ASSESSMENT OF COLOBUS MONKEY HABITAT PREFERENCE IN KARURA FOREST, NAIROBI COUNTY KENYA

BY

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DECLARATION

This project report is my original work, and it has not been presented for award of degree in any other university.

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C50/88745/2016

Date: ____________________Signature ______________

This project report has been submitted for examination with my approval as the University supervisor.

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DEDICATION

I wholeheartedly dedicate this work in memory of my papa Eliud Wekesa who believed in me and always wanted to see me excel higher academically, RIP papa. A special dedication goes to my Mama Redempta Wekesa for her unconditional support, both financially, mentally and spiritually, all this achievement is for you Mama.

In addition, I would like to dedicate this work to my brother Ken Arthur Wekesa who constantly reminded me the importance of working hard and burning my last fuel just to ensure I finalize the research project. We stayed late into the night together cracking jokes just to ensure I complete my write up.

Finally, I dedicate this work to all the scientists with passion for ecological, biodiversity conservation and management on earth particularly on primates. Mother Nature needs people like you.

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ABSTRACT

Habitat selection is a reflection of the responses of individual's species to spatial variation in the distribution of resources, other organisms, and environmental conditions. This study assessed the habitat selection of *C. guereza* monkey in Karura forest. The purpose of the study was to evaluate the habitat preference and selection by *C. guereza* monkeys in Karura forest, the main focus was to establish the habitat types within the forest and to compare the utilization of indigenous and exotic forest. The study adopted both cross-sectional and longitudinal study designs. Data was obtained from both primary and secondary sources. Primary data was from species direct observation, photography and note taking, while secondary data relied mainly on literature reviews from scholars, satellite images, videos and websites. The research was conducted over twelve weeks duration and it involved monitoring of seven families of the *C. guereza* monkeys and the habitat they inhibited. Habitat types classification in Karura forest was done by analyzing vegetation cover using satellite image obtained from USGS website in November 2018. The satellite image was from path 168 and row 061 of Landsat 8 OLI and TIRS sensor. The habitat types were classified by using the Landsat 8 satellite images that uses the Operational Landmager and Thermal Infrared Sensors. Kernel Density Estimation (KDE) was used to determine the habitat preference by *C. guereza*. Results from this study indicate that *C. guereza* monkeys display an uneven habitat preference across indigenous and exotic habitat types within the forest. There is high preference for indigenous forest as a result of availability of food in these habitats. The most dominant trees species that were observed to be highly utilized by *C. guereza* included *Vepris trichocarpa*, *Olea Africana*, *Craibia brownie*, *Warburgia ugandensis, Rawsonia lucida* and *Vepris simplicifolia*. From this study no records of exotic tree species formed part of the diet of colobus monkey, a few of the exotic trees utilized by this monkeys were used for resting. This study observed that the *C. guereza* in Karura forest spend relatively very minimum time resting compared to other studies involving similar monkeys. Most studies have recorded about 50% of the time the *C. guereza* spends in resting, which is contrary to this study since it recorded only 22% of the total time spent resting. Thus, based on this observation the study concluded that the re-introduced *C. guereza* in Karura forest, are struggling with adaptation into the forest. The finding of the study recommends that Karura forest management should focus on increased re-planting of indigenous plant species that are highly utilized by *C. guereza* within the forest in order to provide suitable habitat for them. In addition, further studies including the carrying capacity of Karura forest, reproduction success, ecological and

behavioral aspects of *C. guereza* monkey in the study area should be conducted before reintroducing more *C. guereza* into the forest.

LIST OF ACRONYMS

CITES -Convention on International Trade in Endangered Species

FKF **-**Friends of Karura Forest

GIS -Geographical Information System

GPS **-**Geographical Positioning System

KDE -Kernel Density Estimate

KFS -Kenya Forest Services

IPR - Institute of Primate Research

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Chapter One-Background

1.0 Introduction

Habitat can be described as a set of characteristic of environmental factors that a species uses for its existence and reproduction. On the other hand, habitat use has been described as the way in which a species uses habitats to meet its needs (Block and Brennan, 1993). Habitat selection therefore is a hierarchical process of interaction that may result in the uneven use of habitats to influence survival and fitness of species (Hutto, 1985). In addition, Morris (2003) described habitat selection as a non-random set of available habitats, a process where species specially use, or occupy.

The performance of habitat selection enables species to co-exist while individually seeking an optimal environment condition (Rozensweig, 1981). The contributing factors to the variations of habitat include territorial behavior or site loyalty, distribution of resources that is food availability and accessibility and location of other animals. These factors, along with other spatial and temporal factors, jointly play into animals' tendency to confine themselves to a particular habitat. The densities of primate populations fluctuate across different landscapes but even within the boundaries of their home ranges, space has also been observed to be used unevenly by various species (Warner, 2002). The spatial distribution of tropical forest primates has been shown to be affected by the spatial configuration of vegetation, as forest structure differs significantly between known habitat areas and non-habitat areas (Palminteri *et al.*, 2012).

Tropical forests support an immense diversity of primates, with each species giving preference to different levels of vegetation (Cannon & Leighton 1994). The niche separations among arboreal primates have often been categorized according to the vertical stratification during travel and feeding. This stratification has often been attributed to differences in the locomotor behavior of species. For instance, the efficient travel of forest primates through the rainforest canopy is constrained by their capacity to use available structure as well as to cross any tree canopy gaps (Cant, 1992). The ability to traverse gaps depends on the size of the gap itself along with the presence of the appropriate structures at either end of the gap needed by the animal to facilitate crossing (Cannon & Leighton, 1994). The presence of a higher degree of canopy connectivity, with more canopies interconnected by lateral branches and lianas, would therefore be expected to facilitate travel through a forest canopy (Madden *et al.*, 2010). The relative number and diversity of available travel paths through a forest would also depend on the morphological and behavioral qualities of each species. Different species of primates are therefore adapted to specific forest habitats through their ability to travel efficiently through that particular forest structure.

This study focused on the *C. guereza* a monkey species that is physically black with a white covering and a tail tuft. They are mainly found in diverse regions of equatorial Africa covering approximately 268,000 km^2. They are distributed from lowland tropical rainforest towards the montane forests of the upper Donga river. *C.guereza* are also found in the equatorial areas of Africa in Nigeria, east and west of the Niger river, and locally distributed in relic forests north of the rainforest zone. Their tropical rainforest distribution ranges from southern Sudan, Uganda then towards the Kenyan and Ethiopian highlands, Mount Kilimanjaro, Mount Meru and the Kahé District of Tanzania.

1.1 Statement of the Research Problem

Habitat selection often reflects the responses of individuals to spatial variation in the distribution of resources, other organisms, or environmental conditions. In order for habitat selection to meet shifting patterns in the spatial distribution of resources, which can have profound effects on population dynamics and community structure, habitats may be perceived differently by different sex or age classes (Morris & Knight, 1996). This is a supporting argument that habitat selection provides a unifying framework for investigating pattern and process in ecological systems. Some habitats, are always preferred and selected due to the fact that they provide high concentrations of food, shelter, and other resources needed for growth and reproduction, as well as appropriate climatic and edaphic conditions. Alternatively, selected habitats may contain resources that differ little from those of avoided habitats, but often reduced risks of competition, parasitism, or other deleterious interactions with other organisms.

Restoration of degraded tropical forests always focuses on replanting indigenous trees, it rarely includes the re-introduction of lost faunal diversity. The *C. guereza* in Karura forest are one of the rare re-introduction of lost faunal diversity in an effort of restoring the Karura Forest Ecosystem. These *C. guereza* were translocated from degraded habitats on the fringes of the Aberdares forest as part of the Colobus re-introduction project with a goal of restoring the secondary forest of Karura to its original state. The Friends of Karura Forest (FKF) in collaboration with the Institute of Primate Research (IPR) started to reintroduce the arboreal *C. guereza* into Karura which seemingly roamed the rich ecosystem many years ago.

The new habitat (Karura forest) presented new challenges to *C. guereza* a species whose arboreality had been lost after spending the better part of their lives in semi-terrestrial to terrestrial habitats. Jumping distance estimation and reaching out for young leaves while 20-30 metres up the canopy in Karura forest will be problematic. These *C. guereza* are expected to adjust and adopt to the new habitat and it is important to understanding how the species is coping and adjusting in this urban forest. Foraging and availability of food in this habitat are key to ensure their survival and continuity, thus, which tree species are being utilization between exotic and indigenous tree species. The study focused on the preferred habitat by the *C. guereza* factoring in the risk of food availability and habitat availability in Karura forest ecosystem. Despite the insights gained by evaluating the effects of predation on selection of foraging habitats, not all species appear responsive to predation risk therefore indicating that other factors must be important. This study focused in assessing the habitat selection preference by *C. guereza,* this included the most utilized tree species and habitat. The knowledge of the factors driving habitat selection for this particular primate is important for future managing and conservation of the identified habitats preferred, this would additional advice further re-introduction of *C. guereza* into Karura Forest.

1.2 Research Questions

This study focused on answering the following questions:

1 What was the most utilized habitat in Karura forest by *C. guereza*?

2 What were the factors that influence the most preferred habitat utilization in Karura forest?

3 If there are differences in habitat utilization in different vegetation formation, to establish what these might mean in terms of the future conservation of this subspecies in Karura Forest

1.3 Study Objectives

The general objective of the study was to examine the habitat preference and selection of *C. guereza* in Karura forest.

The specific objectives were to: -

1. Examine the *C. guereza* habitat type in Karura forest

2. Evaluate habitat preference of *C. guereza* in Karura forest

3. Compare the utilization of indigenous and exotic habitats by *C. guereza* in Karura forest

1.4 Study Hypotheses

The following hypotheses were tested: -

1. Ho- There is no significant difference in vegetation density of the habitat types preferred by *C. guereza*.
2. H_{O}- There is no significance difference between habitat preference in indigenous and exotic habitats by *C. guereza* in Karura forest

1.5 Justification and Significance of the Study

The translocation of *C. guereza* to Karura forest has ensured the conservation of this endangered species of monkeys as well as trying to restore Karura forest to its original state to provide ecosystem services for all (Friends of Karura, 2017). This research enabled a clear understanding on the mechanism underlying the selection of habitat and thus help in predicting how anthropogenic changes to landscape are likely to affect distribution of *C. guereza* species and its population. As such the research would inform the Karura forest management about the status of biophysical environment that is favorable to the *C. guereza,* especially in terms of vegetation species diversity and most preferred habitats. This study highlights the specific tree species that the Karura forest management can consider during the replanting exercise. As a result, the management would be able to prioritize and strategize on effective conservation and management of the critical vegetation species that might be facing any threats. The Karura Forest management would also use the findings of this research to design future strategies in boosting the conservation of other *C. guereza* that might be facing threats due to habitat loss. The study has recommended strategies that the management can implement in order to create space to ensure the hosting of more *C. guereza.*

1.6 Scope and Limitation of the Study

The study was conducted in Karura forest main block but focused on the *C. guereza* habitat types selected only covering both indigenous and exotic species. This was done through direct observation in monitoring of the *C. guereza* home range patterns at different spots of the forest. The study involved tracking the *C. guereza* during the day time at varying times, mainly in the early morning and evening hours. Thus, unlike monitoring the animal using radioactive chips, this study only covered the habitat selection and preference for *C. guereza* for specific times of the day at intervals physically using classical ecology. In addition, the study was limited by technology as the research did not have appropriate equipment for night vision and was the study was therefore conducted during the daytime.

