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Can we rely on forest reserves for primate conservation?

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Abstract

Tropical forests contain much of the world's biodiversity, yet their rate of decline is increasing. The strategy most frequently used to protect this biodiversity is to make parks and reserves. While there is a great deal of research on the effectiveness of parks for protecting biodiversity, there is little research on how well extractive reserves conserve biodiversity. Here, we evaluate the effectiveness of four forest reserves in western Uganda at maintaining populations of primates and compare census data from the reserves to data from the neighbouring well-protected Kibale National Park. The relative abundance of the five most common primates in the park was approximately four times that of the forest reserves. In the forest reserves, evidence of new human encroachment was seen every 500 m, while in the park it was seen every 100,000 m. Two recommendations emerge from our research: (i) for forest reserves, such as those studied here, to have conservation value for primates, extraction must be reduced and (ii) until the long-term viability of the populations in forest reserves can be ascertained, they should not be considered in estimates of the sizes of endangered species protected ranges.

Key words: bushmeat, extractive reserves, forest reserves, human encroachment, Kibale National Park, logging

Résumé

Les forêts tropicales abritent une grande partie de la diversité mondiale et pourtant, le rythme de leur déclin s'accélère. La stratégie la plus souvent utilisée pour protéger la biodiversité est de créer des parcs et des réserves. S'il existe de nombreuses recherches sur l'efficacité des parcs pour protéger la biodiversité, il y en a peu sur celle des réserves extractives à préserver la biodiversité. Nous avons évalué ici l'efficacité de quatre réserves forestières de l'ouest de l'Ouganda pour préserver des populations de primates et nous comparons les données des recensements des réserves à celles du très protégé Parc National de Kibale voisin. L'abondance relative des cinq primates les plus communs du parc était à peu près cinq fois celle observée dans les réserves. Dans les réserves forestières, on observait de signes de nouveaux envahissements humains tous les 500 m, alors que dans le parc, c'était tous les 100,000 m. Deux recommandations ressortent de notre recherche: (i) pour des réserves forestières comme celles qui sont étudiées ici, il faut réduire les extractions pour avoir encore une valeur de conservation pour les primates et (ii) tant que la viabilité à long terme des populations vivant dans les réserves forestières ne peut pas être assurée, ces forêts ne devraient pas être comptabilisées dans les estimations de la surface protégée de l'aire de répartition des espèces menacées en danger.

Introduction

Tropical forests are thought to support 60% of all known species (Laurance, 1999; Dirzo & Raven, 2003), yet they represent only 7% of the land area (Bradshaw, Sodhi & Brook, 2009). Despite this, approximately 2.3 million km^2 of forest was lost globally between 2000 and 2012 and only 0.8 million km^2 was gained (Hansen *et al.*, 2013); this loss is just larger than the area of Mexico and approximately the size of the Democratic Republic of Congo. Most importantly for concerns over biodiversity, the rate of decline in tropical forest increased by 2101 km^2 per year during this time (Hansen *et al.*, 2013). This hits primates particularly hard as 80 to 90% of all primate species are found in tropical forests (Struhsaker, 1997; Mittermeier *et al.*, 2009), and deforestation will also have cascading effects because primates play an integral role in the ecology of maintaining and modifying their habitats

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(Chapman, 1989; Estrada & Coates-Estrada, 1996; Chaves *et al.*, 2011; Chapman *et al.*, 2013a). This loss is partially due to the fact that cropland in tropical countries expanded by 48,000 km^2 per year between 1999 and 2008, largely at the expense of forest (Phalan *et al.*, 2013). The situation is made much worse because in many countries primates are hunted and even low levels of extraction can have devastating effects for long-lived, slow reproducing species such as primates. For example, in a protected area where human population density was low (*c.*1 person per km^2) and enforcement of hunting laws was active, hunting reduced monkey density by 30% (Poulsen, Clark & Bolker, 2011).

In Uganda, the country of this study, the situation is critical. Closed-canopy tropical forest once covered 20% of the country, but deforestation reduced this to just 3% (Howard *et al.*, 2000). Furthermore, Uganda lost 18% of its remaining forest between 1990 and 2000 (Howard *et al.*, 2000), and the most recent estimate suggests that the annual rate of loss of tropical high forest is 7% (Pomeroy & Tushabe, 2004).

