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Diet of the Ashy Red Colobus (*Piliocolobus tephrosceles*) and Crop-Raiding in a Forest-Farm Mosaic, Mbuzi, Rukwa Region, Tanzania

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Abstract: The Ashy red colobus monkey (*Piliocolobus tephrosceles*) was recently discovered in the Mbuzi Forest. Since then its forests have been degraded, fragmented and converted into farmland. In this study I documented the diet, including cultivated crops, of four groups in the Mbuzi forest-farm mosaic during two months in the crop-growing season, July–August 2011. Each group was followed for nine days; 36 days overall. It was not possible to extend the study in subsequent years because the forest was so fragmented that the monkeys were no longer staying in some patches. The monkeys fed mostly on wild plants. Crop-raiding was limited to beans, and occurred in the evenings when the farmers had left the fields. Extreme fragmentation, degradation and widespread forest conversion into farmland have drastically reduced the abundance of food trees; and it is likely that this has resulted in their crop-raiding. They are persecuted for this behavior, and retaliatory killing by farmers is probably contributing to their decline in the Mbuzi Forest. The conservation of intact montane forests on the Ufipa Plateau is crucial and urgent. Measures must include conservation education, community involvement and improved law enforcement, as well as provisions for local communities to reduce the destruction of the remaining forest patches.

Key Words: Ashy red colobus, *Piliocolobus tephrosceles*, *Procolobus rufomitratus tephrosceles*, diet, bean-crop raiding, Mbuzi Forest

Introduction

Folivorous monkeys such as the Ashy red colobus, *Piliocolobus tephrosceles* (Elliot, 1907)[1], select the most nutritive and easily digestible items, rich in proteins, such as young leaves and leaf buds (Chapman and Chapman 2002). They also eat other plant parts and arthropods to supplement their diet. Seasonal food-switching is common among primates as a strategy to meet their dietary requirements (Li *et al.* 2010). Differences in habitat quality also affect habitat use by primates; for instance, *P. tephrosceles* spends more time in patches with a high density and diversity of food trees than patches with a low food tree density and diversity (Kibaja 2012). The carrying capacity of their habitats is compromised if it is unscrupulously degraded by human activities.

Piliocolobus tephrosceles is categorized as 'Endangered' on the IUCN Red List (Struhsaker 2008), the only viable population possibly being in Kibale, with at least 17,000 individuals (Struhsaker 2005). There has, however, been a decline in population and group sizes in past years (Chapman *et al.* 2007) due to, among other factors, predation by chimpanzees (*Pan troglodytes*) (Watts and Mitani 2002; Fourier *et al.* 2008; Struhsaker, 2008). On the Ufipa Plateau (Mbizi and Mbuzi forests) where there are no chimpanzees the monkeys are prone to extinction due to other forces. The human activities degrading and insularizing the forest have been reported by Davenport *et al.* (2007); and they continue to worsen in the Mbuzi Forest, which is gradually being converted into farmland. Such habitat alterations have negative effects on the diet and feeding patterns of the monkeys. Human-grown foods also affect the monkey's dietary preferences. Tesfaye *et al*. (2013) noted that Boutourlini's blue monkeys (*Cercopithecus mitis boutourlinii*) raided crops of farms surrounding forest fragments but not those adjoining larger intact forests. While some primates, notably frugivores, can in some circumstances co-exist with humans, folivorous

[1] Following Groves (2007). Classified as *Procolobus rufomitratus tephrosceles* in the IUCN Red List (Struhsaker 2008, 2010).

monkeys have more difficulty. Assessment of the monkeys' diets in these vulnerable habitats and surrounding agro-ecosystems is paramount.

Here I present my preliminary findings on the wild and cultivated foods eaten by Ashy red colobus monkeys in extremely degraded habitats. The results are a wake-up call for primatologists and conservationists to forestall the likely impacts of human activities to habitats of isolated vulnerable populations of primates in unprotected areas such as the Mbuzi Forest.