1.7 Operational Definitions

The table 1 below highlights the definitions of terms used in the project report

Table 1: Definitions of terms

Term		**Definition**
Basal Behaviors	Feeding(F)	Insertion of leaves, flowers, fruits, into the mouth, also chewing.
	Resting (R)	It includes any inactive motionless state like lying down, sleeping or sitting ideal
	Moving (M)	It includes the animal's subsequent steps and is completely in motion without engaging in any other activity
	Grooming (G)	Individual picking through the fur itself or for another individual, including scratching.
Social behaviors	Socializing/playing	One individual is chasing or being chased by another individual or two or more individuals are wrestling without distressed behavior.
	Vocalizing (V)	Individuals engages in calling
	Aggression (A)	Individuals engage in contest interactions like fighting, threatening, chasing or any other unfriendly behavior
	Out of sight (OS)	Individual is out of sight, lost or the behavior is not clear
Patch		Habitat type within the study area
Resource		Tree species that colobus monkey utilizes

Chapter Two- Literature Review

2.0 Introduction

This chapter discusses the available literature and empirical literature of the *C. guereza*. The major themes considered in the literature review include; a) the concept of habitat, b) *C. guereza* Social structure and behavior, c) *C. guereza* feeding habits, d) threats to *C. guereza*, e) research gaps. The last part presents the theoretical and conceptual frameworks.

2.1 The concept of Habitat and Habitat use

According to Krausman (1999) habitat can be defined as the resources and conditions present in an area that produce occupancy, including survival and reproduction, by a given organism. In addition, Leopold (1933) explained that a habitat is more than vegetation or vegetation structure but the sum of the specific resources that are needed by organisms. For instance, a study by Wallace (2010) in Central and Southern Peru in Mexico, on factors influencing habitat use and ranging patterns by spider monkey, the most important factor that influences spider monkey ranging behavior and habitat use was the availability and distribution of fruit resources in the forest as this is the specific resource that is being utilized by the monkey. Another study by Chapman *et al.*, (2001) conducted in the Mexican Lacandona rainforest indicated that *C.guereza* selected trees for sleeping (sleeping sites and sleeping trees, respectively. Beneath these trees they deposit copious amounts of dung in latrines. This behavior results in a clumped deposition pattern of seeds and nutrients that directly impacts the regeneration of tropical forests.

In Kakamega Forest, Kenya Von Hippel *et al.*, (2000) indicated that the distribution of *C. guereza* was highly influenced by human activities, he noted that in Kakamega Forest, these monkeys experienced a striking decline in density over a six-year period during which the forest was degraded by human activity. The *C. guereza* in Karura forest, with the fact of being re-introduced into this ecosystem unlike the above studies where they selected habitats in areas the occurred natural will be an interesting adaptation. Thus depending on their nutritional needs, sleeping sites and predation risk among other factors, they will select the most suitable and productive habitat.

Habitat use is a way in which an animal uses the physical and biological resources in a habitat (Krausman, 1999). Habitats may be used for foraging, cover, nesting, escape, dens, or other life history traits. The various activities of an animal require specific environmental components that may vary on a seasonal or yearly basis. A species may use one habitat in summer and another in winter. This same habitat may be used by another species in reverse order. Several interacting factors have an influence on habitat selection for an individual i.e competition, cover and availability of food. Competition is involved because each individual is involved in intra specific and inter specific relationships that partition the available resources within an environment. Competition may result in a species failing to select a habitat suitable in all other resources or may determine spatial distribution within the habitat.

A study on scramble competition among colobus monkeys at Boabeng-Fiema (Saj & Sicotte, 2007) in Ghana found out that competition for food to meet the dietary and energy demand among the groups influenced there ranging patterns. Smaller groups will go for short distances looking for food compared to large groups that will range longer distances to meet their daily dietary need. This is directly influenced by availability of food.

According to another study by Fashing, (2004), on activity and ranging patterns of *Colobus angolensis* in Ruwenzori in Nyungwe forest, it was found that *Colobus angolensis* at Nyungwe spend markedly less time resting, spend more time feeding and moving, and travel much longer distances per hour than *C.guereza* in other forests. It was noted that adults colobines group devoted 62% of their time to feeding and moving. They spent an additional 32% of their time resting and 5% of their time grooming. Aggression accounted for <1% of activity records though scan sampling regimens are probably prone to underestimating time spent engaged in ephemeral events such as aggression. Females and males devoted similar amounts of time to feeding. However, females spent more time moving and grooming than males did and considerably less time resting. Another study by Wahungu (2005) conducted in Tana river flood plains in Kenya on changes in forest fragment sizes and primate population indicated that reduced forest sizes and fragmentation have far-reaching consequences for primate populations. The study found out that the Tana River colobus have small home ranges and no recorded ability of moving between patches. This may be explained by several factors: evidence shows that the ability of colobines to live on edges may be related to a dietary preference for secondary growth (Onderdonk & Chapman, 2000).

2.1.1 Habitat quality and availability

The type and quality of habitat are important determinants of *C. guereza* survival. Different habitat types provide different foraging opportunities (Rasmussen, 2006), which in turn influences their foraging activity, and survival. Quality habitat provides a level of critical resources especially in the heterogeneous habitat. For example, a study in Madagascar found out that heterogeneous forest habitat provides spatial heterogeneity of food for many primates and other wild animals (Barton *et al*., 1992) compared to homogenous habitat that has limited food varieties. According to another study conducted in a rain forest in Gabon (Brugiere *et al.*, 2002), heterogeneous habitat supports larger populations of primates because they can access various choices of diet categories among the available food resources. Thus, diversity and continuous availability of resources determine the quality of foraging habitats for most primates (Marshall, 2007), although some species have a fairly restricted diet for example, Chimpanzees (*Pan troglodytes*), Baboons (*Papio anubis*) and Guenons (*Cercopithecus spp.)*. Additionally another study (Nielsen, 2012) on animal evolution found out that use of trees for foraging and travelling appears to be species specific, for example Olive colobus (*Procolobus verus)* use the understory (0-15m) whereas King colobus (*Colobus polykomos)* and Western red colobus (*Colobus badius)* use higher up in the canopy (5-40m). Their home range size can be quite variable from 2.5 hectares to over 100 hectares. Distance travelled per day by a group of colobines averages 500 to 600 m.

The quality of habitat for primates is affected by many factors including habitat fragmentation, habitat loss, modification in tree canopy, changes in vegetation composition and structure, changes in species diversity, and decline in quality and quantity of food resources (Arroyo-Rodríguez *et al*., 2008). While different species of primates may demonstrate different levels of tolerance to habitat fragmentation, habitat structure and anthropogenic disturbance are known to affect primate abundance (Pyritz *et al.*, 2010). It has been noted that habitat destruction that leads to habitat loss causes decline in populations and eventually extinction in many primates' populations example (Chapman *et al.*, 2001)). According to (Madden *et al.*, 2010) in a study conducted in an Urban Forest Landscape in Panamá, habitat loss decreases patch size and hence food availability, which subsequently diminishes population density of primates, the occupancy of primates in disturbed habitat is related to patch size and food availability because vegetation cover varies among different fragmented landscapes. In addition, the smaller the patch size the lower the density of large trees and plant richness, which in turn affect daily behavioral activities of primates.

According to another study by Arroyo-Rodrfguez (2006) in Mexico, the abundance of primates is related to vegetation attributes such as the abundance, and basal area of major food resources. For instance, howler Monkeys (*Alouatta paliata*) in Los Tuxtlas, Mexico are able to survive in small fragmented habitat due to greater density of large trees, greater basal area of persistent tree species, and greater basal area of top food species). However, fragmented habitat affects the availability of food resources that leads to reducing primate density and changing primate behavior. Thus, the ability of primates to maintain their population density in habitat fragments is due to availability of food resources. Even the availability of specific or preferred food resources may affect the quality of habitat for certain primate species. For instance, in Kalimantan, Indonesia, specific types of food resources determine the quality of habitat for Red Leaf Monkeys (*Presbytis rubicund rubida*) rather than general measures of the availability of food resources (Marshall, 2007).

Primates display varying degrees of behavioral flexibility that allow them to adjust their diet to temporal changes in food availability. This trait might be critical for the survival of folivorous-frugivorous species inhabiting small forest fragments, where the availability of food resources tends to be lower than in large fragments and continuous forests. Scientist Chaves (2016) conducted a 36-months study in northeastern Argentina. The aim of the study was to test the hypothesis that brown howler monkeys (*Alouatta guariba clamitans*) are able to adjust their diet in response to local and seasonal changes in resource availability. From the study, it was observed that brown howlers exploited similarly rich diets in small fragments that were found in the study area. The study established that the consumption of young leaves was higher in small than in large fragments, whereas the consumption of other plant items did not show a pattern related to fragment size. Regarding the contribution of growth forms as food sources, only the exploitation of palms tree (Palmae T,) showed a pattern related to fragment size. The availability of seasonal food items–ripe fruits and young leaves–influenced their consumption in both habitat types. Therefore, brown howlers cope with local and seasonal fluctuations in food availability by opportunistically exploiting resources. In this respect, it was discovered that brown howlers alter their diet in response to local and seasonal changes in food availability (Chaves, 2016) by adopting flexible strategies. These strategies included the consumption of plant items from alien species and a higher consumption of young leaves in small fragments. The *C. guereza* in Karura forest are also expected to adjust to changes of the new ecosystems that they have been re-introduced into. However, this study did not compare the habitat selection in regards to seasonal variation as the research had limited time, only 12 weeks.

A different study on the effects of habitat disturbance and food supply on population densities of three primate species in the Kakamega forest, Kenya (Mammides, 2009) found close correlation between food trees and group densities. Among the four ecological areas of the Kakamega forest studies, there was a significant correlation between diversity of food trees and group densities of black and white *(C. guereza),* redtails *(Cercopithecus ascanius)* and blue monkeys (*Cercopithecus mitis*). Fairly unexpectedly, however, there was no correlation between monkey group densities and basal area density of their respective food trees, this indicated that despite the availability of food trees the monkeys will still not occupy that particular habitat. In addition, the main influence on primate ranging behavior is food abundance and distribution (Bennett, 1986). Temporal variations in the availability and distribution of preferred resources shape primates' ranging patterns and can affect the size and shape of home ranges (Harvey & Clutton, 1981). Other factors known to affect primate ranging behavior include the position of water resources location of sleeping sites (Chapman *et al.,* 1989), climatic extremes (Chivers, 1974), the need to patrol boundary areas of the home range. Research by Costantini & Kopan (2010) involving a number of animal species and humans has shown that objects, including food, in the proximal environment automatically activate, and facilitate possibilities for motoric movements in interaction with the objects, so-called affordances. To test this idea, two experiments with long-tailed macaques (*Macaca fascicularis*) in America investigated whether monkeys experience difficulties in reaching their food as a result of the distance between the monkey and the food. The study established that the observation of accessible food leads to less inhibition of reaching movements to obtain the food than the observation of inaccessible food in long-tailed macaques. This suggests a habitat that has food but the food is not accessible will not be easily selected. On the other hand, a habitat with easy access to food will be more selected and inhabited. This study will therefore find out the correlation of habitat availability and food accessibility.

2.1.2 Habitat Selection

Habitat selection as a hierarchical process involving a series of innate and learned behavioral decisions made by an animal about what habitat it would use at different scales of the environment (Hutto,1985). On Classical studies of habitat selection in America, Wecker *et al.*, (1964) using deer mice (*Peromyscus maniculatus*) revealed that the main factors for habitat selection include heredity and experience of a particular deer mice species. On the other hand (Rosenzweig, 1981) emphasized that habitat selection was generated by foraging decisions. However, foraging is only one behavior driving habitat selection. Habitat may be selected for cover availability, forage quality and quantity, and resting or denning sites. Each of these may vary seasonally. If an individual or species demonstrates disproportional use for any factor, then selection is liable for those criteria (Block & Brennan, 1993). Another scientist Hilden (1965) in Mexico designed his ideas on habitat selection by classifying the differences between proximate and ultimate factors. Proximate factors serve as cues an animal uses to determine the suitability of a site including the specific vegetation composition within a desired habitat. Reproductive success and survival of the species are the ultimate reasons that influence a species to select a habitat (Hilden, 1965). The ability to persist is governed by ultimate factors such as forage availability, shelter, and avoiding predators (Litvaitis *et al.*, 1996).

