Edge Effects on Ranging and Foraging Behaviour of L'hoest's Monkey (*Cercopithecus lhoesti*) in Bwindi Impenetrable National Park, Uganda

By Tharcisse Ukizintambara

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Abstract

Bwindi Impenetrable National Park (BINP) is characterized by heavily degraded edge microhabitats and a clear forest-farmland interface alongside almost pristine interior forests. This project investigated how an edge-interior gradient in vegetation structure and composition, as well as other edge effects could influence the behaviour of the little known l'hoest's monkeys (*Cercopithecus lhoesti*). EstimateS 8.0 found that trees species were more abundant but less diverse on the forest edges compared with farther away towards the interior. Friedman test showed that the edge group had greater mean day and home ranges than the interior group (2174m and 1666m; and 85ha and 66ha respectively) and that the edge group spent more time being vigilant while the interior group socialised more (χ^2=3.769, p≤0.10). The interior group ate more leaves than the edge group (χ^2=3.769, p≤0.10). However, the edge group typically fed more on other items such as barks, gum, animal matters and roots than the interior group (p≤0.05). The edge group was especially incomparable in raiding potato roots, maize, sorghum and beans outside the park to supplement their food intake. In doing so, l'hoest's monkeys faced intense persecution from local farmers who used all sorts of methods to prevent them from entering crops. Farm guards mainly children were positioned on the forest edge throughout the day and the crop season. This period is very critical for the conservation of l'hoest's monkeys and other crop-raiders due to increased tension between people and wildlife. This study has improved our understanding of the behaviour and survival of l'hoest's monkeys and raised concerns about their conservation as tension between park managers, farmers, and wildlife on the edges of BINP is escalating.

Introduction

Demographic responses of species to habitat fragmentation have received considerable attention in the last few decades. Studies have focused on the abundance and distribution of plants and animals species in relation to edge proximity (Olupot, 2004). Predation and parasitism on avian populations have also been a focus in edge effect studies. However very little have been done on the effects of landscape fragmentation and resulting edge effects on the behaviour of species. This gap was recognized by Lima and Zohner (1996) who called for a "better linkage between behavioural ecology and landscape-level ecological processes" followed by Yahner and Mahan (1997) who found that consequences of habitat fragmentation on sociality and behaviour of vertebrates was an "untapped topic" and launched a new era of studies looking at the effects of habitat fragmentation on the behavioural time budgets of individual animals. Yahner and Mahan (1997) believe that the understanding of how species expend time and energy conducting day-to-day activities in a given landscape is considerable relevant. Despite the nature of data that are too localized, the interpretation of how individuals are affected by local landscape patterns and characteristics is very timely for the conservation of species in, on the rise, fragmented landscape.

Few studies have been done on the densities and distribution of primates in fragmented landscape and so far only one was conducted on forest edge effects on lemurs in Madagascar

(Lehman et al, 2006). Following Yahner and Mahan (1997) it is obvious that factors influencing the behaviour of primate species cannot be comprehended without a systematic investigation of the characteristics of their habitat and group activity budgets. Long-term research on species' ecological behaviour is important for the formulation of hypotheses about what, how much, and where primate species feed and how they organize their self-defence mechanisms (Treves, 1997) in order to survive in a hostile environment.

L'hoest's monkeys (*Cercopithecus lhoesti*) are semi-terrestrial primates; they can spend over 80% of their time near the forest floor (Figure 1).
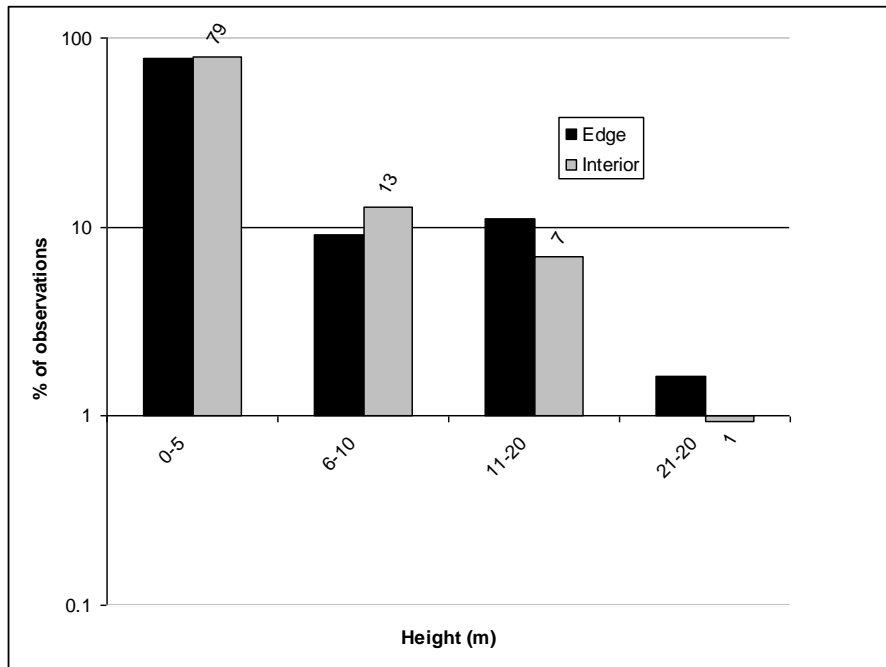

