

Fragmentation Study

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History of Fragmentation in Region

Kakamega Forest is a mid-altitude rainforest (1400-1700m) in western Kenya. Geological, biological, and historical evidence suggests that mid-altitude rainforests in western Kenya were once continuous with the Guineo-Congolian rainforests of west and central Africa (Kokwaro 1988, Mitchell 2004, Wagner et al. 2008). The migration to and settlement of Uganda and western Kenya by the agricultural Bantus led to some clearing of the grass/forest mosaic during the last thousand years or so. Reports and maps from late 19th and early 20th century indicate that western Kenya forests were continuous in a patchy network west into Uganda and south towards Lake Victoria, but were probably separated from the montane forests north and east up the Nandi escarpment (<1800 m). Maps from 1913 show continuous forest south but not west, north, and east. There was much clearing of forest in this region by British colonialists building the trans-African railroad (Mitchell 2004).

In 1933, Kakamega Forest was declared a national forest and the boundaries were delineated (Kokwaro 1988, Mitchell 2004). It was apparently still continuous with other forests south (e.g. South Nandi Forest), but not continuous with any sizable forest west, north, and east. The gazetted forest consisted of a main forest block (Kakamega - 23,785 ha) and two smaller blocks (Kisere - 400 ha, Malava - 780 ha) to the north. There is some evidence that small natural grass glades, present now, dotted the interior of Kakamega Forest, along with a few small (<0.5 ha) squatter farms (Mitchell 2004).

Between 1933 and 1965 two events happened with regards to fragmentation of Kakamega Forest. First, considerable areas south of Kakamega Forest and southern areas of the gazetted Kakamega Forest were cleared for subsistence agriculture and logging. This separated Kakamega Forest from all other forests in all directions. Second, sections of forest in the interior were being cleared, leading to the eventual fragmentation of Kakamega Forest itself into smaller patches.

Between 1965 and mid 1980's, the interior clearing continued resulting in two swaths that separated Kakamega Forest into three smaller fragments (Kakamega proper, Yala, and Ikuywa)(Lung and Schaab 2007, Glenday 2006). In addition, forest loss continued along the southern edge of Yala and Ikuywa fragments, and also along the west edge of Kakamega proper (near Kakamega town) reducing the size of all fragments.

During the last few decades, most forest lost has stopped, but small areas of forest were cleared in the southern regions. Interestingly, some small regions (~700 ha) were reforested either naturally (around glades) or purposely (around Isecheno forest station)(Glenday 2006). As of 2001, indigenous forest in the main gazetted forest block covers approximately 15,000 hectares in three fragments (Glenday 2006).

In summary, by 1933 Kakamega Forest was a single forest covering approximately 24,000 hectares. It was continuous with forest south and potentially had tenuous connections to the west through a patchy forest network confined to riparian regions. By the beginning of the 21st century the forest was reduced in size to about 15,000 hectares, separated from all other forests, and fragmented into numerous smaller patches.

Fragmentation Effects on Biodiversity

The effects of forest fragmentation on biodiversity are generally grouped into size/isolation effects and edge effects. Fragmentation of continuous forest results in smaller forest patches separated by non-forest land (i.e. matrices)(Andrens 1996). Reduced size and isolation can lead to reduced populations and/or changes in genetic variability and reduced fitness which can lead to extinctions; thus, decreased species diversity is associated with smaller, more isolated fragments (MacArthur and Wilson 1967). The remaining forest patches are often embedded in a landscape of high human use. In Sub-saharan Africa, where high human densities are correlated with areas of high endemism and species richness, this can lead to further dramatic effects on species diversity through continual degradation of forest patches (Peres 2001). The combined influences of high human populations and poverty in Africa are contributing to an alarming rate of forest loss equal to 5.7 million hectares annually (FAO 2001).

The boundary between the forest and the matrices (usually of human use) create edge effects which vary by the species and the type of matrix. Edge effects can be biological (e.g. predation) or abiotic (e.g. temperature), decrease the effective available area for a species, and thus influence population sizes.

A recent global meta-analysis of tropical forest fragmentation on primates (Harcourt and Doherty 2005) found that average fragment size ($<1.0 \text{ km}^2$) was too small to support adequate primate populations, that decreasing forest size has led to a decrease in primate species richness at all spatial scales, and that studies were lacking in Africa. Harcourt and Doherty (2005) also found that African studies showed weaker relations between forest size and species richness, but they suggest this was probably due to either confounding effects of isolation distance, too few studies, and that long-term human occupancy of the African continent may influence human-primate interactions.

