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Preliminary Study of Diet and Home Range of Blue Monkeys (*Cercopithecus mitis doggetti*) Living in a Small Urban Forest in Southern Rwanda

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Abstract: Human activities such as logging, agriculture, hunting, mining, and urbanization are major causes of deforestation and fragmentation of tropical forests globally. This has caused many primate populations to become isolated in small, fragmented forests surrounded by human-dominated landscapes in rural or urban areas. We present preliminary results from a short study of a group of Doggett's blue monkeys (*Cercopithecus mitis doggetti*) that live in the Ruhande Arboretum Forest in Huye, Rwanda, an urban setting. This species is known to inhabit tropical montane forest in Rwanda and to eat mainly fruits in the tree canopy. The Arboretum is a plantation forest of 50 x 50 m plots planted with mostly non-native hardwood species, along with bamboo and some native hardwood species, and a very small remnant tropical forest patch, surrounded by roads, homes, shops, and agriculture fields. To understand how the blue monkeys use the Arboretum, we studied their diet and habitat use through scan sampling. We used 5-minute scans to record the first activity observed by each individual and the GPS location of each scan. Results showed that during this short study, the diet was composed mainly of fruits. They spent most of their time in the natural forest remnant patch and areas near agricultural fields. The group was most often found in the forest canopy. The blue monkeys only rarely came into the agricultural fields to forage on crops during the study period. The availability of fruit species in the forest and crops in surrounding agricultural fields can predict the use of the forest by this group. Although this was a very short, preliminary study, results suggest the blue monkeys maintain arboreality and rely on fruits inside the Arboretum, valuable information for conservation management. We recommend further research covering all seasons to have more accurate data about their movements and to develop conservation plans for this forest monkey.

Key words: ***blue monkey, forest fragmentation, frugivory, guenon, Rwanda***

INTRODUCTION

Anthropogenic activities such as agriculture, logging and wood harvesting, livestock farming, hunting, mining, and road construction cause loss of habitat for 90% of the primate species globally that rely on forest habitats (Chapman *et al.* 2006; Estrada 2013; Estrada *et al.* 2017; Corrêa *et al.* 2018). Habitat loss due to deforestation and forest fragmentation is the main threat that primate species living in tropical forests are facing today (Chapman & Lambert 2000; Chapman *et al.* 2006, 2007; Tesfaye *et al.* 2013). The loss and fragmentation of habitat is almost unavoidable in areas with rising

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urbanization (Crooks 2002) and has driven many primate populations to inhabit small isolated forest fragments (Estrada *et al.* 2017; Mekonnen *et al.* 2020) surrounded by human-dominated landscapes.

To persist in such landscapes, primate populations must have flexibility in diet and behaviors to adjust to living alongside humans in rural, urban, and semi-urban settings (Hill 2000). Many primate species exhibit flexible behaviors that allow them to adjust their diets and ranging behaviors in human modified habitats (Corrêa *et al.* 2018). Primate species have responded to changes in resource availability in small isolated fragments by increasing their feeding on 1) fallback foods such as leaves, 2) food from secondary growth such as lianas and climbers, and 3) human crops and exotic species (Mekonnen *et al.* 2018). Neotropical primates that live in an anthropogenic matrix within small or highly disturbed fragments, for example, often vary their food diets relying on exotic or cultivated crop species found in the matrix (Corrêa *et al*. 2018).

Primates inhabiting forest remnants located within anthropogenic matrices in the rural-urban interface often create negative impacts for farmers managing the surrounding agricultural fields (Corrêa *et al*. 2018; Mekonnen *et al*. 2020). This can lead to mortality of those primates, and different conservation efforts have been undertaken to mitigate and resolve these threats (e.g., Radhakrishna & Sinha 2011). Presence of food trees (including key food resources) in fragmented habitats can be essential to the survival of primate populations constrained to isolated forest fragments (Gould & Cowen 2020). For the long-term survival of frugivorous primates in tropical forest remnants, implementation of management plans must be grounded on the conservation of fruit tree species (Mwavu & Witkowski 2009). Less than five percent of tropical rainforests are legally protected from human exploitation, and tropical forest primate species have a high risk of extinction, as their ranges are often not in protected areas (Chapman & Lambert 2000). This makes the protection and sustainable management of these remnant forests even more critical.

