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## Research Article

## Evidence for an edge effect on avian nest predation in fragmented afro-montane forests in the Bamenda-Banso Highlands, NW Cameroon

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## Abstract

Habitat loss and fragmentation in tropical areas have long been presumed to reduce avian nesting success due to increased predation rates. Nevertheless, this prediction remains largely untested in tropical areas, because empirical data on the impacts of forest fragmentation on nest predation at both the landscape and patch scales in the tropics are still scarce, especially in West Africa. In this study, we examined the edge effects on nest predation rates in a large montane forest block and small forest fragments. Artificial nests used for our experiments mimicked the real nests of passerines confined to montane forest undergrowth in the Bamenda-Banso Highlands, the Northwest region of Cameroon, an endemic bird area of high conservation priority. We found equal overall predation rates in the landscape dominated by the large forest block as well as in the landscape consisting of small forest fragments, implying that the probability of nest failure was not significantly affected by habitat fragmentation on a landscape scale. However, predation rates were higher close to forest edges in the small forest remnants. Since such remnants represent the majority of local montane forests, this result suggests that the edge effect on bird nest predation may reduce nest survival and the population viability of many range-restricted bird species confined to the remaining natural habitats of the Bamenda-Banso Highlands.

**Keywords:** artificial nests, zebra finch eggs, montane forest, endemic species, Cameroon Mountains

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## Introduction

Nest predation is the leading cause of reduced reproductive output in birds [1, 2]. Landscape modification, mainly habitat loss and fragmentation, may either directly or indirectly affect avian nest survival [3, 4]. An increase of nest predation rate is expected to occur in forest remnants as a result of the increased nesting density of birds in remaining patches [5, 6], or reduced nest site availability and poorer nest concealment due to alteration of the vegetation structure [7]. Nest predation is therefore considered an important contributory factor to population declines and local extinctions of birds in fragmented tropical landscapes [4, 8].

Avian nest predation rates are affected also by local scale attributes such as patch size and the extent of edges [9]. Close to forest margins, both abiotic factors and biotic interactions are modified more than in intact forest cores [10, 11]. In many cases, higher rates of nest predation have been documented along edges than in forest interiors [12, 13], and many bird populations suffer from increased nesting mortality in fragmented landscapes with a higher proportion of edges [14]. However, edge effects have mainly been documented in northern temperate forests [13, 15]. The few studies on this topic conducted in the tropics have not consistently shown an edge-related increase of predation rates [see 16 for a review], and some have even found a reversed pattern with higher predation rates in forest interiors than in margins [17, 18]. In Africa, edge effects on predation have been investigated only in eastern [see e.g. 7, 18-20] and southern regions [21]. Heterogeneity in the investigated habitat and edge types, different nest predator communities, and various experimental methodologies have resulted in varying nest predation patterns [16]. As already noted by Vetter et al. [16], an extensive study on natural nests of eight common species in an East African montane forest reported highly variable results even among different bird species of the same bird community, reaching from edge effects to reverse edge effects [4]. Therefore, since edge effects seem to vary with site settings and the landscape context, further studies in areas of priority conservation concern are needed [16].

