Deriving Conservation Status for a High Altitude Population: Golden Monkeys of Mgahinga Gorilla National Park, Uganda

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Introduction

Human modification of ecosystems is threatening biodiversity on a global scale. For example, it is estimated that, during the 1990s, 16 million ha of forest were lost globally each and every year, of which 15.2 million ha were tropical forest (FAO 2005, 2010). Furthermore, even when the physical structure of the forest remains intact, subsistence and commercial hunting has had profound impacts on animal populations. For example, Chapman and Peres (2001) estimate that 3.8 million primates are consumed annually in the Brazilian Amazon alone. Human modification of ecosystems have also contributed to the approximate 0.6 °C warming of the earth's climate over the past 100 years, and some estimates suggest that the climate could warm by up by 5.8 °C this century (IPPC 2001; Walther et al. 2002). Such changes have led to an increase in the number of species being considered endangered (http://www.iucnredlist.org/ January 2012 update).

In Uganda, the country where this study focuses, threats to biodiversity are similarly grave. Closed-canopy tropical forest once covered 20 % of the country, but deforestation has reduced this to just 3 %, with 18 % of forest lost between 1990 and 2000 (Howard et al. 2000). The most recent estimate suggests that the annual rate of loss for tropical high forest in Uganda is 7 %, while 5 % of woodland and 4 % of bushland is lost each year (Pomeroy and Tushabe 2004). The

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highland areas of Uganda are an area of particular importance because of their high level of endemism (Bibby et al. 1992; Plumptre et al. 2003). To protect these endemic species, Uganda has set aside approximately 2,500 km^2 of high altitude land in national parks, including Mgahinga Gorilla, Bwindi Impenetrable, Rwenzori, and Mt. Elgon National Parks. Nonetheless, high altitude wildlife populations in Uganda are still particularly vulnerable to climate change and associated loss of habitat as animals typically have no refuge as they are confined by the tops of mountains and lack of forests at lower elevations due to human landscape modification. As in many tropical regions, human population densities at high elevations are extremely high (e.g., 400 + people/km^2) in Uganda compared to nontropical regions due to the amiable climate and rich soils that facilitate agriculture (Struhsaker 2010).

Setting up a system of protected areas is the primary conservation strategy used to protect most threatened species. This is particularly the case for high altitude species, because there is the additional desire to protect watersheds. Yet, little is known about long-term ecosystem dynamics in most protected areas that are essentially biological islands. Thus, what will happen to species in parks over the long term is unclear. Conservation workers often assume that once a species is protected inside a national park, it is no longer at risk and populations will either be stable or increase in size (Chapman et al. 2010). As we demonstrate here, this is not necessarily the case and continuous monitoring of the conservation status of endangered species, even for populations protected inside national parks, is needed.

A variety of approaches can be taken to investigate the conservation status of a species within a national park. If long-term data are available on changes in both population size and habitat structure, one can evaluate if regeneration or degradation of the habitat corresponds with predictable changes in population size (Plumptre and Reynolds 1994; Struhsaker 1976, 1997). Another approach is to evaluate the nutritional requirements of a species and consider whether the habitat in question is providing those needs (Balcomb et al. 2000; Chapman et al. 2004; Ganzhorn 1995; Rode et al. 2006; Twinomugisha et al. 2006). A third valuable approach is to identify a behavioral index, where variation in a particular behavior or suite of behaviors demonstrates the animal's resource needs, and subsequently evaluate how changes in the habitat relate to changes in this behavioral index. For example, animals are typically viewed to move around their home ranges in ways that maximize the intake of required nutrients, while minimizing their travel and search costs (Pyke 1984; Rode et al. 2006). If this is the case, by examining the ranging patterns of a species and evaluating the resource availability in different areas of the home range, one can identify the most critical resources of the species. Subsequently, the effects of anthropogenic habitat change on the availability of those resources can be evaluated and then used to predict how future habitat change may alter resource availability. Lastly, the reproductive rates of a population can be compared to other populations of the same or similar species, with the expectation that populations that are having many infants per female are likely living in the most suitable environment and thus most likely to survive into the future.