Blue monkeys (*Cercopithecus mitis*) are members of the highly diverse group of guenons that live in the tropical forests of Africa (Butynski 2002; Lawes *et al.* 2013). The subspecies *C. mitis doggetti*, officially named Doggett's Blue Monkey (hereafter, blue monkey), is listed as Least Concern and ranges through Burundi, the Democratic Republic of Congo, Rwanda, Tanzania, and Uganda (Butynski & de Jong 2022). They appear to be less abundant in human-modified habitats compared to more intact forest (Lawes 1992, 2004; Chapman *et al*. 2000; Fashing *et al.* 2012), have been considered forest dependent (Cords & Chowdhury 2010), and spend more time in the forest canopy than on the ground (Gautier-Hion 1988; Kaplin & Moermond 1998; Lawes 2004). Previous studies in Nyungwe showed that nearly 50% of the diet of *C. m. doggetti* is composed of fruits (Kaplin *et al.* 1998; Kaplin & Moermond 1998), and they are important seed dispersers (Kaplin *et al.* 1998; Kaplin & Moermond 1998; Lambert & Garber 1998). *Cercopithecus* monkeys are usually considered to have flexible diets (Gautier 1988; Kaplin & Moermond 1998; Twinomugisha *et al.* 2006; Lawes *et al*. 2013; Tuyisingize *et al.* 2022), and eat leaves and insects as alternatives when fruit is low in availability (Kaplin *et al.* 1998; Treves 1999). Although blue monkeys are generally found in intact tropical forests, they have been observed in isolated forest fragments (e.g., Tesfaye *et al*. 2013). Urban areas are growing in both population and land cover (Güneralp *et al*. 2017) increasing the probability of creation of new isolated forest fragments, making it urgent to understand how forest-dwelling primates can exist in forest fragments surrounded by human-dominated landscapes.

The aim of this study was to provide insights into how blue monkeys, an arboreal primate species typically found in tropical forest, persist in a small urban forest surrounded by a human-dominated landscape in southern Rwanda. We examined the ranging behavior and diet of *Cercopithecus mitis doggetti,* a subspecies of the blue monkey inhabiting the Ruhande Arboretum Forest, focusing on the use of different habitat types, and diet composition. We wanted to find out if there are particular habitats that blue monkeys use more frequently than others within this forest fragment. This preliminary study is meant to generate further interest in studying this species in this forest fragment across different seasons.

METHODS

Study area

The study was conducted in the Ruhande Arboretum Forest, a plantation forest established in 1933, located in southern Rwanda (latitude 2°36′S, longitude 29°44′E) with an elevation ranging between 1,638 and 1737 m (Nsabimana 2013). The climate of the region is tropical humid, with mean annual precipitation of 1232 mm and an average annual temperature of 19.6 °C (Nsabimana *et al.* 2008). The Arboretum Forest is planted with 204 plant species including 32 native and 172 exotic

species in 477 plots of 50 x 50 m each, covering a total surface area of 177.49 ha (Rwanda Environment Management Authority 2018). Plots are separated by 6 m wide alleys or pathways. Approximately 79% of all plots (377 plots) are composed of exotic or non-native species and 13% (61 plots) contain indigenous species (single species plots). The remaining plots (8%, 39 plots) are either unplanted or contain a mixture of tree species. The most common tree species planted in the single-species plots are *Grevillea robusta* (19 plots), *Pinus patula* (17 plots), *Cupressus lusitanica* (13 plots), *Eucalyptus grandis* (12 plots), and *Eucalyptus tereticornis* (11 plots). There is a very small remnant tropical forest patch of 11.6 ha dominated by *Polyscias fulva* trees within the Arboretum boundaries (Dusenge *et al*. 2015).