Methods

Study site

The study was conducted in the Mbuzi Forest in the Rukwa Region, Tanzania (Fig. 1). The forest is on the eastern ridge of the Ufipa Plateau in Nkasi District, northeast of Chala and 54 km northwest of Mbizi Forest (Davenport *et al.* 2007). The Ufipa Plateau covers an area of 7,249.4 km². It is an uplifted highland lying between the wings of the Albertine rift valley, east of Lake Tanganyika, and the Rukwa valley. The soils are ferralitic. Elevations range from 1,000 to 2,661 m above sea level, and annual rainfall is 800–1,200 mm. The plateau is an important agro-economic zone, supplying the marketed surplus of agricultural produce of the region (Anonymous 1998). The high population growth and concentration of people in the area have intensified land-use (Anonymous 1998).

The Mbizi Forest is protected as a forest reserve, but the Mbuzi Forest is not. The Mbuzi Forest is threatened with degradation, resulting from various forms of uncontrolled forest use (Davenport *et al.* 2007). It lies between 1,990 and 2,122 m above sea level and, according to Davenport *et al.* (2007), the forest covers about 611 ha. The area is now probably considerably smaller due to ongoing fragmentation and conversion into cultivated land in recent years.

The Mbuzi Forest has been segmented into several forest patches. In this study, a forest fragment refers to a forest patch that has been broken from the once continuous area of the forest as a result of clearing for cultivation. I surveyed all fragments and only four were occupied by red colobus, each having a single group (G1, G2, G3 and G4): A (7º30'57.85097"S, 31º22'46.53323"E), B (7º30'30.76018"S, 31º22'42.39630"E), C (7º30'9.33958"S, 31º22'35.32957"E), and D (7º30'43.99333"S, 31º23'24.51921"E) (Fig. 2).

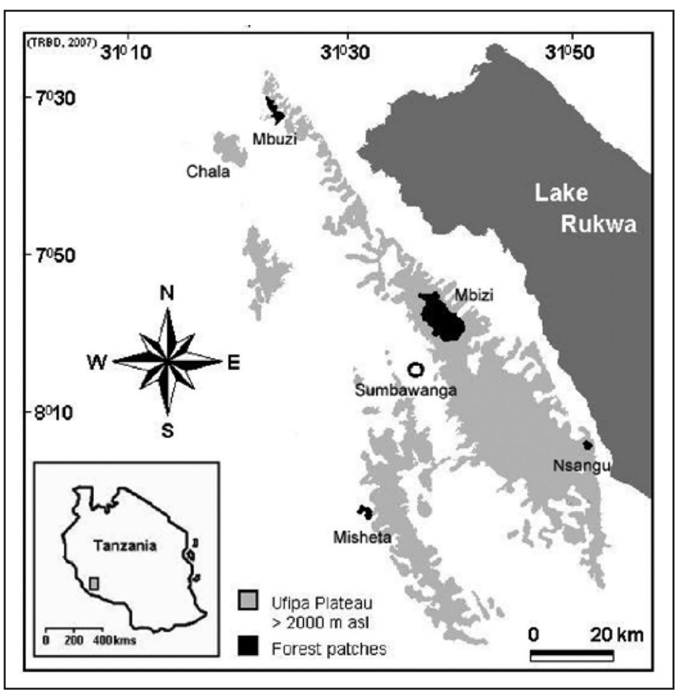

Figure 1. Mbuzi Forest on the Ufipa Plateau, Rukwa Region. From Davenport *et al.* (2007).

Feeding data collection and analysis

Each of the four groups was followed for nine days, making a total of 36 days for the four groups inhabiting Mbuzi Forest (Fig. 2). The study was conducted during the crop-growing season from July to August 2011. It was not possible to extend the study in other years because the forest was so fragmented that the monkeys were fleeing some forest patches. I recorded the activities of the groups when following them, using an instantaneous scan sampling protocol (Altmann 1974), recording activities during five-minute scans at 15-minute intervals (Martin and Bateson 1993; Kitegile 2006). In each scan sample, I noted the activities of all visible monkeys. If feeding, the food item, plant part and plant species were identified. After each scan, I recorded my location with a Global Positioning System (GPS), and noted also the habitat type, time spent in a habitat, group size and weather conditions.