Here, we build and synthesize a series of our studies and use each of these approaches to examine the conservation status of the endangered golden monkey (*Cercopithecus mitis kandti*) in Mgahinga Gorilla National Park, Uganda. The golden monkey is a high altitude specialist that has a small distribution (less than 5,000 km^2) and is found only in the Virunga volcanoes and Nyungwe National Park from 2,500 to 3,550 m (Aveling 1984; Kingdon 1971). The golden monkeys in the Virungas are likely the only remaining viable populations, as the Nyungwe population is very small; however, even within protected areas in Virungas their populations have been documented to be in decline (Twinomugisha and Chapman 2007). The population in Mgahinga spends 60 % of its time eating bamboo (*Arundinaria alpina*), but tree fruits appear to be critical in their diet and habitat selection (Twinomugisha et al. 2006). These populations occur mostly in bamboo and bamboo forest mix (http://www.iucnredlist.org/apps/redlist/details/4236/0) (Sheil et al. 2012) where fruiting trees are extremely rare and are represented by only a few species (Kalina 1991; Schaller 1963). First, we report on changes in abundance of the golden monkey based on three surveys conducted between 1989 and 2003. Second, we evaluate the nutritional ecology of this population to determine which resources are particularly important and consider the availability of potentially limiting foods. Third, we quantify ranging behavior to determine how the use of their home range varied in relation to spatial and temporal variation in resource availability. Lastly, we compared the reproductive rate of this population to other published rates for this species.

Methods

Study Site

Mgahinga Gorilla National Park, Uganda (33 km^2) encompasses the slopes of three volcanoes (Mgahinga 3,474 m, Muhabura 4,127 m, and Sabinyo 3,634 m) and is part of the greater Virunga Conservation Area, which covers 434 km^2 (Fig. 1). Mgahinga was first gazetted in 1930 as the Gorilla Game Sanctuary and covered 33.7 km^2, but in 1939, 15.5 km^2 were reclassified to crown forest to allow bamboo (*Arundinaria (Synarundinalia) alpina*) extraction (Malpas and Infield 1981). Due to an increasing shortage of land for agriculture, the forest reserve was further reduced by 10.4 km^2 in 1951 (Uganda National Parks 1996). In 1964, the Gorilla Game Sanctuary was renamed the Gorilla Game Reserve and enlarged to 47.5 km^2; however, this boundary was never demarcated and people remained settled on 13.8 km^2 (Malpas and Infield 1981; Uganda National Parks 1996). Anthropogenic pressure on this conservation area was compounded by illegal poaching of wildlife and bamboo harvesting. By the latter half of the 1980s, the

Gorilla Game Reserve had attracted international attention, and as a result, a number of conservation projects were initiated. This attention culminated in upgrading the reserve to a national park in 1991, which offers the highest level of protection under the Ugandan constitution (Uganda National Parks 1996). During the same year, the Global Environmental Facility of the World Bank established a trust fund to contribute to conservation efforts in and around the park (Uganda National Parks 1996). In June 1992, the Uganda government reached an agreement with the local people settled in the park and they were re-located. The vegetation types of the park are diverse and are broadly classified into three belts: alpine, subalpine (ericaceous), and montane forest (Fig. 1), with the subalpine belt being composed of moorland, montane grassland, and ericaceous zones.

Survey

We conducted line transect censuses twice a month during two periods totaling 13 months (March to August 1998 and January 2003 to July 2003). We compared our findings to a census conducted in 1989 by Werikhe (1991). Our censuses were conducted by walking approximately 1 km/h along three 4 km and one 5.7 km transects (Fig. 1). The transects were set along compass bearings and did not follow existing trains or altitudinal zones. One of the 4 km transects traversed a previously encroached and degraded part of the park that has been recovering since 1992. Werikhe (1991) conducted censuses in a similar fashion along eight

