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Awareness, Habitats and Population Status of the Endangered *Rungwecebus kipunji* in Mt. Rungwe Nature Reserve, Tanzania

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ABSTRACT

The Mount Rungwe Nature Reserve in Tanzania is a significant ecological area that protects the endangered Rungwecebus kipunji. The goal of the study was to analyze the ecological habitat and population of R. kipunji in Mount Rungwe Nature Reserve. During our study, we recorded 412 (mean: 41.2 ± S.E: 5.7) R. kipunji individuals in the reserve. The R. kipunji population was found in a comparatively low abundance at sites with a significant number of anthropogenic activities. Human activities were observed to occur less frequently (χ^2 = 40.76, p = 0.0001) inside the nature reserve (n = 33, 17.19%) than outside and/or along the border zones (n = 159, 82.81%). Respectively, the peeling of tree bark and firewood collection were the most common anthropogenic indicators found inside and outside the forest reserve. We also found that >40% of male and > 30% of female respondents were aware of R. kipunji's presence. We found that 30% of female and 32% of male respondents had previously received conservation education. In comparison to other age groups, >25% of respondents aged > 45 years old claimed to have already learned about R. kipunji. Furthermore, 48% of the respondents claimed that Mount Rungwe Nature Reserve helps them live by providing fuelwood and building materials. People aged 31–43 and > 43 years old collect fuelwood and building materials, respectively, while those under 31 years old collect food resources. In summary, our findings imply that, to improve R. kipunji, local residents surrounding the forest reserve should be made aware of the species to reduce anthropogenic activities within and along the reserve's buffer zones. Thus, our findings suggest that the R. kipunji populations and habitat quality in Mount Rungwe Nature Reserve could be used as a benchmark for the conservation of other endangered species elsewhere.

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1. Introduction

Loss of ecological habitat suitability as a result of human activities is the greatest threat facing biodiversity conservation (Brooks et al. 2002). Habitat loss and alteration influence the floral composition and structure of the forests and, hence, negatively affect wildlife conservation. It is known that suitable habitats and connectivity between them define wildlife habitat quality, given its importance to wildlife diet. Thus, primate populations living in fragmented landscapes are endangered by the loss of connectivity between suitable habitats and loss of vegetation cover (Bonnin et al. 2020). Primates, like other mammal species, exhibit dispersal behaviour (Armitage et al., 2011). Dispersal behaviour is one of the most important aspects of population dynamics and gene flow (Armitage et al., 2011). Habitat fragmentation because of loss of connectivity among suitable habitats affects primates' conservation, and, thus, their populations. For instance, Eriksson et al. (2004) reported the gene flow and overall genetic diversity of great apes to be affected by barriers impeding their dispersal. Equally, habitat loss, degradation, and fragmentation can have similar effects because they lead to reduced potential for dispersal and movement of large-bodied mammals (Piel et al., 2017), particularly when the distance between patches becomes larger (Stamps et al., 2005). When there is less or no dispersal between populations, the population's genetic and evolutionary potential can be compromised (Walker and Pusey, 2020).

Moreover, this can affect the long-term persistence of populations and increase the risk of local extinction. Effective conservation and management of primates depend on how accurately we assess and monitor their population distribution and the challenges affecting species persistence. Many primate populations across Africa are dwindling primarily due to human activities in their habitats (Jones et al., 2005). The human-induced alterations in conserved areas have caused large changes in land use and land cover patterns. Studies on how human-induced changes in primate habitats affect primates have been conducted. For instance, Maijo et al. (2020) showed that severe anthropogenic disturbances in the Masito–Ugalla ecosystem, influenced the loss of chimpanzee plant food species. He also revealed that anthropogenic disturbance in the Masito–Ugalla ecosystem has negatively influenced chimpanzee habitat use, a relationship that threatens the persistence of chimpanzee populations living outside national parks (Maijo et al., 2020). Moreover, anthropogenic disturbance was also found to affect the density of arboreal primate species in the Udzungwa Mountains of Tanzania and negatively affected primate density (Cavada et al., 2019). Similarly, anthropogenic disturbance in Kibale National Park in Uganda was found to affect the abundance and group size of red colobus and red-tailed guenon (Chapman and Chapman, 2000).

While studies on other primate species have been conducted, few studies on *Rungwecebus kipunji* have been conducted. *Rungwecebus kipunji* is an endangered species of Old-World monkey (Davenport et al., 2006; Davenport et al., 2008, 2014) and endemic to Tanzania. It is found in both the Rungwe–Livingstone Forest in the Southern Highlands and the Ndundulu Forest Reserve in the south-west of Tanzania (Davenport et al., 2006; Davenport et al., 2008). *Rungwecebus kipunji* exhibits both arboreal and foraging behavior (Jones et al., 2005; Davenport et al., 2006). An increasing rate of human encroachment in the Mount Rungwe Nature Reserve (MRNR) and along its buffer zones threatens the survival of *R. kipunji*. The destruction and fragmentation of forest structure are the most serious threats to *R. kipunji* populations and MRNR ecosystem health (Davenport et al., 2006).

