Diet and Travel Distances of Golden Monkey (*Cercopithecus mitis kandti*) in a Pine Plantation Outside Gishwati-Mukura National Park, Rwanda

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Abstract: Primates living in fragmented and degraded forest environments face multiple challenges such as the reduced availability of food resources. We used the group scan method to study the diet and travel distance of endangered golden monkeys (*Cercopithecus mitis kandti*) inhabiting exotic pine plantations (*Pinus patula*) outside their native forests in the highly fragmented Gishwati-Mukura landscape, Rwanda, from July to August 2018. We found that golden monkeys consumed parts of at least 17 plant species. Notably, their diet consisted largely of pinecones and needles and differed from the frugi-/folivorous diet of other golden monkeys inhabiting patches of native vegetation. We also found that the mean hourly travel distance of the population inhabiting the pine plantation is longer than that of their counterparts who live in native forests. The dietary flexibility in studied groups indicates their adaptability to non-native forests. The high intake of pine might be representative of availability, rather than preference, given its ubiquitous presence in these plantations and the lack of alternative, native plant food resources. The differences in travel patterns are potentially due to the more scattered availability of native food resources, and higher disturbance in pine forests compared to native forests. Future studies are needed to determine the long-term sustainability or probability of persistence of golden monkeys in exotic pine plantations to inform conservation management outside protected areas.

Key words: Diet, golden monkey, native forest, habitat fragmentation, exotic pine plantation, travel distance

INTRODUCTION

Human-driven conversion and alteration of native vegetation, specifically the rapid destruction of tropical forests (Arroyo-Rodríguez *et al*. 2013), induces the loss, fragmentation, and degradation of primate habitat (Carvalho *et al.* 2019). These alterations ultimately restrict the range and abundance of primates (Sean 2011; Sharma *et al.* 2012; Estrada *et al*. 2017), leaving many species on the verge of extinction (Estrada *et al.* 2012). As fragmentation and loss of suitable habitat and food resources also force primates to visit human-dominated landscapes, they are increasingly involved in human-wildlife conflicts (Hill 2018), experience changes in population connectivity and gene flow (Chapman *et al.* 2013; Su *et al*. 2022), and are exposed to infectious diseases and new forms of

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Figure 1. Adult male golden monkey (*Cercopithecus mitis kandti*) feeding on needles of a pine tree (*Pinus patula*). Photograph by Marcel Ngabikwiye.

predation (Chapman *et al*. 2013). Although some primates occasionally use non-native food or habitat resources (see e.g., Tesfaye *et al.* 2013; Chaves & Bicca-Marques 2016; Spehar & Rayadin 2017;), others are forced to rely heavily on non-native vegetation following habitat loss and fragmentation (Torres-Romero *et al*. 2023). While the long-term impacts of such forced shifts on the diet is currently unknown, we can learn from case studies on differences in the diet and travel distance between primates living in natural habitats compared to those living in anthropogenically altered habitats. For example, little is known of the ecology of golden monkeys (*Cercopithecus mitis kandti*) that occupy patches of pine-dominated (*Pinus patula*) plantation forests outside the protected Gishwati-Mukura National Park (GMNP) in Rwanda (Tuyisingize *et al*. 2022).

The golden monkey, or golden guenon, is an endangered subspecies of blue monkey that is affected by habitat loss, fragmentation, and degradation (Butynski & de Jong 2020). The range of this primate is restricted to two isolated fragments: the Virunga massif (Rwanda, Uganda, and Democratic Republic of the Congo) and GMNP (Butynski & de Jong 2020; Siegel *et al.* 2020). These two fragments of native vegetation were disconnected in the late 1950s by the conversion of habitat into a largely agricultural landscape (Spinage 1972). Both fragments have since experienced additional reduction and degradation of habitat (Nyandwi & Mukashema 2011), with the Gishwati section of GMNP being reduced to approximately two percent of its original cover since the 1980s (from ~280 to <10 km^2; Plumptre *et al*. 2001; Nyandwi & Mukashema 2011). Following this conversion of native forest to other land cover types (predominantly agricultural land), some golden monkeys shifted their range to occupy pine plantations (Tuyisingize *et al*. 2022; Figure 1).