The Arboretum Forest is home to wildlife species including blue monkeys, vervet monkeys, duikers, birds, and bats. Human settlements and agricultural fields dominated by maize, sorghum, beans, and sweet potatoes surround the forest, as well as fish ponds at the Rwasave pisciculture research station (Nsabimana *et al*. 2013). People often enter the Arboretum to walk, jog, and collect firewood or fodder for livestock. The forest is managed by the Rwanda Forestry Authority (RFA).

The blue monkeys found in the Arboretum Forest are not habituated to humans, making them difficult to find and observe. Neither previously published studies nor recorded information was available for the blue monkeys in this forest fragment. We conducted pilot observations over four days to assess if the observer who would be collecting data (EK) would be able to follow and observe the monkeys given they were not habituated, and to allow for practice in the data collection process. Since they are surrounded by human-dominated landscape, the blue monkeys do encounter people on a regular basis, and no hunting of the monkeys has been observed in this forest nor elsewhere in Rwanda where this species exists.

Data collection

EK followed the group four to six consecutive days beginning on 22 May, with one day of rest between consecutive days of observations, ending on 7 June. A field assistant went out the day before the consecutive follows were to begin to find the monkeys and locate their sleeping tree to facilitate finding them for the start of the data collection the next morning. We attempted dawn to dusk follows, and obtained between six and 11 (mean: 9.2 ± SD 1.9) hours per day of observations from 0600-1800 h. We used scan sampling to record data, with five minutes of scanning and recording, and 15 minutes' interval between two successive scans for a total of three scans per hour. We made every attempt to score an individual only once in each scan by scanning the group from one side to the other side of the group, scoring the first behavior in view, and moving on to the next individual (Kaplin *et al*. 1998; Kaplin 2001). Activities recorded included: feeding (inserting food in mouth), foraging (searching for food or handling food items), moving, resting, observing, and social interactions (playing, grooming, and fighting). Individual sex was not recorded because it was difficult to identify the sex of juveniles and sub-adults. When an individual was observed feeding, we attempted to identify the food item.

We also recorded data on how the blue monkeys use the Arboretum Forest. Three different habitat types were identified, and we also recorded when the monkeys were in a 50 x 50 m plot during a scan. The habitat types recorded included: remnant tropical forest patch (native tree species including *Polyscias fulva, Markhamia lutea, Erythrina abyssinica, Ficus sur, Podocarpus falcatus,* and *Bridelia micrantha*, as well as non-native trees including *Calliandra colothyrsus* and *Grevillea robusta* and many native and non-native lianas and herbaceous vegetation), open canopy forest within the Arboretum boundary composed of a mix of native and non-native species not planted in the 50 x 50 m plots, and Kabutare natural area (area adjacent to the Arboretum Forest composed of a mix of non-native and native bushes and bamboo). When the monkeys were in a 50 x 50 m plot of trees planted in the Arboretum, we recorded that plot as a 'habitat type' using the name of the species planted in that plot. As mentioned above, some plots included more than one tree species: *Bischofia javanica blume-Vitex keniensis, Grevillea robusta-Entandrophragma* spp., and *Cupressus-Pinus* plots. Habitat types were scored in each scan when the blue monkey was in that habitat during the scan. We recorded when the monkeys were on the ground in order to determine how much time they spent on the ground during the study. We recorded point locations (elevation, latitude, longitude) every thirty minutes using a handheld Garmin GPSMAP 78 unit (Tesfaye *et al*. 2013).

Data analysis

To assess food consumption, we grouped food items according to plant species, plant parts, and their families. Food plant species were also grouped into indigenous or exotic, fruit or non-fruit species. We calculated the average number of scores for each food category per day, and the same

for activity scores per day, and then calculated the average percentage of scores devoted to each food category or activity across the whole sampling period. We measured the size of home range using the minimum convex polygon approach with the GPS waypoints collected during group follows using QGIS (Quantum Geographic Information System) version 3.6 (Mekonnen *et al.* 2020). To examine habitat use, we calculated the average percentage of scores in each habitat type recorded in all scans.

