FACTORS INFLUENCING POPULATION AND INTERSPECIFIC INTERACTION OF THREE PRIMATES IN SOUTH NANDI FOREST, KENYA

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Thesis submitted to the Graduate School in partial fulfillment for the requirements of a Master of Science in Natural Resources Management Degree of Egerton University.

EGERTON UNIVERSITY

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DECLARATION AND APPROVAL

DECLARATION

I hereby solemnly declare that the work presented in this dissertation is my original work and that to the best of my knowledge; it has not been presented for a degree inthis University or any other University.

Signed…………………………... Date…………………………..

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APPROVAL

This thesis has been submitted with our approval as University supervisors

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DEDICATION

This work is dedicated to my brothers and sisters Francis Mutuku, Patrick Mutiso, Hellen Mwelu, Elizabeth Nduku, Angela Mumo, Martha Kalondu and Cecilia Muthio for their financial and moral support during the entire period of my study. It is also posthumously dedicated to my late parents (Annunciata Mutono and Peter Wambua) and sister (Stellamaris Ndunge). This thesis is in memory of my mother who always encouraged me to work hard and to always put God first in everything that I do. I specifically dedicate this thesis to my eldest brother Francis who has been my second father and role model.

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ABSTRACT

The distribution of non-human primates in tropical forests is highly influenced by vegetation structure, interspecific interactions and human-induced threats. Reported disturbance in the form of charcoal burning, farming, tree extraction for construction poles or timber, encroachment along the forest boundaries and unplanned infrastructure interferes with the forest edges and interiors, which affect the distribution of primate species. The purpose of this study was to assess the population of the Black and White Colobus (*Colobus guereza*), Blue Monkey (*Cercopithecus mitis*) and Red-tailed Monkey (*Cercopithecus ascanius*) in the forest edge and interior in South Nandi Forest during the dry and wet seasons. Their interspecific interactions as well as effects of factors such as human-induced threats, canopy cover, height of trees and stem density were also assessed. The study adopted an ecological survey design with 7 random line transects being established at both the interior and edge locations. The population densities of Black and White Colobus and Blue Monkey were derived using distance sampling. Observations for the Red-tailed Monkey did not attain the minimum required for distance sampling to be used hence their densities were not estimated. Overall, there was a high density of Blue Monkey (0.88±0.19 animals/ha) as compared to the Black and White Colobus (0.63±0.16 animals/ha). The forest interior had high populations of the Blue Monkey (0.99±0.30 animals/ha) and Black and White Colobus (0.89±0.30 animals/ha) as compared to the forest edge. Primate observations were high during the wet season as compared to the dry season. More observations (78 observations) were made for the Black and White Colobus in the wet season as compared to the Blue Monkey (59 observations) and Red-tailed Monkey (9 observations). Blue Monkey interacted more with both the Black and White Colobus and the Red-tailed Monkey with the level of interaction being high (45%) between the Black and White Colobus and the Blue Monkey. These two species form feeding associations especially during the dry season when food is scarce. Major trees utilized included *Prunus africana* and *Croton megalocarpus*. Even though the highest averages for stem density (Mean= 56.2), height (Mean= 20.3) and canopy cover (Mean= 64.0) were recorded in the forest interior, independent samples t-test showed there was no significant difference ($p>0.05$) of these factors in the forest edge and interior. Awareness raising among the locals through the Community Forest Associations should be carried out to sensitize them on impacts of illegal activities to the primate populations. Monitoring should be done for long term effects of human activities on primate populations and distributions

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LIST OF ABBREVIATIONS AND ACRONYMS

ACCNNR : African Convention on the Conservation of Nature and Natural Resources

CFAs : Community Forest Associations

CITES : Convention on International Trade in Endangered Species

FAO : Food and Agriculture Organization of the United Nations

GPS : Global Positioning Systems

IUCN : International Union for Conservation of Nature

IUCN-SSC : IUCN Species Survival Commission

KFS : Kenya Forest Service

LATF : Lusaka Agreement Task Force

NMK : National Museums of Kenya

PELIS : Plantation, Establishment, Livelihood, Improvement, Scheme

UNEP/UNESCO : United Nations Environment Programme/ United Nations Educational, Scientific and Cultural Organization

UNEP-GRASP : United Nations Environment Programme - Great Apes Survival Partnership

CHAPTER ONE

INTRODUCTION

1.1 Background information

According to FAO (2015), the total land covered by forests has reduced by 3% from 4128 million ha in 1990 to 3999 million ha in 2015, largely due to deforestation. Tropical forests are often subject to both legal and illegal human activities resulting in forest loss and fragmentation. These activities increase accessibility and exposure of the forest interior to anthropogenic activities and wild species become vulnerable especially where hunting of species is involved (Michalski and Peres, 2005).