The population of *R. kipunji* is subjected to isolated subpopulations following the loss of the forest corridor that joins MRNR and Mt. Livingstone (Davenport et al., 2006). The loss of the corridor has made the MRNR and Mt. Livingstone *R. Kipunji* populations fragmented a situation that further threatens their populations (Davenport et al., 2006; Davenport et al., 2008). The first assessment of the population status, distribution, and conservation status of *R. Kipunji* was conducted in the Southern Highlands forests and Udzungwa Mountains of southern Tanzania (Davenport et al.,

2008). It was found that the management actions in these areas were not effective (Davenport et al., 2006; Davenport et al., 2008). Several factors, i.e., forest degradation, hunting, and predation on *R. kipunji* by crowned eagles, contribute to the decline of *R. kipunji's* abundance. The current rates of forest degradation and loss, especially through logging and charcoal production, remain unabated and could lead to the local extinction of the MRNR and *R. kipunji* populations. Human activities decrease habitat suitability and accelerate habitat fragmentation.

Thus, the primary goal of our study was to assess the awareness, habitat, and population status of the endangered *R. kipunji* in MRNR. Thus, we report on the population and habitat status of the species and the usefulness of this information in implementing effective management and conservation education to improve ecological habitats and ultimately reduce the species' extinction risk. In addition, we report on the assessment of *R. kipunji* ecological habitat condition and the identification of anthropogenic factors threatening its habitats in MRNR.

2. Materials and Methodology

2.1. Description of the study area

The research was carried out at Tanzania's Mount Rungwe Nature Reserve (MRNR) in the Mbeya region. It receives the most rainfall from November to April, while frosts are common from June to August. The MRNR is rich in biodiversity and is a significant ecological area that protects endangered and rare species (Mwakosya and Mligo, 2014). It is situated in the Rungwe district (9o03 9o12 S and 33o35 33o45 E, with a total area of 13652.1 ha) (Davenport et al., 2008; Mwakosya and Mligo, 2014). It supplies native biota with macro-and microhabitats and ecological benefits to local communities. MRNR's three main vegetation types are: montane woodland, bushed grassland, and bamboo belt. Some of the common trees include *Aphloia theiformis, Albizia gummifera, Bersama abyssinica, Ficalhoa laurifolia, Maesa lanceolata*, and *Schefflera goetzenii*. The *kipunji* (*Rungwecebus kipunji*) and the Rungwe Galago (*Paragalago* sp) are two of the world's twenty–five endangered and rare primates that live in the forest (Davenportet al., 2006; Davenportet al., 2008, 2014). Other animals found in MRNR include the Abbott's duiker (*Cephalophus spadix*), a very rare and vulnerable antelope, as well as numerous species of bush babies, chameleons, lizards, frogs, fish, and invertebrates. The MRNR is also an important water tower in the region, providing water to numerous communities and towns in the Mbeya, Rungwe, and Kyela districts for domestic, agricultural, and industrial usage. It also serves as a catchment area for important rivers and streams.

2.2. *Field* surveys and data collection

Field surveys were conducted between November 2020 and June 2021 in the MRNR to study the population and habitat status of *R. kipunji*, as well as any possible threats from human activity (Fig 1a). For each month, this was done three times per week. Complete count methods were used to determine the population of *R. kipunji* (Davenportet al., 2008). The method is largely regarded as the most accurate primate census technique. Survey sites were selected based on earlier research (Davenport et al., 2006; Mwakosya and Mligo, 2014), and interviews or talks with locals, and MRNR employees. Each day, new places were surveyed, and some sites were revisited if there were a lot of fruiting trees and other primates. Between 08.30 a.m. and 18.30 p.m., each team of three people walked carefully and quietly while checking the understory and canopy. Observers located and tracked *R. kipunji* group and counted all individuals in the group using direct observations (Fig 1b). They followed the *R. kipunji* group at a distance of 20–50 m to reduce stress on the group while also allowing the observer to retain contact (Davenportet al., 2008). Only one observer per team counted individuals of *R. kipunji*. A Garmin etrex 20 was used to record the GPS locations for each *R. kipunji* group.

Figure1

(a) Field Team in MRNR Counting the Number of (b) R. kipunji and (c) Focus Group Discussion to Assess People's Awareness and Perception about R. kipunji

2.3 Assessing R. kipunji ecological habitats

The particle Between November 2020 and January 2021, the ecological habitat condition of *R. kipunji* in the reserve was assessed. Human activities that interfered with the native habitats of *R. kipunji* were used to quantify anthropogenic disturbances (Maijo et al., 2020; Morgan et al., 2018). We employed direct field observations to record the type and frequency of human activity that is thought to have an impact on the MRNR ecosystem's health (Maijo et al., 2020). Every five days each week, the survey was done along several 500 m transects. Six plots (20 m x 50 m) were built to record signs of anthropogenic disturbances such as grazing, charcoal production, farming, and fire occurrences along the transect line and inside each plot. In addition, we assessed habitat conditions for the areas bordering the nature reserve, i.e., ca. 20 m away from the MRNR. Different human activities were recorded based on visible signs, for instance, burnt vegetation, fuelwood collection, cut down trees, livestock, settlements, farms, and logging. Agricultural activity was determined based on the presence of cultivated fields or farms, and areas

cleared for cultivation near the border zones. Moreover, visible livestock herds, dung or droppings, and their footprints represented livestock grazing.

