# Chapter 7
# Going, Going, Gone: A 15-Year History of the Decline of Primates in Forest Fragments near Kibale National Park, Uganda

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**Abstract** Given accelerating trends of deforestation and human population growth, immediate and innovative solutions to conserve biodiversity are sorely needed. Between 1995 and 2010, we regularly monitored the population size and structure of colobus monkey populations in the forest fragments outside of Kibale National

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Park, Uganda. Through this monitoring we assessed the monkeys' gastrointestinal parasites and fecal cortisol levels. Over 15 years, we documented a rapid decline in the number of fragments that supported primates, largely as a result of tree removal. Fecal cortisol levels of primates found in the fragments were consistently higher than in populations found in the continuous forest of the national park. The fragment populations also harbored gastrointestinal parasites rarely found in the main forest and exchanged bacteria with nearby people and livestock at high rates, suggesting that fragmentation facilitates disease transmission. Fragments supported the fuelwood needs of an average of 32 people living immediately adjacent to the fragment, and partially supported families up to three farms away (~400 m, representing 576 people). Intensive fuelwood harvesting occurred when neighboring households engaged in brewing beer (an average of 9.6 % of the households), distilling gin (8.8 %), or producing charcoal (14.5 %). Our data suggest that the future of small and unprotected forest fragments is bleak; a scenario that is unfortunately typical outside protected areas in many tropical regions.

## Introduction

Tropical habitats around the world are experiencing increasing stress; the majority of which results from direct (e.g., deforestation) or indirect (e.g., climate change) human activities. This increased stress is largely due to human population growth: our species has grown by 3.7 billion people in the last 50 years (Potts 2007) and is expected to reach between eight and ten billion people in the next 50 years (United Nations 2009). The majority of this growth will occur in tropical countries (Potts 2007) and will substantially increase the demands for environmental products and services (Houghton 1994). For example, the net loss in global forest area between 2000 and 2005 was ~7.3 million ha per year (~200 km$^2$ of forest per day, (FAO 2005)). This does not consider the vast areas being selectively logged or the forests degraded by fire. For example, during the 1997/1998 El Niño, seven million ha of forest burned in Brazil and Indonesia alone (Chapman and Peres 2001). Even when the physical structure of the forest remains intact, subsistence and commercial hunting can have a profound impact on forest animal populations. For example, it is estimated that 3.8 million primates are eaten annually in the Brazilian Amazon (Chapman and Peres 2001).

In the face of these threats, parks and protected areas have become the main tools of most national strategies to conserve biodiversity and ecosystem processes (Bruner et al. 2001). Tropical forest parks are thought to be particularly important in protecting biodiversity since they contain over half of the world's known species (Wilson 1992). However, these statistics invoke the question: What about the remaining half of the world's biodiversity? Such questioning has led a number of researchers to examine the conservation value of disturbed lands (Brown and Lugo 1994), the potential of restoration (Chapman and Chapman 1999; Lamb et al. 2005), and, given their increasing frequency of occurrence, the conservation significance of