The question becomes, where are primates protected? Unfortunately, with a few exceptions, evidence suggests that primates gradually die out in unprotected fragmented landscapes around the globe (Nijman, 2013 – Indonesia, Aggimarangsee, 2013 – Thailand, Chalise, 2013 – Nepal). For example, Chapman *et al.* (2013b) studied 20 unprotected fragments containing five species of primates near Kibale National Park, Uganda, and documented an 81% decline in fragment occupancy in over just 15 years. Thus, the primary approach used to conserve forests and the primates the forests support has been the establishment of protected areas. Unfortunately, such areas are vulnerable to anthropogenic pressures (Bruner *et al.*, 2001). Protected areas are generally effective at preventing land clearing, but are less effective at preventing logging, human-created fire, cattle grazing and bushmeat hunting (Bruner *et al.*, 2001; Naughton, Alix-Garcia & Chapman, 2011), which typically are initiated by members of nearby communities (West, Igoe & Brockington, 2006; Hartter, Goldman & Southworth, 2011). There is a great deal of research concerning the effectiveness of national parks for protecting primates (Mugume, 2003; Wanyama *et al.*, 2009; Chapman *et al.*, 2010b), but much less research on the effectiveness of forest reserves at protecting primates and biodiversity in general (Plumptre & Reynolds, 1994; Fashing & Cords, 2000). Forest reserves form a large percentage of protected tropical forests are typically considered in estimates of remaining forest and primate habitat (Harcourt & Doherty, 2005, Chapman, Lawes & Eeley, 2006; FAO, 2010, 2012) and are often assumed to be an effective means of protecting primate populations (Plumptre & Reynolds, 1994). Is this assumption generally valid?

In the case of Uganda, as in many countries, most forest reserves are small and are increasingly becoming isolated as they are surrounded by expanding of agricultural activities (Naughton-Treves, 1997; Baranga, 2004; Hartter, 2010). Within these forests, human activities (charcoal burning, pole cutting, firewood collection, hunting and timber cutting) are ongoing (Pomeroy & Tushabe, 2004; Naughton, Kammen & Chapman, 2006). Some of these activities are legally sanctioned, while others are not (Howard *et al.*, 2000), but they all typically lead to habitat loss for the primates. The last biodiversity inventory conducted in 1996 showed that various species of primates like red colobus (*Procolobus rufomitratus),* black and white colobus *(Colobus guereza)*, blue monkey (*Cercopithecus mitis*), redtail monkeys *(Cercopithecus ascanius),* L'hoest's monkey (*Cercopithecus lhoesti*) and grey-checked mangabey *(Lophocebus albigena*) still existed in many of these forest reserves (Uganda, 1996). However, some forest reserves have been cleared in the last decade (Masette *et al.*, In Press), and all have suffered increasing degradation.

The objective of this study was to begin to address this research gap by evaluating the effectiveness of four forest reserves in western Uganda at maintaining primate populations. Reserves were selected as a function of size, surrounding human population density and the adjacent agricultural activities. The fragments were all close to the well-protected Kibale National Park, and as the primates of Kibale are well-studied (Struhsaker & Leland, 1979; Chapman, Struhsaker & Lambert, 2005b; Lwanga *et al.*, 2011), there existed a baseline for comparison to an assumed control, an assumption that we evaluate.

Methods

Study areas

The study was conducted in four forest reserves in western Uganda (Matiiri, Itwara, Kibego and Buhungiro; Fig. 1) from September 2008 to April 2010. These forests are remnants of extensive forests that once covered most of the western arm of the East African Rift Valley (Hamilton, 1974, 1984) from western Uganda to the Kenyan border

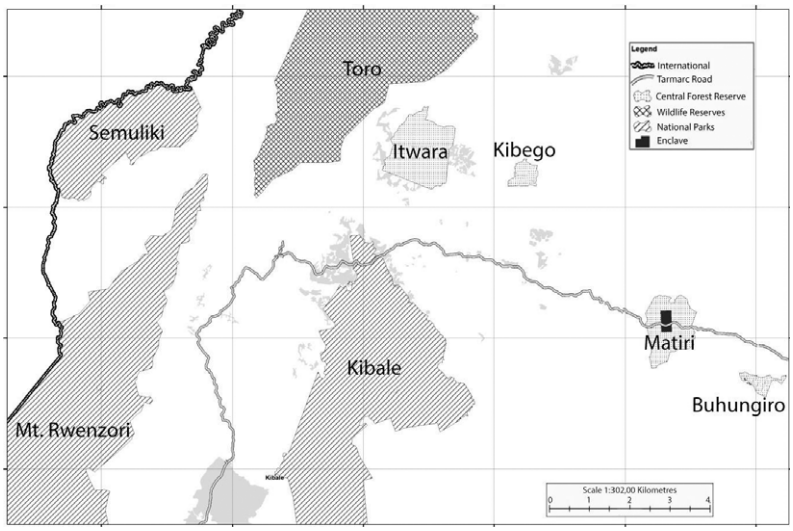

Fig 1 Location map of the four forest reserves showing other major conservation areas and surrounding human activities