RESULTS

We obtained a total of 428 scans during this study. The blue monkeys were active (not resting) in 77% of the scan records and resting in the remaining 23% of scans. We recorded a total of 2500 activity scan records, and moving was the dominant activity (50%, $\bar{x}$ = 76/day, SD = 25/day), followed by resting (23%, $\bar{x}$ = 38/day, SD = 11/day), feeding (16%, $\bar{x}$ = 27/day, SD = 8/day), playing (6%, $\bar{x}$ = 11/day, SD = 5/day), and other activities (observing, grooming, alarming, foraging, and fighting) (5%, $\bar{x}$ = 15/day, SD = 4/day). They spent most of their time in the trees (99% of 2500 scan records) rather than on the ground (1%).

Diet and Plant species

A total of 35 plant species in 28 families were consumed by the monkeys, along with several unidentified species of insects and fungi (Table 1). They fed on twenty-four exotic and eleven indigenous plant species in this study. This includes ten exotic fruit species and five indigenous fruit species (Table 1). We recorded two crop species, taro root (*Colocasia esculenta*) and sorghum (*Sorghum nigrum*) consumed by this group, comprising 3% of the diet (395 scan records) (Table 2). We observed this group feeding on amaranth (*Amaranthus*), another vegetable crop grown outside the Arboretum, but this feeding was not recorded because it was not observed during a scan. Fruits of *Bischofia javanica blume*, a non-native tree, dominated the diet (Table 2). Several plant species such as *Hoevia dulcis, Terminalia catappa, Maesa lanceolata, Amphicarpea bracteata,* and *Xanthosoma sagittifolium* were infrequently consumed during this study. Fruits and leaves dominated the diet of the blue monkeys with 51% and 36% of the diet recorded (395 scan records), respectively (Table 3).

Habitat type use

Twenty-eight different habitat types were observed to be used by this group of blue monkeys in this study (Table 4). The blue monkeys spent more than half of the recorded observations using the natural forest patch and Kabutare natural area (dominated by *Bambusa vulgaris* trees) within the Arboretum. The natural forest remnant patch had native trees creating a relatively closed canopy which likely provides shelter and resting sites for the group. Habitat types dominated by exotic plant species were used more frequently when they were searching or feeding, and many of those exotic species were fruit species (Table 4). The blue monkeys were observed to exit the Arboretum and forage on crops only four times during this study. The monkeys used an estimated total area of 70.7 ha as the size of their home range recorded in this study (Figure 4). This area includes a small part of Kabutare natural area that is adjacent to the Arboretum Forest.

DISCUSSION

Assessing diet

Prior studies on the diet and feeding ecology of blue monkeys have shown they are mainly frugivorous (Gautier-Hion 1988; Lawes *et al.* 1990; Kaplin & Moermond 1998; Pazol & Cords 2005; Worman & Chapman 2006; Tesfaye *et al.* 2013; Takahashi *et al.* 2019). This is the first study of *Cercopithecus mitis doggetti* species in urban forest fragment in Rwanda, and results show that the blue monkeys were able to maintain a mainly fruit diet by feeding on a non-native fruit (*Bischofia javanica blume*) that was available inside the Arboretum during the study period. Research by Bicca-Marques & Calegaro-Marques (1994) and Wimberger *et al.* (2017) showed that monkeys in fragmented forests similarly consumed more fruits from exotic species than indigenous species, depending on availability, as a way to maintain fruit in the diet. Takahashi *et al.* (2022) show that non-natural foods can be important in blue monkey diet, sometimes comprising more than half of the calories in the daily diet.

While fruits represent an important source of energy for these frugivores (Lambert & Garber 1998; Takahashi *et al.* 2019), they consume other food items to gain proteins, vitamins, and minerals that are scarce or not found in fruits (Takahashi *et al.* 2019). In this study, the blue monkeys supplemented their diet with small dry branches and sheaths of bamboo that seemed to be more difficult to chew or digest but likely provided additional nutritional value. Tesfaye *et al.* (2013) found that blue monkeys in a highly disturbed forest fragment in Ethiopia consumed more shoots and young leaves and

Table 1. Plant species and parts eaten by blue monkeys in Ruhande Arboretum Forest, Rwanda.