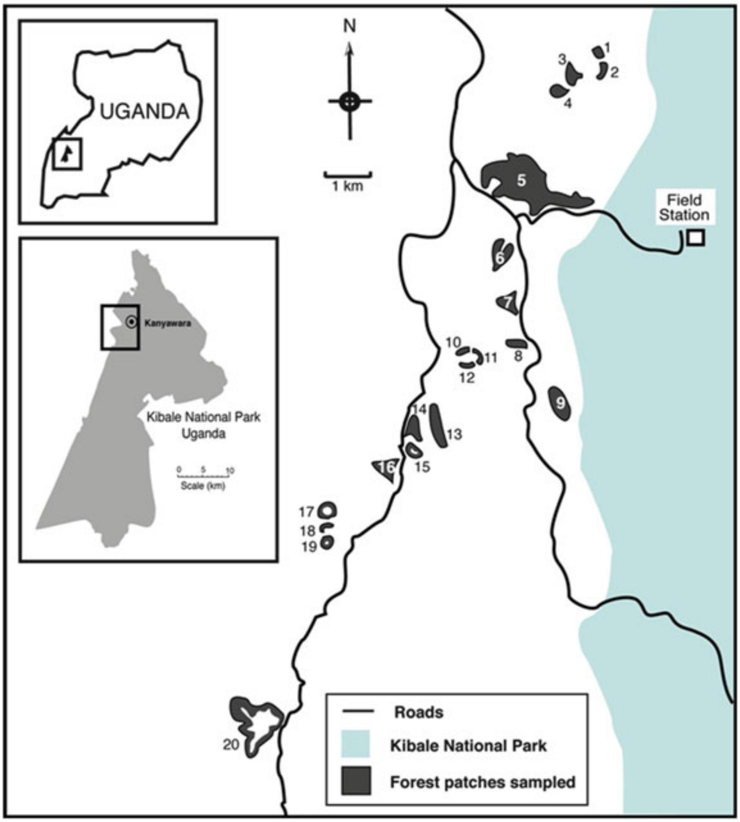


**Fig. 7.1** Twenty forest patches surveyed outside of Kibale National Park, Uganda, starting in 1995 (*note*: this does not represent all forest patches in the region). *1* = Kiko #3; *2* = Kiko #4; *3* = Kiko #2; *4* = Kiko #1; *5* = Kasisi; *6* = Rusenyi; *7* = Kyaibombo; *8* = Durama; *9* = C. K.'s Durama; *10* = Rutoma #1; *11* = Rutoma #4; *12* = Rutoma #3; *13* = Rutoma #2; *14* = Nkuruba—fish pond; *15* = Nkuruba—lake; *16* = Ruihamba; *17* = Lake Nyanswiga; *18* = Dry Lake; *19* = Lake Nyaherya; *20* = Lake Mwamba. In 2010 only Lake Nyaherya, Ruihamba, Lake Nkuruba, and CK Durama still supported colobus monkeys

forest fragments (Chapman et al. 2007; Harcourt and Doherty 2005; Hartter and Southworth 2009; Marsh 2003). However, when conservation strategies rely on unprotected forest fragments to conserve biodiversity, a number of assumptions are inherent and the validity of these assumptions is largely unknown. Two of the most critical assumptions are (1) that the fragments will maintain their value to conserve biodiversity over time and (2) that the animal populations within the fragments will be healthy.

A principal objective of our research program over the last 15 years has been to test whether these assumptions are valid. We conducted our investigations in a series of community-owned forest fragments adjacent to Kibale National Park, Uganda (Fig. 7.1). We focused our research on two species of colobus monkeys: red colobus

(*Procolobus rufomitratus*) and black-and-white colobus (*Colobus guereza*). These species were chosen because the red colobus is endangered, neither species moves among forest fragments, and noninvasive methods can be used to monitor their physiological status and health (Chapman et al. 2005), making these species a valuable study system.

## Forest Fragments Near Kibale National Park, Uganda

Kibale National Park (hereafter Kibale) can itself be considered a large fragment as it is 795 $km^2$ surrounded by agriculture, grazing land, and tea plantations. It is a mid-altitude, moist evergreen forest in central-western Uganda, Africa (0 13′–0 41′N and 30 19′–30 32′E), in the foothills of the Ruwenzori Mountains (Struhsaker 1997; Chapman and Lambert 2000). Kibale was designated a Forest Reserve in 1932 and became a National Park in 1993 (Fig. 7.2). Most of the area inside the boundary was protected to at least some degree after becoming a forest reserve (Chapman and Lambert 2000), but forested areas outside the boundary were not.