Most African studies on forest fragmentation have occurred in the Kibale forest complex in western Uganda (Chapman and Onderdonk 1998, 2000; Skorupa 1986; Fairgrieve and Muhumuza 2003). Because Kakamega Forest has affinities with the forests of Uganda (Wagner et al. 2008, Mitchell 2004) we use these studies as a platform to discuss studies and potential fragmentation effects in Kakamega Forest. Our focus here is on birds and primates because of their relatively large home ranges, large body sizes, and slower growth rates compared to invertebrates and smaller mammals. Below we discuss species/area relationships found in Kibale and Kakamega Forests, and edge effects associated with both natural (e.g. abiotic conditions) and human (e.g. hunting, timber use) influences associated with matrices of human use and degradation of remaining forests.

Kibale National Park. Kibale National Park consists of a large forest block surrounded by 20+ fragments of forest (Onderdonk and Chapman 2000). Forest fragments range in size from 0.8 ha to 130 ha with most being less than 10 ha; they are separated from the main forest block by 0.2-7.2 km (mean = 2.8 km) and from each other by 50-300 m (mean = 121 m). The matrix in between consists of farmland, natural grassland, and grazing areas. Kibale harbors more than ten species of primates.

Fragmentation appears to influence primate species differently. Some primate species appear to be unaffected by fragmentation (e.g. Black and white colobus – *Colobus guereza*) and are found in all fragments regardless of size and isolation. Others species, which are common in the main forest block, are absent from all fragments (e.g. Blue monkey – *Cercopithecus mitis*)(Onderdonk and Chapman 2000). The authors contribute this to the large home range of

blue monkey (36-253 ha) compared to black and white colobus, redbelted, and red colobus (6-35 ha), and their more specialized fruit diet (Struhsaker 1978; Struhsaker and Leland 1979). Other studies of primates suggest home range size and frugivorous diet are important factors in species persistence in forest fragments (Estrada and Coates-Estrada 1996; Lovejoy et al. 1986). Consequently, the population of blue monkeys in the Kibale complex has declined steadily over the last quarter century.

The relationship between frugivores like the blue monkey and the fruit trees that provide much of their food has also been studied. Frugivorous primates can be important dispersers of seeds for forest trees. Chapman and Onderdonk (1998) found that Kibale forest fragments, which had lower numbers of primates, had low seedling densities and seedling diversity. More studies are needed to test whether long-term persistence of fruit trees or frugivores is dependent upon this relationship.

Kakamega Forest. Kakamega Forest currently consists of a large forest block and six forest fragments (Peters et al. 2009). The main forest block is approximately 8245 hectares (excluding natural glades) and forest fragments range in size from 65 ha to 1370 ha. The fragments are separated from the main forest block by 1.3-9.4 km and from each other by 0.2–9.4 km (Brooks et al. 1999; Peters et al. 2009). All fragments have been separated for at least 35 years (Mitchell 2004). Of the total forest area, only 4454 hectares is protected by law (Mitchell 2004). The forest fragments are embedded in a matrix of subsistence agriculture of various crops (e.g. maize, beans, tea), exotic plantations (e.g. *Pinus*, *Eucalyptus*), regenerating forest, and grasslands (Lung and Schaab 2007).

Several studies exploring fragmentation have been conducted on flora and fauna in Kakamega Forest. Some of these studies focused on species/area relationships (e.g. Brooks et al. 1999; Peters et al. 2009), while other studies focused on edge and disturbance relationships (e.g. Farwig 2006; Mammides et al. 2009; Maina and Jackson 2003). Brooks et al. (1999) predicted the effects of fragment size and isolation on forest bird species persistence in terms of relaxation (i.e. loss of species number from extinction during a time period following fragmentation). The relaxation index (RI) “indicates how close a fragment is to suffering so many extinctions that it reaches a new, lower equilibrium number of species” (Brooks et al. 1999, pg 1144). They found that small fragments take between 25-100 years to “relax” halfway toward a new, lower number of species (see Table below). The smallest and most isolated fragment had the shortest half life (time to lose half of original species) and they assessed that it had already lost 40% of its original species. The main forest island may have only lost three of its original predicted 62 bird species.