2.4 Assessing the awareness of local people about R. kipunji

We conducted focus group discussions and interviews to assess local people's knowledge concerning *R. kipunji* and its conservation status (Fig. 1c). In the villages of Bujingijira, Malambo, Ngalikali, Kibisi, Syukula, and Ilolo, data was collected from 225 respondents. They were selected if they had lived in the village for > 10 years and were aged ≥ 18 years old. The respondents were asked a variety of questions: (i) Do you know what *kipunji* is? (ii) Have you ever received education in your village about k*ipunji* conservation? (iii) How does MRNR assist you in making a living? (iv) Is*R. kipunji* endangering your livelihood by eating or destroying your crops, and (v) Is *R. kipunji* killed in retaliation for agricultural destruction? To enable the respondents to recognize the species and respond to the questions that were asked, we showed them a poster with a colored *R. kipunji* picture.

2.5 Data processing

Excel was used to process the data collected. Using Yates' Chi-Square test, the frequencies of human activities inside and outside MRNR (i.e., ca.20 m away from the border zone) were compared. A disturbed site had a higher than 10% frequency of occurrence of human activities, whereas a slightly disturbed site had fewer records (5–9% frequency of occurrence). Mildly disturbed sites were also defined as those with a frequency of human activity of less than 5%.

3. Results and Discussion

3.1. R. kipunji population status and ecological habitat

A total of 412 (mean: 41.2 ± S.E: 5.7) *R. Kipunji* individuals and ten groups were recorded in MRNR during our study. A high abundance of *R. kipunji* was recorded inside the MRNR, i.e., in Syukula (16.75%), Bujingijila (14.56%), Ilolo (14.08%) and Kibisi (13.11%) villages (Table 1). These areas were insignificantly disturbed, i.e., they had very few anthropogenic activities. Sites with a high number of anthropogenic activities (i.e., disturbed areas) had a relatively low abundance of *R. kipunji* (Table 1). This indicates that human activities and associated disturbances negatively affect the *R. kipunji* populations (Zhao et al., 2018). This is because they interfere with the native habitats used by *R. kipunji* for roosting, feeding, and raising their young (Davenport et al., 2008; Mwakosya and Mligo, 2014). Moreover, anthropogenic deeds may *alter R. kipunji's* diurnal activities, including foraging, physiological, and reproductive behaviour (Chowdhury et al., 2020). Since the species is endangered and its population is limited in the southern highlands' MRNR (Jones et al., 2005), protecting it is essential. However, to ensure the conservation of *R. kipunji*, we suggest that the current population status may be used as a baseline data for implementing conservation actions.

Table 1
Rungwecebus kipunji Population and Habitat Status within and near MRNR Border Zones

Site (village)	Abundance	Relative abundance	Habitat status	
			Inside MNFR	Near MRNR border zones
Mkukwa	31	7.52	Somewhat disturbed	Disturbed
Mpata	18	4.37	Somewhat disturbed	Less disturbed
Ngalikali	26	6.31	Somewhat disturbed	Less disturbed
Kibisi	54	13.11	Mildly disturbed	Less disturbed
Mbeghele	39	9.47	Mildly disturbed	Somewhat disturbed
Ilolo	58	14.08	Mildly disturbed	Disturbed
Ndala	21	5.10	Somewhat disturbed	Disturbed
Bujingijira	60	14.56	Mildly disturbed	Less disturbed
Syukula	69	16.75	Mildly disturbed	Somewhat disturbed
Malambo	36	8.74	Mildly disturbed	Less disturbed

We also found that the occurrence frequency of human activities inside MRNR was less (n = 33, 17.19%) compared to outside or at the border zones (n = 159, 82.81%) ($\chi^2_{(10, N = 12)} = 40.76$, $p < 0.0001$) (Table 2). The anthropogenic sign occurrence frequencies recorded during our study differed significantly between inside and outside the MRNR ($\chi^2_{(10, N = 12)} = 40.76$, $p < 0.0001$). The most frequent anthropogenic signs recorded from both inside and outside the nature reserve were the peeling of tree barks inside the reserve and the collection of firewood outside the reserve. This reveals that local people encroach on the forest reserve to remove tree backs for remedies and collect fuelwood for domestic use.

Overall, fewer signs of human activity were recorded inside MRNR compared to outside areas surrounding MRNR border zones (Table 2). The areas located outside (i.e., the nearby MRNR buffer zones) experience more disturbances from human activities. This is because these areas are communal lands, and so they are less managed. Thus, if these areas are not protected, ongoing anthropogenic activities could enter into the nature reserve and lead to a serious negative impact on the *R. kipunji* population. Figure 2 shows the location of *R. kipunji* in MRNR that was recorded during our study.