Some primate species are very sensitive to slight changes in vegetation structure and composition (Cowlishaw and Dunbar, 2000), because they have specific ecological requirements, with about 90% living in tropical forests (Mittermeier, 1988). Furthermore, many such species are locally endemic or are rare and exhibit disjunct distribution (Richards, 1996). Such narrow distributions predispose many tropical forest species to increased risk of extinction when habitats are modified (Terborgh, 1992) because protected areas even if effectively protected cannot conserve species whose range fall outside the protected area. Despite the fact that these diverse ecosystems should be under legal protection, only a paltry 12% of forests are legally protected from human exploitation (Bruinsma *et al*., 2015). Still, many of these areas are subject to illegal exploitation (Redford, 1992; Oates, 1996; Chapman and Onderdonk, 1998; Chapman *et al*., 1999). Therefore, the future of these important species is threatened by escalating rates of forest conversion and degradation (Johns and Skorupa, 1987; Struhsaker 1987; Brown and Lugo, 1990).

Effects of forest loss and degradation on species have been demonstrated through various studies on birds (Newmark, 1991; Githiru and Lens, 2007; O'Dea and Whittaker, 2007; Mac Nally *et al*., 2009), insects (Warren *et al*., 2001; Tscharntke *et al*., 2002) and mammals (Andren, 1994; Chapman and Onderdonk, 1998; Cowlishaw, 1999; Crooks 2002). Most primates however have decreased in population due to loss of their habitats e.g. Orangutans (Cawthon, 2005; Johnson *et al*., 2005: Geladas, Dunbar, 1998; Yihune *et al*., 2009) and Lemurs (Irwin *et al*., 2005; Bodin *et al*., 2006). However, for primates, effects of disturbance vary depending on the primate species and habitat (Skorupa, 1988; Plumptre and Johns, 2001). A study conducted by Plumptre and Johns (2001) showed that Chimpanzee (*Pan* *troglodytes*) densities increased with disturbance in Lope, Gabon but decreased in Kalinzu, Uganda.

The three focal species of this study; *Cercopithecus ascanius* (Red-tailed Monkey), *Cercopithecus mitis* (Blue Monkey) and *Colobus guereza* (Eastern Black and White Colobus) belong to the *Cercopithecidae* family and are found in tropical forests in Africa including South Nandi Forest. Even though they are listed as Least Concern (LC) according to the IUCN 2015, continuous habitat destruction and fragmentation poses a great threat to the future survival of these species. It is also important to understand the interspecific interaction of these species because these interactions in some cases could influence the spatial distribution of primates within a given habitat (Kingdon *et al*., 2013).

While some research has been undertaken at the South Nandi Forest, especially on insects (NMK, 2012) there has been no research focus on primates despite their economic importance and increased disturbance from humans which affect their distribution. Any form of disturbance could alter their habitat to an extent that it influences spatial distribution, population density, habitat selection and use by a given species or an assemblage of primate species. It is against this background that this study was conceived to understand the population status of the three primate species in South Nandi Forest, their spatial distribution and the factors influencing the distribution. This is vital in the implementation of proper habitat management interventions, overall decision making as well as policy formulation and implementation at various hierarchical levels such as at the forest management level, national level and regional levels.

1.2 Statement of the Problem

Loss and destruction of forest ecosystems is happening all over Kenya and South Nandi is not an exception. Despite the documentation of the presence of the three primate species through a biodiversity survey conducted in South Nandi Forests in 2012 by NMK, presence-absence in function of a given species is not adequate for effective management of species. The current population status of the three primate species remained unknown for South Nandi Forest. Illegal human activities such as unsustainable honey harvesting and logging target specific tree species e.g. *Prunus africana* which comprise the major diet trees for the primate species especially the Black and White Colobus Monkey. Logging also causes habitat destruction and fragmentation and this affects the distribution of the primates. Additionally, the effect and response by the primates to habitat changes such as vegetation structure both at micro-habitat and macrohabitat levels was hitherto unknown at this forest. This may make it difficult for management and decision making process that involves restoration of degraded forest areas, enhanced enforcement and improved management effectiveness in South Nandi Forest. Primates are also very good indicators of the status of the environment and the adverse changes in their habitats could havean effect such as food availability on other taxonomic groups.