To estimate the relative importance of each habitat type, I summed the total feeding records (the sum of all the daily feeding records) for each food item in each. The Chi-square test was used to test the significance of variation in frequency of feeding records for the seeds of cultivated beans and items from wild species eaten in farms, and of feeding records of wild food items between forests and farms.

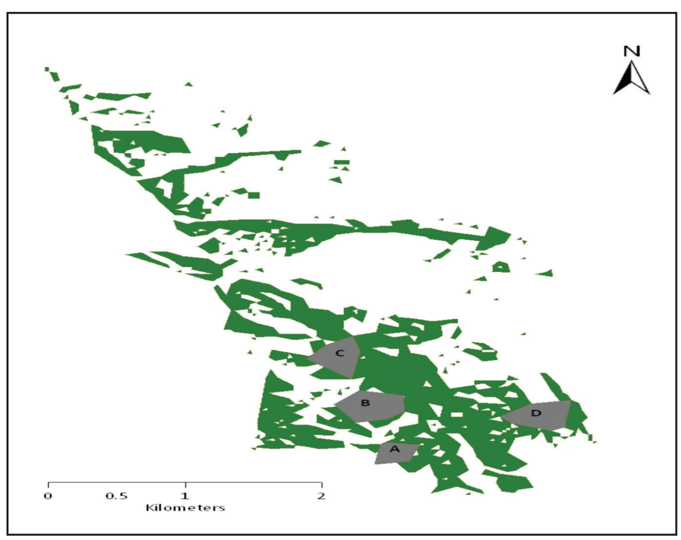

Figure 2. Locations of the four colobus groups in the forest fragments A–D, as shown by shaded polygons, in Mbuzi Forest, Tanzania.

Table 1. Frequency of parts eaten by four groups (G1–G4) of *Piliocolobus tephrosceles* in forest fragments (A-D) in a forest-farm mosaic, Mbuzi, Tanzania.

		Groups (forest fragments)				
	Food items	**G1(A)**	**G2(B)**	**G3 (C)**	**G4 (D)**	**Total**
Wild plant foods	Leaves	256	526	555	513	1850
	Leaf buds	199	94	63	18	374
	Bark	4	1	1	34	40
	Shoots	1	4	8	0	13
	Petioles & cork	0	0	8	5	13
	Dry twigs	0	0	0	12	12
	Flowers & fruits	2	0	1	0	3
	Lichens	0	2	33	39	74
Bean	**Seeds**	**36**	**2**	**0**	**0**	**38**
	Total	498	629	669	621	2417

Botanical data collection and analyses

I sampled the vegetation in the forest patches habitually used by the Ashy red colobus monkeys. Reconnaissance surveys revealed that the monkeys in the Mbuzi Forest feed on a variety of plants, including trees, shrubs, and lianas, and sometimes even herbs on the ground. The botanical data for trees are considered here for the computation of food selection ratios. Vegetation sampling involved two random plots in each habitat type (open canopy, closed canopy forest and forest edge) in each of the four forest fragments, totaling 22 plots in the forest fragments and 8 plots in the farms. Sampling involved the following quadrat dimensions with modification from Mligo *et al.* (2009) (a) 25 × 20 m quadrats for trees; covering 1.1 ha (22 plots) in the forests and 0.4 ha (8 plots) in the farms (b) 5 × 2 m quadrats nested in the bigger quadrat for shrubs and (c) 1 × 1 m quadrat nested in the 5 × 2 m quadrats for the herbaceous layer (i.e. forbs, seedlings and grasses). The following were recorded in each quadrat: scientific name of the plant, the girth of the trees at breast height, or above the buttress if large fig trees (*Ficus*), using a tape measure, and an estimate of cover for herbs in 1 × 1 m plots.

Tree density was determined by recording the number of trees in a known area and dividing it by the area from which they were sampled, later converted into number of trees per hectare: Density of species (D) = number of trees of each species / total area sampled (ha). The basal area was calculated by using the formula: $BA = \pi (DBH / 2)^2$, where BA = basal area, $\pi = 3.14$; and DBH = diameter of a tree at breast height. The basal area was used to compute the selection ratios of food trees in the forests and farms. The formula used was as follows: $SR = \%f_n / \%BA_n$, where SR = selection ratio of a food tree species n; $\%f_n$ = percentage of tree feeding records of species n in the study period; $\%BA_n$ = percentage basal area (BA) for tree species n in a given habitat. Unpaired two-sample t test (computed in PAST: Paleontological Statistics Version 2.17 Software by Hammer 2012) was used to test the significance of the differences in density and basal area of trees in the diet between forests and farms.