Table 1. Summary of Brooks et al. (1999). S_{orig} = predicted number of species before fragmentation; S_{now} = observed number of species in 1996; $S_{relaxed}$ = predicted number of species after relaxation. RI = relaxation index; $\frac{1}{2}$ Life = number of years to loss $\frac{1}{2}$ of species.

Fragment	Size (ha)	Distance	S_{orig}	S_{now}	$S_{relaxed}$	RI	$\frac{1}{2}$ life (yrs)
Malava	100	9.0	32	19	18	0.05	23
Kisere	400	1.6	39	32	26	0.45	55
Ikuywa	1450	0.5	48	44	36	0.69	38
Yala	1500	0.5	48	44	36	0.67	42
Main	8600	-	62	59	56	0.49	80

Peters et al. (2009) studied the effects of fragment size on army ant abundance and raid rates in Kakamega Forest fragments. Army ants can play keystone roles in tropical forests

because their raids affect the density and enhance the diversity of other arthropods (Franks 1982, Otis et al. 1986), and provide food for dependent species such as ant-following birds (Willis and Oniki 1978). Because of their large home ranges, role as top-predators, and low colony densities they are susceptible to habitat fragmentation (Turner 1996). Peters et al. (2009) found that one species (*Dorylus wilverthi*) was less abundant and had lower raid rates in smaller fragments than in the main forest block. A second species (*D. molestus*) was more abundant and had higher raid rates in smaller fragments. *Dorylus molestus* was also more common in agricultural matrix between fragments. Because of the differences in abundance and activity of each species between fragments, the overall abundance of army ants was equivalent among all fragments. They conclude that similar ecologically important species may react differently to fragmentation and species compensation maintains abundance.

Maina and Jackson (2003) studied the effects of human disturbance on bird nest predation along edges in Kakamega forest fragments. They found that nest predation was lower in fragments with more human disturbance. They suggest that in forest fragments that no longer have top predators (e.g. leopards), mesopredators (e.g. civets, mongoose) may be “released” and have larger influences on prey; in fragments with more access and disturbance by humans (defined in this study by frequency of trails), dogs may act as top predators and minimize mesopredator activity and thus lower nest predation. A few studies in this region have shown that human access and disturbance are ubiquitous and high (Bleher et al. 2006, Lung et al. 2008). This disturbance has usually been cited as detrimental to forest biodiversity but there may also be positive interactions (see also Farwig et al. 2006).

While no specific studies have been conducted on the influences of fragmentation on primates in Kakamega forest, numerous studies provide insight into possible effects. Studies in biologically and contextually similar forests in Uganda have documented declines in blue monkey (*C. mitis*) populations and density (Teelen 2007), and the disappearance of blue monkeys from small forest fragments (Onderdonk and Chapman 2000). Blue monkeys have attributes that make them more susceptible to fragmentation of forests (large home ranges and frugivorous diet). In addition, blue monkeys have been observed to change their diet to include more unripe fruits and bark in disturbed forests (Fairgrieve and Muhumuva 2003). In addition, decreases in blue monkey density are associated with abundance of feeding tree species (Teelen 2007), and important fruit trees like *Prunus africanu*, and its relationship to surrounding fruit tree diversity, appear to influence the activities of frugivores like the blue monkey (Farwig et al. 2006).

In Kakamega Forest, Fashing and Cords (2000) documented the decline in blue monkey group density over the last 20 years. In the same area, *P. africanus* has experienced a die-off during the same time period (Fashing 2004). In addition, Mammides et al. (2009) have documented a strong positive relationship between blue monkey density and diversity of food trees. The blue monkey, a primate with a fairly strict frugivorous diet and large home range, appears susceptible to effects associated with fragmentation (decreased habitat area and disturbance). Unlike other primates with similar attributes (e.g. chimpanzee), they also appear less willing to cross matrices between fragments thus making them even more susceptible to fragmentation (Onderdonk and Chapman 2000).