Family	Plant species	Part eaten	Indigenous/exotic
Araceae	*Colocasia esculenta*	Leaves	Exotic
Araliaceae	*Polyscias fulva*	Leaves	Indigenous
Bignoniaceae	*Campsis radicans*	Fruits	Exotic
Bignoniaceae	*Markhamia lutea*	Leaves	Exotic
Combretaceae	*Terminalia catappa*	Fruits	Exotic
Convolvulaceae	*Ipomea sp*	Leaves	Exotic
Cupressaceae	*Cupressus lusitanica*	Leaves, seeds	Exotic
Dioscoreaceae	*Dioscorea villosa*	Leaves	Exotic
Euphorbiaceae	*Bischofia javanica blume*	Fruits	Exotic
Euphorbiaceae	*Bridelia micrantha*	Fruits	Indigenous
Euphorbiaceae	*Macaranga kilimandscharica*	Fruits	Indigenous
Fabaceae	*Amphicarpea bracteata*	Leaves	Exotic
Fabaceae	*Calliandra calothyrsus*	Leaves, seeds	Exotic
Fabaceae	*Erythrina abyssinica*	Leaves, flowers	Indigenous
Fabaceae	*Liana sp*	Leaves, stems	Indigenous
Fagaceae	*Quercus suber*	Fruits	Exotic
Lamiaceae	*Vitex keniensis*	Fruits	Exotic
Mimosoideae	*Newtonia buchananii*	Fruits, flowers	Indigenous
Moraceae	*Ficus sp*	Fruits, leaves	Indigenous
Myrsinaceae	*Maesa lanceolata*	Leaves	Indigenous
Myrtaceae	*Eucalyptus amygdalina*	Leaves, seeds	Exotic
Myrtaceae	*Psidium guajava*	Fruits	Exotic
Myrtaceae	*Syzygium zambalavi*	Fruits	Exotic
Oleaceae	*Jasminum officinale*	Leaves	Exotic
Oleaceae	*Jasminum sambac*	Leaves	Exotic
Poaceae	*Bambusa vulgaris*	Leaves, branches, sheaths	Exotic
Poaceae	*Dendrocalamus giganteus*	Leaves, sheaths	Exotic
Poaceae	*Sorghum nigrum*	Grains	Exotic
Podocarpaceae	*Podocarpus falcatus*	Leaves	Indigenous
Proteaceae	*Grevillea robusta*	Leaves, flowers	Exotic
Rhamnaceae	*Hovenia dulcis*	Leaves	Exotic
Rosaceae	*Prunus africana*	Fruits	Indigenous
Rosaceae	*Prunus caretta*	Fruits	Exotic
Simaroubaceae	*Brucea javanica*	Fruits	Exotic
Vitaceae	*Vitis sp*	Leaves	Exotic

Table 2. Percentage scores of all observed food species eaten by blue monkeys, Ruhande Arboretum Forest, Rwanda.

Food species	Indigenous/Exotic species	%
Bischofia javanica blume	Exotic	15.95
Bambusa vulgaris	Exotic	13.16
Polyscias fulva	Indigenous	11.39
Newtonia buchananii	Indigenous	9.87
Calliandra calothyrsus	Exotic	8.86
Brucea javanica	Exotic	8.35
Macaranga kilimandscharica	Indigenous	5.32
Vitex keniensis	Exotic	3.54
Quercus suber	Exotic	2.78
Sorghum nigrum	Exotic	2.53
Ficus sp.	Indigenous	1.77
Ipomea sp.	Exotic	1.77
Insects	—	1.27
Prunus caretta	Exotic	1.27
Bridelia micrantha	Indigenous	1.01
Jasminum sambac	Exotic	1.01
Syzygium zambalavi	Exotic	1.01
Cupressus lusitanica	Exotic	0.76
Dendrocalamus giganteus	Exotic	0.76
Fungi	—	0.76
Grevillea robusta	Exotic	0.76
Erythrina abyssinica	Indigenous	0.76
Eucalyptus amygdalina	Exotic	0.51
Markhamia lutea	Indigenous	0.51
Liana sp.	Indigenous	0.51
Prunus africana	Indigenous	0.51
Psidium guajava	Exotic	0.51
Vitis sp.	Exotic	0.51
Amphicarpea bracteata	Exotic	0.25
Campsis radicans	Exotic	0.25
Dioscorea villosa	Exotic	0.25
Hovenia dulcis	Exotic	0.25
Jasminum officinale	Exotic	0.25
Terminalia catappa	Exotic	0.25
Maesa lanceolata	Indigenous	0.25
Podocarpus falcatus	Indigenous	0.25
Colocasia esculenta	Exotic	0.25