and beyond; but because of increased human settlement and agricultural practices, deforestation occurred rapidly and only forest fragments remain. Of the fragments selected for study, Matiiri (64 km^2) and Itwara (84 km^2) are larger than Kibego (12 km^2) and Buhungiro (8 km^2). Itwara and Kibego are surrounded by high human population density (172–199 people per km^2), while Matiiri and Buhungiro are surrounded by slightly lower population density (95–117 people per km^2 (Uganda, 2002). Human activities around the forests also differ; Kibego and Itwara are primarily surrounded by large tea plantations, while Matiiri and Buhungiro are surrounded by subsistence farming (Uganda, 1996, 2000, Uganda, 2002). All forest reserves are managed by Uganda National Forest Authority which allows some human activities alongside conservation (Naughton-Treves, 1999; Uganda, 2001; Plumptre, Cox & Mugume, 2003, Isabirye-Basuta, 2013). Primate density and human encroachment in the four fragments are compared to the neighbouring Kibale National Park, a 795 km^2 area composed predominantly of mature moist semi-deciduous and evergreen forest, but also including a variety of other habitats such as grassland, woodland, lakes, wetland and colonizing forest (Chapman & Lambert, 2000; Omeja *et al.*, 2011). Until 1993, Kibale was a forest reserve and in the northern quarter was divided into compartments that were subjected to varying degrees of logging (Chapman *et al.*, 2010a; Omeja *et al.*, 2012). In 1993, the area was declared a national park, extraction was halted, and the level of protection increased. In the *c.* 20 years since the area became a national park, some primate populations have increased over sixfold (Chapman *et al.*, 2010b).

Data collection

Primates were counted along transects using standard line transect census method (National Research Council, 1981; Chapman *et al.*, 2010b), which are thought to be appropriate for estimating densities of large-bodied diurnal species such as these (National Research Council, 1981). When a social group was sighted, a quick count was made of the total number of noninfants in the group. This should be considered a crude minimum estimate of group size as it is both difficult to count primate groups quickly during a census (Gogarten *et al.*, 2015) and these are unhabituated animals that often move away from the observer. We express relative abundance of primates following a number of recent methodological studies demonstrating this as an appropriate method under conditions where animals are observed in dense vegetation, directly above the transect line (Chapman, Fedigan & Fedigan, 1988; Teelen, 2007; Hassel-Finnegan *et al.*, 2008; Chapman *et al.*, 2010b; Lwanga *et al.*, 2011).

By necessity, the number of transects and their total length varied as a function of the size of the reserve (Itwara, n = 6, 37.3 km; Matiiri n = 5, 25 km; Kibego

n = 3, 8.5 km; Buhungiro n = 3, 5.5 km). Transects were located at most 2 km apart and were sampled between 8 am and 12 pm and between 3 pm and 7 pm (Mugume, 2003) once a month for the first 8 months and then twice a month for the next 12 months. Samples from the same day were averaged. In addition, all visible signs of primates, such as dung and foot prints, were identified and mapped using a GPS, but as species identity could not always be assured to 100% certainty from such signs, this information was not used in the analysis, but is discussed. Canopy cover preference was assessed every 100 m using a densiometer to relate average percentage canopy cover for each transect and primate encounter rate.

It is unusual to actually observe humans actively engaged in illegal activities within a protected forest (Porter-Bolland *et al.*, 2012); thus, indirect signs such as pole cuttings, tree stumps, gardens, signs of hunting and charcoal burning were used as indices of human disturbance. Data on these signs were recorded along each transect. Particular care was taken not to record the same sign on subsequent sampling of the transect.