In addition, we found traces of cattle grazing inside the MRNR (Table 2), indicating that livestock occasionally feed in the reserve. More signs of cattle grazing were discovered near the MRNR boundary zones. Allowing animals to graze near MRNR boundary zones could extend unlawful grazing in the core nature reserve and affect the *R. kipunji* natural ecosystem. It could also result in fragmentation and decreased resource patches and food availability for *R. Kipunji* (i.e., fruit, seeds, leaves, tree barks, lichen, moss, and invertebrates) (Davenport et al., 2006). Change in the nature reserve's biological integrity could eventually have a greater impact on the distribution (Mugume et al., 2015) and diurnal behaviour (i.e., feeding, rooting, and reproductive behaviour) of the species (Chowdhury et al., 2020; Maijo et al., 2020; Zhao et al., 2018).

Figure 2

A Map Showing the Location of R. kipunji in the Mount Rungwe Nature Forest Reserve

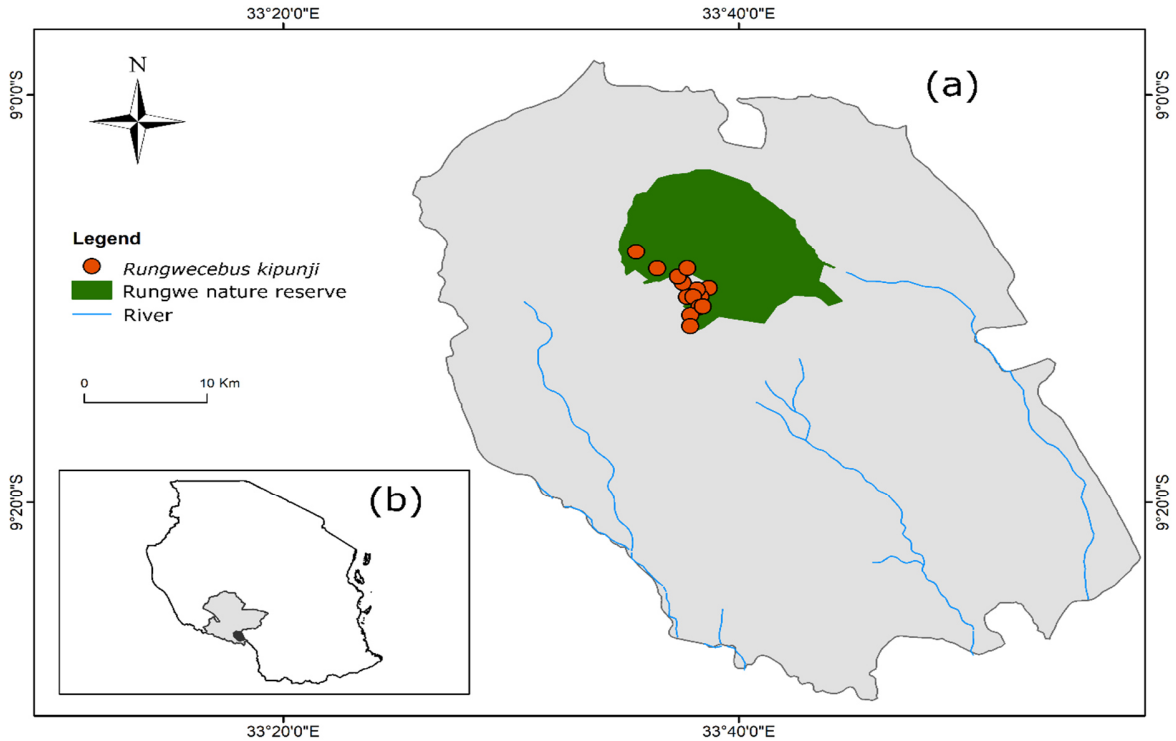


Table 2

The Frequency with Which Human Activities Occur both Inside and Outside the Nature Reserve

Human activities	Signs	Occurrence frequency	
		Inside MRNR	Near MRNR border zones
Fire	Burnt vegetation	0	4
Livestock grazing	Cattle herds	0	3
	Footprints	2	24
	Dungs	6	29
	Cleared areas for farming	0	11
Agriculture	Cultivated fields	0	17
Logging	Logging sites	0	0
	Cut logs or tree cut down	5	12
Fuelwood collection	Charcoal production	0	3
	Collected or harvested firewood	7	32
Harvesting medicinal plants	Peeling of tree barks	10	23
	Digging for tree roots	3	1

Generally, increased anthropogenic activities have the potential to alter MRNR natural habitats (Leweri and Ojija, 2018), resulting in a decline in the population of *R. kipunji* (Mugume et al., 2015). The study recommends that the MRNR authorities should monitor and manage human activities near the MRNR border zones. Furthermore, preceding studies have shown that understanding the abundance and habitats of the species before implementing conservation measures is vital (Davenport et al., 2008; Maijo et al., 2020). Accordingly, knowledge concerning the current abundance and habitat status of *R. kipunji* is imperative for planning effective conservation strategies to protect the nature reserve.

3.2. *People's awareness and conservation education about R. kipunji*

A total of 225 respondents of different ages and education levels (Table 3) were assessed for their knowledge about *R. kipunji.* We found that >40% of male and > 30% of female respondents were aware of the presence of *R. kipunji* and initiatives to protect the species in MRNR (Fig 3a). They are reported to have obtained this awareness from the Wildlife Conservation Society (WCS) and MRNR authorities, which regularly conduct village meetings to raise awareness about the conservation of the forest reserve and its biodiversity, including *R. kipunji*.

