INFLUENCE OF MAN-MADE FEATURES AND FOREST STRATUM ON THE ABUNDANCE OF IRINGA RED COLOBUS MONKEY (*PILIOCOLOBUS GORDONORUM*) IN THE MAGOMBERA FOREST, TANZANIA

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ABSTRACT

Magombera forest has a rich fauna of Iringa colobus monkey (IRCM) (Piliocolobus gordonorum) that is facing high anthropogenic pressure. This study, aimed at assessing the influence of distance from railways, farms, and settlements as man-made features and the stratum status of the forest on the abundance of IRCM. The abundance was observed to insignificantly decline (p>0.05) as you move closer to the man-made features. Open canopy and tree cutting showed an insignificant likelihood of decreasing the abundance of IRCM. Anthropogenic factors are essential when considering the sustainable conservation of IRCM in the Magombera forest. Awareness of the local communities surrounding the forest should be emphasized. Another, best way to reduce the pressure to the forest which is the habitat for IRCM, would be to provide sustainable alternative livelihoods such as beekeeping, and tourism ventures which will reduce their unsustainable dependence on the forest and thus act as support strategies for the IRCM conservation.

Keywords: Magombera forest, Iringa red colobus monkey, Abundance, Anthropogenic pressure, Local communities, Awareness

INTRODUCTION

The endemic Iringa red colobus monkey (IRCM) - *Piliocolobus gordonorum* Matschie, 1900 (Primates: Cercopithecidae) is among nonhuman primates which are found in the Udzungwa ecosystem (Araldi *et al*., 2014). Other monkey species which can be easily seen in the forest include the blue monkey - *Cercopithecus mitis* Wolf, 1822 (Primates: Cercopithecidae), Angolan colobus - *Colobus angolensis palliatus* P. Sclater, 1860 (Primates: Cercopithecidae), while the yellow baboon - *Papio cynocephalus* Linnaeus, 1766 (Primates: Cercopithecidae), Black-and-white colobus monkey - *Colobus guereza* Rüppell, 1835 (Primates: Cercopithecidae) and vervet monkey - *Chlorocebus pygerythrus* F. Cuvier, 1821 (Primates: Cercopithecidae) can be seen adjacent the forest. Magombera forest is among the fragmented forests with uneven distribution and abundance of IRCM, also with an endemic Magombera chameleon - *Kinyongia magomberae* Menegon *et al*., 2009 (Squamata: Chamaeleonidae) (Marshall, 2008; Menegon *et al*., 2009). The forest has not only wildlife which is endemic but also plant species such as Luke's Cynometra tree - *Cynometra lukei* Beentje (Fabales: Fabaceae), Large leave Memecylon tree - *Memecylon afroschismaticum* R. D. Stone (Myrtales: Melastomataceae) and Heinsen's Isolona tree - *Isolona heinsenii* Engl. and Diels (Magnoliales: Annonaceae). The high potentiality of the forest has made it to be declared in 2019 as new forest reserve in Tanzania (The Citizen, 2021). Due to the conservation status of IRCM, there is an urgent need of understanding their distribution and abundance, and the associating factors for effective and efficient sustainable conservation.

Studies have shown that, the abundance and distribution of primate are influenced by different factors such as; environment suitability (VanDerWal, *et al*., 2009), habitat disturbance and food availability (Mammides *et al*., 2009), habitat selection (Boyce *et al*., 2016) and patch and landscape scale (Anzures-Dadda and Manson, 2007). Few studies have focused on assessing the influence of man-made features such as railways, settlements and farms. Moreover, few studies have also focused on the influence of the stratum on the monkey distribution as well.

In Magombera forest, the man-made features that influenced the distribution and abundance of the IRCM were rarely documented. Likewise, there is also limited information on the influence of the stratum. This study focused on assessing the abundance of IRCM in the Magombera forest as influenced by man-made features such as; settlements, farms and railways, and as well as non-man-made features such as; stratum, canopy, sub-canopy and grassland).

MATERIALS AND METHODS

Study Area: This study took place from June 2018 to February 2019 in the Magombera forest (Figure 1), a lowland forest that together with others are believed to be patches of the Udzungwa ecosystem, a biodiversity hotspot with endemic species that are endangered, while some other are extinct (Sigala *et al*., 2021; 2022; 2023).