Fragmentation Analysis of Forest Again Reforestation Project

The objective of **Forest Again** is to reforest regions between two forest fragments in Kakamega Forest (Yala and Kakamega main forest). Currently, this region between indigenous forest fragments consists primarily of abandoned agriculture, grassland, and hardwood plantations. Forest Again's plan to reforest approximately 470 hectares of the abandoned agriculture and grassland would result in a corridor between the smaller Yala fragment and the main forest block, increase the total area of indigenous forest, and reduce exposure of forest edges in areas that have high human use.

Here we examine the potential benefits of reforestation in relation to the above documented biodiversity effects occurring in Kakamega Forest as a direct or indirect consequence of fragmentation. We also provide an analysis of predicted benefits and uncertainties associated with (1) providing a corridor between Yala and the main forest block, (2) increasing the total forest area, and (3) reducing exposure of forest edges to disturbance. Specifically, we provide the following:

1. A landscape metric analysis before and after reforestation with emphasis on edge effects and human disturbance.
2. An analysis of historical effects of fragmentation on forest bird communities and predicted outcomes of reforestation related to species/area models.
3. A habitat analysis of a forest dependent species – Blue monkey (*Cercopithecus mitis*) and the predicted influence of **Forest Again** on the availability of habitat and potential population consequences.

1. Landscape Metric Analysis

Landscape metrics are the result of GIS analyses. They provide spatial information (e.g. area of patches in a landscape, distance between patches) regarding landscapes. Here we present the results of a landscape metric analysis of Kakamega Forest in reference to the proposed reforestation. We used a 2001 satellite image (Landsat TM/ETM+), and land cover maps of this region generated from this satellite image by the Kenya Department of Remote Sensing and Resource Surveys (DRSRS). We use only the main forest gazetted boundary demarcated in 1933 (which excludes several small forest islands north of the main forest block) in our analyses (see below). Using ArcMap 9.2 (ESRI 2006) spatial analyst tools and Hawth's tools extension for ArcGIS, we calculated the following for the forest landscape in 1933, 2001, and post-reforestation:

1. Total gazetted area (ha)
2. Total indigenous forest area (ha)
3. Ratio of indigenous forest to total area
4. Total edge length (km) – defined as the boundary between indigenous forest and all other landscape patch types (includes residential agriculture, grass/shrub land, plantations).
5. Ratio of indigenous forest area to edge
6. Number of indigenous forest patches
7. Mean area (and standard deviation) of indigenous forest patches
8. Mean shortest distance between indigenous forest patches
9. Ratio of *forested edges to nonforested edges (within project region only)

*forested edge refer to matrices adjacent to indigenous forest that are forest-like (e.g. plantations); non-forested edges refer to matrices adjacent to indigenous forest that are non-forested (e.g. grasslands, agriculture).