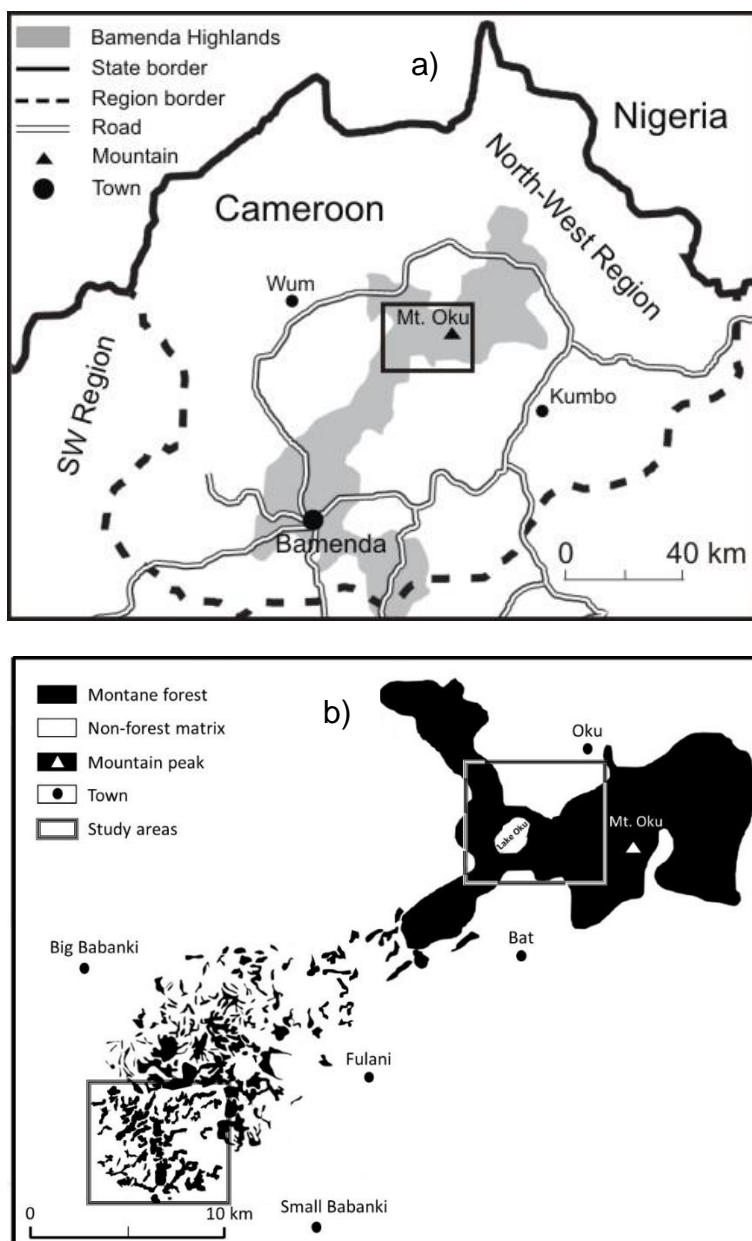
In this study, we used artificial nest experiments to compare the edge effects on avian nest depredation rates in a protected large montane forest remnant and adjacent fragmented forests in Cameroon. The long-term stability and spatial isolation of the montane environment of the Cameroon Mts. have resulted in increased speciation rates and therefore high levels of endemism of various taxonomic groups [22-24]. At the same time, montane cloud forests in Africa are critically threatened, because the higher elevated areas are densely populated due to the decreased prevalence of human malaria and suitable conditions for farming. Much of the Bamenda-Banso Highlands, a sub-region of the Cameroon Mountains, were once covered by forests, but they have dramatically declined since the 1960s through conversion for pastures and farmland [25-26]. Currently, most of the montane forests in the Bamenda-Banso Highlands are confined to steep valleys, and these fragments are very small in area, except the protected largest forest block on Mt. Oku [27]. Many endemic bird species, which are almost strictly confined to montane forest habitats [28-31], are therefore being exposed to dramatic habitat area reductions and consequent ecological changes. These changes may result in altered nest survival. Studies based on artificial nests can provide only limited inference about the real predation pressure on natural nests and must be interpreted cautiously [4, 7, 32-33]. However, we are convinced that artificial nests experiments may suggest the consequences of habitat changes on the nest survival of forest bird species, which is of urgent conservation importance.

In the present study we ask: (i) if the overall predation rate on artificial songbird nests differs between the fragmented landscape and the large continuous block of montane forest, (ii) if the artificial nests experience higher predation at forest edges than nests in the forest interior, and (iii) whether the montane forest fragmentation influences the predation rate at the edges. To address these questions,

we conducted experiments using artificial nests that imitated real nests of small forest understorey passerines.