The number of male respondents who were aware of *R. kipunji* was high, perhaps because of the more free time they had to attend meetings compared to women whose time was limited by household chores, i.e., cooking, fetching fuelwood, and farming. Age-wise, we found that *R. kipunji* was not new to 55% of respondents who were also older than 31 years. (Fig 3b). It appears that in the surveyed villages, people older than 31 years are knowledgeable about *R. kipunji* than younger ones. This is attributed to the fact that young people aged less than 31 spend more time in school and thus have limited time to participate in village meetings.

Table 3

Characteristics of Respondents

Characteristic	Category	Respondent abundance
Gender	Male	46% (104)
	Female	54% (121)
Age	18–30	22% (50)
	31 – 43	43% (96)
	>43	35% (79)
Education level	Primary education	29% (66)
	Secondary education	34% (76)
	Diploma	25% (56)
	University	12% (27)

Overall, 78% of respondents claimed to be aware of the presence of *R. kipunji* and its conservation initiatives in MRNR (Fig 3c). During our study, we found that 30% and 32% of female and male respondents had previously received conservation education,

respectively (Fig 4a). Compared to other age groups, >25% of respondents aged > 45 years old asserted to have already been educated about *R. kipunji* (Fig. 4b). Generally, >50% of respondents claimed to have received *R. kipunji* conservation (Fig 4c). A few respondents (22%) were not knowledgeable about *R. kipunji,* and possibly these are people who never attended village conservation education meetings. People lacking conservation education and awareness are likely to involve themselves in illegal activities that cause forest degradation. We believe that these are villagers with a greater contribution to the number of anthropogenic activities recorded in MRNR (Mugume et al., 2015). Hence, MRNR conservation stakeholders should educate more people about the importance of the species and the nature reserve.

Figure 3
Local People's Knowledge Concerning R. kipunji in MRNR according to (a) Gender, (b) Age, and (c) Overall Respondent Population