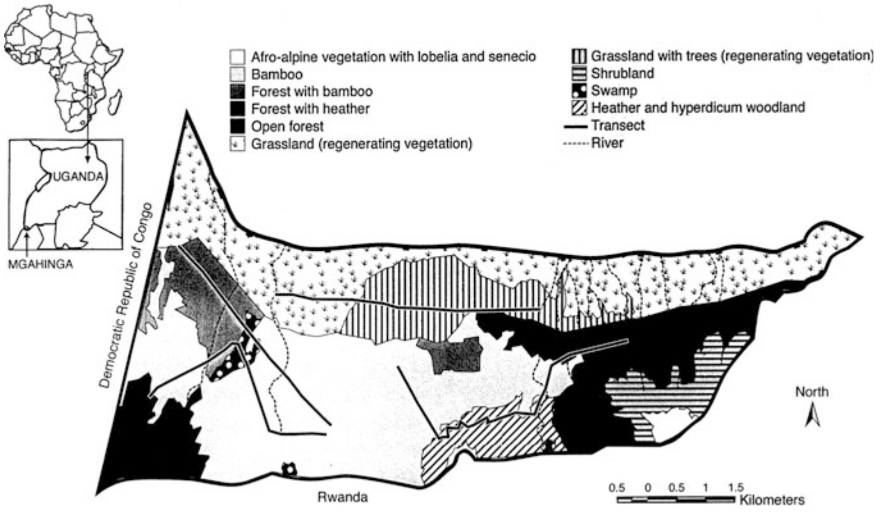

Fig. 1 A map of Mgahinga Gorilla National Park, Uganda, illustrating its major vegetation types and the transects used in golden monkey censuses

transects (ranging from 2.7 to 4.5 km) in the part of Mgahinga that was not settled. Werikhe's transects followed existing trails that mostly ran along an altitudinal gradient, and cut across vegetation types.

Upon sighting a social group we recorded the location, sighting angle, sighting distance from observer, height above ground, vegetation type, and number of individuals. Sighting distance was visually estimated. Most of the censuses began between 0640 and 0830 h and lasted to 1,040 and 1,140 h for all 4 km transects and until 1,400 h for the 5.7 km transect. Sighting distance frequencies were graphed and the Maximum Reliable Sighting Distance was estimated as that distance beyond which the sighting frequency declined by ≥50 % (National Research Council 1981). The Maximum Reliable Sighting Distance was 25 m. Sightings beyond 25 m were few and were dropped from the analyses.

In addition, as an index of relative abundance, we estimated the number of groups seen per km of census trail walked (Chapman et al. 2000; Mitani et al. 2000). This index does not take into account differences in visibility among periods or differences in the ability of the observers to detect animals; however, it is less likely to be biased by differences among observers in the ability to estimate sighting distance and difficulties in determining transect width (Teelen 2007). In our study, DT conducted all surveys, so it is unlikely that there were differences in the ability to detect golden monkeys between periods. We calculated the density and relative abundance twice: once, using all transects, and again by excluding the area in the regeneration zone that was not used by golden monkeys in 2003 and not sampled by Werikhe (1991). This will enable us to compare the density of golden monkeys in the entire national park with the density areas that are suitable habitat for golden monkeys.

Nutritional Ecology

Golden monkey diet was quantified during two periods. Starting in January 1998, two already partially habituated groups were further habituated for 2 months. In March 1998, instantaneous scan samples of feeding were conducted during day-long follows (dawn to dusk) for three consecutive days each month for 7 months (March to September 1998). Four 5 min scan samples separated by 10 min intervals were conducted each hour on as many individuals as possible. In a single scan, a feeding observation by any individual on a particular food item was scored only once unless the same individual fed on different parts of the same food plant. Group 1 was followed for 19 days during which 69 h of observations were made. Group 2 was followed for 17 days (85 h). At times, observations were difficult to make as the group could enter dense clumps of bamboo. Feeding observations were also recorded opportunistically. Furthermore, secondary indications (e.g., discarded fruit) and interviews of park rangers about the foods that they observed golden monkeys eating were used for determining diet. In the second period between January and August 2003, the same methods were used on a third group (Group 3), which was observed for a total of 57 days (485 h). On average, the group was observed for 7 days each month (range = 3–11 days). Given the greater duration of the second period, we focus on this period for all diet and nutritional analyses.

For nutritional analyses, food items were collected in a way that mimicked the golden monkey's feeding. For example, if the animals ate leaf petioles, the length of petiole typically consumed was collected. Samples were air-dried in a shaded area, sealed in plastic bags, and brought to University of Florida for nutritional analyses. For each sample, we quantified protein (nitrogen), fiber (Acid Detergent Fiber, ADF), sugars (organic acids and simple sugars [mono- and oligosaccharides]), and evaluated the presence or absence of three secondary compounds thought to deter monkey foraging (alkaloids, saponins, and cyanogenic glycosides). Details of the nutritional analysis can be found in Chapman and Chapman (2002) and Twinomugisha et al. (2006).