The Magombera forest ecosystem is home to many endemic and endangered flora and fauna species like the IRCM (Ngongolo *et al*., 2019). Other species which can be found in the forest include Elephant (*Loxodonta africana*), Buffalo (*Syncerus caffer*), Leopard (*Panthera pardus*), and Hippopotamus (*Hippopotamus amphibius*). The forest located in Kilombero Valley in Mororogor region, Tanzania is 26 Km^2 (The Citizen, 2021) in size and it is bordered by the Selous Game Reserve which is among largest protected area in Africa with an area of about 50,000 Km^2 making a huge habitat for numerous wildlife species.

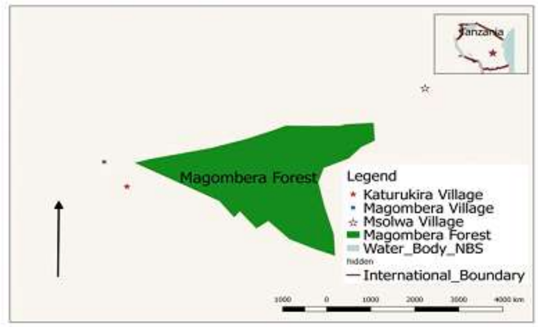

Figure 1: Map showing the Magombera Forest area (QGIS, 2023)

Data Collection Method: Three transects were randomly set in the forest and data were collected through direct field observation. The transects were walked from morning at a speed of 1 km/h. The data recorded upon sighting the IRCM troop were; demographic structures (age and sex), and habitat stratum utilized by IRCM such as canopy, under-canopy and on the ground. The habitat stratum is essential for the abundance and distribution of IRCM. If more than 60% of the individuals were observed in the sub-canopy, the monkey troop was recorded as belonging to the sub-canopy stratum. The distances of IRCM troops from settlements, farms and railways were classified as long (1501 m and above) and short (0 – 1500 m).

Influence of Man-Made Features: In this study, the man-made features considered were the farms, settlements and railway. The forest is known to be bordered by the Tanzania Zambia Railway (TAZARA) and three villages that surround the forest. The major economic activity of the indigenous is agriculture with the crops produced being sugarcane, maize, bananas, beans, rice, pigeon peas and coconut. We anticipated that distance from these man-made features would have a significant impact on the abundance of the IRCM. Upon sighting the IRCM troop, the distance (in meters) from the sighted troop of IRCM to these features (farms, railway and settlements) was measured using the range finder. The nearest points to the man-made feature (farms, railways and settlements) were considered in determining the distances.

Data Analysis: A generalized linear mixed effect model (GLMM) was used to determine the influence of these factors on the abundance of the IRCM. These factors were considered a fixed effect, while the sighting point was considered a random effect. The differences across three distances were analyzed using the Kruskal-Wallis Test Statistic to comprehend the variation in abundance across age groups. Additionally, the Kruskal-Wallis Test Statistic was employed to assess the variation in abundance among three monkey species (IRCM, Blue monkey, and Black-and-white colobus monkey). Conversely, for the comparison between two variables, specifically short and long distances, canopy and subcanopy, the Mann-Whitney U test statistic was utilized. A Generalized Linear Mixed Effect Model (GLMM) was applied to determine the influence of various factors on IRCM abundance. These factors were considered fixed effects while sighting points were treated as random effects.

RESULTS

Preamble Description of Monkey Species Observed: Three species of monkey were observed and recorded during the study with an overall average abundance of (Mean = 9.85 ± 0.61, Max = 42, range = 41, n = 216, S.D = 8.98, Kurtosis = 1.17). Out of the three species significance highest average score of abundance and observation frequency (Kruskal-Wallis Test Statistic = 67.87, p<0.0001, df = 2) were observed for Iringa red colobus monkey (Mean = 5.895 ± 0.52, Max = 42, range = 41, n = 101, S.D = 9.99) than for Black-and-white colobus monkey (Mean = 15 ± 0.99, Max = 18, range = 17, n = 57, S.D = 3.89) and Blue monkey (Mean = 4.07 ± 0.41, Max = 14, range = 13, n = 58, S.D = 3.11).

Demographic Structure of Iringa Red Colobus Monkey: The observed monkey was classified as shown in Table 1. The highest abundance was observed for adult females while being low for sub-adult females (Table 1). The variation in abundance was observed to be statistically significant (Friedman Test Statistic = 135.74, p<0.0001, df = 6).

Influence of Distance from Man-Made Features: The man-made features considered were settlements, farms and railways. The longest distance from settlements, farms and railways were 3500 m (3.5 km), 3100 m (3.1 Km) and 4500 m (4.5 km) respectively. The distance with the highest abundance of IRCM from settlements, farms and railway had 42 individuals at a distance of 1300 m, 700 m and 1450 respectively. In overall, a higher abundance of IRCM was observed at long distances (≥1501 m) (Figures 2, 3 and 4). However, the difference in abundance between long and short distance either settlement (Mann-Whitney U test statistic = 816.0, p = 0.62, df = 1), farms (Mann-Whitney U test statistic = 420.50, p = 0.776, df = 1) or railway (Mann-Whitney U test statistic = 827.00, p = 0.374, df = 1). It was observed that the closer to the settlement, farm and railway insignificantly lowered the abundance of IRCM.