Table 2. Feeding records of plant food items in forests and farms, Mbuzi, Tanzania.

Food items	**Forests**		**Farms**		**Total frequency**
	F	**%F**	**F**	**%F**	
Leaves	1801	77.7	49	49.5	1,850
Leaf buds	368	15.9	6	6.1	374
Bark	40	1.7	0	0	40
Bean seeds	**-**	**-**	**38**	**38.4**	**38**
Shoots	12	0.5	1	1.0	13
Petioles and cork	13	0.5	-	-	13
Dry twigs	7	0.3	5	5.1	12
Flowers and fruits	3	0.1	-	-	3
Lichens	74	3.2	-	-	74
Total	**2318**	**100**	**99**	**100**	**2,417**

Results

Of 2,417 feeding records, 2,379 (98.4%) were of wild foods. Cultivated bean seeds amounted to 38 records (1.6%) in the forest-farm mosaic. Consumption of wild food items was higher in forests (97.4%, n = 2318) than in farms (2.6%; n = 61). In the farms, the monkeys ate more wild food items (61.6%, n = 61) than cultivated bean seeds (38.4% n = 38) ($\chi^2 = 5.343$, df = 1; P = 0.021). The percentage frequency of feeding records between wild plant items (not cultivated beans) and bean seeds differed significantly among the monkey groups G1–G4 (Contingency table: $\chi^2 = 129.970$; $P < 0.0001$). Only groups G1 and G2 ate bean seeds (Table 1).

Leaves comprised the majority of the diet in both forests and farms (Table 2). Among the cultivated crops, only beans (*Phaseolus*) were eaten, complementing the wild plant foods. The monkeys ate fresh beans (seeds) and discarded the pods. They would raid the bean crops in the early morning and (mostly) late evenings at around 1700 h–1900 h (Fig. 3) when peasant farmers were not around. Whereas, the farmers guarded the bean plantations, farms with other crops were

Table 3. Feeding records of food plants in the forest fragments and fields, Mbuzi, Tanzania.