Table 3. Percentage scores of all food items eaten by blue monkeys, Ruhande Arboretum Forest, Rwanda.

Food items	%
Fruits	50.76
Leaves	36.04
Seeds	3.30
Branches	2.54
Grains	2.54
Flowers	1.78
Insects	1.27
Fungi	0.76
Sheaths	0.51
Stems	0.25
Twigs	0.25

far less fruits, highlighting the potential for high flexibility in blue monkey diets, especially relevant for persistence in degraded or small remnant forest patches.

Habitat use

The blue monkeys in this study spent most of their time in the canopy rather than on the ground, similar to findings of blue monkeys in other forests (Gautier-Hion 1988; Kaplin & Moermond 1998; Lawes 2004). Most of their activities such as moving, resting, feeding, grooming, playing, and sleeping were done in the canopy. They used the ground when they were playing and foraging on crops (*Sorghum nigrum* and *Colocasia esculenta*). This suggests that the blue monkeys may use the forest most of the time (natural forest patch and other areas with closed canopy within Ruhande Arboretum) and come out into the human dominated landscape to crop forage in the agricultural fields near the forest briefly, but since this was a very short study more research is needed across the different seasons to determine the consistency of this habitat use. In a comparative study of blue monkeys in intact and fragmented forests, only the monkeys in the fragmented forest engaged in crop foraging to supplement their diet (Tesfaye *et al*. 2013).

CONCLUSION

Forests in urban settings are generally more disturbed, fragmented, isolated, and susceptible to edge effects than intact forests. This increases threats

Table 4. Percentage scores of habitat type use for blue monkeys in Ruhande Arboretum Forest, Rwanda.

Habitat types	**%**
Natural forest	34.31
Kabutare natural area	18.86
Bischofia javanica blume-Vitex keniensis plots	11.60
Eucalyptus plots	6.46
Cypress plots	4.74
Cypress-Pine plots	4.09
Grevillea plots	3.69
Calliandra plots	3.25
Symphonia globulifera plots	2.05
Terminalia catappa plots	1.89
Quercus polymorpha plots	1.69
Brucea javanica plots	1.57
Pinus plots	1.12
Quercus suber plots	0.88
Polyscias fulva plots	0.72
Podocarpus falcatus plots	0.40
Carapa grandiflora plots	0.32
Distylium racemosum plots	0.28
Podocarpus latifolius plots	0.28
Syzygium zambalavi plots	0.28
Open canopy forest	0.28
Zanthxylum gilletii plots	0.24
Bambusa vulgaris cultiva plots	0.24
Cedrela serrata plots	0.20
Ekebergia capensis plots	0.20
Prunus caretta plots	0.16
Grevillea-Entandrophragma plots	0.12
Syncarpia procera plots	0.08

(including habitat loss and fragmentation, predation, and pollution) to the primates inhabiting them, and creates limitations for their diet composition. The blue monkeys inhabiting the Arboretum, an urban forest composed of mainly non-native tree species with a small patch of native tropical forest surrounded by human-dominated landscape in southern Rwanda, maintained a fruit diet in this short study. Blue monkeys are considered very flexible in