Data analysis

Primate abundance was expressed as the number of social groups seen per km transect. Human disturbance was expressed as the number of new signs per kilometre of transect. The relationship between human activities and primate distribution was performed by Kendall's relationship test. Kendall's correlation coefficient was used to test the relationship between relative primate abundance and percentage canopy cover.

Results

The presence of each primate species, their relative abundance (if present) and the estimate of the minimum size of the social group are presented in Table 1. Only Itwara had all of the five common species found in Kibale National Park, while the others had between one and three species. Black and white colobus occurred in all forest reserves and had similar group sizes. Kibale has 13 primate species (Chapman *et al.*, 2000). As the rarely seen species were never seen in the forest reserves, this seems reasonable to assume they were absent, and, thus the forest reserves have a reduced species richness (nocturnal species were not assessed here, and three nocturnal primates are found in Kibale).

Human activities included charcoal burning, gardening, grazing, hunting, pitsawing and pole cutting (Table 2). Charcoal burning was not seen in Buhungiro, while gardens were only seen in Matiiri and Buhungiro. There was no significant difference between the encounter rates of pitsawing, pole cutting, hunting and grazing among the four forest reserves (Kruskal–Wallis N = 20, $P = 0.457$ for all cases).

Analysis among transect samples revealed that in Kibego, there was a positive correlation between numbers of black and white colobus and numbers of poles cut (Kendall; $P = 0.015$, N = 20). At Matiiri, there was a positive correlation between number of black and white colobus with grazing (Kendall; $P = 0.026$, N = 20). Similarly, in Buhungiro, there was a positive correlation between number of black and white colobus and gardening and grazing (Kendall; $P = 0.043$, N = 20 and Kendall;

Table 1 Relative primate abundance (No. of groups per km) and average group size in four forest reserves and Kibale National Park in western Uganda

Primate species	Estimate	Itwara	Kibego	Matiiri	Buhungiro	Kibale NP*
Blue monkey	Relative abundance	0.039	0	0	0	0.09
(*Cercopithecus mitis*)	Average group size	3.2				10.4
Black and white colobus	Relative abundance	0.10	0.30	0.19	0.31	0.15
(Colobus guereza)	Average group size	3.09	3.19	3.18	3.22	7.7
Mangabey	Relative abundance	0.02	0	0	0	0.09
(Lophocebus albigena)	Average group size	3.16				19
Redtail monkey	Relative abundance	0.13	0.03	0	0	0.31
(Cercopithecus ascanius)	Average group size	4.97	4.10	<40	0.0	21.1
Red Colobus	Relative abundance	0.0034.75	00	0.0023.5	00	0.5652.1
(Procolobus rufomitratus)	Average group size					

*Chapman unpublished data/data on group size from Gogarten *et al.* 2015.

Table 2 Encounter rate of signs of human activities of different types (#/km of transect) found in four forest reserves and Kibale National Park (K 30 forestry compartment) in western Uganda

	Buhungiro	Itwara	Kibego	Matiiri	Kibale NP
Charcoal processing	0.000	0.013	0.006	0.025	0
Gardening	0.096	0.000	0.000	0.014	0
Grazing	0.297	0.001	0.056	0.273	0
Hunting	0.010	0.038	0.050	0.025	0.01
Other human activities	0.211	0.083	0.285	0.115	0
Pitsawing	0.019	0.008	0.025	0.031	0
Pole cutting	0.038	0.013	0.235	0.041	0
Total signs	0.670	0.156	0.656	0.513	0.01

$P = 0.001$, N = 20; respectively). Also in Itwara, there was a positive correlation between number of black and white colobus with pitsawing (Kendall $P = 0.034$, N = 20). This likely reflects the previously reported ability of black and white colobus to do well in secondary forests (Oates, 1974; Struhsaker & Oates, 1975). For mangabeys ($P = 0.050$, N = 20) and redtail monkeys (Kendall; $P = 0.050$, N = 20), there were positive correlations among transects at Itwara between relative abundance of groups and hunting, which may reflect hunters being more active in habitats monkeys prefer.

Percentage canopy cover represents both aspects of the habitat (e.g. swamp forest has little canopy cover) and forest disturbance, typically caused by human activities. For redtail monkeys, there was a positive correlation between their relative abundance and percentage canopy cover (Kendall correlation redtail 0.47, $P = 0.01$), but not for the other species (black and white colobus -0.23. $P = 0.20$, blue monkeys 0.16, $P = 0.41$, mangabeys 0.21, $P = 0.28$; n = 18 in all cases).