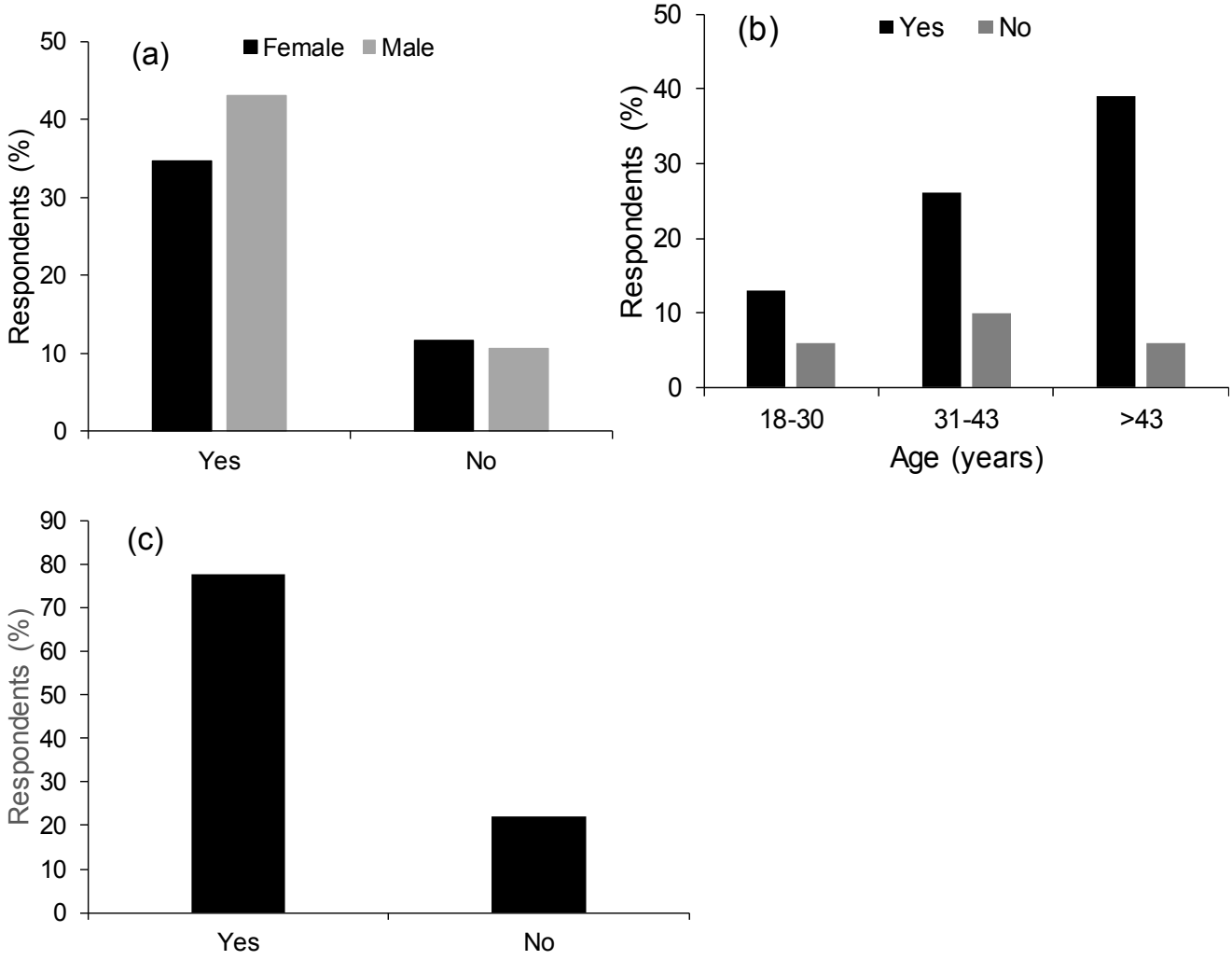
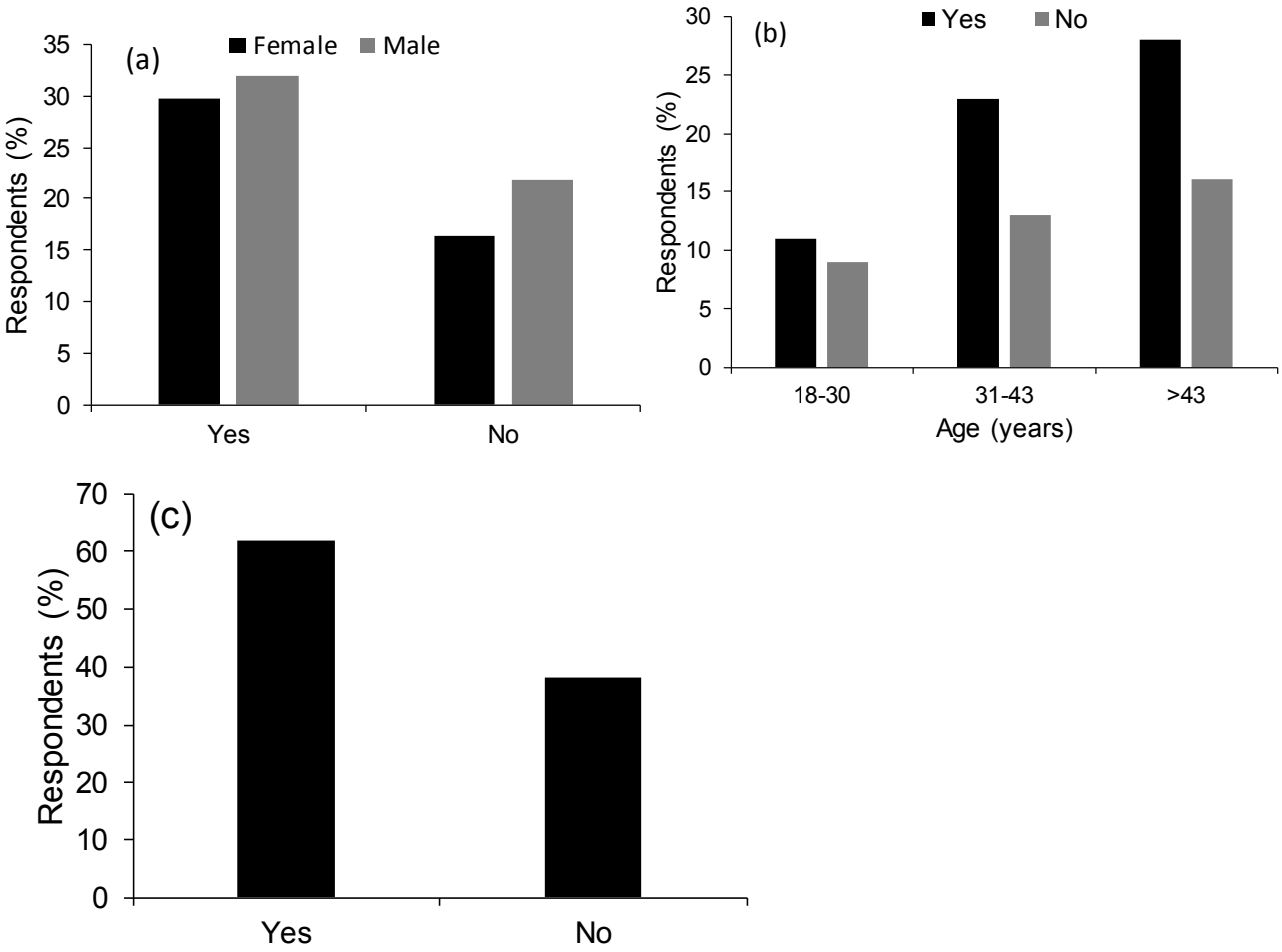


Figure 4
Local People's Knowledge Concerning R. kipunji Conservation Education Conducted in their Villages Based on (a) Gender, (b) Age, and (c) Overall Respondent Population