Historically the Kibale region was noted for its extensive forest and abundant big game (Naughton-Treves 1999). Historians describe western Uganda's forests as sparsely populated before the twentieth century (Osmaston 1959). The Game Department archives of 1934 state: "*The Toro district is the most difficult of the control areas and will be hard work for many years to come. There are some thirty to forty herds of elephant totaling fully 2000 animals, the majority of which live in close proximity to settlements and cultivation. This is only made possible owing to the appalling nature of the country and the density and height of the grass*" p. 319 (Naughton-Treves 1999). However, this situation soon changed and by early 1959 the area had been converted to a series of community-owned forest fragments immersed in a matrix of agricultural lands (as substantiated by early aerial photographs). These fragments tended to persist in areas unfavorable for agriculture, such as wet valley bottoms and steep hillsides; today they contain remnant populations of four of the nine diurnal primate species found in the park (Onderdonk and Chapman 2000).

We would like to stress that much of the previous work on primates living in fragmented habitats involves fragments protected from human use (Laurance and Bierregaard 1997; Tutin et al. 1997). In reality, most fragments are not protected; they are on land managed by private citizens who depend on them for resources. People around Kibale use these forest fragments for activities ranging from forest product extraction (e.g., timber, charcoal, medicinal plants) to slash-and-burn agriculture. In the Kibale region, previous studies have shown that fragments supported the fuelwood needs of an average of 32 people who lived immediately adjacent to the fragment, and partially supported families up to three farms away (~400 m), representing 576 people. Fuelwood harvesting was most intensive when neighboring households were engaged in brewing beer (an average of 9.6 % of the households), distilling gin (8.8 %), or producing charcoal (14.5 %; Naughton et al. 2006).

**Fig. 7.2** A typical forest fragment surrounding a crater lake neighboring Kibale National Park, Uganda

While domestic consumers use the most plant species for fuelwood (>50), their consumption is potentially sustainable because they generally harvest fast-growing species from fallows on their own land or their neighbors' land. In contrast, commercial charcoal producers prefer old-growth hardwood species and are responsible for the greatest loss of natural forest. They access forests by finding landholders who, either willingly or through coercion, allow trees on their lands to be cleared. The impact of charcoal production is exacerbated by a license system in Uganda that undervalues natural forests and rewards rapid harvesting across large areas (Naughton et al. 2006).

## The Fate of Fragments and Primate Populations

In 1995 we censused 20 forest fragments near Kibale that had been isolated for at least 36 years (Onderdonk and Chapman 2000). In each fragment we determined the presence or absence of all diurnal primate species, and estimated the population size of black-and-white colobus (since 1995) and red colobus (since 2000). We measured the fragment area, distance to the nearest fragment, distance to Kibale, and counted the number of food trees. We recensused the same fragments in 2000 (Chapman et al. 2007), 2003, and 2010. From 1995–2010 there was a drastic decline in the number of fragments occupied and in population size for both colobines (Fig. 7.3).

In 2000 and 2003 we measured all the trees (>10 cm DBH) in each fragment including all red colobus food trees to examine changes in the food available to each population. All fragments showed evidence of forest clearing; however, the extent of clearing was extremely variable (Chapman et al. 2006b). The average size of the fragments containing red colobus in 2000 was 4.4 ha (range 1.2–6.4, $n = 8$). In 2000 there were on average 99 trees/ha in each fragment (range 27–259 trees/ha), while in 2003 there were 86 trees/ha (range 30–230 trees/ha). The basal area of trees in the fragments averaged 9002 $m^2$ in 2000 (range 1981–39,012 $m^2$) and 5293 $m^2$ in 2003 (range 1772–28,397 $m^2$). The cumulative basal area of red colobus food trees was 915 $m^2$ in 2000 (range 317–2,430 $m^2$) and 535 $m^2$ in 2003 (42–2387 $m^2$). Thus, although forest change was highly variable between fragments, on average the basal area of food trees declined by 29.5 % over the 3 years. In 2000, exotic species, primarily *Eucalyptus grandis*, constituted 16 % of the food tree basal area, while in 2003 this value had risen to 28 % (Chapman et al. 2006b, 2007).