Family	Food plant	Author(s)	Forests		Farms		Parts eaten
			F	%F	F	%F	
Chrysobalanaceae	[a]*Parinari excelsa*	Sabine	990	44.0	43	43.9	YL, LB
Mimosaceae	[a]*Newtonia buchananii*	Baker	335	14.9	6	6.1	YL, LB
Moraceae	[a]*Ficus thonningii*	Blume	299	13.3			YL, LB
Celastraceae	[a]*Catha edulis*	(Vahl) Forssk ex Endl	2	0.1			B
Sapotaceae	[a]*Chrysophyllum gorungosanum*	Engl.	204	9.1			YL, LB
Convolvulaceae	[c]*Ipomea ficifolia*	Lindl.	68	3.0	1	1.0	YL. LS
Mimosaceae	[a]*Albizia gummifera*	A. Sm	55	2.4			YL, LS
Fabaceae	[c]Phaseolus **sp.**	**(Herb. Linn)**	**0**	**0.0**	**39**	**39.8**	**SD**
Myrsinaceae	[a]*Rapanea melanophloeos*	(L.) Mez	34	1.5			B
Myrtaceae	[a]*Syzygium guineense*	Wall	34	1.5			YL
Parmeliaceae	[e]*Parmotrema* sp.		27	1.2			
Euphorbiaceae	[a]*Croton megalocarpus*	Del.	24	1.1			YL, B
Moraceae	[a]*Ficus natalensis*	Hochst.	22	1.0			LB
Araliaceae	[a]*Polyscias fulva*	(Hiern) Harms	19	0.8			LS, ML
Ebenaceae	[a]*Euclea divinorum*	(Hiern)	18	0.8			B, YL
Compositae	[c]*Crassocephalum vitellinum*	(Benth.) S. Moore	18	0.8			YL
Acanthaceae	[c]*Brillantaisia owariensis*	(P. Beauv)	12	0.5			YL
Araliaceae	[a]*Schefflera goetzenii*	(Harms)	11	0.5			LB
Boraginaceae	[a]*Ehretia amoena*	Klotzsch	11	0.5			YL
Agavaceae	[a]*Dracaena steudneri*	(Schweinf. ex Engl.)	3	0.1	7	7.1	L, YS
Cucurbitaceae	[c]*Momordica foetida*	Schumacher	9	0.4	1	1.0	YL
Parmeliaceae	[e]*Usnea* sp.		9	0.4			
Melianthaceae	[a]*Bersama abyssinica*	Fresen.	5	0.2			YL
Solanaceae	[c]*Solanum terminale*	Forssk.	5	0.2			YL
Rubiaceae	[a]*Tarenna graveolens*	(S.moore) Bremek	4	0.2			B, YL
Compositae	[b]*Vernonia amygdalina*	Del.	4	0.2			YL
	[d]Unidentified liana		4	0.2			L
Rubiaceae	[a]*Psychotria goetzei*	(K. Schum)	3	0.1			LB
Stilbaceae	[a]*Nuxia congesta*	R. Br. Ex Fresen	3	0.1			FR, Fl
Proteaceae	[a]*Faurea saligna*	Harv.	3	0.1			B
Anacardiaceae	[b]*Rhus natalensis*	Bemh. Ex Krauss	2	0.1			YL
Phytolaccaceae	[b]*Phytolacca dodecandra*	Vitten	2	0.1			YL, LB
Cacastraceae	[a]*Elaeodendron buchananii*	(Loes.) Loes.	2	0.1			YL
Meliaceae	[a]*Lepidotrichilia volkensii*	(Gürke) Leroy	2	0.1			YL
	[c]Unidentified herb		2	0.1			L
Myrsinaceae	[a]*Maesa lanceolata*	Forssk	1	0.04			YL
Rubiaceae	[a]*Hallea rubrostipulata*	(Schumann) Havil	1	0.04			YL
Rutaceae	[a]*Clausena anisata*	(Wild.) Hook.f.ex Benth	1	0.04			YL
Icacinaceae	[a]*Apodytes dimidiata*	C. A. Sm.	1	0.04			YL
Mimosaceae	[a]*Acacia tortilis*	Del.			1	1.0	YL
	Unidentified parasitic plant		1	0.04			

YL = Young leaves; ML= Mature leaves; LB= Leaf buds; LS= Leaf stalks; YS = Young shoots; L = Leaves; FR = Fruits; Fl = Flowers; SD = Seeds; B = Barks; F = Feeding records, %F = % feeding. Superscript a = tree; b = shrub; c = herb; d = liana; e = lichen.

Table 4. Overall selection ratios for trees in the forest and farms in Mbuzi, Tanzania.

Food plant	Forests				Farms			
	F	%F	%BA	SR	F	%F	%BA	SR
Parinari excelsa	990	47.5	45.5	1.0	43	75.4	45.1	1.7
Newtonia buchananii	335	16.1	9.5	1.7	6	10.5	6.8	1.5
Ficus thonningii	299	14.3	1.4	10.2				
Catha edulis	2	0.1	1.4	0.1				
Chrysophyllum gorungosanum	204	9.8	5.3	1.8				
Albizia gummifera	55	2.6	0.8	3.3				
Rapanea melanophloeos	34	1.6	2.3	0.7				
Syzygium guineense	34	1.6	5.2	0.3				
Croton megalocarpus	24	1.2	13.4	0.1				
Ficus natalensis	22	1.1	0.2	5.3				
Polyscias fulva	19	0.9						
Euclea divinorum	18	0.9	0.9	1.0				
Schefflera goetzenii	11	0.5						
Ehretia amoena	11	0.5	2.6	0.2				
Dracaena steudneri	3	0.1	0.3	0.5	7	12.3	4.3	2.9
Bersama abyssinica	5	0.2	3.5	0.1				
Tarenna graveolens	4	0.2						
Psychotria goetzei	3	0.1	2.3	0.1				
Nuxia congesta	3	0.1	3.5	0.0				
Faurea saligna	3	0.1	0.1	1.4				
Elaeodendron buchananii	2	0.1						
Lepidotrichilia volkensii	2	0.1	0.2	0.5				
Maesa lanceolata	1	0.05	1.7	0.03				
Hallea rubrostipulata	1	0.05						
Clausena anisata	1	0.05						
Acacia tortilis	0	0.0			1	1.8	1.34	1.3

F = Feeding records, %F = % feeding records; BA = Basal area of food tree n; SR = Selection ratio of food tree n.