In Africa, the *C. guereza* are predominantly found in forests and savanna woodlands within, and to the north, of the moist forests of central Africa. In East Africa, particularly in Kenya, they are found in Central Kenya along Mt Kenya and Abadares region, others are distributed in Mau forest ecosystem and coastal region. Other habitat types include primary, secondary, riparian, gallery, and upland forest, and moist lowland, medium-altitude and highland forests, rainforests, swamp forests and wooded grassland (Harris & Chapman, 2007). This species also inhabits disturbed, secondary, or colonizing forests, and prefers degraded forests to old growth when both are available (Lwanga, 2006). Habitat selection is therefore an active behavioral process by an animal. Each animal species searches for features within an environment that are directly or indirectly associated with the resources that an animal would need to reproduce, survive, and persist. Habitat selection is a compilation of innate and learned behaviors that includes foraging, ranging patterns and habitat choice that lie on a continuum of closed to open genetic programs (Hela *et al.*, 1964).

2.2 *Colobus guereza* Social structure and behavior

C.guereza generally live in small social families of several adult females and a single adult male (Oates, 1994). Group size tends to number about 10 to 15 individuals. Some troops may contain multiple adult males but this may be associated with either male replacements or young males maturing in their natal families.

According to a study in England (von Hippel 1996), the *C. guereza* were found out to be social animals who live in cohesive, mixed-gender groups averaging 3 to 15 individuals; however, groups as large as 23 have been reported in England. A group is typically comprised of one adult male, several adult (reproducing) females, juveniles, and infants. Occasionally, a group might hold several adult males; however, this is a temporary situation and the superfluous males eventually wear out their welcome and exit the group. In addition, groups of up to 23 have been studied and group sizes of up to 30-40 individuals are reported in the southern gallery forests of the Central African Republic. This large groups size tend to be found in contiguous forest.

Another study by Kruger (1998), on group size and composition of *Colobus guereza* in Kyambura Gorge, Southwest Uganda reported typical group sizes of 8 individuals, mostly with 1 adult male. In the study *C. guereza* territories were identified to be much smaller between 0.2-0.5 ha than their home ranges. It was only the adult males that defended territories by roaring in the morning, in the late afternoon, or at night. When two groups came very close to one another, the adult males displayed with erected penes and sometimes tongue clicking. In Ethiopia, a study on Population structure and feeding ecology of *C. guereza* in Borena-Sayint National Park found out that the *C. guereza* groups ranged from 4 to 13 individuals. However, the mean group size was 7.7 individuals. In most cases, one adult male, three adult females, two sub-adults, two young and/or infant are typical to the area (Monfort, 2003). It was observed that the number of adult males in *C. guereza* groups in this study is related to habitat type (von Hippel, 1996). Larger multi-male groups usually live in continuous forests but smaller one male group likely resides in patchy forests. The group size of these monkeys can be influenced by logging history, predation risk and feeding competition (Fashing, 2006). In Kenya, *C. guereza* are found in the highlands of Mt Kenya region and the coastal areas. They live in troops of about five to ten animals, comprising of a dominant male, several females, and their infants. Some groups will temporarily have multiple males, but they leave once they have matured. The females, however, remain with their birth group for their entire life. Each troop has a well-defined territory, which is defended from other groups (https://www.awf.org/wildlife-conservation/colobus-monkey). These monkeys rarely descend to the ground. They use branches as trampolines, jumping up and down on them to get liftoff for leaps of up to 15 meters (50 feet). They leap up and then drop downward, falling with outstretched arms and legs to grab the next branch

2.3 *Colobus guereza* Feeding habits

The *C. guereza* are diurnal primates, with trichromatic vision allowing them to see more shades of colors than other primates. This characteristic is good for spotting ripe and unripe fruit, and also young darker colored leaves. As such they spend a large part of their day foraging for food in high to low light conditions (Yamashita *et al.,* 2005). In addition, *C. guereza* are folivores-frugivores having a diet mainly of leaves, although buds and fruits are also included. According to a study in Northern America (Yamashita, 2015) about 35-75% of their diet consists of young leaves, which are easier to digest and are less toxic. However, at times they may not have the choice of young leaves and therefore feed on mature leaves that are difficult to digest. In addition, *C. guereza are* arboreal in nature and the types of forest they can inhabit are wide ranging from primary and secondary forests, highland and lowland forests, tropical rainforests, coastal evergreen forests, swamp forests, semi deciduous forest, riverine and gallery forest. They are also found in degraded or partially logged forests. In addition, these primates are generally forest bound and do not leave a forest patch unless to colonize a new fragment (Harris & Chapman, 2007).

Similarly, a study in equatorial Africa (Nowak, 1991), established that the *Colobus guereza* diet consists primarily of leaves with about 58% of young unripe leaves, 12.5% mature leaves, 13.5% fruits, 4% leaf buds, and 2% blossoms. However, this distribution is highly varied seasonally and geographically, thus at times mature leaves may account up to 34% of the diet. *Colobus guereza* in this region seem to prefer leaves that are less susceptible to seasonal fluctuations. In Kenya, a study in Kakamega forest (Fashing, 2007) established that nutritional factors are among the most important influences on primate food choice. The study similarly concluded that leaves forms a greater percentage of the *colobus guereza* diet compared to barks, stem and fruits. The diet of *C. guereza* in Kakamega forest consisted of 23.7% young leaves, 29.1% mature leaves, 37.4% whole fruits, 1.2% seeds, 0.5% flowers, 2.5% bark, and 5.7% unclassified items. The *C. guereza* consumed soil occasionally as well.

2.4 Threats to *Colobus guereza*

Africa contains a number of the world's biodiversity hotspots, including; the Western African Forests and the Eastern Arc (8th hottest hotspot in the world) and Coastal forests of Tanzania and Kenya, all crucial habitats of colobus monkeys (Myers et al., 2000). In addition to ongoing deforestation; hunting, diseases and climate change are major threats to colobus monkey populations in these forests (Pavelka *et al.,* 2007). Particularly for East African tropical forests rapid human population growth has had a drastic effect. These forests are increasingly used for bush meat, fuelwood, poles, timber and charcoal production and are leveled for growing crops and exotic trees. This has led to widespread forest fragmentation. *C.guereza* being highly arboreal are especially vulnerable to these threats, as they require leaves, fruits and seeds for survival.

Tropical forests are often subject to both legal and illegal human activities resulting in forest loss and fragmentation, as well as changes in vegetation structure and composition that may affect forest dwelling animals (Cowlishaw & Dunbar, 2000). The conservation of organisms living in tropical forests depends on their ability to withstand anthropogenic habitat disturbance (Onderdonk & Chapman, 2000). Most primate populations today face ongoing habitat disturbance (Mittermeier *et al.,* 2006) and its effects are likely to increase as human populations grow. The translocation of this monkey to Karura forest was highly triggered by the impact of habitat fragmentation as a result of human encroachment into their habitat for agricultural purposes, as such, a lot of the habitats were destroyed leaving the monkeys with no option but intrude the farmland to meet their food demand. A lot of human wildlife conflict lead to the death of the endangered *C. guereza.*

2.5 Research gap

The above review reveals that many of the previous researchers concentrated on the habitat use and selection, feeding and social behaviors of primates that naturally occur in the studied area. Very little has been studied on the *C. guereza* reintroduction into a new ecosystem. Therefore, this study focused on habitat use and selection of *C. guereza* that has been re-introduced in Karura Forest an urban forest ecosystem after their natural habitat had been fragmented and they were facing threats of human wildlife conflict, the primates in this area needs to adjust and find a way of surviving as 'foreigners' in an already established urban forest set up.

2.6 Theoretical framework

2.6.1. Ideal Free Distribution (IFD) theory

Ideal free distribution by Fretwell (1972) in ecology is a way in which animals distribute themselves among several patches of resources. The word "ideal" implies that animals are aware of each patch's quality, and they choose to forage in the patch with the highest quality. The term "free" implies that animals are capable of moving unhindered from one patch to another. The theory states that the number of individual animals that will adopt in various patches is proportional to the amount of resources available in each patch (Fretwell, 1972). For example, if patch A contains twice as many resources as patch B, there will be twice as many individuals foraging in patch A as in patch B. This theory predicts that the distribution of animals among patches will minimize resource competition and maximize fitness.

The reintroduction of colobus monkey into Karura forest will act as an experiment in the confirmation of this theory. As the monkeys were released into the forest, they identified different patches with resources that they need to survive. The monkeys were able to mark their territories and live with their families depending on how much the resource will support them. The monkeys were free to choose their patches and only live at the most comfortable patch they assumed. This theory has the following assumptions;

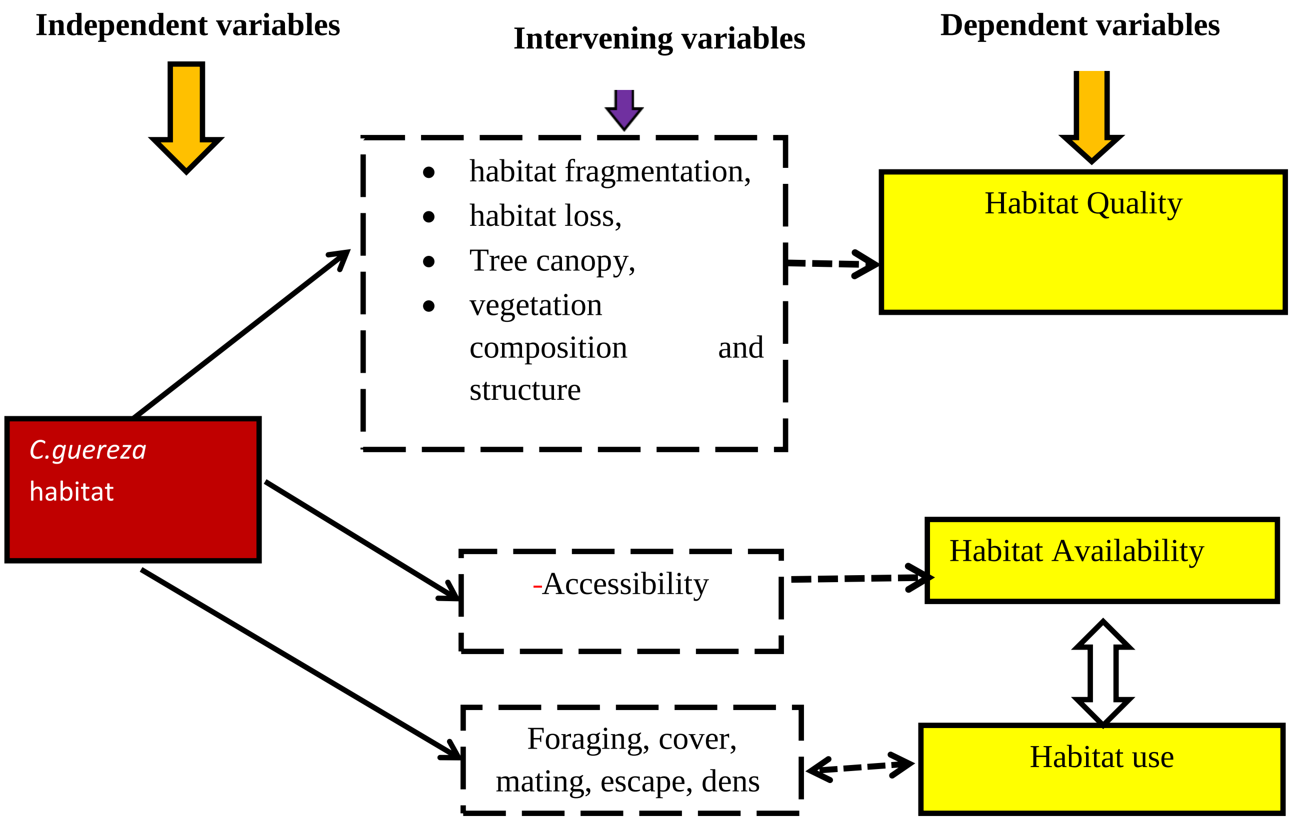
- Each available patch has an individual quality that is determined by the amount of resources available in each patch. Given that there is no any competition in each patch, individuals can assess the quality of each patch based merely on the resources available.
- Individuals are free to move to the highest quality patch. However, this can be violated by dominant individuals within a species who may keep a weaker individual from reaching the ideal patch.
- Individuals are aware of the value of each patch so that they can choose the ideal patch.