Figure.1. Vertical distribution between edge and interior groups of l'hoest's monkeys in Bwindi Impenetrable National Park, Uganda (this study)

L'hoest's monkeys are restricted to the western mountains of Burundi, Rwanda and Uganda and the eastern highlands and lowlands of the Democratic Republic of Congo (DRC) in the Albertine Rift (Oates, 1996). These montane forests are highly threatened ecosystems (Chapman & Chapman, 1996) and the l'hoest's monkey species is vulnerable to extinction (Lee et al., 1988). However, l'hoest's monkeys are believed to tolerate human-induced disturbances (Johns & Skorupa, 1987) and forest edges (Butynski, 1990, McNeilage et al., 2001) in Uganda. In Rwanda, l'hoest's monkeys were observed to regularly use disturbed forests (Kaplin, 2001; Kaplin & Moermond, 2000). Such ranging patterns show clear contrasts with what field observations had predicted for many forest primates that once species have adapted to mature primary forest they become intolerant to disturbed secondary forests (Johns & Skorupa. 1987, Grant et al., 1992). Even so, rhesus macaques (*Macaca mulata*) were found feeding in heavily disturbed parts of the forests in Pakistan (Richard et al., 1989) and the noted adaptation to a savanna dwelling lifestyle by vervet monkeys (Fedigan & Fedigan, 1988).

Many hypotheses have been formulated to explain general mechanisms of edge responses by species (Atkinson, 2003). Such general hypotheses must, however, be scrutinized and put into the context of the target taxa and their localized habitats. The adaptation to edge conditions will receive special emphasis since the long-term survival of l'hoest's monkeys and any other species may depend on their quick adaptation to rapidly changing environments and increasing edge habitats.

As I mentioned above, the generalist-feeding strategies of l'hoest's monkeys may have evolved over a long period of time. As for now, these semi-terrestrial monkeys frequent regularly and in higher densities open canopy, disturbed habitats, secondary forests, forest edges and farmlands (Kaplin, 2002, McNeilage et al., 2001, Naughton-Treves, et al., 1998, Butynski, 1985). These adaptive socio-behavioural and ecological characteristics of a species should be taken into consideration when predicting and interpreting how the species will respond to forest edge effects. In this case, l'hoest's monkey can be viewed as an ecological model system (Wolff & Schauber, 1997) to be used in assessing several hypotheses regarding habitat loss, forest fragmentation, and edge effects. For example, Bourlière (1985) and Tashiro (2005) hypothesize respectively that primates can change their feeding habits according to habitat and that l'hoest's monkeys are highly flexible in various habitats through their use of available food resources.
This study aimed at examining how these responses of primates to disturbances are manifested within l'hoest's monkey subpopulations living on the edges of BINP. More specifically, contrasting with an interior group, I investigated whether the edge group of l'hoest's monkeys has developed any foraging plasticity or tolerance to disturbances on the edges of BINP and the conservation implications of these forest edge effects on behavioural ecology of the species in BINP.

Study site
Bwindi Impenetrable National Park (321km^2) (hereafter referred to as Bwindi) is located in the southwest of Uganda ($0^053´-1^008´N$ and $29^035´-29^050´E$). Bwindi borders with the Democratic Republic of Congo to the west on the eastern edge of the western rift valley or Albertine Rift within the districts of Kabale, Kisoro and Rukungiri. This study was based in Kabale district. Bwindi was gazetted as a national park in 1991 and declared a UNESCO world heritage in 1994 for its biodiversity richness. Bwindi is believed to hold the richest faunal community in East Africa, including over 214 species of forest birds (336 species in total), 120 species of mammals (including 7 species of diurnal primates), and 202 species of butterflies (84% of the country's total).