## Methods

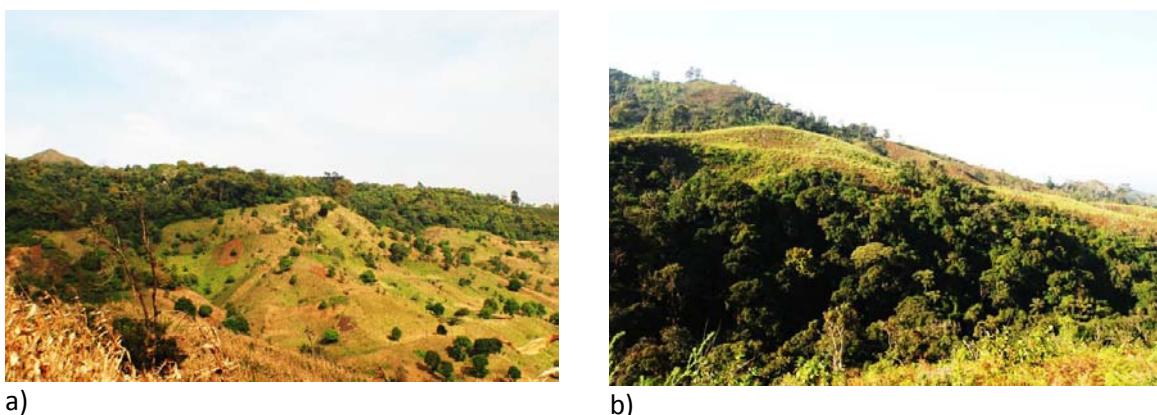
The study was conducted in the Bamenda-Banso Highlands, a part of the Cameroon Mountains in the N.W. province of Cameroon (Fig. 1a). The Bamenda-Banso Highlands mostly span an altitudinal range from 1,500 to 2,500 m a.s.l.; the highest peak is Mt. Oku at 3,011 m a.s.l. There is a single long wet season from March to the end of October, and a shorter dry season from November to the end of February. The average yearly precipitation varies between 1,700 and 2,300 mm with approximately 190 rainy days per year [34]. The average monthly temperatures range from 15.3°C to 24.5°C. Most of the montane forest birds breed between early November until the end of February, i. e. during the dry season [35-36].



**Fig. 1. a)** Location of the study area, NW Cameroon. Areas above 1500 m a. s. l. are in grey. **b)** Detailed map of the two study sites (delineated by rectangles) – the fragmented Kefem forest and continuous Kilum-Ijim forest block on Mt. Oku. Exact locations of study fragments and detailed information on artificial nest placements at forest edges and in the forest interior for both study sites are given in a map in Appendix 2.

The artificial nest experiments were conducted at two sites: the Kilum-Ijim forest and Kefem forest. These sites are situated about 30 km apart and differ in the degree of montane forest fragmentation (Fig. 1b). The area of each of our study sites was about 20 km<sup>2</sup>. The Kilum-Ijim forest (6°11'35"N 10°27'42"E, 2,200 m a.s.l.) is the largest remaining patch of Afro-montane forest in western Africa (total area over 20,000 hectares), located around Mt. Oku [26]. Nevertheless, between 1958 and 1988, more than 50% of the natural montane forest around Mt. Oku was destroyed. Since 1988, efforts for regeneration of the forest have been carried out, and the forest area had increased by 10% by 1999 [37]. About 370,000 people currently live within a day's walk of this compact forest block, and the land is intensively cultivated around the protected area [26]. The matrix around the forest is formed mainly by cassava and corn fields. The transition between forest and matrix is very abrupt, forming a sharp forest edge (Fig. 2a). Detailed information on vegetation is given in Appendix 1.

The Kefem forest is situated about 10 km southeast of Big Babanki village (6°02'23"N 10°17'47"E, 1,900–2,200 m a.s.l.). This upper montane forest is highly fragmented, covering only about 40% of the landscape (Fig. 1b). The forest fragments are mostly confined to steep valleys and are interconnected by strips of residual forest vegetation along the sides of streams. There are four relatively larger forest patches in the area, ranging from about 45 to 100 ha, but most of the patches cover only 1 to 20 ha. Detailed information on vegetation is given in Appendix 1. The transition zone between the forest remnants and matrix is not as sharp as in the case of the Kilum-Ijim forest (Fig. 2b) as the Kefem matrix is dominated by Kikuyu Grass (*Pennisetum clandestinum*) pastures, shrubby secondary growth, tall grasslands dominated by Bracken (*Pteridium aquilinum*) and Elephant Grass (*Pennisetum purpureum*), and vegetable fields (corn, black nightshade, beans, potatoes). Artificial bushfires annually burn most of the matrix during the dry season.