Table 5. Density and basal area of food trees in forest fragments and farms, Mbuzi, Tanzania.

Forest fragments	Farms	Unpaired two-sample t test
447 trees/ha	123 trees/ha	t = 4.224; df = 28; P = 0.013
22 trees/plot	6 trees/plot	t = 2.997; df =28; P = 0.040
28.59 m²/ha	10.24 m²/ha	t = 4.200; df = 28; P = 0.014

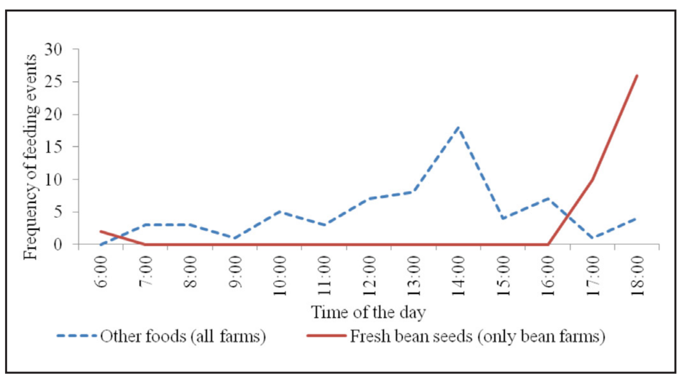

Figure 3. Bean crop raiding and other foods eaten with respect to times of the day (bean seeds were eaten only in bean farms). Other foods = food items other than bean seeds eaten in all farms with different crops such as maize, wheat, beans and sorghum, Mbuzi, Tanzania.

rarely guarded, and in those farms monkeys were seen to forage for wild foods and rest in the trees.

The monkeys were seen eating items of 36 identified higher plants, along with two lichens, and some herbs, a liana and a parasitic plant that we were unable to identify. The difference in feeding frequencies on wild species and the bean crop (*Phaseolus*) in the farms was significant ($\chi^2 = 4.082$; df = 1; P = 0.043). The most frequently eaten items in both forests and farmland were the young leaves and leaf buds of *Parinari excelsa* (Table 3). Despite having the most feeding records, *P. excelsa* trees had low selection ratios, possibly because of their highest basal area in both forests and farms. *Ficus thonningii, F. natalensis* and *Albizia gummifera* were mostly selected relative to their abundances in the forests, whereas *Dracaena steudneri* was selected more than expected from its abundance in farms (Table 4). The density and basal area of the trees providing food for monkeys were greater in the forest than in the farms (around the fields) (Table 5).

Discussion

Young leaves and leaf buds were predominant in the diet of the Ashy red colobus in the forest and the farmland. They spent more time feeding in the forest than the farmland, associated with a smaller basal area and lower density of wild food trees in farmland (Table 5). Some of the important food trees (for example, *P. excelsa*) have been reported as staple food plants for *P. tephrosceles* in Kibale National Park, Uganda (Isbell 2012). Some species in the diet had high selection ratios in the forest and were not found in the farms. Some tree species with a high selection ratio in farms (for example, *D. steudneri*) had low selection ratios in the forest. This indicates that they select certain food plant species based on accessibility, availability, abundance and nutritional content. Some species that were selected by monkeys were not abundant and some which were abundant scored low selection ratios despite their having a high number of feeding records. Mturi (1991) regarded the less eaten plant species to be ‘unpreferred’ when their selection ratios were less than one (1.0). However, even though ‘unpreferred’ they may still make up a significant portion of the diet. Mturi (1991) provided two explanations for this: (1) plant species exploited less than expected had selection ratios of less than one (1.0) but made up a significant portion of the diet just because they were abundant (for example *P. excelsa*); (2) they might not be ‘unpreferred’, but they were eaten less than expected from their abundance because they were highly abundant and there is a limit to the extent they could be eaten by the monkeys, either due simply to quantity or because of the need to diversify the diet for nutritional reasons. A number of studies have indicated that the plant species that are highly selected despite their low abundance, have a high protein content and low levels of secondary compounds (McKey and Gartlan 1981; Mturi 1991; Fashing *et al.* 2007; Chapman and Chapman 2002). Despite the observed variation in selection ratios of food trees, the conservation of all plant species in the forest is of paramount importance as it is possible that plants eaten less would contribute significantly to the diet of the monkeys for nutritional balance. The red colobus monkeys would occasionally go to the ground to feed on herbaceous vegetation and beans in the forest and farms, respectively.