1.3 Study Objectives

1.3.1 Broad Objective

To ensure effective conservation and management of primate populations through increased biological knowledge.

1.3.2 Specific Objectives

1. To determine the population density of the three monkey species in South Nandi Forest during dry and wet season
2. To assess the interspecific interaction between the different species of monkeys
3. To evaluate the factors affecting spatial distribution of the three monkey species in the forest edge and interior

1.4 Research Questions

1. What is the population density per hectare of the Black and White Colobus, Blue Monkey and Red-tailed Monkey species in South Nandi Forest during the dry and wet seasons?

2. How do the three species interact among themselves?

3. How are the population density, spatial distribution, occurrence and of the three primate species influenced by factors affecting vegetation structure in the forest interior and forest edge?

1.5 Justification of the Study

Most primate populations today face ongoing habitat disturbance (Mittermeier *et al*., 2007) and its effects are likely to increase as human populations increase. Disturbance negatively influence primates through habitat change and reduced food availability (Fimbel *et al*., 2001) which affects their distribution and densities within a given area (Johns, 1988, 1991). Census data of primate populations are an integral part of primate conservation for two reasons. First, population density estimates are important variables to consider when determining conservation priorities and creating management plans for primate populations (Ganzhorn *et al*., 1997). Secondly, these estimates are valuable to researchers trying to understand socio-ecological differences between primate populations (Butynski, 1990).

South Nandi Forest is a gazetted forest area and information on population sizes and population densities across a gradient of forest disturbance was very useful to the forest managers because it identified the areas of the forest which require great conservation interventions. Knowledge generated maybe useful for red-listing process in cases where the species populations are significantly reducing. Mapping the spatial distribution of each species provided useful baseline information for future monitoring of the species. Such information was also useful in promoting primates as wildlife-based tourism for the region. The information was applied in awareness creation of the surrounding local communities on their sustainable use of the forest so as to reduce anthropogenic pressure that could negatively impact the population of these species. Information on disturbance is to be used by Kenya Forest Service(KFS) to effectively enforce existing regulations against illegal activities as well as unsustainable use of the forest for increased conservation outcomes. Distribution maps provided information on the areas highly preferred by the three different species and will be used in forest management initiatives, land use planning and decision making at site, national or global level.

1.6 Scope of the Study

The study was confined to the South Nandi Forest even though the species are also present in the adjacent forests of North Nandi and Kakamega Forest. Other forests around South Nandi Forest were not considered during the study. In as much as there may be other primate species (e.g. Baboons, bushbabies), this study was only focusing on the three species of primates Blue Monkey (*Cercopithecus mitis*), Red-tailed monkey(*Cercopithecus ascanius*) and Black and White Colobus monkey(*Colobus guereza*). In order to understand the effect of seasonality on the distribution of the primate species, the study was confined to the dry season (February and March) and wet season (April and May) of 2015. The study was also confined to the natural forest only.

1.7 Limitations and Assumptions

Heavy rains which are usually experienced in the area occasionally interfered with the sampling schedule. This was addressed by postponing the transect walks which prolonged the research period. The major assumption was that the number of sightings for the different species of monkeys would reach the minimum number of observations required for population density estimates to be established using Distance Sampling analysis procedure. The observations for the Red-tailed Monkey did not attain the minimum observations required hence averages were used to represent the population numbers.

1.8 Operational Definition of Study Variables

Disturbance **:** is a temporary and/ or permanent change in environmental conditions that causes a pronounced change in the ecosystem.

Interspecific interaction **:** refers to the observation of groups or individuals of different species together at a distance of less than 2m from each other

Non-human primate **:** refers to mammals of the order Primates other than humans. They typically have flexible hands and feet with opposable first digits, good eyesight and in higher apes, a high developed brain. They include lemurs, lorises, monkeys and the great apes

Population density **:** refers to the number of primate species per hectare

Relative abundance **:** refers to how common or rare a species is relative to other species in a given habitat

Spatial distribution **:** refers to the location of individuals of different species in a given location

Vegetation structure **:** it is the horizontal, vertical and temporal arrangement of vegetation according to Barkman, 1979. For this study stem density, canopy cover and tree height were considered.

Vulnerable **:** species facing a high risk of extinction in the wild in the medium-term future.