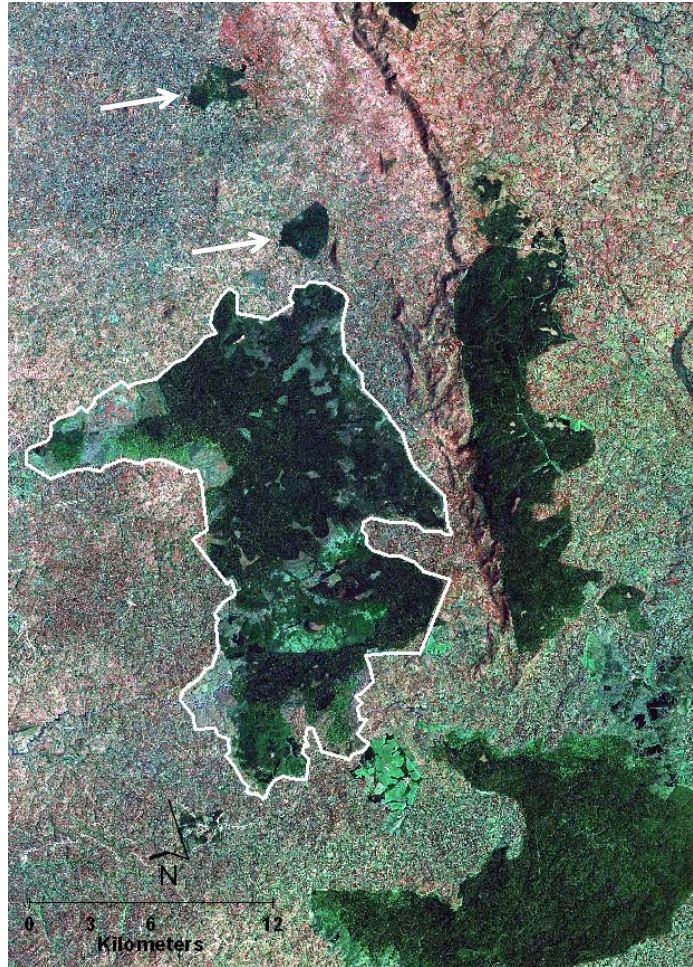


Figure 1. Satellite image (2001) of Kakemaga Forest showing main gazetted forest area (white outline). The two smaller northern forests (white arrows) are also part of national forest, but are not included in these analyses.

Results

The total gazetted area of indigenous forest in the main block in 1933 was calculated at 24,598 ha, similar to other recent estimates (Glenday 2006, Lung and Schaab 2006) and the area recorded at the time it was gazetted (Mitchell 2004). The calculated edge length was 101.9 km and the area to edge ratio was 2.41. By 2001, indigenous forest area consisted of 3 fragments (1519 ha, 1534 ha, and 12,361 ha) totaling 15,414 hectares (including natural interior glades). By this time, indigenous forest represented only 62.7% of the total gazetted area (Figure 2). The total length of edges of the three fragments was 125.6 km, an increase from 1933 by 23.7 km. Area to edge ratio was 1.23, 50% lower than 1933. In the project area, the ratio of indigenous forest edges adjacent to forest-like matrices (e.g. hardwood plantations) versus adjacent to non-forest matrices (e.g. agriculture, shrub-land) was 0.89. The mean shortest distance between fragments was 1.3 km.

Upon successful completion of reforestation between Yala and Kakamega fragments, indigenous forest will consist of two fragments (1519 ha and 14,355 ha) totaling 15,874 hectares (Figure 2). This represents an increase in indigenous forest area of 460 hectares. While total edges sums to 140.2 km (an increase of 14.6 km from 2001), the area to edge ratio increases by

67% to 1.90 and the ratio of indigenous forest exposed to forest-like vs non-forest matrices increases by 2.5 times. The mean shortest distance between fragments decreases by 1/3 of a kilometer.

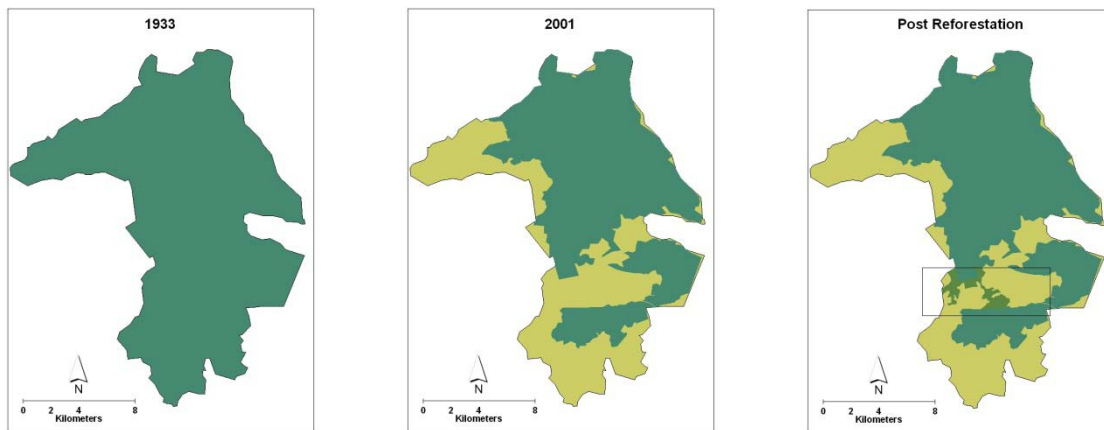


Figure 2: Land cover series 1933, 2001, and post-reforestation. Indigenous forest in dark green, project region within black rectangle and reforestation sites in light green.

Discussion

Fragmentation of natural landscapes influences biodiversity by reducing habitat area, changing the configuration of patches and movement of species between patches, and increasing edge effects. The history of deforestation of Kakamega Forest from 1933 to 2001 has not only resulted in a loss of forest habitat, but has fragmented the remaining habitat into 3 smaller fragments separated by large distances, decreased the area to edge ratio, and increased the amount of forest edge exposed primarily to human-dominated matrices (e.g. residential agriculture). Forest edges adjacent to non-forest matrices result in “edge effects,” which are changes in both the abiotic and biotic conditions within forest habitat.