Bwindi is therefore an important locality for the conservation of Afromontane fauna, in particular those endemic to the mountains of the western rift valley such as l'hoest's monkeys. Globally threatened species include eastern chimpanzee (*Pan troglodytes schweinfurthi*), l'hoests monkey (*Cercopithecus l'hoesti*), African elephant (*Loxodonta africana)* numbering an estimated 30 individuals (Said *et al.*, 1995) and the African giant swallowtail butterfly (*Papilio antimachus)* (Howard, 1991). Buffaloes are said to have been poached to extinction in the late 1960s and leopards were wiped out more recently (Nkurunungi, 2003).

Bwindi is an island forest in a sea of small farmlands in one of the country's most densely populated rural areas with an average of 227 people/km^2 nearly 3 times the current national average (Baker, 2004). Twinomugisha (2007) has reported a density as high as *ca.*700 people/km^2 in adjacent Kisoro District. These high densities of subsistence agricultural communities have obviously a tremendous impact on the forest ecosystem especially at the forest edge ecotone.

Behavioural data collection
The identification of l'hoest's monkey groups started in October 2005 followed by selection of two groups, one on the edge and the other far away towards the forest interior. The habituation process took my 4 field assistants and me over 8 months of intensive work including trails cutting. The overall systematic behavioural data collection was conducted over 13 months from July 2006 to February 2007 and from May to September 2007). Using point (instantaneous) scan sampling and ad libitum methods (Martin & Bateson, 1986, Altmann, 1974), every five minutes, I took notes of activities in which individuals were involved from dawn to dusk. Each scan lasted two minutes. These activities include, feeding, travelling, resting, socializing (i.e. grooming, playing), being vigilant, vocalizing and others (such as urinating, nursing infants, mating, displaying, etc.).

During these 13 months I conducted 140 daily follows tallying 1242 human-hours and 7474 and 7430 scans for respectively edge and interior groups of l'hoest's monkeys. These figures exclude the time spent and data took by my field assistants while tracking l'hoest's monkeys during my leave days. They also collected valuable data especially on daily travel routes and observed rare activities and events such as predator attacks. We also opportunistically recorded the presence of humans, feral dogs, jackals, golden cats, baboons, chimpanzees, eagles, snakes and other real or perceived disturbances to the species (such as the passage of cars or airplanes) whenever we encountered them, heard them or came across signs of disturbing activities during vegetation sampling (see below) and on daily travel routes of l'hoest's monkeys.

Vegetation sampling
I established 30 and 20 circular vegetation plots (10m radius) respectively inside the home ranges of the edge and the interior groups of l'hoest's monkeys. For the edge plots, I randomly chose a starting point on the farthest south eastern corner of the boundary line and the group home range. I located the first, second and third plots at 15m, 165m and 315m on a perpendicular line with the boundary line respectively. Other plots were located at exactly 150m and 100m alternatively from preceding plots. For the interior group, all plots were randomly located in the home range at least at a 100m from one another.

All plots were geo-referenced in UTM ARC 1960 system using Garmin 12XL GPS. To acquire a good reading, a GPS antenna was necessary for dense canopy forest habitats. Within the plots, I conducted an inventory of all tree stems of ≥5cm diameter at breast height (DBH) because trees of over 5cm DBH are supposed to produce fruits, support and, provide cover for l'hoest's monkeys. The height of each tree was also estimated (White & Edwards, 2000). These data were useful in comparing the distribution, composition and structure of the vegetation between the

edge and interior forest microhabitats of Bwindi and assessing how the ranging and foraging behaviour of l'hoest's monkeys was influenced by the vegetation.

To examine differences in the abundance of terrestrial herbaceous vegetation (THV), four1m^2 quadrats were established at every 90° from the north of each circular plot. I surveyed in total 120 and 80 quadrats one the edge and in the interior forest respectively. I estimated percent cover of terrestrial herbaceous vegetation in each 1m^2 quadrat using a 10cm x 10cm frame and when possible identified to species all herbs found in quadrats, especially those eaten by l'hoest's monkeys. Samples of unknown species were taken to the herbarium of the Institute of Tropical Forest Conservation (ITFC) for further identification. I measured the canopy vegetation cover from the centre of each quadrat using a densiometer.