Ranging

We quantified patterns of habitat use between January 2003 and February 2004 based on all-day (0700–1,900 h) follows of one habituated golden monkey group over 105 days (Group 3). Observations were started after 12 months of habituating the group (January 2002 to December 2002). Habituation took time partly because, hunters and bamboo harvesters disrupted habituation efforts; individuals that were upset at the loss of opportunities to conduct illegal activities threw stones at the animals.

To systematically follow monkeys and place feeding observations and food availability data in a spatial context, a grid system with 0.25 ha cells (corners marked with flagging) was laid over an area perceived to be the group's entire home range. This grid size was selected because the group was typically spread across an area smaller than this. During each follow, the grid cell containing the center of the group was recorded every 15 min.

To quantify possible environmental drivers of habitat selection, we examined density of food trees, abundance of shrub and vine food plants and bamboo culm density, and phenology of food plants. This facilitated an evaluation of the pattern of grid cell use relative to food availability. In each grid cell, the following data were collected on each food trees $\geq$5 cm DBH (diameter at breast height): species identity, number, and size (DBH). The $\geq$5 cm lower limit was used since *Galiniera coffeoides* and *Hypericum revolutum* provided food items when trees reached this size. DBH of trees is a good indicator of fruit and leaf abundance (Catchpole and Wheeler 1992; Chapman et al. 1992; Harrington 1979). In total, 12,133 trees were measured. Phenological observations were made each month to quantify the temporal changes in food availability using a 0–8 phenophase scale (Kaplin et al. 1998; Lawes and Piper 1992; National Research Council 1981). Bamboo was very dense in some areas, thus to quantify its density, DBH, height, and broad age classes, measurements were made in six 0.5 m x 50 m strip subplots laid at regular intervals in each 0.25 ha grid cell and 103,548 bamboo stems were measured. Percentage vine and shrub coverage were also determined for 12 species that bear food items (estimated in 10 % intervals). We graphically contrasted range use to spatial and temporal variation in resources using Surfer Version 7.0.

Demography

We compiled group counts of any subspecies of *C. mitis* from any location in Africa from the literature and determined the number of infants that were present per adult female. We assumed that populations having many infants per female were a prospering population. We determined the number of infants per female for five subspecies of *C. mitis*.

Results

Survey

The density of golden monkey groups (degraded habitat included) declined from 5.11 groups/km^2 in 1998 to 3.31 groups/km^2 in 2003 (Table 1) (Twinomugisha et al. 2003). This decline was also evident if the regenerating habitat was excluded from the calculations (1998: 6.03 groups/km^2; 2003: 4.28 groups/km^2). In 1989, the density was 3.24 groups/km^2 (Werikhe 1991). Werikhe conducted censuses at a time when the regenerating zone was being used by people, thus his results excluded this zone. Unlike the 1998 census, no monkeys were encountered in the regenerating habitat in 2003. These results suggest an increase in golden monkey group density between 1989 and 1998, but a decline between 1998 and 2003 (the time of best park protection).

Table 1 Sighting rates and density estimates of golden monkeys in Mgahinga Gorilla National Park, Uganda, in 1989, 1998, and 2003

Park Area	Groups Seen	Censuses #	Census Length(km)	Census Area	Groups/ km	Sighting Rate/km
Set 1 2003	46	56	247.8	12.39	3.31	0.19
Set 2 2003	46	42	191.8	9.59	4.28	0.24
Set 1 1998[a]	–	–	–	–	5.11	0.44
Set 2 1998[a]	–	–	–	–	6.03	0.52
Set 2 1989+	–	–	–	–	3.24	0.91

Set 1 includes the area regenerating after human encroachment, while Set 2 does not
[a] From Twinomugisha et al. (2003), + from Werikhe (1991)

Evaluating changes in relative abundance indicated a progressive decline between 1989 and 2003 (Table 1). Encounter rates of monkey groups for each vegetation zone were lower in 2003 than in 1998 (Table 2). In three vegetation zones (i.e., *Hypericum* woodland, swamp-meadow, and regenerating), no social groups were sighted in 2003, but groups were previously seen in these habitats in 1998.