CHAPTER TWO

LITERATURE REVIEW

2.1 Global Biogeography of Primates in the World

Primates are an extremely diverse taxonomic group comprising 612 species distributed in many parts of the tropics (IUCN, 2012). However, new species continue to be discovered including Milton's Titi Monkey(*Callicebus miltoni*)), which is the newest addition discovered in Amazon Forest in 2014 (Dalponte *et al*., 2014). Primate species vary depending on different morphological factors and exhibit a wide range of characteristics that help distinguish them from other mammals (Rowe and Myers, 2015). They range in size from the pygmy mouse lemur to the wild gorilla (Dobson and Lyles, 1989). With the exception of humans who inhabit every continent on the planet, most primates live in tropical or subtropical regions of the America, Asia and Africa.

The distribution of primates is determined by climatic factors, predation factors, availability and competition for available resources and social factors such as land use and water availability (Lehman and Fleagle, 2006). About 51 non-primate species are found in Africa. These include families such as Lorisidae, which is widely distributed in Central Africa, Lemuridae (Lemurs, Aye-aye) endemic to Madagascar, Cercopithecidae (monkeys, baboons) and Hominidae (the great apes)(Estes, 1992). Four species of the latter family namely Eastern Gorillas (*Gorilla beringei*) and Western Gorillas (*Gorilla gorilla)*, Chimpanzee (*Pan troglodytes)* and Bonobos (*Pan paniscus*) endemic to Africa are either Critically Endangered or Endangered. Primates also exhibit local endemism at site level (e.g. Tana River Mangabey and Tana River Red Colobus), a country (e.g. Ethiopia for Geladas) or a region level (e.g. Africa for Gorillas and Chimpanzees).

Twelve genera, 19 species and 23 subspecies of primates have been recorded in Kenya (De Jong and Butynski, 2012). Being an afro-montane forest, South Nandi offers a suitable habitat for different primate species which prefer tropical forests. The primate species which inhabit the forest include Olive Baboons (*Papio anubis*), Black and White Colobus (*Colobus guereza*), Blue Monkey (*Cercopithecus mitis*) and Red-tailed Monkey (*Cercopithecus ascanius*).

2.2 Ecological and Economic Importance of Primates

2.2.1 Ecological Roles of Primates

Primates comprise between 25% - 40% of the frugivore biomass in tropical forests and eat large quantities of fruit and defecate or spit large number of viable seeds (Wrangham *et al*., 1994; Lambert, 1997; Stevenson, 2011). In a forest ecosystem where the canopy is very thick and agents of seed dispersal such as wind are a limiting factor, some primate species act as seed dispersers (Levey *et al*., 2008). They enable seeds to reach new sites for colonization which influences demography, genetics, spatial distribution and future vegetation composition (Lambert and Garber, 1998). Due to their extreme importance in seed dispersal primate species can be referred to as ecosystem engineers due to the significant ecological role that they play (Andresen, 2000; Kaplin and Lambert, 2002). Primates also play a very significant role in forest regeneration and restoration of disturbed areas through seed dispersal (Albert *et al*., 2013; Simon *et al*., 2016) and are also good indicators of ecosystem health (Cranfield, 2008; Howells *et al*., 2011).

Primate frugivory and seed dispersal has been quantified in different studies (Wrangham *et al*., 1994; Chapman and Chapman, 1996; Kaplin and Moermond, 1998; Lambert, 1999; Stevenson, 2000; Dew, 2001). According to Lambert (2001), guenon monkeys in the sub-family *Cercopithecinae* (e.g.Patas monkey, Red-tailed Monkeys and Blue Monkeys) have cheek pouches in which they store fruits, which they feed on and process after moving away from fruiting trees probably to avoid predation and reduce competition between conspecifics. As they forage in the canopy, they swallow fleshy pulp and spit out seeds, many of which get scattered across the forest floor at low densities, thus potentially avoiding high risk of mortality and increasing the odds for survival and subsequent germination and establishment. For example, in Borneo, a single gibbon group (*Hylobates muelleri agilis*) dispersed a minimum of 6,400 seeds/km^2 each year from 160 plant species (McConkey *et al*., 2002). Lemurs play a significant role in plant pollination of some plant species when feeding on nectars (Overdorff, 1992; Muchlinski and Perry, 2011). Some primate species such as monkeys are prey species for different forest predators like the African fish eagle (Sanders *et al*., 2003) and other birds of prey, snakes and the leopard. They probably therefore have some impact on predator populations in a given habitat and are part of the trophic levels or food chains.