Results and discussion
ArcView 3.2 was used to create a geographical database including locating vegetation plots and mapping l'hoest's monkey travel routes. Adaptive Kernel analysis was used to calculate the home ranges at 95% of raster resolution. MS Excel 2003 organized data and computed simple descriptive models. EstimateS 8.0 (Colwell, 2006) was used to calculate plant species abundance and richness indexes. The edge data was stratified into four zones (outside, on the edge [0-50m[, near the edge [50-250m[and over 250m towards the interior forest). The parametric T-test and the non-parametric Friedman test (SPSS 10) were used to detect differences in vegetation and behavioural variables between these edge zones and between edge and interior forest.

As mentioned before, forest edge effects account for complex causal mechanisms that affect the ecology of species due to varying climate conditions, inter-specific interactions and the level of disturbances. My data found the existence of edge effects on plants species and also the distribution and behaviour of l'hoest's monkeys.

EstimateS 8.0 was used to evaluate the abundance and diversity of terrestrial herbaceous vegetation (THV) species eaten by l'hoest's monkeys between the edge zones. I found that in [0-50m[zone, the number of stems was higher than in over 250m zone (4367, 2091) whereas the Shannon diversity index (H') was lower on the edge than away from the edge (1.21 and 2.02 respectively). Comparing total vegetation composition between the edge and the interior home ranges, I realized that food trees and THV were more diverse and more abundant on the edge than in the interior microhabitats (t = 3.74, df = 64 and t = 6.24, df = 121 respectively, p≤0.001). I recorded 58 and 43 tree species on the edge and in the interior home ranges of l'hoest's monkeys. One of the most dominant species was *Xymalos monospora* (Apocynaceae) on the edge and *Neaboutonia macrocalyx* (Euphorbiaceae) in the interior. L'hoest's monkeys devoured the pith of both species especially during dry season when food was scarce. The folded old and dry leaves of *Xymalos monospora* also attracted a variety of insects which the monkeys fed on.

Among 128 species of THV found in the edge microhabitat, l'hoest's monkeys fed on approximately 77% of them including some introduced species. In the interior, over 85% of the 95 species of THV inventoried were eaten by l'hoest's monkeys. *Panicum sp.* was the most abundant THV species found in both edge and interior microhabitats. The vegetation canopy of

edge microhabitats was more closed than in the interior microhabitats (t= 5.28, df = 71, p≤0.001), in contrast, ground vegetation was more abundant in the interior than on forest edges. The average cover of ground vegetation was 48% and 87% while canopy cover was 53% and 70% respectively for the edge and the interior home ranges.

Therefore, unstable secondary forests dominated the edges of the park due to edge effects whereas relatively stable large clearings, secondary forest and mature forests characterized the interior where changes could occasionally occur in tree fall gaps and on elephant feeding paths. For behavioural data, Friedman test showed that over 13 months the edge group had greater mean day and home ranges than the interior group (2174m and 1666m; and 85ha and 66ha respectively) and that the edge group spent more time being vigilant while the interior group socialised more (χ^2=3.769, p≤0.10). Time allocated to other activities (travelling, resting, feeding and vocalizing) was not statistically different between both groups (p≥0.15) (Table 1).

Table 1: Activity budgets of l'hoest's monkeys between edge and interior groups in Bwindi (Mean percentage and standard deviation)

L'hoest's group	Activities											
	Feeding		Rest		Social		Travel		Vigilance		Vocal	
	Edge	Interior	Edge	Interior	Edge	Interior	Edge	Interior	Edge	Interior	Edge	Interior
Percent	34.48	33.26	23.76	23.1	3.7	4.56	29.95	31.08	2.61	2.13	4.5	4.27
Std Dev.	2.54	3.9	6.74	4.41	1.3	1.29	5.1	4.32	1.34	0.92	1	1.12

The interior group ate more leaves than the edge group (χ^2=3.769, p≤0.10). The consumption of flowers, fruits, invertebrates, pith and seed was not statistically different between groups. However, the edge group typically fed more on other items such as barks, gum, animal matters and roots than the interior group (p≤0.05). A closer look on the edge group ranging behaviour showed that the main purpose of l'hoest's monkeys being outside the park was for feeding (χ^2=10754, p≤0.05). Monkeys were more inactive on the forest edge (0-50m) mostly waiting to raid crops. They foraged more in the >250m zone (χ^2=13.800, p≤0.005). The edge group was especially incomparable in raiding potato roots, maize, sorghum and beans outside the park to supplement their food intake. These crops were considered as "other" category (Table 2).