Existing research on golden monkeys concentrated primarily on populations residing in protected areas (see e.g., Twinomugisha *et al*. 2006; Tuyisingize *et al.* 2022). Consequently, there is a scarcity of information regarding the ecology of golden monkeys that utilize pine plantations. Here, we present a first step to filling this data gap by focusing on golden monkey diet and travel patterns. We predicted these behaviors differ from those found in populations inhabiting native forest fragments. Specifically, we hypothesized that golden monkeys within our research area exhibit dietary habits distinct from those inhabiting the nearby native forests of GMNP. We expected them to consume parts of *P. patula*, a plant not

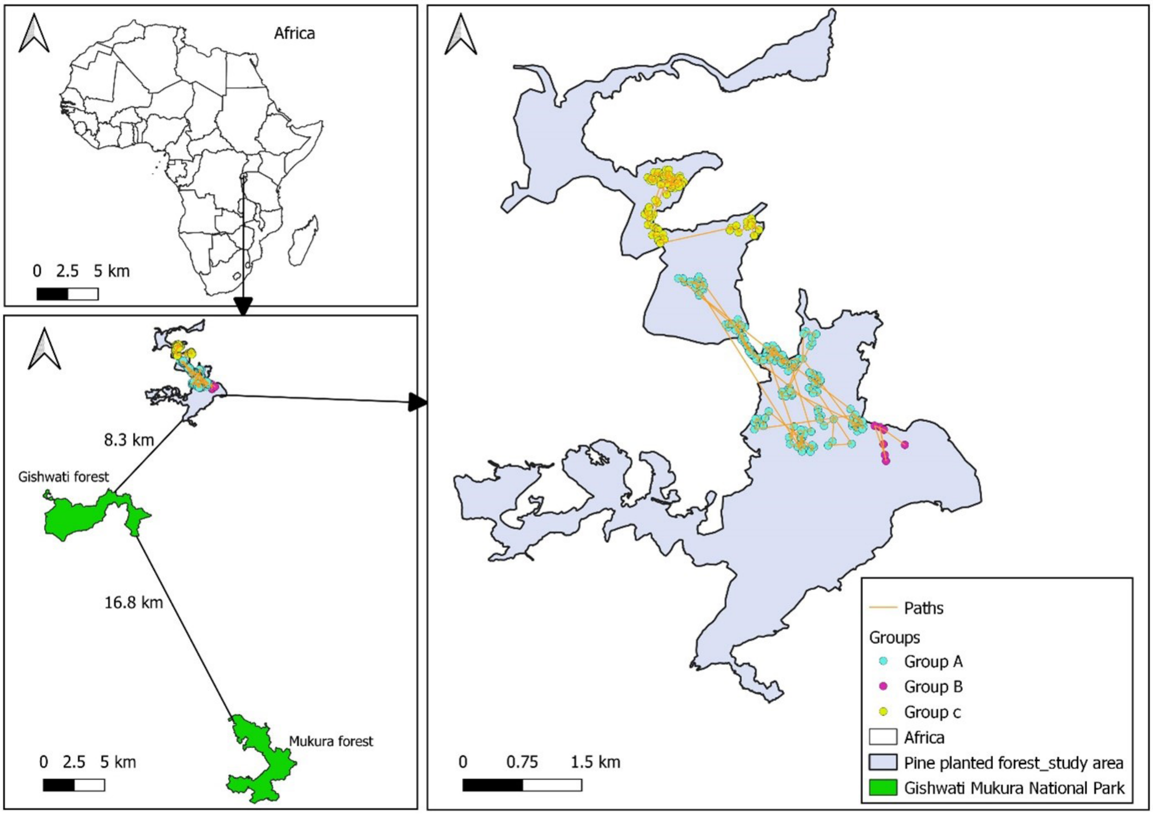

Figure 2. Study area near Gishwati-Mukura National Park, Rwanda.

typically eaten by golden monkeys living in the nearby forest of GMNP (Tuyisingize *et al.* 2022), alongside native key food species for energy and protein supplementation (Beeson 1989; Lawes 1991; Twinomuguisha *et al.* 2007; Tuyisingize *et al.* 2022). We also expected golden monkeys to travel relatively long distances as native food resources are scarcer and more scattered.

METHODS

In July and August 2018, we studied three semi-habituated golden monkey groups that inhabit patches of pine forest approximately halfway between Volcanoes National Park and GMNP (~12 km from both; 1°43’20.64” S, 29° 28’0.17” E (Figure 2). This forest, found at 2,100 – 2,500 m elevation, is dominated by exotic *Pinus patula*, *Acacia* sp., and *Eucalyptus* sp. trees (Nyandwi & Mukashema 2011).

We conducted daily follows of three golden monkey groups (Tables 1 and 2), but the number of sampling days varied due to logistical difficulties and group visibility. Because the monkeys are semi-habituated, we were able to make observations from fairly close range. From 08:00 to 14:00, once we found a group of monkeys, we positioned ourselves on the periphery of the group. We conducted 5 minutes of scan sampling with a 20-minute interval between

Table 1. Group composition of golden monkey study groups A, B, and C in the pine plantation outside Gishwati-Mukura National Park, Rwanda.