2.2.2 Role of Primates in Ecotourism

Ecotourism has become a popular global recreation and one of the world's major trade activities. In 2010, worldwide, there were over 940 million international tourist arrivals, representing a growth of 6.6% (as compared to 2009) amounting to an overall annual export income of over $1 trillion (UNTWO, 2011). For many developing countries wildlife-based tourism is one of the main sources of foreign exchange income and number one export category (Okello, 2014). According to Macfie and Williamson (2010) global tourists are increasingly travelling to remote international wildlife sites where they can view endangered species in their natural habitats rather than in captivity especially for the primates

Diurnal primates are the only relatively easily viewed mammals in most tropical rain forests (Williamson and Feistner, 2003) and great apes often feature highly on the list of primates that tourists would like to see in the wild. With habitat conservation dependent on the economic income from ecotourism (Stronza, 2007) the presence of many primate species represent the only chance of long-term habitat conservation in African countries (Gippoliti and Carpaneto, 1995). In Rwanda, for instance, the mountain gorilla (*Gorilla gorilla beringei*) is among the major sources of foreign currency income, with Volcanoes National Park revenue totaling 800,000 U.S.$ yearly (Harcourt, 1992). Nowadays, the viewing of mountain gorillas in Uganda yields an income of US$ 140 a day/per visitor at the Bwindi Impenetrable and Mgahinga National Parks (Moyini and Uwimbabazi, 2000).

2.3 Effects of Vegetation Structure on Distribution of Primates

Local animal species distribution patterns in different ecosystems have been suggested to be causally related to tree species richness, plant productivity, seasonality, habitat heterogeneity, and historical geographical factors (Ricklefs and Schluter, 1993; Rozenzweig and Abramsky, 1993).

The density and diversity of primates in natural forests both in the tropics and neo-tropical areas are known to depend on primary forest productivity, precipitation and climatic seasonality (Peres, 1997; Pinto *et al*., 2009). Different species of monkeys occupy different forest microhabitats, preferring different forest strata or forest types of different structure to avoid competition, resource partitioning or niche partitioning e.g., liana thickets (Wallace *et al.*, 1998). In forest habitat, structural variables of the vegetation, direct and indirect anthropogenic impacts majorly affect primate abundance and diversity (Rylands, 1987; Chapman and Peres 2001). Logging, grazing, conversion to agriculture, resource extraction and wild fires have caused massive alterations of forest composition, structure and diversity of tropical forests and this in turn affects the distribution of different species of primates in forests (Peter and Lee, 2002).

A study on Orangutan behavioral ecology concluded that changes to forest structure could have negative effects on their population densities (MacKinnon, 1974; Wich, 2009) since they most exclusively travel through the forest canopy. Loss of larger trees could lead to loss of continuous arboreal pathways which could decrease their travelling efficiency (Rao and van Schaik, 1997). At Kibale Forest, the population of Blue and Red-tailed Monkeys declined significantly after logging that affected the vegetation structure of the forest (Plumptre and Reynolds, 1994). According to Van Kreveld and Roerhorst (2009) the population of Chimpanzees is highly sensitive to logging and deforestation leading to isolation of the populations to small forest remnants in Central Africa. A study on Diademed Sifaka (*Propithecus diadema*) found out that in disturbed habitats the species had a lower mass, smaller home ranges, consumed less canopy tree fruit and showed reduced scent marking, aggression and play behavior than in undisturbed forest (Irwin, 2006; 2008a, b).

In Kenya, natural forest habitats are continually being destroyed due to the burgeoning human population, which results in increased demand for fuel wood, timber products and farmlands, and the concomitant demand for land for human settlements and infrastructural development (FAO, 1990). As a consequence, forest and other habitat structures are destroyed, which in turn affect primate populations due to decrease in forested areas resulting to reduced opportunities for dispersal and increased competition from other primate species (Mwenja, 2004).

2.4 Seasonality and its Effects on Primate Habitat Use

According toOverdorff (1996) the variation in activity and habitat use by primates mainly result from group size and composition, seasonal changes in food supply and/or the presence or absence of other sympatric congeneric species. During the dry season, the plant productivity in tropical forests is limited (van Schaik *et al.*, 1993) and this causes scarcity of fruits affecting the foraging behavior of most primate species. Studies on tarsiers (Gursky, 2000), *Eulemurfulvus* (Overdorff, 1996), and Muriquis (Strier, 1991) showed that foraging time increases during the dry season. Food scarcity causes the primates to shift into more abundant but low nutrient food options (Muruthi *et al.*, 1991; Wrangham *et al.*, 1991, 1998) and this increase the foraging time during the dry season relative to the wet season.