Nutritional Ecology

Golden monkey diet varied over time and between groups (Table 3). For example, the frequency with which young leaves (including bamboo [*Arundinaria alpine*]) were eaten varied between groups from 11.3 to 58.6 %, while the use of insects varied from 8.0 to 30.5 % (Table 3). Bamboo was particularly important in the diet of all golden monkey groups and they fed on bamboo leaves, culms, and shoots. The group observed in the 2003 ate bamboo for an average of 52.4 % of their foraging time and up to 61.7 % in any particular month (Fig. 2). Fruiting trees are rare in Mgahinga; however, fruit was still a major component of the diet of some golden monkey groups (average 26.3 %; Table 1).

The golden monkey diet was not very diverse; in 2003, they fed on between 3 and 12 species of plants per month, with only 16 plant species eaten in total and four of these were added from opportunistic observations. Over all time periods and across all groups the golden monkey fed on only 33 plant species. Their simple diet is further illustrated by the fact that in 2003 the group only fed on four food items from two species for more than 10 % of their feeding time: young bamboo leaves (33.4 %), *Maesa lanceolata* fruits (20.8 %), bamboo shoots (15.3 %), and bamboo branchlets (11.6 %).

In 2003, diet selection appeared to be strongly influenced by the availability of *M. lanceolata* fruit (Fig. 2). This species fruited primarily in the last month of the dry season (August) and during the first two months of the rainy season

Table 2 Sighting rates of golden monkeys in different habitats in Mgahinga Gorilla National Park, Uganda, in 1998 and 2003. Transect lengths are the same in both periods

		2003			1998		
Vegetation Type	Transect Length(km)	Groups Seen	Census km	Groups/ km	Groups Seen	Census km	Groups/ km
Bamboo mixed	1.9	7	26.6	0.26	33	35.6	0.93
Pure bamboo	6.3	36	87.5	0.41	60	105.5	0.57
Heath forest	1.9	2	26.6	0.08	7	33.4	0.21
Open forest	0.9	1	11.9	0.08	14	17.9	0.78
Swamp	0.4	0	5.6	0.00	1	7.0	0.14
Hypericum	2.4	0	33.6	0.00	10	43.2	0.23
Regenerating	4.0	0	56.0	0.00	2	56.0	0.13

Table 3 The percentage of foraging effort devoted to different plant parts by the golden monkey of Mgahinga National Park, Uganda

	1998 (Group 1)	1998 (Group 2)	2003 (Group 3)	Average
Fruit	31.1	36.7	11.0	26.3
Young leaves	47.4	11.3	58.6	39.1
Flowers	0.4	14.0	21.9	12.1
Stems	5.8	7.0	0.3	4.4
Insects	10.5	30.5	8.0	16.3
Other	4.8	0.5	0.2	1.8

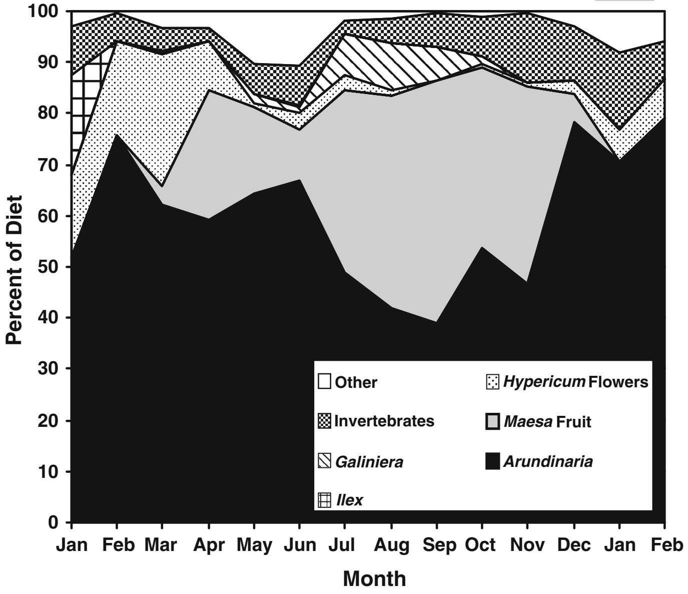

Fig. 2 The foraging effort that a group of golden monkeys (*Cercopithecus mitis kandti*) in Mgahinga Gorilla National Park, Uganda, invested each month on the major food items during 14 months covering 105 days between January 2003 and February 2004