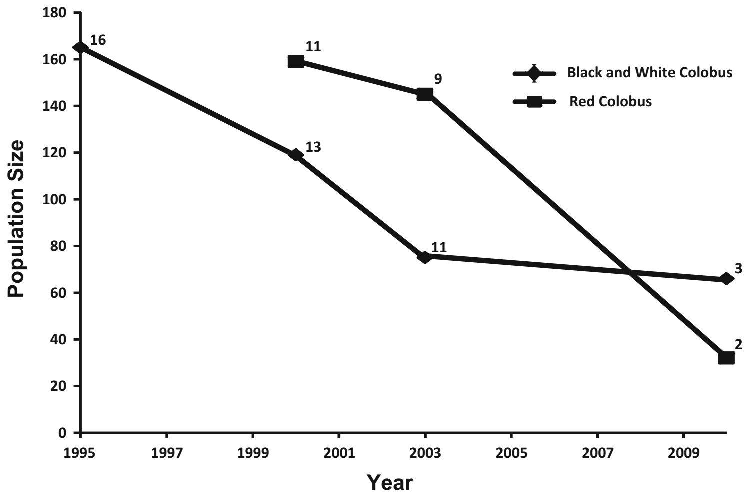


**Fig. 7.3** The population size of *red* (*squares*) and *black*-and-*white* (*diamonds*) colobus in a series of forest fragments adjacent to Kibale National Park, Uganda. The number above each point is the number of fragments that the species were found at that time

The changes in the forest fragments had dramatic consequences on the resident primate populations. Black-and-white colobus populations declined by 60 % between 1995 and 2010, while red colobus populations declined by 83 % between 2000 and 2010 (Fig. 7.3). Over the 15 years many of the initial fragments were largely cleared and resident primate populations were no longer present. In fact by 2010, 92 % of the colobus monkeys were found in only two fragments, and 65 % of all the monkeys were found in one specific fragment—Lake Nkuruba. This site is unique because in 1991 a small-scale ecotourism operation, established by C. Chapman, L. Chapman, and M. Steenbeek, maintained the forest and improved the local communities' welfare. After a short period of external input, the ecotourism operation was turned over to the local community that it is still protecting this forest fragment.

## Health of the Primates in the Fragments

The Kibale EcoHealth Project (http://svmweb.vetmed.wisc.edu/KibaleEcoHealth/) was founded in 2004 by Tony Goldberg as an ecological study of animal and human health in the Kibale region. The project is an attempt to evaluate the "ecohealth paradigm" using scientific rigor. Ecohealth refers to the idea that human and animal health are inherently connected to each other and to the physical environment (Goldberg et al. 2012). Thus, improving the health of any component of the animal health, human health, and environment triangle will improve the health of the other two.

Some of our initial studies focused on gastrointestinal parasites. We documented that elevated parasite infections were associated with logging or an increase in the proportion of forest edge (Chapman et al. 2006a, 2010; Gillespie et al. 2005). When we turned to studying forest fragments, we discovered that indices of animal health were affected in a number of ways. We were particularly interested in whether food availability and parasite infections synergistically affected red colobus abundance and if these animals showed physiological signs of stress. We monitored gastrointestinal parasites, evaluated faecal cortisol levels (an indicator of physiological stress), and determined changes in food availability in eight fragments between 2000 and 2003. During this time, the red colobus populations in fragments declined by 21 %. The change in red colobus population size was correlated both with food availability and a number of indices of parasite infections. In addition, the stress levels of groups inhabiting the fragments were approximately 3.5 times greater than those living within Kibale. In fact, red colobus from Kibale seldom had cortisol values as high as the lowest values of those in fragments (Chapman et al. 2006b).