Influence of Stratum on the Abundance of the Monkey: An insignificant higher abundance of IRCM was observed in the sub-canopy compared to the canopy (Figure 5) (Mann-Whitney U test statistic = 1129.00, p = 0.630, df = 1). However, the stratum and openness of the forest were looked at together, it was observed that the abundance between the canopy and sub-canopy was significant when the canopy is open (Mann-Whitney U test statistic = 0.046, p≤0.0001, df = 1) (Figure 6). Glmer showed that the abundance of IRCM was insignificantly decreasing when the forest is open, cut and in sub-stratum (Table 2).

DISCUSSION

Generally, man-made features didn't have significant impacts on the abundance of IRCM, However, the abundance varied in terms of stratum categories the monkey is spending and age structure.

Table 1: Demographic structure of the Iringa red colobus monkey in the Magombera Forest (n = 101)

Variables	Adult Male	Adult Female	Sub-adult Male	Sub-adult Female	Juvenile Male	Juvenile Female	Infants
Maximum	12.00	21.00	13.00	9.00	10.00	8.00	10.00
Minimum	1.00	1.00	1.00	1.00	2.00	1.00	1.00
Mean	2.74	4.69	1.74	1.33	1.38	1.61	2.22
95% CI Upper	3.19	5.48	2.19	1.78	1.74	1.98	2.67
95% CI Lower	2.29	3.91	1.28	0.89	1.03	1.23	1.77
Standard Error	0.23	0.39	0.23	0.22	0.18	0.19	0.23
Standard Deviation	2.27	3.95	2.32	2.22	1.79	1.87	2.26

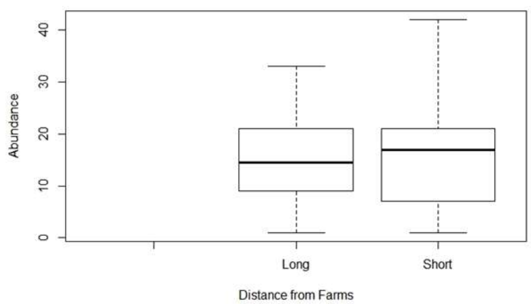

Figure 2: The distances of IRCM troop (abundance) from farms (cultivated areas). *Long distance ≥1501 m, while short distance ≤1500 m*

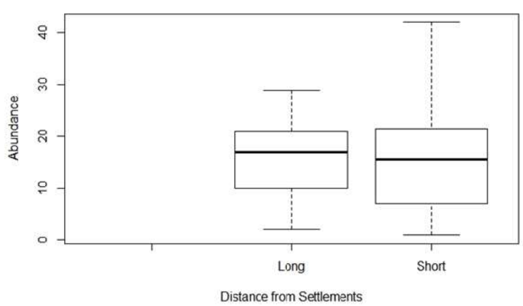

Figure 3: The distances of IRCM troops (abundance) from settlements (nearby villages/settlements). *Long distance ≥1501 m, while short distance ≤1500 m*

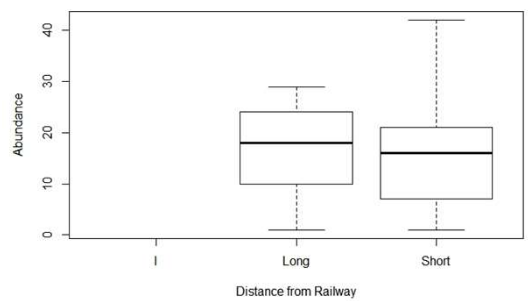

Figure 4: The distances of IRCM troops (abundance) from TAZARA railway. *Long distance ≥1501 m, while short distance ≤1500 m*

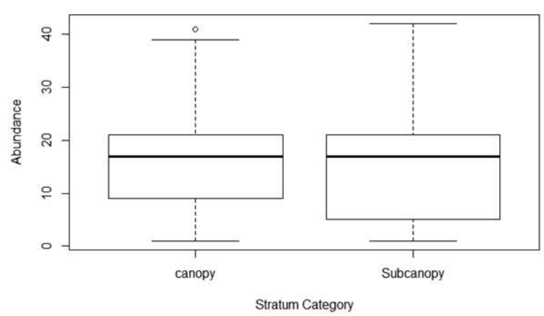

Figure 5: The abundance of IRCM troop in two categories of the stratum (canopy and sub-canopy). *Long distance ≥1501 m, while short distance ≤1500 m*

Variation in Abundance among Monkey Species in the Forest: In comparison with other monkey species, IRCM was observed to be the most abundant in the Magombera forest. Marshall *et al.* (2005) studying the monkeys' population in the Udzungwa Mountain region showed that the abundance of IRCM negatively correlated with the elevation.