In our study we found that deforestation between 1933 and 2001 increased forest edges exposed to human-dominated matrices by almost 25 kilometers and decreased the area to edge ratio by 50%. The area to edge ratio is a helpful index in assessing the potential effects of fragmentation on forest interior species. Edge effects can decrease the effective available habitat area of forest dependent species (e.g. primates and birds). For example, many birds in tropical forests are interior species and avoid edges because food availability and foraging is inhibited (Terborgh 1988).

Edge effects in forests can be exaggerated when human disturbance is also taking place. Edges of natural habitat adjacent to human dominated landscapes (e.g. residences, agriculture) are exposed to human exploitation and the level of use can be influenced by the contrast between forest and matrix. For example, Lung et al. (2008) found that access to and levels of human use in Kakamega Forest were influenced by the matrix type: more access and use occurred in forest edges adjacent to human-dominated matrices (e.g. residential agriculture) vs. exotic plantation matrices. This use is primarily fuel-and pole-wood collection as well as charcoal production and debarking of medicinal trees. Lung et al. (2008) found that this use extends at least 100 meters into the forest and other studies suggest that this use may extend up to 500 meters (Mutangah 1996).

The magnitude and the extent of penetration of edge effects depend upon the level of contrast between the matrix and forest. For example, when the contrast is high between the forest and the matrix (e.g. agriculture), the edge effects can be more intense and more spatially extensive (Laurance and Yensen 1991, Mesquita et al. 1999). In addition, the magnitude of effect in terms of penetration into the forest depends upon the process or parameter in question. For example, abiotic conditions such as soil moisture content and vapour pressure deficit have been found to penetrate less than 50 meters into forest, while leaf litter invertebrate abundance and species composition can be influenced over 100 meters into the forest (Laurance et al. 1997).

Rainforest boundaries are often surrounded by dense human populations dependent on forest resources, making the need for understanding human-ecosystem interactions essential (Struhsaker 1997, Guthiga and Mburu 2006). The extent of this pressure, for a given population density, is largely dependent upon the size and shape of a forest (e.g. smaller, thinner patches are more vulnerable) and the degree of access (Peres and Terborgh 1995). For example, increased forest access strongly influenced the level of illegal logging in Indonesian forests (Hiller et al. 2004). The degree of forest access is influenced by physical features (e.g. roads and trails, adjacent vegetation type), and social features (e.g. use of adjacent land, management regime, etc.). For example, areas with more funding for management may be safer from illegal human encroachment (Peres & Terborgh 1995, Peres & Lake 2003, Bleher et al. 2006). However, tropical forests provide essential products for forest adjacent people (who generally used forests before government management regimes were initiated) and they often continue to extract products and utilize its resources regardless of legal issues (DeBann 2003, Guthiga and Mburu 2006).

Our analysis of post-reforestation shows not only will total forest area increase by 460 hectares, but numerous landscape metrics such as patch number and configuration, area to edge ratio, and edge exposed to high contrast matrices will be positively influenced. The number patches decreases to two and the mean shortest distance decreases by almost half a kilometer. The area to edge ratio increases by 67% and the amount of forest edges exposed to high contrast matrices is reduced by almost 300%. These changes may provide more habitat for forest-dependent species, enable more movement of species between patches, and reduce the magnitude of edge effects and the extent they penetrate into forest.

Many studies are needed to more accurately assess the effects of current fragmentation on abiotic and biotic conditions. This should include studies to examine the influence of matrix type on the magnitude and extent of penetration of abiotic (e.g. soil moisture, humidity, air temperature, leaf conductance and water content, nutrient content in soils and plants, number of tree fall gaps, rate of litter fall, carbon sequestration variables) and biotic (e.g. invasion of exotic and/or disturbance-adapted plants, seedling growth rates and survival, plant species composition and abundance, bird density and composition, insect density and composition, foliage density, canopy height and cover, invasion of disturbance-adapted animals) edge effects.