Figure 4. Guides showing a skin of red colobus monkey killed on a bean farm, Mbuzi, Tanzania.

Crop raiding by the colobus monkeys was infrequent. Sympatric guenons such as the blue monkey (*Cercopithecus mitis*) also raid crops, but blame was usually directed towards the colobus monkeys, probably because the farmers were asked to preserve the forests as habitats specifically for the Endangered red colobus monkeys. Blue monkeys did not stay in the fragments surrounded by farms; they would move far off after feeding, while the red colobus monkeys would stay in the fragments, only raiding crops if there were no people around. The monkeys ate the beans and discarded the pods. Group 1 raided bean crops more than others; fragment A was surrounded by bean farms, whereas farms around the other fragments also cultivated maize, wheat and sorghum. Farmers cultivating beans guarded their crops. Those growing other crops rarely did so, and the monkeys could be seen foraging and resting in the trees on these farms near the edge of the forest.

The colobus monkeys raided bean crops in the evenings around 1700 h–1900 h (Fig. 3) after the farmers had left to go home (see also Strum 2010). The farmers tend to kill the monkeys with the help of dogs because of this behavior. During the preliminary surveys in July 2011, we found a skin of an adult red colobus placed in a tree near the forest to intimidate other monkeys not to raid crops (Fig. 4). Retaliatory killing of monkeys by farmers is believed to be one of the factors leading to the decline of red colobus in the Mbuzi Forest, and Struhsaker (2005) listed hunting as a major threat facing red colobus monkeys in their natural habitats. Exposure of colobus monkeys to parasites and pathogens at the forest-farm interface is possible, as reported by Chapman *et al.* (2006) in Kibale National Park.

Tentative explanations have been offered as to why *P. tephrosceles* feed on fresh bean seeds. Seeds are rich in fats, proteins, and minerals such as phosphorus, which are limiting to vegetarians (Janson and Chapman 1999). It is here argued that the monkeys feed on fresh beans owing to their digestibility, for supplementary protein, or because of reduced food availability due to ongoing forest fragmentation, degradation and destruction. All the four fragments occupied by the monkeys are extremely fragmented and degraded, as previously reported by Davenport *et al.* (2007). Although degradation was not quantified in this study, it is possible that it has drastically reduced the numbers of food trees for monkeys. Young leaves and flowers of the beans were also eaten by the monkeys.

Fragmentation processes continue to increasingly divide and isolate the forest fragments. Forest clearance is evidently aggravated by a lack of clarity as to forest ownership, creating conflicts among the farmers. The local government authority categorically orders that forests, which farmers believe to be their property, be preserved, in particular for the Endangered Ashy red colobus. Protracted disputes regarding ownership and infrequent patrols by the District Forestry and Wildlife Division result in the forests being divided up amongst the villagers. Other common challenges reported by Oates (2013) are evident in the Mbuzi Forest. It is possible that in many areas nothing or very little remains to support the monkeys; probably the reason for their decline in the Mbuzi Forest on the Ufipa Plateau of the Rukwa Region.

The continued existence of *P. tephrosceles* in the Mbuzi Forest will depend on the effective conservation of their remaining forest patches, addressing the causes of their deterioration and allowing them to recover. Conservation interventions should consider community conservation measures, the provision of adequate funding to local governments for effective law enforcement, and the settlement of forest ownership conflicts, and conservation education, as suggested by Oates (2013).

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