Our interest in the ecohealth concept led us to focus on possible human–primate disease transmission. Microscopic evaluation of gastrointestinal helminths is inadequate for understanding cross-species transmission because many helminths are host specific, yet morphologically indistinguishable at the species level. This was clearly illustrated by elegant studies of nodular worms, *Oesophagostomum bifurcum*, in West Africa: Traditional parasitological analyses suggested a transmission link between humans and nonhuman primates, but subsequent molecular analyses demonstrated that the parasites infecting nonhuman primates were entirely distinct from those infecting humans (Gasser et al. 2006, 2009). We therefore turned to the common gastrointestinal bacterium *Escherichia coli*, which inhabits the gastrointestinal tracts of all vertebrates, but is highly variable genetically and clinically (Donnenberg 2002). Using this system we documented that people living near forest fragments harbored *E. coli* bacteria approximately 75% more similar to bacteria from primates living in these fragments than to bacteria from primates living within Kibale (Goldberg et al. 2008b). Furthermore, genetic similarity between bacteria from human, livestock, and primates increased by approximately threefold as anthropogenic disturbance within fragments increased from moderate to high (Goldberg et al. 2008b).

While *E. coli* is typically not pathogenic, other microbes can cause significant clinical effects (Bonnell et al. 2010; Garcia 1999). For example, we found the pathogenic gastrointestinal protozoans *Giardia duodenalis* and *Cryptosporidium parvum* in red colobus living in fragments (Salzer et al. 2007). In the case of *G. duodenalis*, molecular analyses indicated two genotypes: one (assemblage B IV) appears to move from people to red colobus, while the other (assemblage E) appears to move from livestock to red colobus (Johnston et al. 2010). Of perhaps even greater concern for public health, we have subsequently identified novel pathogens in this system (Goldberg et al. 2008a; Goldberg et al. 2009). We found evidence of a previously uncharacterized *Orthopoxvirus* in Kibale red colobus; this pathogen is similar but distinct from cowpox, vaccinia, and monkeypox viruses (Goldberg et al. 2008a). With further investigations, we found three novel simian retroviruses in these red colobus (Goldberg et al. 2009), related to viruses in West Africa that are known to be zoonotic (Wolfe et al. 2004; Wolfe et al. 2005). This last finding is particularly troublesome since primates in the forest fragments near Kibale have regular antagonistic interactions with people that can result in people receiving bites and scratches (Goldberg et al. 2006; Skorupa 1988). As a result, this setting appears to be ideal for novel zoonotic transmissions to occur.

## Discussion

Our results paint a grim picture of the conservation value of the fragmented landscape near Kibale National Park, Uganda. As a result of resource extraction, most fragments did not last more than the 15 years of the study. Furthermore, the primates in these fragments were generally unhealthy and physiologically stressed. Because most fragmented landscapes are not in protected areas, but are locally owned and used by the communities for extractive purposes, our results are generally representative of other landscapes with similar human density and demographic trends (Jacob et al. 2008). However, for other primate species that can use the matrix more effectively or are not forest dependent our findings may not prove general. The fragmented landscape near Kibale is therefore of little conservation value for tropical forests and forest-dependent species, such as colobus monkeys. However, these findings raise five interesting questions.

First, while the fragmented landscape near Kibale appears to be of limited conservation value, it raises the question of when conservation effort should be applied to such habitats. In the case of the Kibale region, there is no evidence that the fragments support wildlife that is not present within the national park. Therefore, it seems reasonable to suggest that conservationists should concentrate their efforts to sustaining the protected area, rather than the surrounding fragments. In the case that endemic species are present within fragments, an argument can be made to protect these fragments. A similar argument could be made if particular fragments have the additional value of facilitating movement corridors. Our study demonstrates the problems associated with protecting small areas of habitat, especially with regard to the declining health and fitness of its inhabitants. However, given the threat of infectious disease, isolated fragmented populations may hold value as safeguards against future epidemics that could occur in larger populations. In the Kibale situation translocations of the red colobus is not an option because there are no known suitable habitat nearby to translocate the animals to. Similarly, it is not possible to manage this region as a metapopulation because it is habitat clearing that causes single populations in the metapopulations to go extinct, thus, there is no habitat remaining to recolonize.