IRCM in the forest can be easily seen, unlike Blue monkeys which are shire and run away upon encountering human beings. Another study has shown that they are opportunistic species, which explains that the abundance of IRCM in this forest can be explained by the habitat fragmentation (patch) behaviour of the forest, low elevation and the behaviour of the monkey, their accurate abundance was more difficult than in the case of IRCM (Rovero *et al.*, 2009). The community of IRCM in Magombera forest is viable as a result of the conservation effort taking place.

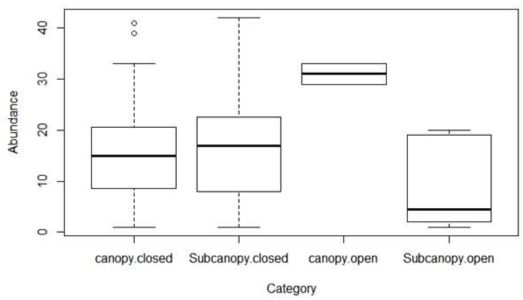

Figure 6: The abundance of IRCM in two categories of stratum and openness. Where stratum was classified as canopy and sub-canopy while openness as open and closed canopy. *Long distance ≥1501 m, while short distance ≤1500 m*

Table 2: The association of abundance of IRCM with distances from settlements, railway and farms, canopy openness, stratum layers and tree cutting

Variables	Estimate	Standard error
Intercept	2.51	0.27
Settlement distance (short)	-0.04	0.24
Farms distance (short)	0.18	0.28
Railway distance (short)	-0.14	0.24
Open canopy	-0.35	0.30
Tree cut	0.08	0.05
Sub-canopy	-0.10	0.14
Variables	**Z value**	**Pr(>|z|)**
Intercept	9.273	<2e-16 ***
Settlement distance (short)	-0.17	0.866
Farms distance (short)	0.66	0.507
Railway distance (short)	-0.61	0.541
Open canopy	-1.18	0.239
Tree cut	1.52	0.128
Sub-canopy	**-0.72**	0.474

Random effect = location, AIC = 747.3, logLik = -365.7, Intercept represents long distances for distances from settlement, railways and farms, closed canopy for openness and canopy layer for canopy stratum

The demographic structure showed existence of both multi-male and multi-female animals per group, also various age structures were observed including adults, sub-adults, juveniles and infants. Previous studies have shown that IRCM is multi-male and multi-female unlike other animal species with one dominant male in a group (Rovero *et al.*, 2009).

Stratum and Abundance of the IRCM: Significantly higher (p<0.001) abundance of IRCM was observed in the top canopy than in the sub-canopy. The top canopy and closed canopy had positive significance on the abundance of the IRCM. Most of the time, the IRCM were observed to be spent in the canopy. During our study, we failed to observe the IRCM on the ground. The canopy dependence for other primate species has been reported in the Udzungwa ecosystem for instance Mountain Galago (*Galagoides orinus*) is known to spend and depend most on the canopy type of vegetation (Rovero *et al.*, 2009; Araldi *et al.*, 2014). This explains why the conservation effort for the Magombera forest is essential for the species which are forest canopy dependent, in which if improper conservation is taking place, there will be a very high chance of such species becoming extinct.

Long distances from man-made features (railways, settlements and farms) were observed to have a positive significant increase in the abundance of the IRCM. This can be explained by the fact that man-made features destroy the habitats for IRCM and other wildlife species. A study by Quinn *et al.* (2017) showed that the habitat loss for wildlife species was accelerated by agricultural activities. Human activities are to be controlled especially when they are impairing the survival of the habitats (forests) and the wildlife species like IRCM.

Conclusion: For the continuous survival of IRCM and the Magombera forest flora and fauna, proper conservation efforts are required. These efforts should be by the government of Tanzania in collaboration with conservation stakeholders; however, the participation of local communities around the forest is very crucial in the conservation. Furthermore, conservation education, law enforcement and creating alternative livelihoods such beekeeping (Mahulu, 2016; Ngongolo *et al.*, 2019) to the local communities adjacent the forest will ensure sustainable survival of the forest.

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