2.7 Conceptual Framework

For purposes of this research, ‘patch’ refers to the habitat type and ‘resource’ refers to the tree species that colobus monkey utilizes. The interactions of *C. guereza* in Karura forest highly depend on the available resource that are randomly distributed within the forest.

Groups of colobuses will highly adopt to the most ideal patch depending on their preference. Other factors of interaction will include proximity of the patches to human interaction i.e. human settlement, public roads, walking paths within the forest among others. Figure 1 shows the conceptual framework adopted from the Ideal free distribution theory.

Figure 1: Conceptual framework



Key of the variables

Direct influence of independent variable on intervening variable

Inverse/ reverse relationship between dependent variables

Influence intervening variables on dependent variable

Direct Inverse effect between intervening variables and dependent variable

Source (Researcher 2018)

Chapter Three-Study Area and Methodology

3.1 Study Area

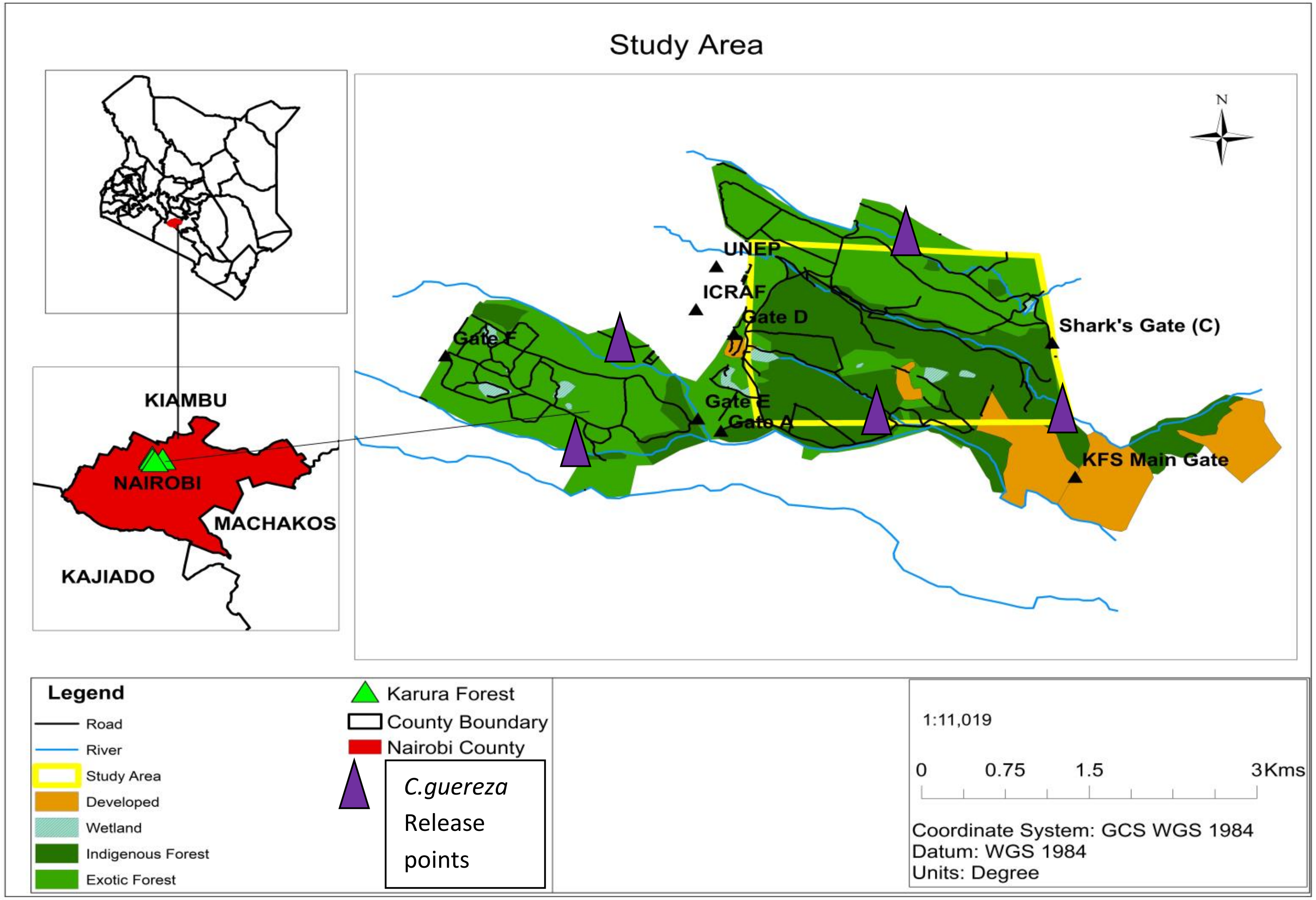
3.1.1 Overview of Karura Forest

Karura Forest Reserve is an urban forest situated in the northern part of Nairobi County and it forms part of the Nairobi river basin. The forest includes three sections separated by the Limuru Road and the Kiambu Road. The southern boundary of the forest lies along the Getathuru River. The western section (previously known as Sigiria) is delineated by a cut and beaconed line along its boundary with the residential area of New Muthaiga to the west, the residential areas of Gigiri/Rosslyn to the North (along the Thigiru River), Limuru Road to the East and the Getathuru River to the South (Karura Forest Strategic Plan, 2010).

The middle section is bounded by a cut and beaconed line along Limuru Road, the residential area of Muthaiga North and Runda to the west, Rua Ruaka River, Huruma village, a road, and farmland to the north, Kiambu road to the east and Getathuru River1 to the south. The eastern section is bounded by the Kiambu Road to its west, Thika Road to the east, and Muthaiga Golf Club to the south. The study was strictly focused in the middle section of the forest reserve, as this is the area where the *C. guereza* were re-introduced. See figure 2 below.

The Friends of Karura Forest (FKF), a community Forest association undertook to reintroduce the arboreal *C. guereza* in Karura Forest in 2014. This was after identifying the *C. guereza of* Kipipiri community that occupies a highly degraded riverine habitats leading to a lot of human wildlife conflict. As a result, most of this endangered species were killed. Some of the *C. guereza* groups in Kipipiri community barely survived in very small and unsustainable fragments, forcing two or even three groups to merge in some areas and subsist mostly on crop raiding. This resulted in human *C. guereza* conflict. Translocation was the only way to save them. The translocation exercise successfully came to a close in March 2016. A total of 22 families were translocated, out of which 15 were released at the Karura Main block, from this, 7 families established consistent territories this means they will be found on the same home range over and over and will not move to any other space (Friends of Karura, 2017). This study focused on these consistent families as it was practical to monitor them.

Figure 2: Study Area



3.1.2 Physical Environment

Climate

The climate of Karura Forest is characterized by two wet seasons: April-June and October-December. July to August is a cold, cloudy but dry period. From August to October is a sunny and dry period. January, February and early March are hot, dry months. The average annual rainfall at Karura forest Station was recorded over the past 10 years as 928.34 mm with a maximum of 1,239.90 mm and a minimum of 345.00 mm. Temperatures remain constant throughout the year and vary roughly with the times of cloud and sunshine

Geology and Topography

The topography of Karura is gently rolling, occasioned by shallow valleys. Drainage is generally in the southerly and eastern direction. Sometimes insusceptible depressions in the Western Section of Karura (previously called Sigiria forest) hold small local swamps which are threatened by eucalyptus trees (Karura Forest Management Plan 2010-2014).

The Karura Forest lies over tertiary volcanic rocks. Volcanic tuffs with intercalated flows of basaltic larva are the common forms. Both types are occasionally exposed in the deeper river valleys, and the tuffs yield the common grey building stone of the Nairobi district. Occasionally “Chimneys” of larva are found exposed on the tops and rides of ridges as in the both the Western section and Middle section of Karura.

3.1.3 Biological Environment

Flora

Karura forest is divided into two blocks. Block 1, Karura and Eastern Salient the largest block with 765.9ha, and Block 2 Sigiria 275.4 ha. The area of the forest is further subdivided according to vegetation distribution as shown in table 2 below;

Block	Indigenous Forest (*) (**) (Ha)	Exotic Plantation Areas (*) (Ha)	Deforested areas (Ha)	Other (Ha)	Total (Ha)
Karura	213	411	32	37	693
Eastern Salient	25	0	0	80	105
Sigiria	22	222	0	0	244
Total	260	633	32	117	1042
	25%	61%	3%	11%	100%

Table 2: Karura forest vegetation distribution (source Karura Forest Strategic Plan 2014)

(*) These areas include patches of *Lantana camara.*

(**) Indigenous Forest does not include the 95 Ha re-planted in the northern portion of the forest, nor does it include ca. 20 Ha of edaphic grassland glades and Some of the most visible indigenous trees species observed during the field survey include *Croton megalocarpus, Warburgia ugandensis (*Muthiga kik*), Markhamia lutea, Vepris simplicifolia, Juniperus procera (*Cedar*), Craebea brownii, Newtonia buchananii, Ficus thonningii (*Mugumu*), Vepris trichocarpa, Drypettes gerrandii , Craibia brownie, Rawsonia lucida* and *Olea Africana* (Researcher 2018). Exotic forest plantations observed included imports from South America, Australia and the Asian sub-continent, such as *Araucaria cunninghamii, Grevillea robusta, Eucalyptus saligna, E. globule, Cupressus torulosa* and *Cupressus lusitanica* (Researcher 2018)

Fauna

Karura forest is known to host a variety of animals. These include the Suni, Harvey's Duiker (*Cephalophus harveyi*), Bushbucks (*Tragelaphus scriptus),* Genets *(Genetta),* Civets *(Viverridae),* Honey Badgers *(Mellivora capensis),* Bush Babies *(Galagidae),* Porcupines *(Erethizon dorsatum),* Syke's Monkeys*(Cercopithecus albogularis),* Bush Squirrels *(Paraxerus),* Hares *(Lepus)* and the Epauletted-Bat *(Epomophorus wahlbergi).*

A Side-striped Jackal *(Epomophorus wahlbergi)* has been recorded in Sigiria. To date, some 200-bird species have been seen in the forest.

These include Ayres Hawk-eagle *(Hieraaetus ayresii),* the African Crowned Eagle *(Stephanoaetus coronatus),* the Silvery-cheeked Hornbill *(Bycanistes brevis), Turaco hartlaub*, the *Narina trogon*, the African Wood *Owl (Strix woodfordii),* Crested Cranes (*Balearica regulorum),* Sparrows *(Passeridae),* Doves *(Columbidae)* and Weavers *(Ploceidae)* (Karura Forest Management plan 2010-2014). And now the recently reintroduced *C. guereza.*

3.2 Methodology

3.2.1 Study design

The study adopted both cross-sectional and longitudinal study designs. A cross-sectional design is a type of observational study that analyzes data from a population, or a representative subset, at a specific point in time. While longitudinal design is a research design that involves repeated observations of the same variables over short or long periods of time. In this study a representative family of *C. guereza* were studied over a short period of time, 12 weeks. The selected families were studied and records of habitats they inhabited, trees species they utilized and activity they undertook were recorded.

3.2.2 Data sources

The study used both primary and secondary data. The primary data was collected mainly by direct observation, recordings and photography was used to back up this data. Secondary data mainly from literature reviews, satellite images, videos and websites were adopted.

3.2.3 Reconnaissance

A preliminary survey on the study area was conducted for four weeks in September 2018 to identify study sites, this included mapping out the encountered *C. guereza* families and coding them. Based on these reconnaissance surveys, promising sites i.e. consistent reliable families were identified and habitat types were classified based on the dominant vegetation type using the satellite image analysis.