Primate groups may feed and move more widely when food is scarce or when food is patchy or clumped (Chapman, 1988; Barton *et al*., 1992; Isbell and Young, 1993). In some instances, however, seasonality causes little or no change in time budgets (Watts, 1988). Although time budgets themselves may not be altered, how activity is distributed across the day can be affected by seasonal changes in food availability (Sussman, 1974; Strier, 1987). This can affect the primate distribution in the dry and wet seasons in different parts of the forest and can cause increased overlap and conflicts in the primate territories (Gursky, 2000).

2.5 Conservation Status and Threats Facing Primates

2.5.1 Primates of Global Conservation Concern

Twenty percent of primates (123 species) are Endangered or Critically Endangered and 27% of primates are listed as Least Concern under the IUCN Redlist. The Red List also includes all the great apes which are either listed as Endangered or Critically Endangered and all great apes except the Mountain gorillas show decreasing population trends. Most notably, fewer than 300 Cross River gorillas are left in West Africa; as few as 2,000 Eastern Lowland gorillas remain; and it is believed that as few as 6,600 Sumatran orangutans can be found in the wild (Stiles *et al*., 2013). In Africa five different species have been listed in the World's 25 Most Endangered Primates and include; Rondo dwarf galago (*Galagoides rondoensis*), Roloway monkey (*Cercopithecus diana roloway*), Preuss's red colobus (*Piliocolobus preussi*), Tana River red colobus (*Piliocolobus rufomitratus*), Grauer's gorilla (*Gorilla beringei graueri*) (Butynski and Hamerlynck, 2015; Schwitzer *et al*., 2015).

Some primates in the *Cercopithecidae* family are under great conservation concern such as the Endangered Tana River Mangabey (*Cercocebus galeritus*) endemic to the riverine forest patches along the lower Tana River in southeastern Kenya. According to Schwitzer *et al*. (2011); Link *et al*. (2010) and Shephered (2010) destruction of tropical forests, illegal wildlife trade and commercial bush meat hunting have led to decrease in primate populations in Africa and other continents. Species become threatened when their population decline and threats increase.

2.5.2 Effects of Habitat Loss on Primate Populations

Major threats leading to habitat loss in most tropical forests include illegal logging, agricultural expansion and intensification, habitat fragmentation and unsustainable infrastructural development projects (Slingenberg *et al*., 2009; Dernegi, 2010; Chakravarty *et* *al*., 2012). These threats endanger the survival of most primate species and if not effectively addressed could lead to extinction of many species (Cawthon, 2005). Destruction of the vegetation through deforestation for timber, fuel wood, charcoal burning and plantation of exotic plant species completely alter the natural vegetation structure (Schwitzer *et al*., 2011). Adverse changes in vegetation structure affects the different primates found in tropical forests and thus require effective habitat management to secure the tree species preferred by different species of primates (Tweheyo, 2003; Fashing and Gathua, 2004).

According to Dudgeon (2000) the population of Orangutans has fallen by more than 50% over the past 60 years, while at least 55% of its habitat has disappeared over the last 20 years. Main causes of habitat loss include road development, illegal timber harvesting and unsustainable logging, mining and human encroachment with the increase in human population (van Solinge, 2010). With continued escalation to such threats the population of Oragutans could be extinct in the wild in less than 25 years (Mittermeier *et al*.,2006). Elsewhere in Africa, the population of the Endangered Eastern chimpanzee (*Pan troglodytes schweinfurthii*) loss of habitat to agriculture and mining and habitat fragmentation (Plumptre *et al*., 2010). The threats lead to isolation of small populations which are likely to become genetically unviable in the long term (Lacy, 1997).

In Kenya, the population of Tana River Red Colobus and the Tana River Mangabey are both greatly threatened by forest loss and fragmentation caused by a growing human population (Moinde-Fockler *et al*., 2007). The forests the species occupy are mainly cleared for agriculture and human settlements for example an estimated 50% of the original forest has been lost in the last 20 years (Mbora and Meikle, 2004). Subsequently, the current population of the Tana River Red Colobus is less than 1,000 individuals and declining, while the population of the Tana River Mangabey is not much larger and declining (Butynski and Mwangi, 1994).

Habitat loss in form of selective logging could in particular influence the structure of a given forest if the plant is most dominant and also preferred by different species of birds and primates (Mitani *et al*., 2000; Tews *et al*., 2004). Due the recent discovery of the medicinal importance of the African cherry (*Prunus africana*), its populations have been declining in many forests due to its unsustainable bark exploitation for international plant trade (Cunningham and Mbenkum, 1993; Sunderland and Tako, 1999; Hall *et al*., 2000) despite the plant being a very important in the diet composition of the Eastern Black and White Colobus monkey (*Colobus guereza*). According to Fashing (2001)*Prunus africana* contributed 30-50% of the species diet at Kakamega forest. The author also found out that *P. africana* has been rapidly declining in the forest and although Guerezas are considered to be among the most ecologically flexible of the arboreal African monkeys (Plumptre and Reynolds, 1994; Onderdonk and Chapman, 2000; Fashing, 1994; 2001), a serious decline in their main food source might prove difficult for even Guerezas to overcome.