**Fig. 2. a)** A sharp forest edge with matrix dominated by corn and cassava fields at the Kilum-Ijim study site (Mt. Oku). **b)** Forest fragments confined to steep valleys surrounded by secondary growth and pastures at the Kefem forest site (Big Babanki). Photo credits: M. Mikeš.

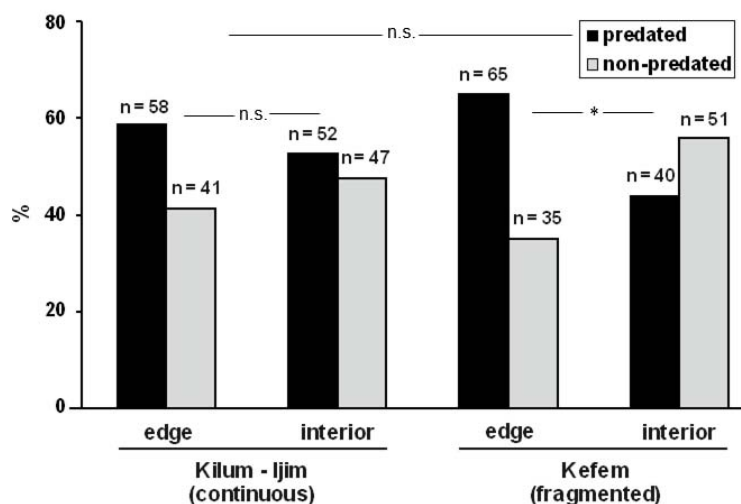
To compare the relative rate of nest predation in the moist montane forest we used artificial bird nests, which have the advantage of standardizing conditions such as exposure time and microhabitat use [31, 38]. Our experiment was carried out in November 2008 and 2009, during the breeding season of most passerine birds [39]. Artificial nests simulated the real open-cup nests of typical passerines breeding in the forest understorey, including endemics (e.g. Banded Wattle-eye *Platysteira laticincta*, White-bellied Crested Flycatcher *Elminia albiventris* or African Hill Babbler *Pseudalcippe abyssinica*). The nests were made of cotton materials; their size was 5 cm in diameter and 5 cm in height, and wall thickness was about 0.8 cm [see also 38]. For greater nest authenticity, the outer surface was covered by forest leaf litter attached by natural starch that produces no smell. Each nest contained one real Zebra Finch



(*Taeniopygia guttata*) egg. All nests were placed in the undergrowth and fixed by wire to shrubs about 1.5 m above the ground. At the Kilum-Ijim study site, we placed 100 nests at the forest edge (about 3 m from the sharp edge between forest and agricultural land) and 100 nests in the forest interior, at least 100 m from the edge. The nests were placed along two continual transects (edge and interior) in the Kilum-Ijim forest (Appendix 2). However, two nests were not found later, which resulted in  $n = 99$  for both treatments. In the Kefem forest, we placed 100 nests at the forest edge and only 91 nests in the forest interior due to the limited amount of interior habitat at this study site (Appendix 3). The nests were here placed in eight forest fragments of sizes from five to 34 ha (5 ha, 12 ha, 16 ha, 17 ha, 19 ha, 21 ha, 25 ha, 34 ha). However, there are no distinct borders between individual forest fragments as they are often interconnected by narrow corridors within the landscape, and it is difficult to delineate the exact borders of fragments (Appendix 3). Individual nests were placed at least 100 m apart to reduce pseudoreplication bias. The fate of all nests was recorded after 11 days and they were considered predated if the egg was missing or cracked. Differences in artificial nest predation rate between the Kilum-Ijim and Kefem forest, and between the edge and interior within each site, were tested using Pearson's Chi-squared test with simulated p-value implemented in the R-package "stats" [40].