Table 2: Diet of l'hoest's monkeys between edge and interior groups in Bwindi (Percentage and standard deviation)

L'hoest's group	Food Type											
	Flowet		Fruit		Invertebrate		Leaves		Other		Pith	
	Edge	Interior	Edge	Interior	Edge	Interior	Edge	Interior	Edge	Interior	Edge	Interior
Percent	10.21	5.72	34.39	37.05	12.68	10.34	27	34.71	5.94	3.37	6.59	5.37
Std Dev.	7.63	3.83	13.65	15.91	7.35	4.19	8.73	10.63	3.19	1.87	5.78	3.84

The group size in both microhabitats has been declining overtime. The number of individuals for the edge and the interior groups varied from initial counts of *ca* 36 and 17 respectively to *ca* 25 and 14 at the end of the study. Each group had one adult male at a time. Three adult males took over the edge group during the course of the study and only one male was resident in the interior group throughout the duration of the study. I recorded two deaths in the interior group (the oldest female due to old age, and one infant which was abandoned by her mother). Four subadult males left the interior group at the same time period. In the edge group, one infant was killed by an eagle, three disappeared probably due to infanticide committed by new adult males and 3 adults might have been killed outside the park by local hunters. One adult male is believed to have been killed in a corn plantation while sustaining serious injuries after being evicted by another male. A large number of subadult males emigrated from the edge group at several occasions. Four and over six births occurred in the interior and edge groups respectively. I witnessed one birth in the edge group at 3pm 6 Sept. 2006.

Both edge and interior groups defended their territory against other groups but the degree of fighting varied between groups and depended on how far in their territory the encounter occurred. Most of the encounters were very vocal and fights lasted for few minutes to over 1 hour. However, there were few friendlier encounters with other groups. Genetic studies will be necessary to determine why these groups do not fight each other. I hypothesized that they might be related. The edge group had to keep away five neighbour groups and a large number of adult solitary males from its 85ha home range including 12ha (14%) outside the park (Figure 2). The interior group protected about 66ha against 7 overlapping groups, most of them ferociously but one gently. Disturbances from solitary males were rare in the interior group home range.

Figure 2: Edge and interior home ranges overlaid on an aerial photograph. The map shows that the edge group often frequents the outside of the park.

The edge and the interior groups had 14 and 11 sleeping sites respectively. Most of the sites were in or near fruiting trees. Three of the edge group sites were strategically located in areas where monkeys could raid the crop very early in the morning or very late in the evening before the farm guards arrived or after they had left.

Conclusion

Edge effects can easily be traced through vegetation distribution and abundance (Olupot, 2004). Nkurunungi et al. (2004) demonstrated how food sources could influence certain aspects of gorilla sociality and ranging patterns. Likewise, plants, including farmers' crops have obviously influenced the behaviour of l'hoest's monkeys in Bwindi. The data analysed so far showed differences within the zones of the edge group and between the edge and the interior groups of l'hoest's monkeys. Activity budgets of the edge group revealed how l'hoest's monkeys have adapted to living in that environment. Due to a high risk of being outside the park, they go out primarily to feed after spending a lot of time of inactivity on the edge making sure that it is safe. Although l'hoest's monkeys were found on the edge and in the interior of the park, their core foraging zones were mostly in proximity of rich food source, including crops and hideout microhabitats. For the edge group, raiding crops provided an alternative food resource rich in nutrients. Unfortunately, crop-raiding jeopardise the survival of l'hoest's monkeys, some can get hurt, injured or even killed by farm guards.

In order to conserve l'hoest's monkeys and protect farmers' crops, I found that a buffer of abandoned farmlands between the forest and the cropland was an effective barrier. This buffer zone should only be used for grazing livestock. Nevertheless, a detailed study should be undertaken around Bwindi to assess the effective size of such buffer zones in relation to the aspects of the landscape and the type of crops planted on the other side. Moreover, planting corn, sorghum, beans, peas and potatoes right on the forest edge should be discouraged as long as an alternative could be provided for the needy farmers. Sensitisation of local people could also be one of the important tools for the conservation of the species in Bwindi. Such conservation outreach should target already established group, such the women group for the promotion of ecotourism in Ruhija (Figure 3).

Figure 3: Women of Ruhija, Bwindi performing a drama in front of my supervisor who accepted to visit them, support their efforts and explain the l'hoest's project to them.

Acknowledgement

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