Habitat loss has also led to reduced opportunities for dispersal, and heightened competition from other species (Fahrig, 1997). Those that have survived have been, and continue to be, pushed to higher altitudes along the rivers, or are left in small, isolated remnant habitats that cannot sustain them, and expose them to poaching (Mwenja, 2004). Today, the majority of the population is spread through very thin, increasingly fragmented, strips of riparian forest on private farms; usually in small, isolated groups (Mwenja, 2007).

2.5.3 Influence of Hunting and Illegal Trade on Primate Population

In Africa, hunting is part of the local culture, and wild meat is an important source of protein. However, the killing of wild animals for the bush meat trade has become a significant factor in the reduction of biodiversity especially primates (Barnes, 2002). Studies conducted over the last 25 years suggest that primates in most regions of West Africa are threatened due to the effects of both forest loss and hunting for the bush meat trade (McGraw, 1998; Oates, 2000; Brashares *et al*., 2004; Refish and Kone, 2005; McGraw, 2007; Campbell *et al*., 2008; Covey, 2009; Campbell, 2011; Gonedele *et al*., 2012).

In Guyana, South America primate population surveys indicate a serious decline in group densities within the last two decades as a result of ongoing hunting and habitat destruction. In general, the group density of all primate species has been reduced by two thirds (Lehman, 2000). In Peru Tambopata-Candamo Reserve, every primate except the saddle-backed tamarin (*Saguinus fuscicollis*) has disappeared due to hunting and human disturbance (Naughton-Treves *et al*., 2003). In the Brazilian Amazon the annual number of hunted primates is estimated at 2.2 to 5.4 million individuals (Altherr, 2007) and this significantly affects the primates' populations leading to their decline. In Central and West Africa, hunting possesses greater threat to ape population decline than habitat destruction (Cawthon, 2005). Ape populations are particularly vulnerable to overexploitation, because they live at relatively low densities and tend to be social, active, and therefore highly visible by day (Rovero, 2012). With increasing urbanization, bush meat consumption has spread from villages to cities, where bush meat is sold in market retailers, restaurants, and cafeterias (Edderai and Dame, 2006).

2.5.4 Influence of Human Wildlife Conflicts to Primate Population

Crop damage by wildlife is a very prevalent form of human-wildlife conflict adjacent to protected areas, and great economic losses from crop raiding impede efforts to protect wildlife (Baranga *et al*., 2012). Humans and nonhuman primates have had a long association and, in many instances, have antagonistic relationships (Fuentes, 2006). However, with increasing conversion of forests to agriculture, crops have become vital supplements to the diet of many nonhuman primates (Struhsaker, 1978; Hill, 2000; Estrada, 2006; Hockings *et al*., 2009). Subsistence farmers living adjacent to protected areas have borne the bulk of the crop depredation associated with primates (Hill, 1997; Tweheyo *et al*., 2005).

Crop raids by primates' lead to killings and this significantly reduces the population of primates. This possesses a great risk of extinction to primates if conservation interventions are not considered (Campbell *et al*., 2008). Human induced mortalities as a result of the conflict adversely affect the species population viability and shift the ecosystem equilibrium leading to its instability. Some primates such as Vervet Monkeys and Baboons are sometimes considered as pests due to the destruction they cause on farms (Hill, 1997) and this may lead to their poisoning by the local farmers leading to the death of several groups (Lee and Priston, 2005) which affects the primate populations.

2.5.5 Effect of Climate Change on Primate Range Shift and Distribution

Understanding the effects of climate change on ranging patterns of primate species is crucial for conservation planning (Luo *et al*., 2015). According to Lehmann *et al*. (2010) monkey species in the world will become increasingly at risk of extinction because of global warming. Particularly, the populations of monkeys and apes in Africa that depend largely on a diet of leaves may be wiped out by a rise in annual temperatures of two degrees Celsius.