Discussion

Primate species one would expect to be present in the forest reserves, based on their presence in the neighbouring Kibale National Park, were often absent in the forest reserves. Furthermore, the relative abundance of the primates present in the forest reserves was much lower than that found in Kibale (Chapman *et al.*, 2010b). The overall relative abundance of primates in Kibale was 1.2 groups per kilometre of transect walked, while the average of this parameter among the forest fragments was 0.28. Thus, the park has over 4 times the relative abundance of primates than forest reserves. It is likely that this difference is a result of the increased human disturbance in the forest reserves. Forest disturbance in the form of pitsawing, pole cutting, charcoal burning and gardening influences primate populations by opening forest canopy, removing potential food trees and making movement of social groups difficult. Hunting has the obvious impact of directly removing individuals from the population. In the forest reserves, evidence of human activities was seen every 500 m of transect walked, while in Kibale National Park, they were seen every 100,000 m, a 200 times difference.

There was no evidence to support the idea that larger forest reserves (Itwara and Matiiri) supported greater primate relative abundance and had less human disturbance than smaller forest reserves (Buhungiro and Kibego). And while the large Itwara Forest Reserve supported five primate species, the large Matiiri Forest Reserve supported a similar species richness as the small forest reserves, indicating that size is not the only factor influencing the richness of the primate community that a forest reserve will support. This supposition is supported by Marshall *et al.* (2010) that documented that forest area in the forest fragments of the Udzungwa Mountains of Tanzania was correlated with other factors such as elevation range and annual moisture index. Further, these authors quantify that species–area relationships are weaker for fragment sizes below 12–40 km^2 and suggest that for small fragments, they may not be reliable for estimating forest monkey richness. Itwara also had fewer signs of human activity. Also the fact that Itwara and Kibego, which are surrounded by relatively high human population, were found to be very similar in terms of illegal human activity and primate abundance as Matiiri and Buhungiro, which are surrounded by a low human population, indicate that human populations around the forest do not necessarily affect primate status and human activity within a forest reserve.

Black and white colobus were by far the most common primate species in the forest reserves, which is not surprising given previous studies showing that they can survive in highly degraded forest environments (Oates, 1974; Struhsaker & Oates, 1975; Chapman & Onderdonk, 1998). Both Itwara and Matiiri had populations of the endangered Ugandan red colobus. The social groups of this species were rare (an estimated 3–5 groups per forest) and each had very few individuals (2–5 individuals; Table 1). These low numbers suggest that these populations are not likely to survive over the long term. In the Matiiri Forest Reserve, only a few social groups of redtail monkeys were seen and not during the census, similarly suggesting that this species will likely not survive for long.

We quantified that forest reserves are experiencing high levels of human activities, and evidence suggests that these activities are extremely damaging to all primate species studied with the exception of black and white colobus. Over the long term, only the largest forest reserve may be able to support populations of the other four species, but their population numbers may be so low that they may not be genetically viable (Lande, 1995) or they may be very susceptible to extinction from disease (Young, 1994; Chapman, Gillespie & Goldberg, 2005a; Chapman *et al.*, 2015). Based on this research, two recommendations emerge. First, if such small and isolated forest reserves are to be of value for sustaining primate populations, their conservation status must be raised, extraction reduced and illegal hunting stopped. Second, at the present time, populations in some such forest reserves should not be considered in estimates of the sizes of endangered species populations as they are unlikely to be viable.

From a broader perspective, it seems likely that without being classified as a forest reserve, these areas would have been clear-cut long ago. Thus, there would be no primates or other animals in these areas, so these forest reserves are providing a valuable function, just one that is not as effective as might be desired for conservation efforts. Previously in Uganda, a number of forest reserves have had their protective status upgraded to that of national parks (e.g. Kibale, Rwenzori, Semliki and Bwindi). A positive action that could be made would be to do biodiversity inventories of the existing forest reserves, as was done here and more extensively by Davenport, Nowak & Perkin (2014) for Tanzania (see also the old inventory for Uganda by Howard, 1991). With this information in hand, conservation groups could advocate to the government that specifically important forest reserves be upgraded to the status of national parks or receive additional funds and protection. With respect to the forest reserves surveyed here, Itwara would seem a logical area to receive added protection, given its size, the richness of the primate community, its proximity to Kibale and the possibility of establishing a corridor between Itwara Forest Reserve and Kibale National Park.

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