(September and October). *M. lanceolata* fruit availability coincided closely with bamboo shooting. At this time, the monkeys switched between areas with *M. lanceolata* and areas of bamboo. Bamboo shooting occurs when the rainy seasons begin. Bamboo availability influenced range use and the monkeys foraged on bamboo shoots in May following the short rains, but on a very low level alongside bamboo leaves. Bamboo shoots, which were eaten with bamboo young leaves, were extensively eaten in October and November and later alongside bamboo branchlets in December as the shoots grew into young bamboo culms. *Hypericum revolutum* flowers were abundant between January and March and were an important food at this time and in February the following year when this tree flowered again (Fig. 2). The monkeys were observed feeding on only two shrub species: *Rhamnus prinoides* fruits (1.2 %) and *Clerodendrum* sp. pith which was eaten only in January 2003 (0.4 %).

Bamboo has a relatively high protein content (22 % of dry matter), but it is a very poor source of sugars (just trace amounts) and its lipid content is low (2 %). Since bamboo was eaten in every month of the year and typically at high levels and is an important source of protein, it is probably vital to the survival of golden monkeys in these mountain forests. The golden monkeys obtained their sugars from the few fruits that were available (e.g., *M. lanceolata* 18 % sugar, *G. coffeoides* 12 %), from flowers (*H. revolutum* 29 %), and from the leaves of *Nuxia congesta* (19 %). No group had a food item in their top 10 most frequently eaten foods that had cyanogenic glycocides, while 50 % of these foods contained alkaloids and 30 % had high saponin levels. There were no correlations between any of the nutritional components and foraging effort (the number of point samples observed feeding on an item/all feeding point samples).

Ranging

The group observed in 2003 ranged over 68 ha (272 quarter ha cells) and fed in 241 cells [$n = 11{,}423$ feeding records made in 3,435 scans, during 14 months covering 105 days(Twinomugisha and Chapman 2008)]. The number of feeding events varied substantially among cells (range, 1–505). The evaluation of habitat preferences was facilitated by the fact that the golden monkeys ate so few species of plants. For the purpose of evaluating range use, five plant species were considered: bamboo 59.9 %, *M. lanceolata* 18.7 %, *H. revolutum* 6.8 %, *G. coffeoides* 2.1 %, and *I. mitis* 1.4 %. Together, along with invertebrates (7.5 %), these items constituted 96.4 % of the monkeys foraging effort over the 14 months. To quantify how food availability influences habitat selection, we examined density of food trees, abundance of shrub and vine food plants and bamboo culm density, and phenology of food plants.

The group tended to concentrate its activity in the northwestern part of its range and several other specific areas (Fig. 3a). The group less frequently used the south of its home range, which had higher cumulative basal area of all five major food plants. However, the southern part of the home range consisted almost entirely of bamboo, while the northern part was mixed tree and bamboo and the regenerating zone (Fig. 3b). The monkeys never used this regenerating wooded grassland in 2003. Excluding bamboo basal area from the graphical presentation reveals that the pattern of range use generally follows the distribution of food tree basal area and range use was most closely depicted by the basal area of only three food tree species (*H. revolutum, M. lanceolata*, and *G. coffeoides*; Fig. 3c). There was a higher food tree species basal area in the north compared to the south of the home range, which corresponds to the group's range use (Fig. 3a, c). The distribution of fruiting *M. lanceolata* alone suggests that home range use is strongly influenced by this one species.

A question arises from evaluating this graphical analysis as to whether feeding is preferred within the vicinity of *M. lanceolata* or if areas are selected to allow the golden monkeys to feed both on bamboo and *M. lanceolata* and possibly other food tree species for a balanced diet. The distribution pattern of bamboo was negatively correlated with that of food tree species (*H. revolutum*, $r = -0.150$, $p < 0.001$, *M. lanceolata*, $r = -0.513$, $p < 0.001$, *G. coffeoides*, $r = -0.268$, $p < 0.001$), thus it appears that food tree abundance is critical in determining range use; however, given the ubiquitous nature of bamboo it was relatively easy for animals to switch between feeding on trees to feeding on bamboo.