Age-sex class	Group A	Group B	Group C
Adult Males	1	1	1
Adult Females	6	4	9
Juveniles	5	2	17
Infants	2	2	6
Group size	14	9	33

Table 2. Observation duration in days and hours spent in the pine plantation by golden monkey study groups and number of scans obtained for each group.

Group	#days	#hours	#scans
Group A	11	38	113
Group B	3	11	33
Group C	7	35	105

each scan (Altmann 1974). While traversing the outer edges of the group during scans, we recorded whether each individual was feeding (harvesting, processing, chewing, or ingesting food) or engaging in other activities. If the activity was feeding, we recorded the food type (e.g., plant species, insect) and parts (cones, fruits, needles, leaves, flowers, shoots, stems, tendrils, and bark). First, we assessed the individual contributions of food items (species parts) to each group's diet. Then, we aggregated the dietary data from all three groups and computed the proportion of food items within the combined diet.

At the end of each scan, using the last monkey following the direction of the group, we recorded its location with a handheld Garmin GPSmap 64X. Then, using QGIS 3.28.12, we calculated the daily travel distance by connecting the consecutive GPS location records of each day. To assess the travel distances of golden monkeys in a non-native habitat compared to their counterparts in the native habitat, we complemented our dataset by including data collected during the same period (July-August 2018) from a habituated group (33 individuals followed over 31 days) residing within the GMNP. The Dian Fossey Gorilla Fund provided these data, which were collected using research methods identical to those outlined above with the exception that GPS points were taken at the approximate center of the group's location.

RESULTS

We found that golden monkeys in our study area consumed a minimum of 21 food plant items from 17 food plant species. Group A consumed 16 food plant species, while Group B and Group C consumed

Table 3. Contribution of food plant species to the diet of golden monkey groups (A-C) in pine plantation.

Food plant species	Status	Group A	Group B	Group C
Pinus patula	Exotic	72.5	66.7	89.9
Oldaenia alpina (bamboo)	Native	5.9		1.2
Acacia mearnsii	Exotic	4.8	13.3	2.4
Basella alba	Native	3		0.6
Coccinia mildbraedii	Native	3	6.7	
Peucedanum linderii	Native	2.2	6.7	
Loberia gibberoa	Native	1.9		
Discopodium penninervium	Native	1.5		2.4
Galium simense	Native	1.5		0.6
Ipomoea involucrate	Native	0.7	6.7	0.6
Isachne mauritiana	Native	0.7		0.6
Rubus steudneri	Native	0.7		0.6
Alnus acuminata	Exotic	0.4		
Maesa lanceolata	Native	0.4		
Rumex bequaertii	Native	0.4		
Solanum nigrum	Native	0.4		
Eucalyptus sp.	Exotic			1.2

Table 4. The mean percentage of consumed food plant species and their parts in the combined diet of the three golden monkey study groups in pine forests of the Gishwati-Mukura landscape ranked by the importance of food plant species.

Rank	Food species	Family	Origin	Leaves	Needles	Cones	Fruits	Bark	Flowers	Pith	Stem	Tendrils	Mean % (±SD)
1	*Pinus patula*	Pinacea	Non-native		33.5	42.9		4.2					80.5 (2.51)
2	*Oldaenia alpina*	Poacea	Native	4.5									4.5 (0.27)
3	*Acacia mearnsii*	Fabacea	Non-native				1.6		2.1				3.7 (0.34)
4	*Coccinia mildbraedii*	Cucurbitaceae	Native				1.9						1.9 (0.17)
5	*Peucedanum linderi*	Apiaceae	Native							1.4			1.4 (0.14)
6	*Galium* sp.	Rubiacea	Native								1.1		1.1 (0.09)
7	*Discopodium penninervium*	Solanaceae	Native				0.2			1.1			1.3 (0.54)
8	*Basella alba*	Basellaceae	Non-native									1.5	1.5 (0.11)
9	*Eucalyptus* sp.	Myrtaceae	Non-native							0.4			0.4 (0.09)
10	*Ipomoea involucrata*	Convolvulaceae	Non-native									0.7	0.7 (0.08)
11	*Loberia gibberoa*	Lobeliaceae	Native							0.7			0.7 (0.08)
12	*Isachne mauritiana*	Poaceae	Native								0.7		0.7 (0.08)
13	*Rubus* sp.	Rosaceae	Native			0.7							0.7 (0.08)
14	*Rumex bequaerti*	Polygonacea	Non-native							0.4			0.4 (0.06)
15	*Alnus acuminata*	Betulaceae	Non-native							0.2			0.2 (0.05)
16	*Maesa lanceolata*	Primulaceae	Non-native				0.2						0.2 (0.05)
17	*Solanum nigrum*	Solanaceae	Non-native	0.2									02 (0.05)
Number of feeding observations				19	134	155	18	18	7	17	2	12	

Table 5. Range and mean of hourly travel distance (in meters) of golden monkey groups in pine plantation forest outside (A-C) and within (GMNP) Gishwati-Mukura National Park, Rwanda.