## Results

Our experiments showed no overall difference in shrub artificial nest predation rate between the Kefem forest remnants (55.6%, 110 from 198 nests predated) and the Kilum-Ijim large forest block (55.0%, 105 from 191 nests predated) after 11 days of exposure. Nests placed close to the forest edge in the fragmented Kefem forest experienced a significantly higher ( $X^2$  ( $N = 191$ ) = 8.52,  $p = 0.002$ , Fig. 3) risk of predation (65 from 100 nests predated) than nests placed in the forest interior (40 from 91 nests predated). The nest predation rate was also slightly higher at forest edges (58 from 99 nests predated) than in the interior (52 from 99 nests) in the large Kilum-Ijim forest; however, the difference here was not significant ( $X^2$  ( $N = 198$ ) = 0.74,  $p = 0.47$ , Fig. 3). We also did not find significant differences in nest predation rates between the two study sites at either the forest edges ( $X^2$  ( $N = 199$ ) = 0.87,  $p = 0.40$ ), or the forest interior ( $X^2$  ( $N = 190$ ) = 1.39,  $p = 0.25$ , Fig. 3).



**Fig. 3. Comparison of 11-day nest predation rates on artificial shrub nests placed at forest edges and in the forest interior in the Kilum-Ijim forest (large forest block) and Kefem forest (small forest fragments) in the Bamenda-Banso Highlands, NW Cameroon.**  
\*  $p < 0.01$ .

## Discussion

Results of artificial nest predation experiments have to be interpreted with caution. Daily survival of artificial nests is usually lower than for real nests, and they typically attract only part of the predator community [32]. In our study, we tried to mimic real nests of small passerines inhabiting the montane forest undergrowth (Fig. 4). We believe that fresh eggs of Zebra Finch placed in open cup nests attracted both visually and chemically oriented predators, including small mouthed mammals, which are able to crack the thin shell of the eggs used [41]. However, the results of our study must be interpreted with caution, because patterns of nest predation on artificial nests may not reflect patterns of nest predation on natural nests [4, 7, 32-33].

Our experiments with artificial nests in the Bamenda-Banso Highlands revealed equal overall predation rates in both the large montane forest block and small fragments. This implies that the probability of nest failure of small passerines with open cup nests may not be significantly affected by habitat fragmentation on a landscape scale. However, predation events were unevenly distributed in relation to forest edges. We found a higher predation rate close to forest edges than in the forest interior in the fragmented landscape. In the landscape dominated by continuous forest, this effect was similar but was much weaker and insignificant. These findings suggest a pronounced edge effect on the rate of artificial nest predation in small fragments of montane forests.

The vast majority of montane forest habitats have already been fragmented in the Bamenda-Banso Highlands, and the Kilum-Ijim forest is the only large forest patch in the area. Bird populations are therefore being forced either to adapt to the fragmented habitats or to disappear [14, 42]. Formerly, we have shown that many range-restricted bird species still survive in the fragmented landscape and their abundances are relatively high [28-29, 43]. However, no information on the viability of these populations over time is available. Fragmentation of the montane forest in the study area is relatively recent [25-26], and the ability of forest birds to survive in degraded environments might be limited [29]. Our study on artificial nest predation rate suggests that birds inhabiting small forest patches may suffer from enhanced predation probability close to edges. Given the fact that the size of most of the forest fragments is only several hectares and they are often linear in shape, edges represent a large proportion of their areas and are often the only forest habitat available [9, 44]. Our results therefore suggest that nest survival rates of birds on edges may be reduced in small forest fragments, and this may have important impacts on the long-term persistence of populations of range-restricted bird species confined to montane forests of the Bamenda-Banso Highlands.

We can discuss the reasons for the increasing edge effect only indirectly, as we were not able to identify predators of eggs in artificial nests and did not evaluate the distribution of predators in relation to forest size and distance to edge. A majority of studies conducted in tropical forests have identified small mammals as the most important predators of eggs [16, 45-46]. Small rodents and shrews also appear to be dominant nest predators in afro-montane forests [4, 18, 20]. It has been suggested that landscape alteration and habitat fragmentation may mediate nest predation risk via changes in predator composition, abundance, and/or behaviour. The two sites studied here are only 30 km apart, but we cannot exclude the possibility that the nest predator communities differ. We suggest that the differences in landscape structure and matrix composition between our study areas may be responsible for changes in nest predation risk [see also 47]. The large forest block at Kilum-Ijim has much sharper edges with a steep transition to cultivated land (see Fig. 2a), whereas the fragmented landscape of the Kefem forest consists of a mosaic of small forest fragments surrounded mostly by semi-natural grasslands, pastures and secondary re-growth (see Fig. 2b). The different nature and extent of human activities in the two types of landscapes, such as hunting pressure, grazing, and the extent and frequency of bushfires, may have led to different predator community structures between