3.3. People's perception of the importance of MRNR and threats to R. kipunji

A majority of male (17%) and female (31%) respondents agree that MRNR is important for their lives as it supplies fuelwood, and building materials (Fig 5a). Mainly older people, over the age of 31 years, collect Fuelwood and building materials, while those under 31 years gather food resources, especially fruits, in the MRNR (Fig 5b). Overall, the majority of respondents (43%) in the studied villages used MRNR to collect fuelwood (Fig 5c). This is because local communities surrounding MRNRdepend on fuel wood (i.e., firewood and charcoal) for cooking and warming. Interestingly, more than 35% of female and 40% of male respondents acknowledged that *R. kipunji* is not threatening their livelihoods, i.e., it does not raid or destroy their crops (Fig 6a). This was also the case for the majority of older people above the age of 31. (Fig 6b). Finally, no one reported killing *R. kipunji* in retaliation for a crop attack, nor did they report hunting *R. kipunji* for food, i.e., stew. These results indicate that the species coexist well with local communities and that there is no conflict between *R. kipunji* and local people living adjacent to MRNR.

Figure 5

Local People's Perception on the Importance of MRNR in Support their Livelihoods Based on (a) Gender, (b) Age, and (c) Overall Respondent Population

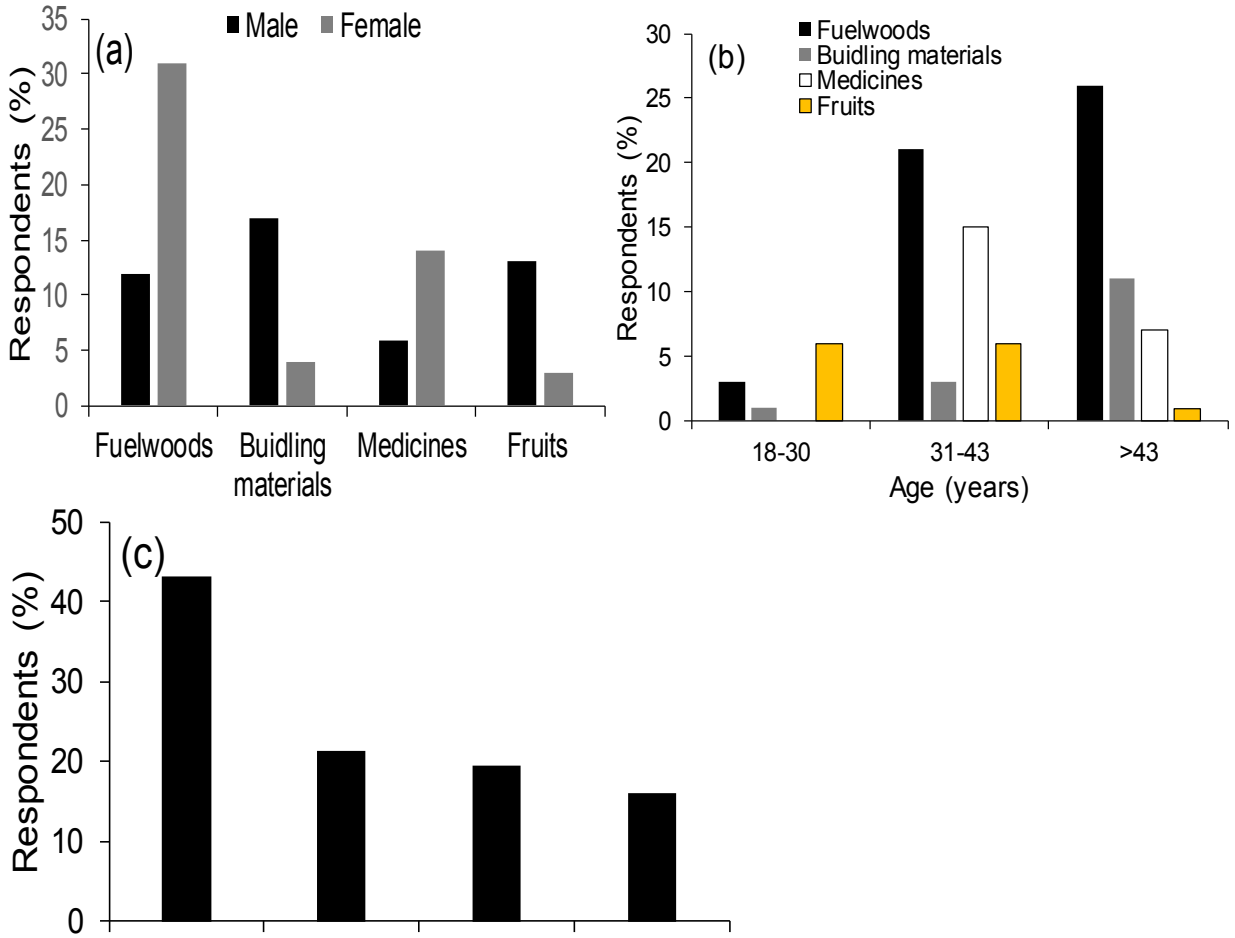
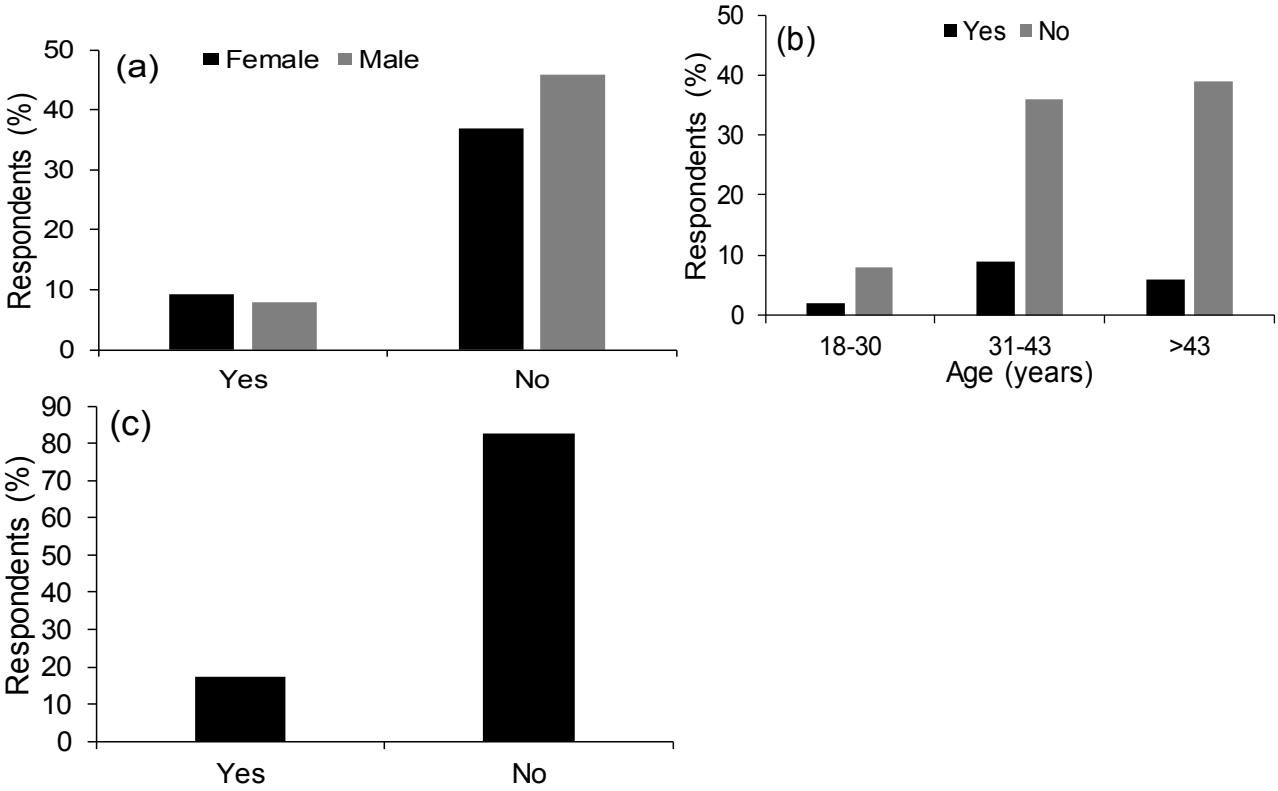