3.2.4 Sampling

Purposive sampling was adopted for this study. The reason for this was because *C. guereza* move a long their home range area and it's only possible to monitor a consistent family within a home range. During the reconnaissance study, the research identified 7 consistent groups out of the 15 released in this block. To identify the different families, the territories were separated by rivers and paths along the forest.

This research was able to distiquish each family mainly by the number of individuals each family had including the composition of males, females and infants respectively. For ease of identification, each family was coded as families using letters E, K, M, P, Q, R and S. The research sampled a total of 7 families. These families were consistent in the territories the occupied and it was easy for the research to monitor. The *C. guereza* families do not overlap, every family forages and ranges within their territories, this enabled the research to avoid the risk of monitoring same family at a different territory.

3.2.5 Habitat preference Analysis

Kernel Density Estimation (KDE) was used to determine the habitat preference for *C. guereza* by analysis the data collected on the occurrence of the different families identified above that is E, K, M, P, Q, R and S. This tool was chosen for its ability to specify the bandwidth selection technique and create isopleths from the raster surface. For this study, a density surface was created using Spatial Ecology's Geospatial Modelling Environment *(http://www.spatialecology.com/gme).* Bandwidth selection was determined by the least-squares cross validation 23 (LSCV) algorithm and the resolution (cell size) was set to 30 meters. The isopleth tool, also within the Geospatial Modelling Environment, was then run on each KDE output, setting the quantiles to 0.95 to produce the 95% isopleth. The Kernel Density Estimate produces a probability surface to determine the areas that are likely frequented by *C. guereza.* Kernels, probabilistic functions fitted to each point, provide the values for a smooth density surface. Calculated values from this surface were used to create the isopleth contours used for home range and core area delineations. Generally, the 95% contour is considered the entire home range and the 50% contour is considered the core area. The areas visited outside of the 95% contour may be considered exploratory in nature (Burt, 1943). Bandwidth for the KDE is generally chosen by either least-squares cross-validation (LSCV), plug-in (PI), solve the equation (STE) or likelihood cross-validation (LCV) methods (Horne & Garton, 2006). The LSCV method determined bandwidth by reducing the squares of the errors between estimated and actual distributions and has been determined to be more appropriate for large sample sizes. In addition, a spatial correlation analysis the Moran index I was used to find out the *C. guereza* distribution in relation to the land cover densities.

3.3 Data collection

3.3.1 Habitat Stratification and vegetation mapping

a) Inventory

The vegetation composition of the study identified families habitats was carried out using a 100X500m belt transect. From each belt a sampling plot (5x10) m was used to mark out a specific area of the study area for vegetation inventory with assistance of a botanist in the field. A total of 100 plots were sampled. Within the sampled plot, the *C. guereza* utilizes very tall trees thus the occurrence of higher plants species (plants above 5 meters) was recorded using an appropriate measure of abundance. The sampled plots were used to quantify the vegetation composition of the study area. In addition, the plots were used to give information on abundance as well as presence, or absence of species both plants and the *C. guereza* availability.

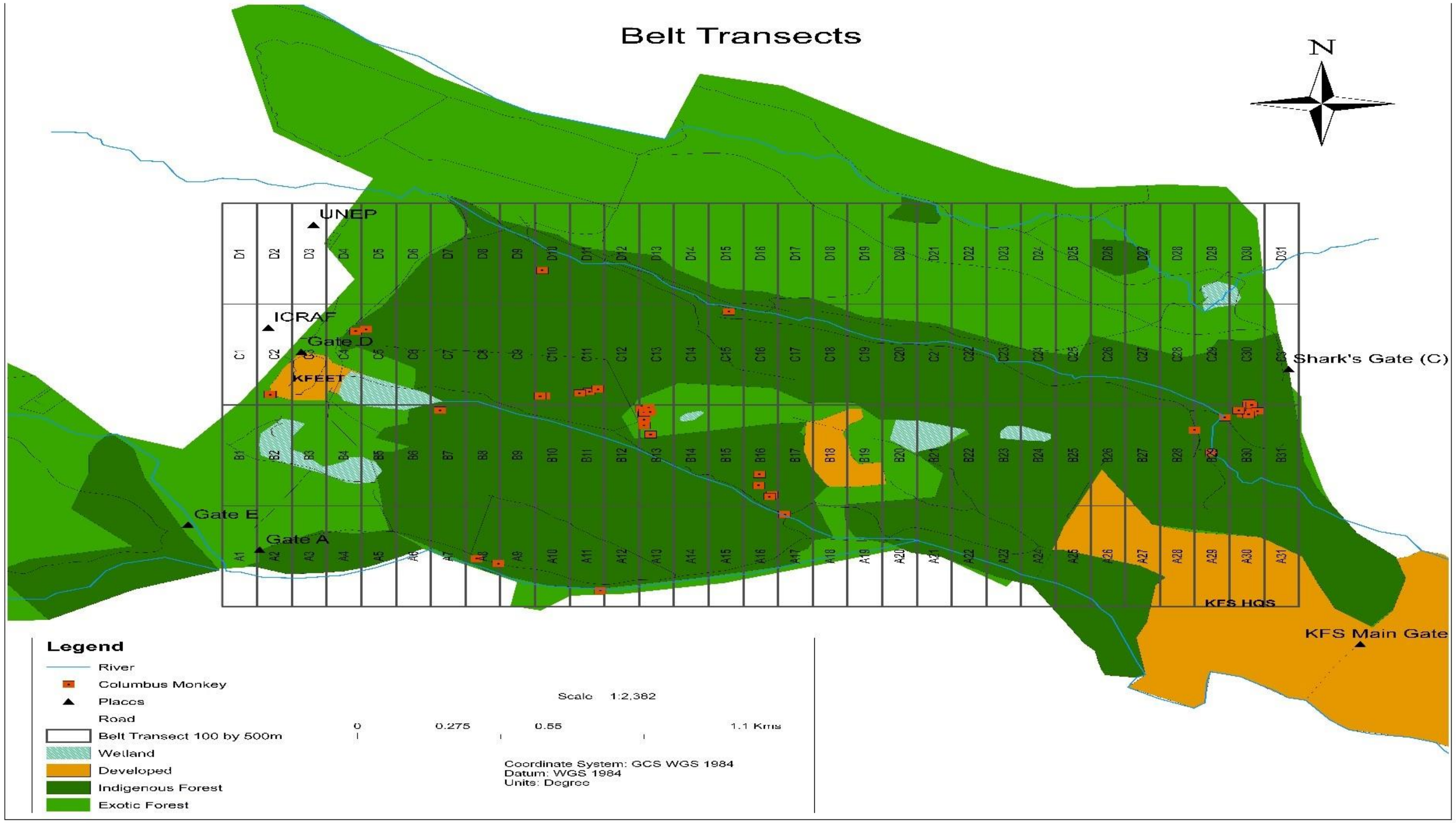


Figure 3 : Belt transect in the study area

b) Vegetation Index

From the data collected, analysis of plant species diversity was calculated using the Shannon-Wiener index, H' in addition, plant species evenness was calculated using the evenness index, J.

<u>Equation-1</u>

H' = - Σ=SiPiPi1ln

Where,

<u>Equation-2</u>

H' is Shannon-Wiener index of diversity

Pi is the proportion of plant species I from the s species.

S is the total species in the area sampled

Evenness of the species was calculated as

E= H'/H maximum

Where,

H' is Shannon-Wiener index of diversity

H maximum is maximum diversity index

c) Habitat Monitoring

Materials used for this study were two pairs of 10x42 Bushnell binoculars, this was used to enhance visibility of the monkeys, the researcher focused on a particular monkey to identify the particular activity it was involved to and the tree species it occupied. A digital photographic camera was used to take photos of the monkey and the trees it occupied while Garmin Global Positioning System (GPS) was used to take coordinates of the location where these monkeys were observed.

d) Indigenous and exotic habitats

The approach adopted in monitoring the *C. guereza* preference in indigenous and exotic forest involved alternate monitoring. The researcher monitored each habitat for two days in a week for 12 weeks.

3.4 Remote sensing and GIS

The habitat types were classified by using the Landsat 8 satellite images downloaded from the USGS website dated November 2018. The satellite images use the Operational LandImager and Thermal Infrared Sensors. The satellite image was from path 168 and row 061 of Landsat 8 OLI and TIRS sensor.

3.4.1 Satellite Image Correction and Image Classification

Thermal Infrared Sensors for data capture the downloaded satellite images were pre-processed using Q GIS to remove both radiometric and geometric errors. This ensured efficient identification of different land cover types. Supervised classification was done using the training sites (GPS points picked at the study area) and reflectance signatures of different cover type classes were created. The signature files were used to run a supervised classification using the maximum likelihood algorithm in ENVI. The classified raster image was converted to a vector file in Q GIS using raster to vector conversion command. Each signature was assigned specific land cover type. The corrected images were used to generate the Normalized Difference Vegetation Index (NDVI) that was used for classification of habitat.

3.4.2 Satellite Image Processing

The satellite image was imported into ENVI software for image processing; false color composite (FCC) was created using the layer stack option in the basic tool. The images were subset into the study area to save on storage space and processing speed. The study area delineation from images was based on collected GPS coordinates, researcher’s knowledge of the area and the digitized Karura forest boundary. Similarly Normalized Differential Vegetation index (NDVI) was done to assess the vegetation density within the forest. NDVI is the ration between the sum of near infrared ray and red ray divided by the difference between the Near Infrared ray and red ray.

The classified land cover types; indigenous forest, exotic forest and the riverine vegetation were presented on a map and used to illustrate the monkey preference to different habitat types using the Kernel density estimation. In addition, the spatial autocorrelation using the Moran index I was done to test the study hypothesis.

3.3 Data Processing and analysis

3.3.1 Activity time budget

Behavioral data were collected using instantaneous scan sampling method described in Altmann (1974). Scan sampling involves the observation of multiple family members. Activity types and dietary data were collected from the 8 selected study troops of monkeys. Data on individual behavior were collected by approaching monkeys to about 7–30 m and observing them with or without binoculars to identify their activities and food items that they consume. During activity scan sampling, the activities of monkeys were recorded every 15 minutes' interval up to 5 minutes' duration from 7.00 a.m. to 11.30 a.m. and again from 3.30 p. m – 6.00 p.m. The activity recorded for each individual was the first activity that lasted for 30 seconds once the monkeys came into view. Care was taken to avoid sampling the same individual more than once in a given scan. However, the same individual could be scanned in successive scans.

The identity of the scanned individual was recorded and the unidentified individual was assigned to one of the age/sex classes as adult male, adult female, sub-adult male, sub-adult female, juvenile male and juvenile female. Families scans were recorded as performing one of the following behavioral records on the standardized data sheet: feeding, moving, resting, playing, aggression, grooming, and vocalization (Fashing, 2001). Feeding was recorded when the monkeys manipulated, masticated and ingested a particular item of food. Moving was recorded when the monkeys change their spatial position within or between the tree or showed any locomotor behavior, including walking, jumping or running. Resting was recorded when the monkeys observed were inactive alone or together either sitting or lying. Playing includes chasing, hitting and other vigorous activities involving exaggerated movements and gestures by more than one monkey that were clearly interacting with each other in a non-aggressive manner (Fashing, 2001). Aggression was recorded when a monkey chased, bit, grabbed, displaced, threatened another monkey or during crying as a result of aggression. Grooming was recorded when a monkey used its hands to explore or to clean its body or the body of another monkey, vocalization was recorded when a monkey is calling.

Chapter Four-Results and Discussion

4.0 Habitat Types

The habitat type within Karura forest was established as illustrated in figure 4 below. The habitat characteristics in Karura Forest is mainly dominated by exotic plantation covering 61% of the total area, followed by indigenous forest plantation at 25%. Unlike other urban forest where urbanization poses enormous challenges to ecosystem's capacity to deliver important ecological services (Taticchi *et al.*, 2010), Karura forest is an urban forest ecosystem with varying functions. The main functions include; the function of landscape, aesthetic function, and the function of preserving the environment -ecological function (Irwan, 2005).