Golden monkey Group	Group Size	Number of days	Daily travel distance (meters)	
			Mean	Range
A	14	11	760	(176 -1454)
B	9	3	304	(67 - 521)
C	33	7	540	(53 - 843)
GMNP group	33	31	144	(30-635)

5 and 10 food plant species, respectively (Table 3). All groups devoted a significant proportion of observed feeding on *P. patula*, ranging from 67% to 90%. By combining the diet of all groups, we found that the vast majority of feeding events included *P. patula* (80.5 ± 2.5% of events) followed by *Oldeania alpina* (4.5 ± 0.3%), *Acacia mearnsii* (3.7 ± 0.3%), *Coccinia mildbreadii* (1.9 ± 0.2%), *Basella alba* (1.5 ± 0.1%), and *Peucedanum linderi* (1.4 ± 0.14%) (Table 4). Cones and needles obtained from *P. patula* accounted for approximately 42.9% (± 1.3) and 33.5% (± 0.1), respectively, among the most-consumed food parts. In contrast, leaves and fruits from other food types contributed approximately 4.7% (± 0.4) and 4.5% (± 0.7), respectively (Table 4).

The mean daily travel distance of golden monkey groups in pine-planted forests was 534 ± 23 m (56-1454) (N = 21) and was longer than the mean travel distance of the GMNP group (Table 5). In addition, the mean distance travelled by the largest study group in the pine plantation (C) was nearly four times longer than the mean for the same-sized GMNP group.

DISCUSSION

Golden monkeys that inhabit the pine plantation forest near GMNP consume parts of at least 17 different plant species, 13 of which are native to the region, and show substantial differences in the recorded diet composition of the three study groups. As hypothesized, dietary habits of golden monkeys in pine-dominated forests strongly differ from those living in the nearby native forests of GMNP. Most of their diet is comprised of the cones and needles of *P. patula*. As these food items are not commonly consumed by predominantly folivore (Virunga massif) or frugivore (core GMNP) golden monkeys, our findings confirm earlier suggestions that golden monkeys exhibit considerable dietary flexibility (Twinomugisha *et al.* 2006; Tuyisingize *et al.* 2022). This study also revealed that golden monkeys residing in pine plantations tend to travel longer distances than their counterparts that live in native forest vegetation, which is in line with our prediction.

The high intake of *P. patula* might be representative of availability, rather than preference, given its ubiquitous presence in these plantations and the lack of alternative, native plant food resources. Alternatively, golden monkeys could have a selective preference for specific nutritional elements found in the *Pinus* genus (Maganga & Wright 1991; McMara 2005), a topic for further study. Similarly, future studies may reveal why the three studied groups vary in diet, though we acknowledge that these differences could be linked to biases in sampling effort.

The relatively long travel distances of golden monkeys in pine plantations could stem from the scarcity and more scattered or patchy distribution of native food resources (e.g., bamboo), a pattern also observed in ranging patterns of lion-tailed macaques, *Macaca silenus*, in the Western Ghats of India (Erinjery *et al.* 2014). Alternatively, long travel distances in pine forests could be caused by a high number of disturbances (e.g., human disturbances) as animals aim to avoid pressure from human presence (Li *et al.* 2005). Finally, travel distances can be influenced by group size, with larger groups travelling longer distances (Gillespie & Chapman 2001), though we found that the GMNP group traveled shorter distances than the groups in the pine plantation even when comparing only groups of the same size.

Although most golden monkeys inhabit fragments of native forests, we found that pine plantations offer additional habitat and food resources, at least in the short term. However, primates that inhabit isolated patches of non-native vegetation may fail to persist in the long term as they are "trapped" in habitat of inferior quality while being disproportionally vulnerable to threats such as predation and human-wildlife conflicts (Estrada *et al* 2012; Chapman *et al.* 2013). Future studies should assess temporal trends in the density and distribution of these golden monkeys, determining their rate of reproduction, and study the prevalence and nature of threats to their long-term persistence. Such deeper information on the golden monkey's use and adaptation to pine plantations will be crucial for the design of effective conservation and management strategies (see e.g., Tuyisingize *et al.* 2023).

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