Second, our study raises the question of what minimum fragment size will permit the long-term health and survival of primates in forest fragments. This question has been of interest since the conservation value of fragments was first considered (Lande 1995; Soule 1987). Our data can be used to evaluate this question over 15 years. This is insufficient to address any genetic issues; however, a large and relatively stable population continued to exist in the one fragment where the canopy trees were not cut: Lake Nkuruba. The persistence of this population suggests that the most essential short-term issue for survival of colobus populations is simply to maintain the forest as intact as possible.

A third question that arises from our study is what primate species are most resilient to living in fragmented landscapes. During the last census in 2010, we asked local agriculturalists if they had seen primates in the study fragments. Many reported that while colobus were no longer present, red-tailed monkeys (*Cercopithecus ascanius*) frequently visited the fragment. Unlike colobus, red-tails travel among fragments and can forage and persist successfully in the agricultural matrix outside of the fragments. Similarly, Pozo-Montuy et al. (2011) reports that howler monkeys (*Alouatta palliata*) in Southern Mexico are capable of using very modified landscapes that have very small fragments and few native trees. They survive by travelling among trees and shrubs (even travelling along barbed-wire fences) and using exotic trees as food sources.

Fourth, our research leads to the question of what conditions create unhealthy primates. In the fragments outside Kibale, poor nutrition is associated with increased stress levels, which are both related to elevated gastrointestinal parasite infections (Chapman et al. 2006b). Similarly, we have demonstrated that contact with humans and livestock can lead to the acquisition of benign and pathogenic parasites by red colobus (Goldberg et al. 2008b; Johnston et al. 2010). Future studies should examine how other human-induced or mediated factors may lead to elevated stress and disease in fragments (e.g., hunting, shared water sources, selective harvesting of food trees).

Lastly, to successfully protect community-owned fragments we need to know what leads community members to degrade forest fragments and what can be done to prevent such activities. This is stepping out of the classical framework of biological research, but such interdisciplinary research is needed to conserve fragmented landscapes where socioeconomic conditions create demands for forest products and new arable land.

To conclude, our study documented a dramatic rate of fragment clearing and colobus decline in 15 years. The primates in this group of fragments were physiologically stressed and had high disease levels, some of which were clearly transmitted among humans, livestock, and primates. We expect that all colobus will disappear from these fragments within the next few years; the only exception is the fragment at Lake Nkuruba that is protected by a small-scale ecotourism operation. The persistence of the forest and primates at this site highlights the potential role that community-based conservation projects can play in protecting forests and wildlife. If current or future researchers find themselves in the situation that we happened upon 15 years ago, they need to think carefully about the appropriate action to take. Reversing the trends of clearing forest and declining primate populations, such as the ones we documented, requires a major conservation effort on a scale and nature that is rarely feasible. Specifically, halting fragment clearing requires the cooperation of local people. To do this, alternative sources of income must be found (e.g., ecotourism), fuelwood supplies from elsewhere must be made available (e.g., a large scale woodlot project, or solar stoves could be provided), and a great deal of effort must be placed on education and outreach. In reality, it is unlikely that a project of this magnitude could be initiated unless the fragments contained species of very special value. Sadly, we believe that this is the reality of biodiversity conservation outside of protected areas in many tropical areas of the world. Thus, if the situation in fragments is well illustrated by the title "Going, Going, Gone" and this pattern is general, the question needs to be asked, should conservationists just place their efforts into protected areas? While the logical extension of our study would suggest that the answer to this question is yes, we have hope that in some locations and at some future time the situations will be different, so that conservation of such community-owned fragments will become a profitable conservation strategy. As we conduct more research into community needs and restoration methods, this may become a reality.

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