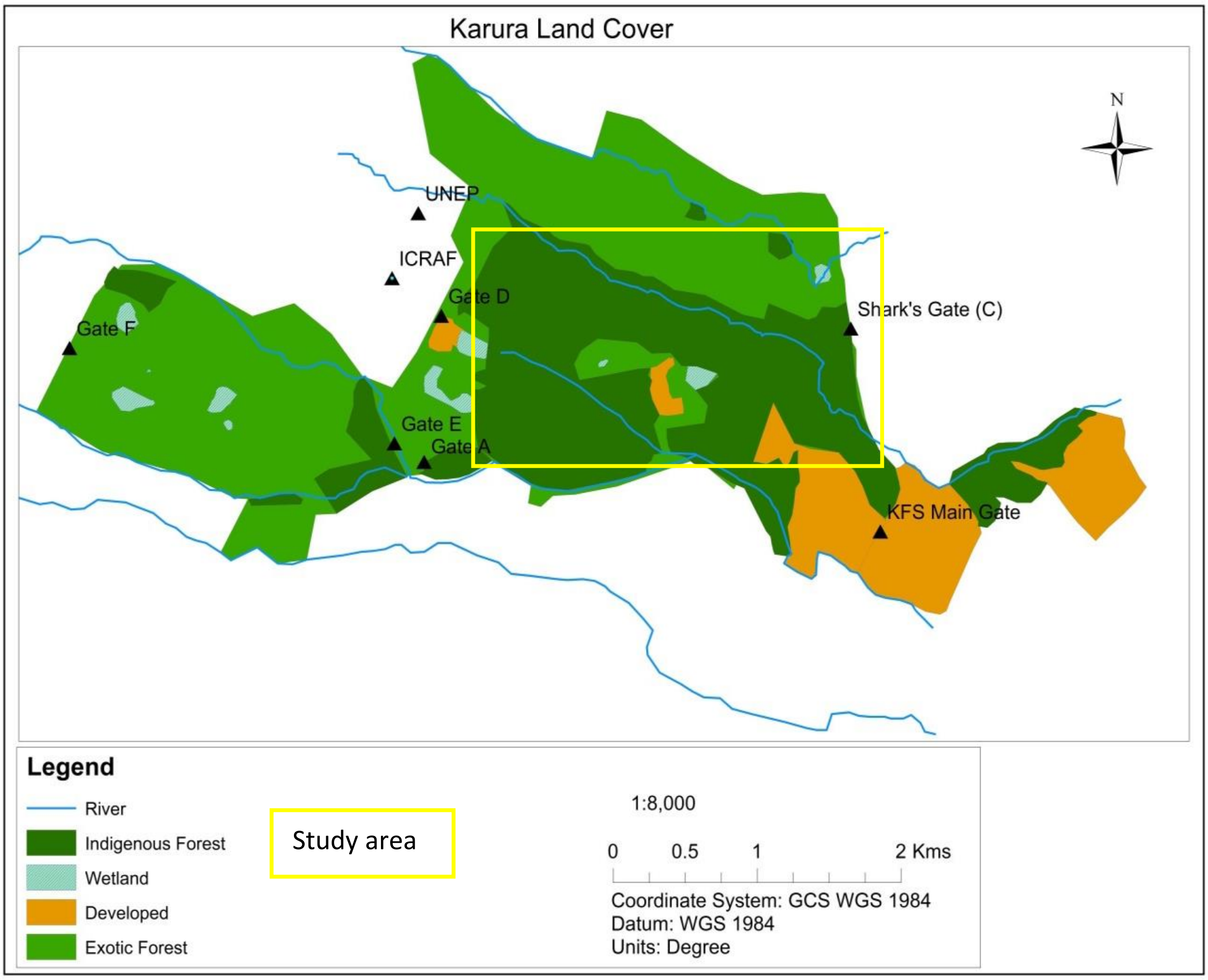


Figure 4: Karura forest habitat types

From the results obtained during the fieldwork involving monitoring of the monkeys, all the observations encountered was in indigenous forest, no observations of *C. guereza* were made in exotic forest. The association of *C. guereza* in indigenous forest is highly correlated with their primary habitat preference of the indigenous forest as a result of availability of food, Among the 10 trees plant species that *C. guereza* fed on in Karura forest, these species were also recorded in their original home in Kipipiri area at the slopes of Aberdare ranges. In addition, some of these species were among the eighteen trees species that had been recorded as food plants by Fashing *et al.*, (2016) in Kakamega Forest. The common species in the three studies included: *Vepris trichocarpa* that reported 20% use in Karura Forest, *Vepris simplicifolia also* formed 20% of the diet of the monkey in Karura forest, *Drypettes gerrandii* only 17% was utilized in Karura, *Craibia brownie, Warburgia ugandensis* and *Rawsonia lucida* that represented 12% of the diet trees in Karura Forest respectively. This study therefore confirms the suitability of indigenous habitats as an appropriate habitat for *C. guereza* within Karura forest.

4.0.1 Habitat vegetation distribution in the study area

The abundance and evenness of plant species within the study area was calculated using the Shannon Weiner index of diversity as illustrated in table 3 below (see Appendix II field work data). From this calculations, the Shannon Weiner index of plant diversity in the study are was found to be H=2.2, this indicated that there is high species diversity in the study are. In addition, the evenness of the species in the study area was 0.8, this indicated that all the species identified are evenly distributed across the study area. The distribution of *C. guereza* in the study area depends on availability of the tree species availably.

Table 3: Shannon diversity index

Shannon Weiner index				
Plant name	**Plant Count**	**Pi=sample/sum**	**InPi**	**Pi*InPi**
Vepris simplicifolia	39	0.202073	-1.59913	-0.32314
Vepris trichocarpa	39	0.202073	-1.59913	-0.32314
Croton megalocapus	3	0.015544	-4.16408	-0.06473
Elaeodendron buchananii	5	0.025907	-3.65325	-0.09464
Uvaria Sheffleri	1	0.005181	-5.26269	-0.02727
Celtis africana	2	0.010363	-4.56954	-0.04735

Shannon Weiner index				
Plant name	**Plant Count**	**Pi=sample/sum**	**InPi**	**Pi*InPi**
ochna ovata	2	0.010363	-4.56954	-0.04735
Rawsonia lucida	24	0.124352	-2.08464	-0.25923
Ficus thonningii	2	0.010363	-4.56954	-0.04735
Drypettes gerrandii	32	0.165803	-1.79695	-0.29794
Craibia brownii	17	0.088083	-2.42948	-0.214
Grewia similis	1	0.005181	-5.26269	-0.02727
Strychnos henningsii	7	0.036269	-3.31678	-0.1203
Allophylus rubifolius	1	0.005181	-5.26269	-0.02727
Calodendrum capense(cape chesnut)	4	0.020725	-3.8764	-0.08034
Olea europaea subsp. cuspidata	1	0.005181	-5.26269	-0.02727
Scutia myrtina	3	0.015544	-4.16408	-0.06473
Warburgia ugandensis	10	0.051813	-2.96011	-0.15337
Sum	**193**			**-2.24668**

Evenness= H/HMAX; H=2.2 **HMAX =ln (N)** =ln (18) =2.8=2.2/2.8=0.8 E=0.8

It can be concluded that the diversity of preferred species by *C. guereza* influences their habitat selection. The presence of heterogeneous habitat in Karura forest provides a suitable habitat for these monkeys. The findings of this study concurs with another study conducted in a rain forest in Gabon (Brugiere *et al.*, 2002),where it concluded that heterogeneous habitat supports larger populations of primates because they can access various choices of diet categories among the available food resources. Thus, diversity and continuous availability of resources determine the quality of foraging habitats for most primates (Marshall, 2007)

4.1 Habitat Preference

4.1.1 *Colobus gureeza* distribution in the identified habitat types

Based on the number of counties of occurrence of *C. guereza* families, this information was used to generate Kernel Density Estimation (KDE). In interns of habitat preference, KDE analysis used occurrence and distribution of *C. guereza*, based on recording of the monkeys in particular tree species like *Vepris trichocarpa*, *Olea Africana*, *Craibia brownie*, *Warburgia* *ugandensis, Rawsonia lucida* and *Vepris simplicifolia* which cumulatively was used to indicate the preferred habitat (Appendix III). The use of specific part of the tree such as resting, playing, feeding and grooming was used to indicate the utilization of the particular habitat (Appendix IV). Both young and mature animals were recorded. A noticeable absence was noted in exotic species areas (figure 5).

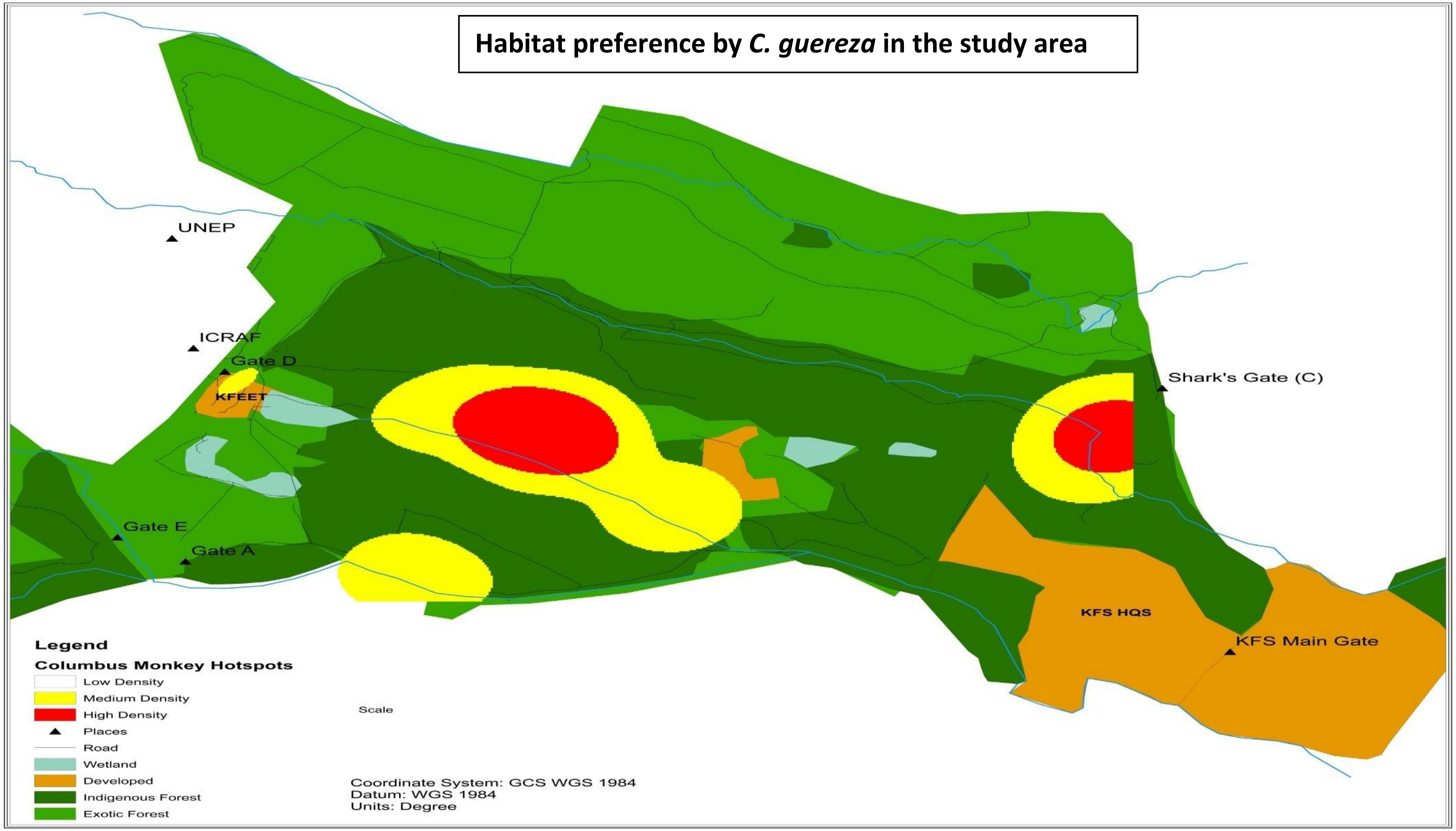


Figure 5: Kernel density estimate for *C. guereza* in Karura Forest

In addition, the *C. guereza* distribution was observed to be more in a high density vegetation mainly associated with indigenous forest. Most of the time the monkeys were observed on thick vegetation this is attributed to the fact that they feed on young leaves. A few times this monkeys occupied open canopy area as they rest and bask in the sun. Figure 6 below shows the distribution of *C. guereza* in relation to vegetation density in the study area.