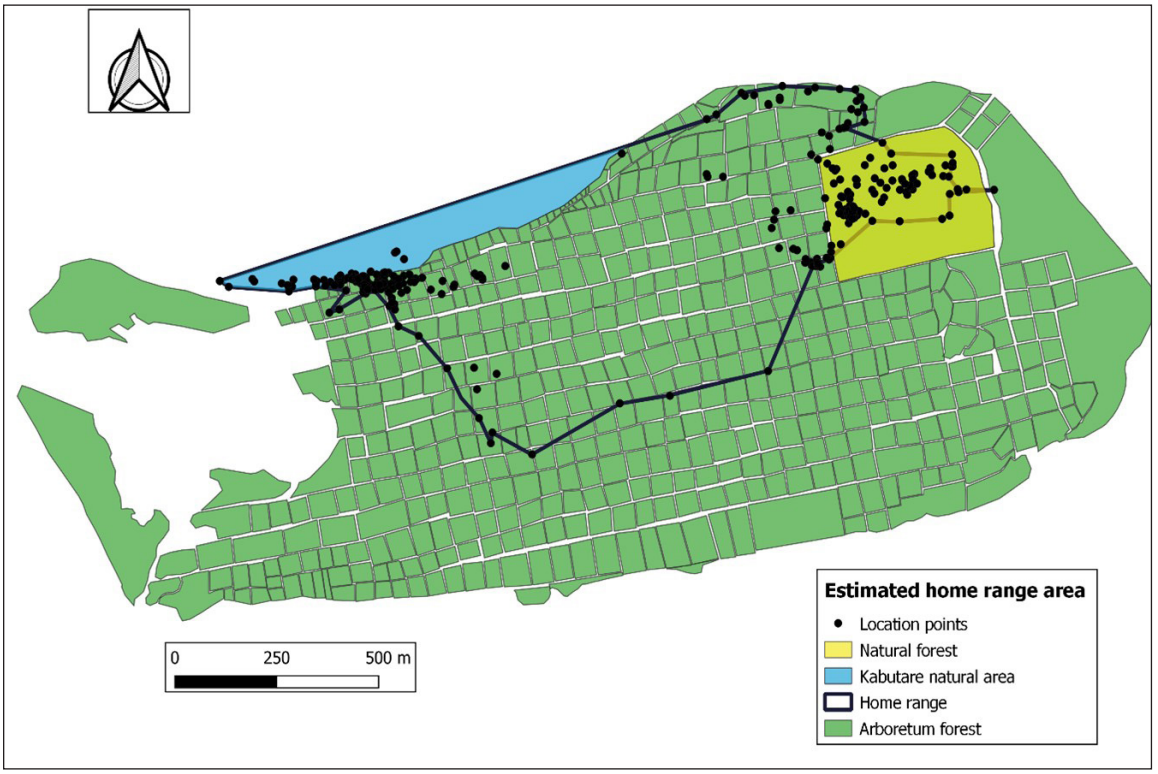

Figure 1. Map of home range of blue monkeys and their use of habitat types in Ruhande Arboretum Forest (shown as black location points). The 50 x 50 m plots are shown as the grids in the Arboretum Forest.

their ability to occupy a wide range of habitat types and forest conditions (Lawes 1991). This may be due to flexibility of their diet composition (e.g., Gautier-Hion 1988; Lawes *et al.* 1990; Tesfaye *et al.* 2013). This flexibility is likely what enables this group of blue monkeys to persist in the Ruhande Arboretum Forest.

Blue monkeys are known to be important seed dispersal agents and are ecologically important as they can contribute to natural forest regeneration (Linden *et al.* 2015). Efforts must be undertaken to conserve these important contributors to the Arboretum's ecological integrity. As a recommendation, further research on this group of monkeys will provide a better understanding of their ecological and economic importance in the Ruhande Arboretum Forest. Studies covering all seasons are needed to understand diet composition variability in such a small forest area they inhabit. An understanding of how the non-natural foods in their diet affect the nutritional quality of the diet are also relevant (Rothman & Bryer 2019). It would be helpful to plant more native species with fruits consumed by the monkeys inside the forest, and to avoid planting crops that blue monkeys are known to consume along the edges of the Arboretum Forest. The blue monkeys only rarely entered adjacent agriculture fields to forage on crops during this study, unlike the sympatric vervet monkeys (*Chlorocebus pygerythrus*), but attention to reducing crop foraging in agricultural fields around the Arboretum Forest is a priority for the protection of this primate species.

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