus*) eggs used in many other studies (e.g. Gibbs 1991, Roper 1992, Haskell 1995, Pangau-Adam *et al.* 2006) or eggs made of plasticine (Maina & Jackson 2003). We may therefore underestimate predation by small-mouthed mammals in particular (Hanson *et al.* 2007; for effects of egg types in artificial nest predation experiments see also Rangen *et al.* 2000, Berry & Lill 2003).

Our predation rates of 28% (ground) and 12% (bush nests) after eight days represent overall daily predation rates of 3% to 4% (ground nests) or 1 to 3% (bush nests). Compared with most other studies these predation rates are indeed rather low (Lindell 2000, Githiru *et al.* 2005, Pangau-Adam *et al.* 2006, Spanhove *et al.* 2009a). However, they were not much lower than those reported from the only other African chicken egg study (Carlson & Hartman 2001), who found ground nest predation rates of between 30 % and 40% after eight days.

Another factor in low predation rates could be an overall low abundance of even medium-sized predators due to widely distributed hunting and trapping activities by local communities in the study area. In our study area, large and medium-sized mammals, including African civets *Civettictis civetta*, genets *Genetta spp.* and other mongooses Viverridae, as well as smaller mammals about the size of the Gambian rat *Cricetomys emini*, are all hunted and snare-trapped to

an increasing extent, triggered by the unavailability of large wildlife in the region (e.g. Waltert *et al.* 2002).

In addition, predator activity during our study period may not be comparable to that of other studies because we worked just before the main breeding season of most birds. Predation on natural songbird nests can quadruple between the earliest and the latest nests within a single breeding season (Spanhove *et al.* 2009a; but see Sieving 1992).

Predator identities. As in many other studies, ground nests had significantly higher predation rates compared with bush nests, probably as a result of the high number of rodent species living at or near ground level (Loiselle & Hoppes 1983, Wilcove 1985, Martin 1987, Pangau-Adam *et al.* 2006). Small predators, potentially including many snakes, may have also contributed most to nest predation records in our study (Gibbs 1991, Laurance *et al.* 1993, Wong *et al.* 1998, Estrada *et al.* 2002). On Sulawesi, small mammals appeared to be the major predators on both ground and bush nests (Pangau-Adam *et al.* 2006). However, based on our rough categorization of predators, we were unable to establish differences in predator assemblages between ground and bush nests. While ground nests in our study may have been principally affected by rats, squirrels Sciuridae, mongooses, African palm civets *Nandinia binotata* and genets, monitor lizards *Varanus sp.*, snakes, humans and dogs, bush nests were mainly affected by more arboreal squirrels, tree snakes, smaller lizards and humans. Avian species (cuckoos Cuculidae, barbets Capitonidae, hornbills Bucerotidae, but no corvids) can be added to this last group (Andr en 1995, Cooper & Francis 1998) as an almost complete assemblage of the Guineo-Congolian forest birds are found in the study area (Rodewald *et al.* 1994), but evidence of bird predation is not easy to detect on bush nests without automatic cameras. Humans may play a negative role in the breeding success of understory birds in cultivated land by collecting eggs (e.g. of francolins) and by destroying nests when clearing farms and fallowland, and this was so in our study in at least eight cases.

Effects of habitat. In this study, ground nest predation rates did not differ significantly between habitat types. Such a lack of an “edge effect” on ground nest predation has also been discussed in other studies (Gibbs 1991, Arango-V lez & Kattan 1997, Wong *et al.* 1998, Carlson & Hartman 2001, Fraser & Whitehead 2005, Spanhove *et al.* 2009a). In our

study area, modified habitat patches are relatively small and embedded in a matrix of near-primary forest. Simply because of their small size these patches may not constitute a distinct habitat for the predator fauna (Gibbs 1991, Chalfoun *et al.* 2002). Therefore the forest-dwelling predators (snakes, mongooses, palm civet and genets) may not have been replaced or augmented by other predators living closer to human settlements (rats, squirrels, dogs). In addition, the relatively high human activity in areas of cultivation, like fences around farms, probably prevent forest-dwelling predators from becoming established in higher numbers (Carlson & Hartman 2001, Pangau-Adam *et al.* 2006). The rather high frequency of medium-sized predator identifications in secondary forests and their low frequency on cultivated land are in agreement with theories on meso-predator release and patterns of bushmeat hunting/snaring (Terborg 1974, Crooks & Soulé 1999).

Several studies from the Neotropics and Southeast Asia indicate different patterns. In fact edge effects were detected in ground nest predation at various types of edges, including transition between a minor road and forest, between logged and unlogged forest, as well as forest and pasture edges (Burkey 1993, Cooper & Francis 1998, Estrada *et al.* 2002) and between indigenous and second growth forest (Gibbs 1991). However, these studies obviously all differ from ours by the landscape context in which the field research was carried out; there was no extensive near-primary forest matrix surrounding the studied "edge" habitats.

Similar to the ground nest predation patterns, bush nests too were unaffected by habitat type in our area, thus once more apparently rejecting the edge effect hypothesis. The reasons may have been similar to those for ground nests. No correlations were found between bush nest predation rates and bush percentage cover and height, implying that the variation of these parameters did not allow for differential opportunities to prey on nests (as in Pangau-Adam *et al.* 2006 or Maina & Jackson 2003).

Conclusions. In summary, we may conclude that in our study area losses of artificial nests might be relatively low in general, probably due to overall low abundance of medium-sized predators. The current small-scale landscape mosaic around villages, embedded in a matrix of near-primary forest, may not allow for completely different predator assemblages or for differing predation levels in different habitat patches.

The results also support the idea that medium-sized predators are more important in secondary forest, while they are relatively unimportant in more human-modified land use systems, probably as a result of human hunting and trapping activities. Lastly, the study also confirms that ground nests are more vulnerable to predation than bush nests.

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