2. Fragmentation Bird Analysis

Here we present a summary of a fragmentation study completed on birds in the Kakamega Forest (Brooks et al. 1999), and an analysis of the potential benefits of reforestation in reference to the predictions of this study. Brooks et al. (1999) estimated the total number of historic forest-dependent birds in Kakamega Forest at 73 species. Using this number as the total number of species, and using the species/area mathematical relationship - $S=cA^z$ (where S is species number, A is area of forest, and c and z are constants), Brooks et al. (1999) estimated the number of bird species in Kakamega Forest fragments with their current area but as if they were still continuous (S_{orig}) and as isolated fragments once extinctions occurred (S_{frag}). Calculating the number of species given an area is dependent upon the z value: higher z values mean less species than lower values. Typical z values for large areas in continuous habitat are approximately equal to 0.15 (Rosenzeig 1995; Diamond 1972), which was used to calculate S_{orig} using:

$$S_{orig}/S_{total} = (A_{frag}/A_{total})^z$$

Here, $S_{total} = 73$, A_{frag} = area of continuous forest that represents the fragment, and A_{total} = area of forest historically (25,000 ha). For the Yala fragment, the equation solving for $S_{orig} = (1500/25000)^{0.15} * 73$ equals 48 species. The relationship is the same when calculating the number of species expected after relaxation in isolated fragments (S_{frag}), but the z value is approximately 0.25 (Rosenzeig 1995; Diamond 1972). For the Yala fragment, the number of species after they have reached their new lower equilibrium is $S_{frag} = (1500/25000)^{0.25} * 73 = 36$ species. Observations over elapsed time in other deforested areas confirm that these estimates are fairly accurate (Pimm and Askins 1995; Brooks et al. 1997; Brooks and Balmford 1996).

Using these equations, we estimated the number of species for two different scenarios for Yala fragment (1500 ha) in context of **Forest Again** reforestation project:

1. The reforestation merely increases the area of Yala fragment by 460 hectares (i.e. species don't use the corridor between Yala and the main forest block).
2. The reforestation increases the area of Yala fragment by 460 hectares and also adds the area of the main forest block (i.e. species use corridor thereby increasing effective area to include main forest block).

Reforestation increases Yala fragment area by 460 ha. Brooks et al. (1999) estimated the area of Yala fragment at 1500 hectares. This is similar to other estimates (Glenday 2006; Mitchell 2004). **Forest Again** reforestation will occur adjacent to and extend Yala fragment by 460 hectares, making the total area of forest equal to 1960 hectares. Using above equations but with the new fragment area of 1960 ha, the number of species predicted at the new equilibrium is 39. This is three species more than predicted with 1500 ha, however, this assumes that most extinctions have not already occurred, although Brooks et al. (1999) documented 44 birds in Yala fragment in 1996.

Reforestation increases Yala fragment by 9100 ha. The primary biodiversity objective of **Forest Again** is to reforest a 460 hectare region that will become a corridor between small isolated Yala fragment and the main forest block (8600 ha). If bird species use the corridor, then the effective area of Yala includes the area of the reforested area plus the main forest block. Brooks et al. (1999) predicted that Yala fragment would lose 12 species in reaching its new equilibrium and that it would take 42 years to lose half this number (i.e. 6 species). Yala was isolated at its present size in 1972 (Brooks et al. 1999); by 2014 Yala is predicted to harbor 42 species (the

original number was 48 species). Conservatively, we estimate that if birds use the corridor and reforestation begins in 2009, then the species number in Yala will not drop below 42 species. This is 6 species more than predicted for Yala fragment if it were to remain the size it is and isolated from the main forest block.