Figure 6

Local People's perception on threats posed by R. kipunji to their livelihoods based on (a) gender, (b) age, and (c) overall respondent population



Our findings show that local people's reliance on fuelwood endangers both *R. kipunji* and the nature reserve. This is because removing or cutting down trees for fuelwood or building materials would restrict the number of tree species accessible for roosting and food for *R. kipunji* (Chowdhury *et al.*, 2020; Zhao *et al.*, 2018). Protecting habitats and plants in MRNR, particularly climbers, a liana, and hemi–epiphytic figs, is critical because they provide food for *R. kipunji* and other species. Furthermore, such tree species assist *R. kipunji* with canopy-to-canopy access, which improves the suitability of their habitat. However, dense tree cover, which hindered observation and counting of *R. kipunji*, hampered the field surveys; the terrain characteristics of the MRNR prevented the survey crew from reaching some of the regions to search for *R. kipunji*, as in prior studies. Despite these limitations, the current survey gives a broad overview of the *R. kipunji* population in the MRNR.

4. Conclusions

To increase *R. kipunji's* conservation, residents living near the forest reserve should be educated about the species and other unique flora and fauna, particularly their contributions to the country's long-term growth. This would allow a reduction in anthropogenic activities and increase the desire to protect the forest. Furthermore, the findings suggest that this study could be utilized as a benchmark for the conservation of other endangered primates around the world. We believe that further conservation efforts are needed to protect the nature reserve and its inhabitants from anthropogenic activities. Children and women, as well as individuals with less formal education, should have

access to *R. kipunji's* awareness and conservation initiatives, as they demonstrate the least understanding. MRNR conservators should investigate available media options for successful dissemination of *R. kipunji* conservation information to local people across the country. Overall, we conclude that anthropogenic alterations have shaped the contemporary forest plant community structure as well as the population of *R. kipunji*. Therefore, conservation and management efforts both inside and outside the forest reserve should be bolstered.

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6. Declarationof Conflicting Interests

The author(s) declared that they had no potential conflicts of interest in relation to the research, authorship, and/or publication of this article.

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