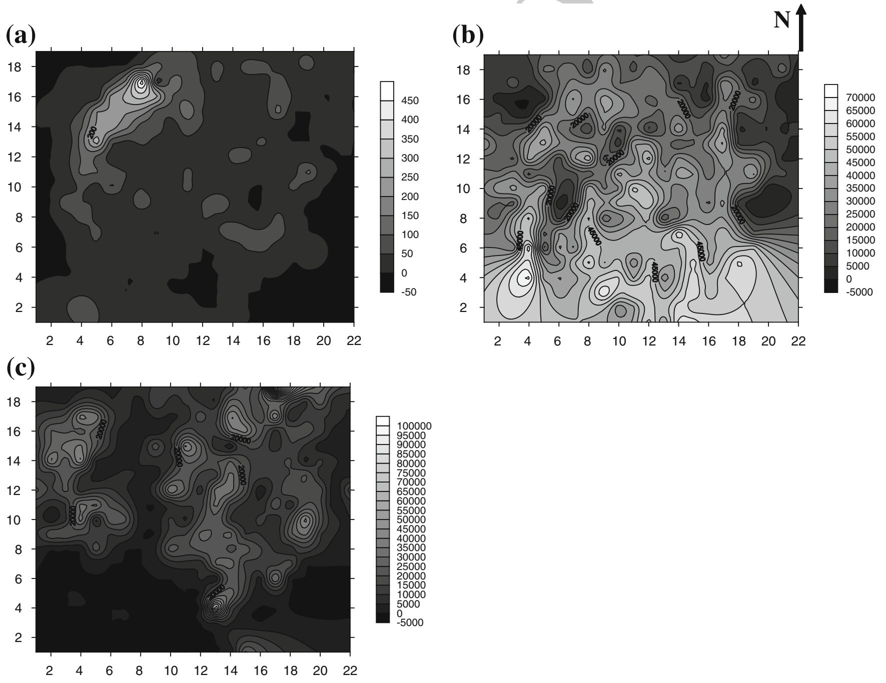

Fig. 3 Contour maps of home range area of one group of golden monkey (*Cercopithecus mitis kandti*) in Mgahinga Gorilla National Park, Uganda, followed from January 2003 to February 2004. Maps show **a** feeding intensities (number of feeding records in grid cells) in different parts during the study, **b** bamboo basal area (*Arundinaria alpina*), and **c** the basal area of three food tree species (*H. revolutum, M. lanceolata*, and *G. coffeoides*) which show a close pattern between food plant distributions and feeding by the group

Demography

The infant to adult female ratio was contrasted among different subspecies of *C. mitis* (Table 4). Golden monkey groups had a lower infant to adult female ratio than *C. m. stuhlmanni*, *C. m. erythrarchus*, or *C. m. labiatus* groups, suggesting that fewer infants are born into golden monkey groups.

Discussion

Both density estimates and sighting rates suggest that while golden monkey population in Mgahinga has received increased protection over the last two decades, their population has declined. These results are supported by the observation that golden monkey groups in Mgahinga had a lower infant to adult female ratio than any other *C. mitis* subspecies for which comparable data exists, suggesting that fewer infants are born into these groups. The information collected on the diet and range use of the golden monkeys provides clues as to why this decline has occurred and offers insights into conservation measures needed to reverse these declines.

The density and species richness of fruiting food trees at Mgahinga is very low, which is typical of high altitude habitats. Despite this fact, the golden monkeys appeared to cope well. Some groups focused their feeding efforts on a few fruiting species, while other groups relied on flowers and leaves and all groups obtained the majority of their protein from bamboo. Twinomugisha et al. (2006) demonstrated that the overall nutritional characteristics of the foods used by the Mgahinga golden monkeys living at a high elevation were not different from those foods used by groups of blue monkeys in Kibale National Park, Uganda, a lower elevation forested park with higher tree diversity. Results indicate that golden monkeys can substitute foods and still obtain a balanced diet. This suggests that a poor diet is not the cause of the population decline. However, it may be important to consider that while the differences in the nutrient content of foods from Kibale

Table 4 Comparison of the infant to female ratio of populations of *C. mitis*

Species	Infant: adult female ratio	Source
C. m. stuhlmanni (Kibale, Uganda)	0.2043	Butynski (1990), Rudran (1978a, b)
C. m. stuhlmanni (Kakamega, Kenya)	0.4225	Cords (1986)
C. m. stuhlmanni (all)	0.2988	Average of above studies
C. m. labiatus	0.5000	Lawes et al. (1990)
C. m. erythrarchus	0.3333	Macleod (2000)
C. m. kandti	0.1282	This Study

and Mgahinga were not statistically different, small differences may be biologically meaningful. Also, there may be differences in nutrients (e.g., mineral content) that were not measured that could impact the Mgahinga population. Furthermore, the nutritional study was done at what was possibly the end of the documented decline. If the nutritional study was done when the population was starting to decline, their diet may have been found to be nutritionally poor.