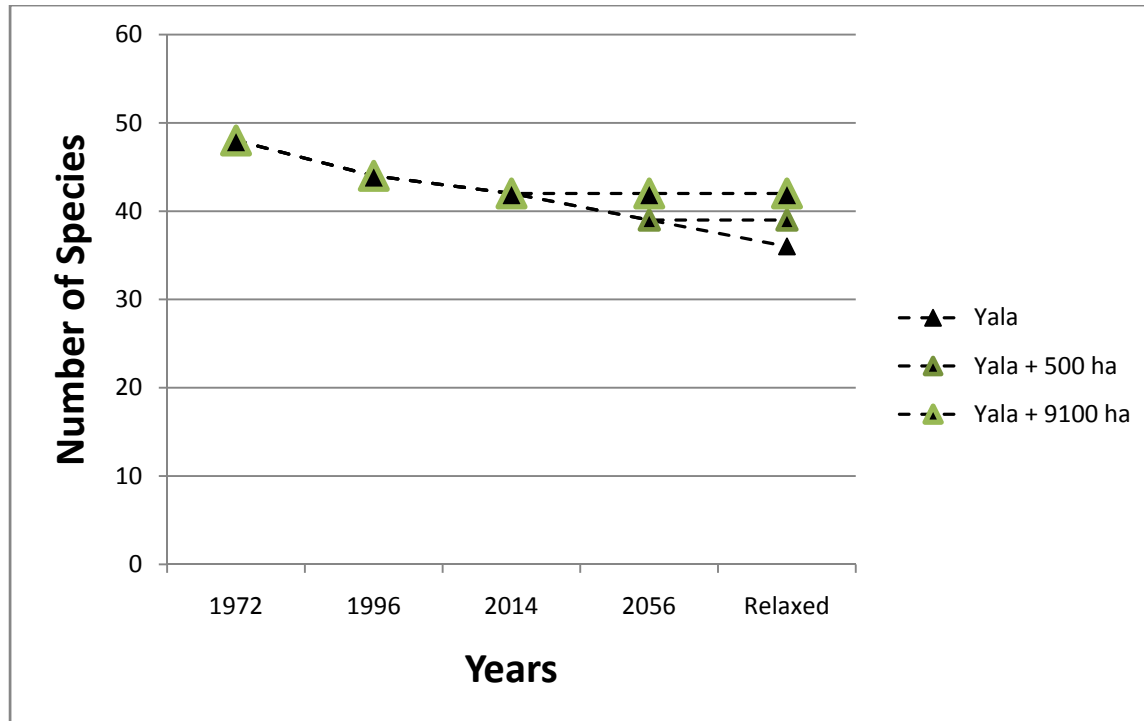


Figure 1: Number of bird species in Yala forest estimated in 1972 and observed in 1996 (Brooks et al. 1999), and predicted for three scenarios – (1) Yala forest remaining as is (Yala), (2) Yala forest with Forest Again but species don't use corridor (Yala + 500 ha), and (3) Yala forest with Forest Again and species use corridor (Yala + 9100 ha).

Discussion

Fragmentation of forest generally results in isolated small patches of habitat in matrices that often do not allow movement between patches. Numerous studies on various species have shown that the diversity of a given group (e.g. birds) is dependent upon the area of habitat (), and can be calculated using: $S = cAz$ (where S is the number of species, A is the area of habitat, and c and z are constants). This mathematical relationship can also be used to predict the new equilibrium number of species after fragmentation and area loss has occurred (i.e. the new number of species after extinctions). Brooks et al. (1999) estimated that fragmentation of Kakamega Forest would result in the loss of 12 species of birds in Yala fragment in reaching its new lower equilibrium number of species. We found that, if birds use the corridor resulting from Forest Again reforestation project, then this number can be reduced in half, thereby effectively saving 6 bird species from loss in Yala forest.

1. Habitat analysis for Blue Monkey

The Blue monkey (*C. mitis*) has several attributes that make it vulnerable to fragmentation (e.g. frugivorous diet, large home range). The blue monkey is absent from all forest fragments except for the main forest in Kibale, Uganda (Onderdonk and Chapman 2000), when other species of primates are present. This species is common in the main forest block in Kakamega, but group density is decreasing (Fashing and Cords 2000) and few individuals inhabit the smaller fragments like Yala (Lung, personal observations).

We conducted an analysis of habitat selection by blue monkey in the main forest block of Kakamega. Eighteen blue monkey groups were located in the forest and measured numerous forest attributes at each location (% canopy cover, over-story tree diversity, size, and dispersion, and understory tree diversity, size, and dispersion). In May, 2009, we will compare these attributes with random locations in the forest that did not have blue monkeys present.

Results

Mean percent canopy cover around blue monkey locations was 84.7% with a standard deviation of 0.06. Mean over-story tree size of the four closest trees was 64 cm dbh with a standard deviation of 14.3. In half of the locations (9/18) all four of the closest overstory trees were different species and were located at a mean distance of 7.7 meters. Understory trees were less diverse with 7/18 locations having all four of the closest species different.

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