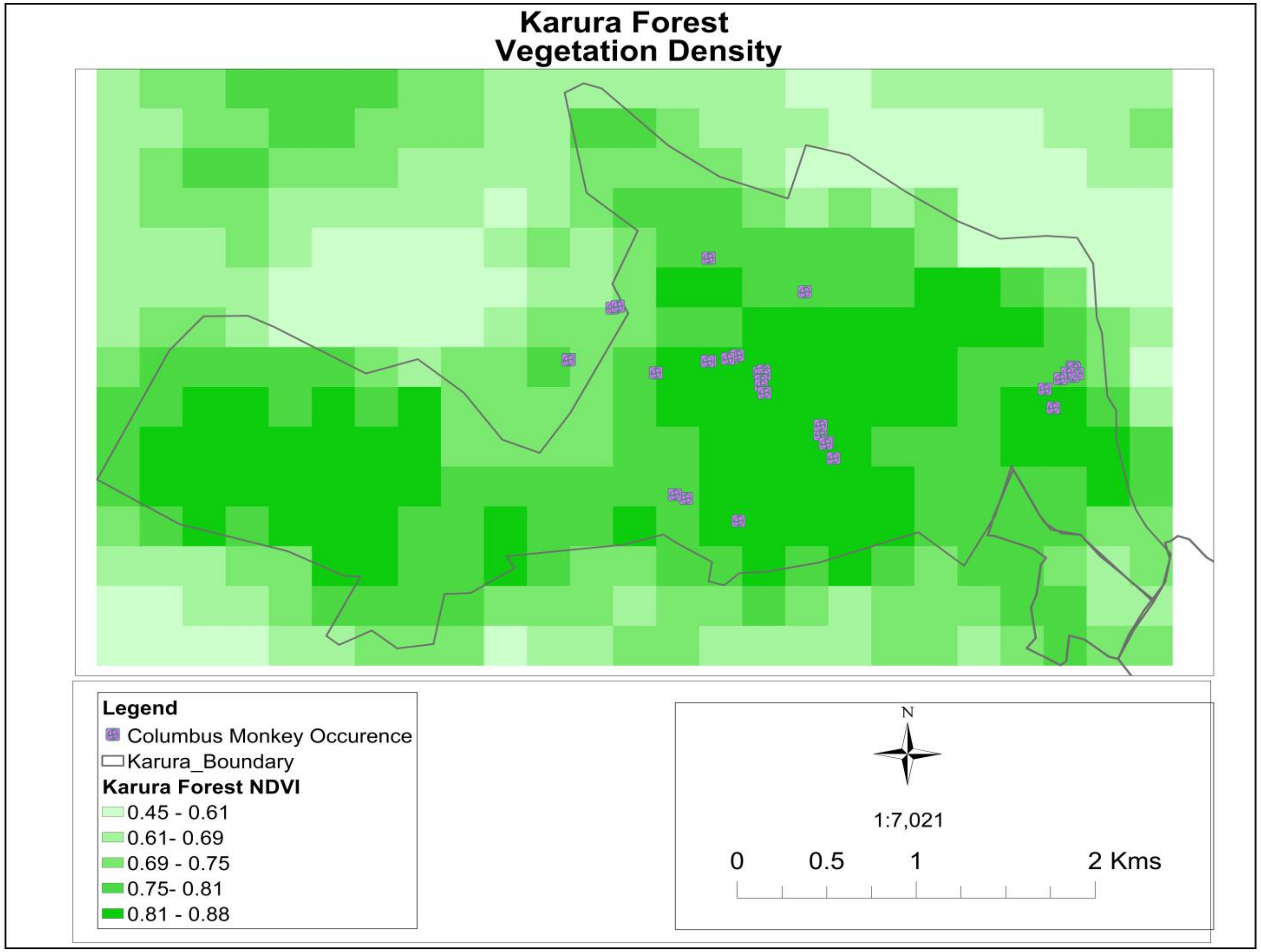


Figure 6: **Vegetation density and *C. guereza* distribution in the study area**

Kernel density estimation was used to test the hypothesis 1, Ho ‘There is no significance difference in habitat preference by *C. guereza* in indigenous and exotic habitats of Karura forest ecosystem. From the KDE indigenous forest accounted for the 95% contour home range for the *C. guereza,* thus rejecting the null hypothesis and the study adopted the alternative hypothesis of ‘There is a significant difference in habitat preference by *Colobus guereza* in indigenous and exotic habitats.

The study further tested hypothesis 2, Ho- There is no significant difference between habitat preference by *C. guereza* and vegetation density of the habitat types. Spatial autocorrelation analysis was done to test this hypothesis. The Moran Index I was established to be 0.71 at 0.05 significant level and Z score was 3.78. Hence Ho_1 was rejected and HA adopted. The *C. guereza* location and vegetation density were strongly correlated (see figure 6 above) this means areas with high vegetation density were favorable for the *C. guereza*, thus there is a significance difference between habitat preference by *C. guereza* and vegetation density of the habitat types.

From these results it confirms the assumptions of the ideal free distribution theory that deals with the distribution of study subjects among habitats of interest in order to make predictions about habitat selection. This theory describes a population that divides itself among different habitats of known size in a way that suits individual fitness. In Karura Forest the *C. guereza* monkeys choose the indigenous habitats as this was the most suitable for their needs. Habitat selection is influenced by several factors that include food availability, presence or absence of predators, and population density. This study found out that predation risk is not a factor of consideration when selecting habitat by *C. guereza* as Karura forest did not have significant number of predators preying on them. This study concurs with the assumption of this theory in regards to food availability as *C. guereza* in Karura forest mosaic appear to reside in a productive habitat where food is readily available.

According to this study, *C. guereza* highly inhabits the tree dominant indigenous forest. This may be linked to the high species diversity of food trees within this area as the study shows that 41 families of both indigenous trees and shrubs constituted food for *C.guereza* as also found out in a study by Kisingo *et al., (*2015) that reported species diversity as a factor for habitat preference for *C.guereza* in Bale Mountains National Park, Southeast Ethiopia. The exotic forest in Karura comprises of *Araucaria cunninghamii* and *Eucalyptus saligna*, plantation, these habitats did not offer species diversity and food favorable for *C. guereza* in the study area.

4.1.2 *Colobus guereza* activities in selected habitat

Activities of primates can be determined by their habitat types. In turn, their habitat is influenced by the availability of food, water, cover and other environmental factors (Riley & Chavan, 2007). Approximate total count for the selected 7 study families E, K, M, P, Q, R and S was undertaken opportunistically. Group E had a total of 9 individuals, K had a total of 15 individuals, M had a total of 11 individuals, P had a total of 3 individuals, Q had a total of 5 individuals, R had a total of 8 individuals, and S had a total of 8 individuals. A total of 1277 individual behavioral observations were recorded from 317 group scans. Each group was monitored for a total of four (days) with observations being recorded in two phases i.e. morning between 7.00 a.m. –to 11.30 a.m. and evening between 3.30 p.m. – 6.00 p.m. The total activity time budget of *C. guereza* from the combined study families in Karura forest is as presented below (see appendix III fieldwork data sheet);

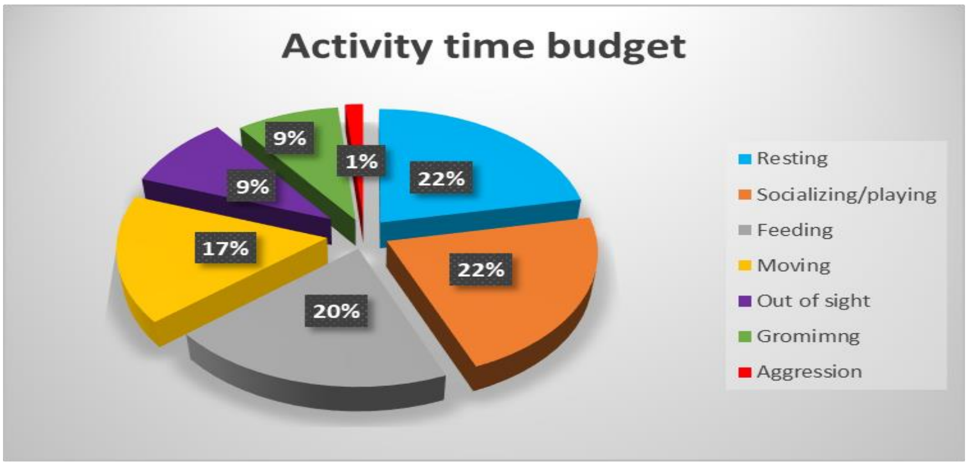


Figure 7: **Activity time budget for *C. guereza***

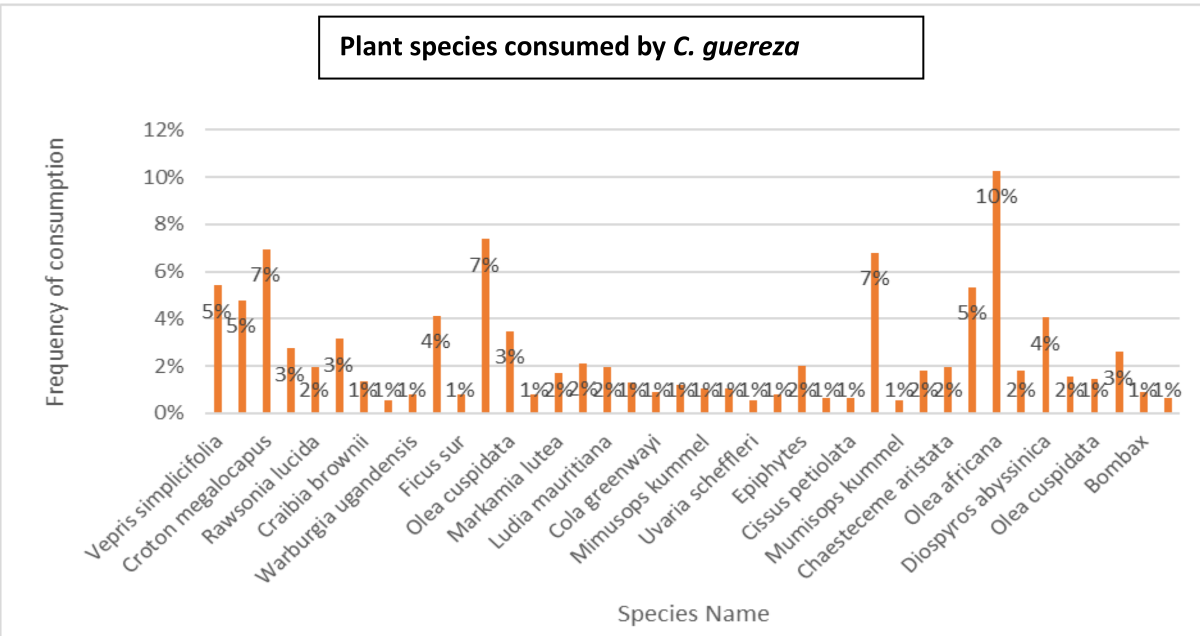
This study concluded that the *C. guereza* spends most of their time resting (22%), playing (22%) and feeding (20%), other activities include moving (17%), grooming (9%), and only 1% on aggressive. Equally, a study in Finote Selam Forest, West Gojjam in Ethiopia found out that *C. guereza* spent much time resting (74.3%),followed by Feeding (14.5%), moving (8.7%) and finally on grooming (2.5%), the resting time for *C.guereza* monkey in Finote Selam Forest, was observed to be too high compared to the findings of this study, this can be attributed to the fact that the *C.guereza* in this study have only been reintroduced into Karura forest 3 years back, and the last group was only re-introduced in 2017. These monkeys are yet to establish their comfortable and fit areas within the forest, adjusting to the long trees canopy of between 20m up to 30m, they have to explore more to meet their body nutrients demand. With time and adaptation, the resting time of *C. guereza* in Karura forest is expected to be more to match the previous studies in other locations.