The observations on the nutritional ecology of the golden monkeys do provide suggestions for the future management of this high altitude population. In general, fruits are known to provide an easily assimilated source of sugars and energy, but have been suggested to supply inadequate amounts of protein (Gaulin 1979). This generalization may explain why some populations of *C. mitis* appear to select foods based on their protein content (Beeson 1989; Lawes 1991). However, none of the groups studied here selected foods high in protein (see discussion of bamboo below). Golden monkeys at Mgahinga consistently fed on bamboo, which has a relatively high protein content (22 % of dry matter), but little sugar. Bamboo was eaten in every month of the year and is an important source of protein that may be vital to the survival of golden monkeys in these high altitude mountain forests. The importance of bamboo is suggested by the fact that in Mgahinga there were higher sighting rates and densities of golden monkeys in the bamboo zone and in forests with bamboo vegetation types than in other habitats. In contrast, the golden monkeys obtained their sugars from the few fruits that were available, from flowers, and from the leaves of *Nuxia congesta*. *Hypericum revolutum* flowers were a particularly important source of sugars (29 % of dry weight) and were available and eaten year round. While, bamboo may be a critical source of protein for the golden monkey, it is very abundant in the habitat, thus it is likely that the availability of the few trees is the critical resource and management should be designed to promote both tree and bamboo growth.

We used a detailed evaluation of the golden monkeys' range use in relation to the spatial and temporal variation of food resources to demonstrate that the distribution of the food trees had a strong positive influence on their range use. Thus, while the ubiquitous bamboo is an important resource for the golden monkey being the leading source of protein and is used extensively throughout the year, the ranging data support the nutritional ecology research in suggesting golden monkey require a combination of resources including food items obtained from trees, vine, and shrubs, in addition to bamboo, to meet all of their nutritional requirements (Twinomugisha and Chapman 2008).

Neither the nutrition nor ranging datasets provide clues as to why the golden monkey population has declined. We offer a relatively simple suggestion for their decline based on changes in habitat selection since 1998. While there were sightings of monkeys in the seven vegetation types in 1998, there were no sightings in three of them in 2003. Similarly, small groups were seen at high elevations in 1989 and 1998, but not in 2003. One possible explanation for this change in distribution is that as the population density of golden monkeys has declined, animals are able to restrict their ranging to only the most preferred habitats. If this is the case, it suggests that prior to 2003 animals were occupying sub-optimal habitats. We suggest that in the 1980s and 1990s the golden monkey density may have been above that which could have been supported by the environment—this is suggested by the abundance of animals in less preferred habitats. If groups from forests outside the park immigrated to the park and sought protection as their original forests were destroyed, this may have pushed the density above that which the habitat could support over the long term. Over the last 14 years, their population may have returned to the level at which the environment could support them. If management recommendation (e.g., evaluation of whether this population was above that thought to be viable from a genetics perspective) was made on the initial population determination, inappropriate management recommendations would have been made. This illustrates the importance of long-term monitoring.

Management Recommendations

Illegal extraction of bamboo and trees pose a serious threat to the conservation of the golden monkey at the high altitude Mgahinga site. Bamboo is the most sought after item by the local community and this extraction may eventually negatively affect its growth leading to poor yield or even a retreat in coverage. We suggest this because in similar bamboo stands on Mt. Elgon, Uganda, Scott (1994) found that bamboo culm size decreased with increasing harvest intensity. The results presented here, however, suggest that tree cutting will have a more significant impact than the bamboo harvest. We suggest restoration in the regenerating zone would be a profitable conservation strategy to promote golden monkey populations and, given the slow rate of regeneration, active intervention and planting will likely be required. The restoration efforts should aim for regenerating a habitat that is a mixture of bamboo and trees, particularly *M. lanceolata* and *H. revolutum*. Such an active reforestation program could add an additional 10.1 km^2 of preferred habitat, which would result in a 75 % increase in bamboo/tree vegetation and facilitate golden monkey population recovery. AQ1

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