the study sites, including the diversity, abundance, and activity of nest predators along the forest edges. Predator communities in small forest fragments can be also altered by the effect of mesopredator release caused by the extinction of top predators, which in turn permits an increase in the number of smaller sized predators that might pose a greater risk for avian nests [48].



**Fig. 4. Depredated artificial nest with shell remnants of a Zebra Finch egg and a real nest of White-bellied Crested Flycatcher (*Elminia albiventris*) with two eggs. Photo credits: M. Mikeš.**

## Implications for conservation

This study on artificial nests suggests that the edges of fragmented forests represent a suboptimal breeding habitat for small passerines nesting in the montane forest undergrowth. Given that most of the forests in the Bamenda-Banso Highlands are already fragmented, populations of many small passerines, including range-restricted globally endangered species, seem to be dependent on fragmented landscapes. Our results suggest that the survival of such species can be significantly reduced near edges of forest fragments. Moreover, small forest fragments are mainly confined to steep valleys and are mostly linear, with a large amount of edges. Therefore, particular conservation actions should aim to 1) eliminate further deforestation of the area, especially due to uncontrolled bushfires, 2) conserve the last larger forest patches and try to maintain their shape as circular as possible to decrease the edge-area ratio. Local communities are already aware of the importance of forest, not only for maintenance of the endemic biodiversity but also for water supplies, non-timber products (e. g. honey and natural medications), and sustainable resource use. However, ambiguity of land ownership, uncontrolled land use, and destructive activities of relatively few farmers and hunters (mainly by establishing bushfires) prevent the effective protection of the last forest remnants.

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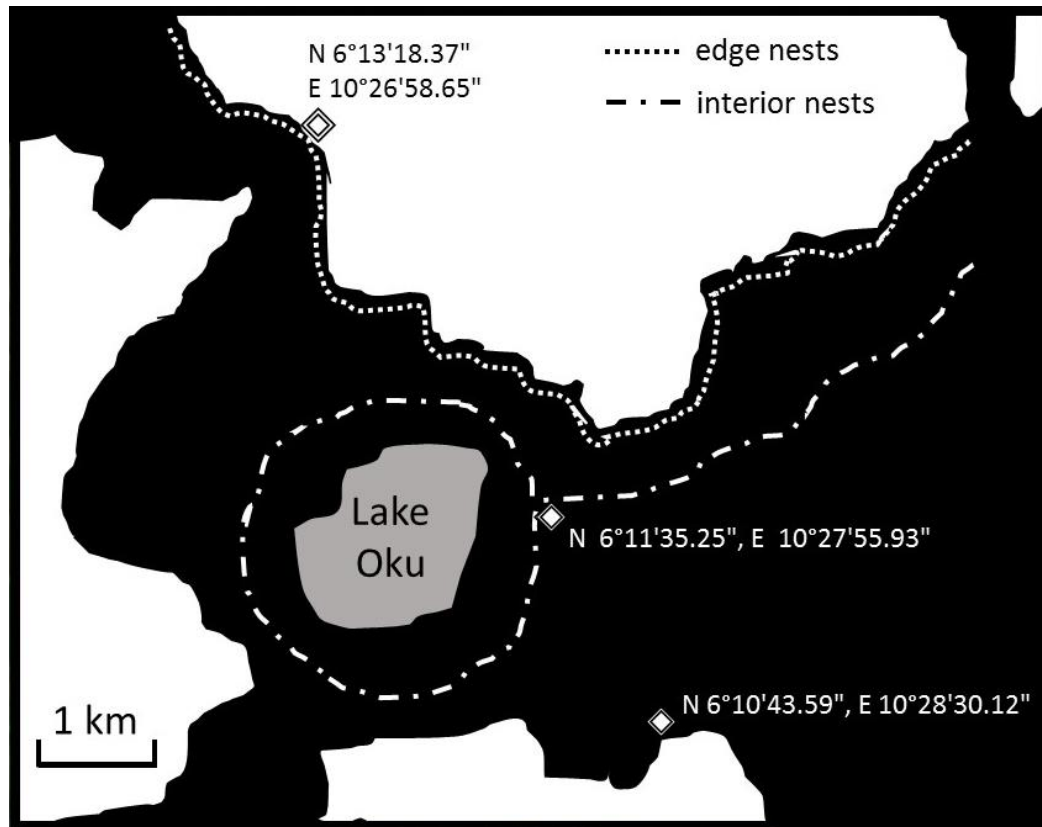
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**Appendix 1.** Detailed information on vegetation of Kilum–Ijim forest (continuous forest) and Kefem forest (fragmented landscape).