In addition, another study by Kisingo (2015) conducted in Rau Forest Reserve, Moshi Tanzania reported that *C. guereza* spent 27.7% of their time moving and spent much time resting at 57.7%, this is also higher unlike the findings of this study, thus indicating that the *C. guereza* in Karura is greatly facing adaptation challenges. According to Marty (2009), *C. guereza* are daytime species and spends most of the day resting with the rest of the time devoted to feeding and moving, the findings of this study greatly contrast with his study as the *C. guereza* in Karura Forest are observed to spend only 22% of their time resting, the distribution of activities are observed to be equally the same.

4.1.3 Tree species utilized by *C. guereza* in selected habitat

The most dominant species that the *C. guereza* utilized in terms of feeding within the study area was *Rawsonia lucida (7%), Ficus sur* (7%), *Olea Africana* (10%), *Schrebella alata* (7%) *Diospyros abyssinica* (7%), *Croton megalocapus* (7%), *Vepris trichocarpa* (5%), *Vepris simplicifolia (5%) and Albizia schimperiana (5%)* as indicated below (See appendix III).

Figure 8: Plants consumed by *C. guereza* in the study area



The main food item consumed during the study period were leaves which comprised 79% of the diet other food items included bark (7%), seeds (7%), fruits (3%) and flowers (4%) as illustrated in the figure 9 below (see appendix III).

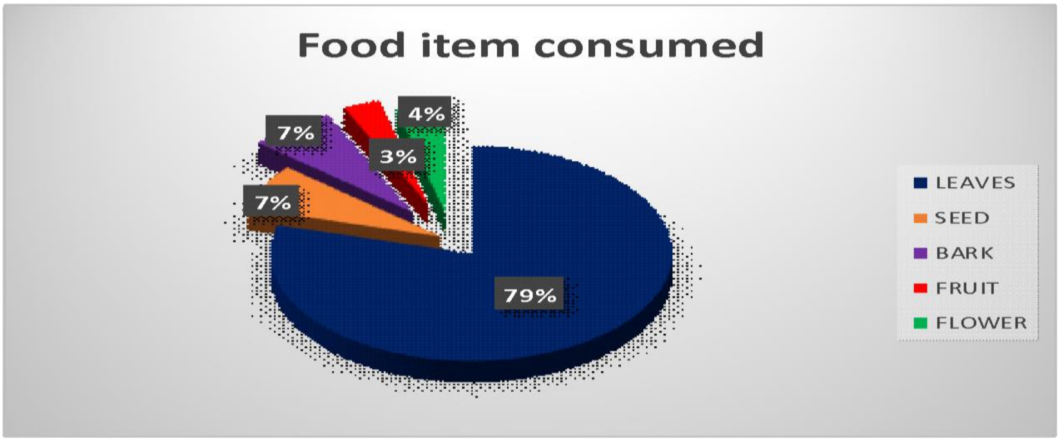


Figure 9: Food item consumed by *C. guereza*

This study found out that *C. guereza* preferred feeding on leaves (79%). Different studies revealed that young leaves have more protein, low fiber content and are more digestible than other part of a plant (Kaplin & Moermond, 2000). This finding thus correlates with the findings of the alternative hypothesis ‘There is significant difference between habitat preference by *C. guereza* and vegetation density of the habitat types’. Most of the *C. guereza* inhibit the indigenous forest habitats due to the availability of food mainly the leaves.

Chapter Five- Summary of findings, Conclusion and Recommendation

5.1 Summary of findings

This study assessed the habitat selection preference of *C. guereza*. The habitat types in Karura forest was established to be indigenous habitats and exotic habitats, this was analyzed using data obtained from USGS website in November 2018. Results from this study established that *C. guereza* holistically inhabited the indigenous habitat within Karura forest. The types of habitat utilization parameters were feeding, resting, moving, playing, aggression and out of sight. *C.guereza* display an uneven habitat preference across indigenous and exotic habitat types within the forest, this monkeys have inhibited the indigenous forest more as a result of availability of food in these habitats. The most dominant trees species that formed part of the diet for *C. guereza* included *Rawsonia lucida (7%)*, *Ficus sur* (7%), *Olea Africana* (10%), *Schrebella alata* (7%) *Diospyros abyssinica* (7%), *Croton megalocapus* (7%), *Vepris trichocarpa (*5%) and *Vepris simplicifolia* (5%). From this study no records of exotic tree species formed part of the diet of colobus monkey, all exotic trees utilized by this monkeys were used for resting. This study observed that the *C. guereza* in Karura forest spend relatively very minimum time resting compared to other studies involving similar monkeys. This can be attributed to slow adaptation of this monkey into the new habitat with the main challenge being the high canopy trees of between 20-30 metres that need to move through to meet their food demand.

5.2 Conclusion

The study established that the *C. guereza* within Karura forest prefer the indigenous habitat of the forest, this is attributed to the tree species diversity in Karura and the even distribution of the species in the study area. The heterogeneous habitat of Karura provided a suitable habitat for *C. guereza*. The findings of this study concur with previous studies comparing the availability and densities of primates in heterogeneous and homogenous habitats and it was established that a high density of primates inhibits heterogeneous habitats compared to homogenous habitats. During the study, no families of *C. guereza* were observed ranging in exotic habitats of Karura forest ecosystem. This study provides baseline information for the conservation of *C. guereza* species in Karura forest since little has been documented in the area. From the findings of the study, Karura forest has relatively great habitat quality for

C. guereza. The recommendations highlighted below should be implemented as an additional support to enhance the habitat availability for *C. guereza* within Karura forest.

5.3 Recommendation

- Karura Forest management should give special attention to replanting and restoring the lost indigenous forest. The main species include:
  - *Vepris trichocarpa*
  - *Vepris simplicifolia*
  - *Drypettes gerrandii*
  - *Craibia brownie*
  - *Warburgia ugandensis*
  - *Rawsonia lucida*
  - *Olea africana*

  These were the dominant trees observed being utilized by *C. guereza* within the forest. Replanting these trees would mean enhancing the habitat availability of *C. guereza* monkeys, this will enable further reintroduction of these species.
- This Study purely focused on habitat selection of *C. guereza*, further studies should be conducted on the different aspects of colobus monkey in the study area, this will include; the population dynamics, impact of reproduction factors, carrying capacity of Karura forest and other ecological and behavioral aspect of *C. guereza* in Karura Forest before reintroducing more *C. guereza* into the forest.

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APPENDIX I: FIELD WORK PHOTOS

C.guereza resting

C.guereza feeding on young leaves

Pathway separating C. guereza territories

Researcher keenly following family E of the sampled *C. guereza*

APPENDIX II: VEGETATION DISTRIBUTION IN THE STUDY AREA

Species Name	**Species Count(Transect (T)**													
	T1	***T2***	***T3***	***T4***	***T5***	***T6***	***T7***	***T8***	***T9***	***T10***	***T11***	***T12***	***T13***	***Total Species Count***
Vepris simplicifolia	*10*	*7*	*3*	*0*	*5*	*3*	*0*	*0*	*2*	*3*	*4*	*0*	*2*	**39**
Vepris trichocarpa	*11*	*5*	*5*	*4*	*1*	*0*	*4*	*0*	*0*	*3*	*2*	*1*	*3*	**39**
Croton megalocapus	*0*	*0*	*0*	*0*	*1*	*1*	*0*	*1*	*0*	*0*	*0*	*0*	*0*	**3**
Elaeodendron buchananii	*1*	*2*	*0*	*0*	*0*	*1*	*0*	*0*	*0*	*0*	*1*	*0*	*1*	**5**
Uvaria Sheffleri	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*1*	*0*	*0*	*0*	*0*	*0*	**1**
Celtis africana	*0*	*0*	*0*	*0*	*1*	*0*	*0*	*0*	*0*	*1*	*0*	*0*	*0*	**2**
ochna ovata	*0*	*0*	*0*	*0*	*0*	*0*	*1*	*0*	*0*	*0*	*1*	*0*	*0*	**2**
Rawsonia lucida	*5*	*4*	*2*	*0*	*0*	*0*	*4*	*0*	*3*	*0*	*1*	*3*	*2*	**24**
Ficus thonningii	*0*	*0*	*1*	*0*	*0*	*1*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	**2**
Drypettes gerrandii	*7*	*3*	*0*	*4*	*5*	*6*	*0*	*4*	*1*	*2*	*0*	*0*	*0*	**32**
Craibia brownii	*2*	*3*	*4*	*0*	*0*	*2*	*1*	*0*	*1*	*3*	*0*	*1*	*0*	**17**
Grewia similis	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*1*	*0*	*0*	*0*	*0*	*0*	**1**
Strychnos henningsii	*1*	*0*	*0*	*2*	*0*	*0*	*1*	*0*	*2*	*0*	*1*	*0*	*0*	**7**
Allophylus rubifolius	*0*	*0*	*0*	*0*	*1*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	***1***
Calodendrum capense(cape chesnut)	*1*	*0*	*0*	*11*	*0*	*0*	*1*	*0*	*0*	*0*	*0*	*1*	*0*	***4***
Olea europaea subsp. cuspidata	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*1*	*0*	*0*	*0*	*0*	*0*	***1***
Scutia myrtina	*1*	*0*	*0*	*0*	*0*	*1*	*0*	*0*	*0*	*1*	*0*	*0*	*0*	***3***
Warburgia ugandensis	*2*	*0*	*0*	*2*	*0*	*3*	*0*	*1*	*1*	*0*	*0*	*1*	*0*	***10***

APPENDIX III: *COLOBUS GUEREZA* COUNTS IN THE STUDY AREA

Tree species	***C.Guereza* Occurrence**
Vepris simplicifolia	67
Vepris trichocarpa	59
Croton megalocapus	86
Celtic africana	34
Rawsonia lucida	24
Drypettes gerrandii	39
Craibia brownii	17
Strychnos henningsii	7
Warburgia ugandensis	10
Ficus sur	10
Strychnos usambalensis	10
Markamia lutea	21
Cassipourea malosana	26
Ludia mauritiana	24
Mimusops kummel	13
Rothmannia urcelliformis	13
Uvaria scheffleri	7
Chrysophyllum Viridifolium	10
Scutia myrtina	8
Cissus petiolata	8
Schrebella alata	84
Euclea divinorium	22
Chaesteceme aristata	24
Olea africana	127
Diospyros abyssinica	50
Olea cuspidata	18

APPENDIX IV: *COLOBUS GUEREZA* BEHAVIORS IN THE STUDY AREA

	C.guereza Behaviors							
Transect	**resting**	**Socializing**	**feeding**	**moving**	**out of sight**	**grooming**	**playing**	**aggression**
1	16	14	15	10	10	9	5	2
2	5	0	5	4	4	2	1	2
3	6	3	6	5	2	0	0	2
4	5	3	5	5	3	2	1	0
5	3	4	5	4	1	2	1	0
6	5	6	5	5	1	2	0	0
7	5	4	4	4	1	3	1	0
8	5	5	3	4	1	4	0	0
9	4	3	4	4	3	3	1	0
10	9	0	7	0	6	0	0	0
11	3	4	4	4	2	4	0	0
12	4	5	4	5	0	3	0	0
13	5	4	6	4	1	1	1	0
14	5	4	6	4	0	2	0	0
Total	**80**	**70**	**79**	**62**	**35**	**37**	**11**	**6**