The upper montane forest at the study elevation of Kilum–Ijim forest is dominated by the strangling species of umbrella trees - *Schefflera abyssinica*, *S. manii* (Araliaceae) that make up 70-90% of stem volume, accompanied by Common Wild Elder *Nuxia congesta* (Buddlejaceae), *Syzygium staudti* (Myrtaceae), True Yellowwood *Podocarpus latifolius* (Podocarpaceae), African Crabwood *Carapa procera* (Meliaceae), Winged Bersama *Bersama abyssinica* (Melianthaceae), African Cherry *Prunus africana* (Rosaceae) and Cape Beech *Rapanea melanophloeos* (Myrsinaceae). Vertical structure of closed-canopy undisturbed montane forest is relatively simple. The upper canopy trees are up to 30-35 m tall, lower canopy stratum is missing and the undergrowth is formed by 3 m tall monocarpic forbs *Oreacanthus manni* (Acanthaceae) and *Plectranthus insignis* (Lamiaceae) [36, Doležal et al. unpubl. data].

The forest remnants at Kefem forest are formed by *Syzygium staudti* (Myrtaceae), *Ixora foliosa* (Rubiaceae), Parasol Tree *Polyscias fulva* (Araliaceae), False Assegai *Maesa lanceolata* (Myrsinaceae), *Canthium dunlapii* (Rubiaceae), and to lesser extent by dominants of undisturbed forests of umbrella trees *Schefflera abyssinica*, *S. manii*, African Crabwood *Carapa procera* (Meliaceae), and Common Wild Elder *Nuxia congesta* (Buddlejaceae). Compared to less disturbed Kilum–Ijim forest, the small remnants of Kefem forest are prone to wind and fire disturbances, leading to more open stands and well developed shrub and lower tree stratum with a higher proportion of woody species typical of secondary regrowth such as Fish Poison Bush *Gnidia glauca* (Thymelaeaceae), Broad-leaved Croton *Croton macrostachyus* (Euphorbiaceae), Peacock Flower *Albizia gummifera* (Fabaceae) and Cheesewood *Pittosporum viridiflorum* (Pittosporaceae) in the tree layer, and *Phyllanthus mannianus* (Euphorbiaceae), *Psychotria peduncularis* (Rubiaceae), Curry bush *Hypericum revolutum*, and *Hypericum roeparianum* (Hypericaceae) in the shrub layer (Doležal et al. unpubl. data).

**Appendix 2.** Map of the study site at the continuous Kilum-Ijim forest. Edge and interior artificial nests were placed here along two continuous transects. The non-forest matrix adjacent to our edge transect is largely dominated by cassava and corn fields.





**Appendix 3.** Map of the study site at the fragmented Kefem forest landscape. Forest fragments used for experiments are shaded in grey. Samples of transects used for placing the edge and interior artificial nests, respectively, are given in one forest fragment. The matrix surrounding the patches of montane forests consists here of a fine and dynamic mosaic of pastures (dominated by Kikuyu Grass *Pennisetum clandestinum*), shrubby secondary growth, Bracken *Pteridium aquilinum* and Elephant Grass *Pennisetum purpureum* tall grasslands, and vegetable fields (corn, black nightshade, beans, potatoes). Artificial bushfires annually burn most of the matrix during the dry season.