In assessing the effect of global warming on general biodiversity several analyses have been used to demonstrate that climate change will affect species distribution and range (Bellard *et al*., 2012). The most common models used to predict such effects are bioclimatic envelope models (Thuiller, 2003), which aim to determine the climate envelope that defines a species' range by correlating its distribution patterns with selected climate variables. Although it is widely appreciated that a species' distribution is also shaped by historical patterns of the distribution of key ecological resources (Ganzhorn, 1998; Reed and Bidner, 2004), few studies have attempted to provide an explanation for the mechanisms that underpin such effects.

A study conducted on the Ethiopian highlands by Dunbar (1998) on Geladas showed that climate change could significantly reduce their distribution and range. The study also showed that, there is a maximum tolerable band size for Gelada in habitats that varied in altitude and latitude under current climatic conditions. It showed that Geladas cannot cope in habitats below 1500m in attitude and that maximum tolerable group size falls off rapidly as attitude raises above 4000m. Malcolm (2002) found a clear and escalating pattern of climate change impacts on bird species around the world suggesting a trend towards major bird extinction from global warming. According to Malcolm and Markham (2000) global warming will also affect birds indirectly through sea level rise, changes in fire regimes, vegetation changes and land use change. Scientists have found that bird extinction rates could be as high as 38% in Europe, and 72% in northeastern Australia, if global warming exceeds 2^0C above pre-industrial levels. Climate change has resulted to loss of Worthen's Sparrow range and population in North East Mexico with climate modeling projecting the remaining habitat to be unsuitable in just 50 years (BirdLife International, 2004).

2.6 Inter-specific Interactions among Primate Species

Non-nomadic primate species tend to form social relationships regardless of their degree of association (Sterck *et al*., 1997). These relationships are gregarious and are usually maintained by some sympatric primate species and are useful during foraging and feeding times (Fleagle *et al*., 1981; Pook and Pook, 1982; Podolsky, 1990) and can also be used as warning systems in predator avoidance (Peres, 1993; Heymann, 1995, 2011;). Among primates, the most common form of interspecific lethal aggression is also observed in those few species that prey upon other sympatric primates (e.g., chimpanzees: Stanford *et al*., 1994; Stanford, 2002; Watts and Mitani, 2002).

Although rarely observed, some cases of interspecific aggression have been also reported among primate species outside of predator–prey interactions, mainly in the context of interspecific resource competition at actual feeding sites (Heymann, 1990; Stevenson *et al*., 2000). For example, in Costa Rica, aggression between White-faced Capuchins (*Cebus* *capucinus*) and Black-handed Spider Monkeys (*Ateles geoffroyi*) can arise at heavily contested food resource sites (Rose *et al*., 2003). In Cercopithecus monkeys, the overlap in foraging heights and diets overlap when they are in poly-specific relationships (Gautier-Hion *et al*., 1983).

At Kenya's Kakamega Forest, apart from the dietary overlap between the Blue Monkey and Red-tailed Monkey (Cords, 1986), mixed-species association of the Blue Monkey and Red-tailed monkey was suggested to be an anti-predator strategy against African Crowned Eagle (*Stephanoaetus coronatus*) (Cords, 1990), which is the major predator on the Cercopithecidae family (Sanders *et al*., 2003). Gautier-Hion *et al.* (1983) observed a reduced predation risk in the West African Forest where three of four successful attacks were made on single-species groups.

2.7 Focal Species for this Study

2.7.1 Geographic Range of Primate Species for this Study

Black and White Colobus (Plate 1) has a wide geographical range from lowland tropical rainforest to the upper reaches of montane forest (Figure 1) as well as *Acacia*-dominated riverine galleries and evergreen thicket forests. They can survive in drier, more degraded forests.

Plate 1: Black and White Colobus, ©jonclark2000

Figure 1: Geographical range of the Black and White Colobus © Chermundy

Red-tailed monkeys (Plate 2) occur in lowland and sub-montane forests, riverine galleries and most stages of colonizing secondary or regenerating forest (except for those on poor soils). They also occur in forest mosaics with a high preponderance of single-stand species, such as ironwood. It is known to occur up to 2,000 m above sea level, (Figure 2).

Plate 1: Red-tailed Monkey, ©Kowari

Figure 2: Geographical range of the Red-tailed Monkey © Oona & IUCN

Blue Monkey (Plate 3) is a widespread African species and ranges from East Africa, Angola and the Democratic Republic of Congo eastwards to the Indian Ocean coastline and Zanzibar Island (Tanzania); in the eastern part of its range it is found from Ethiopia in the north to eastern South Africa in the south (Kingdon *et al*., 2008). It is found from sea level up to 3,800 m (Figure 3).

Plate 2: Blue Monkey ©Yvonne A. de Jong

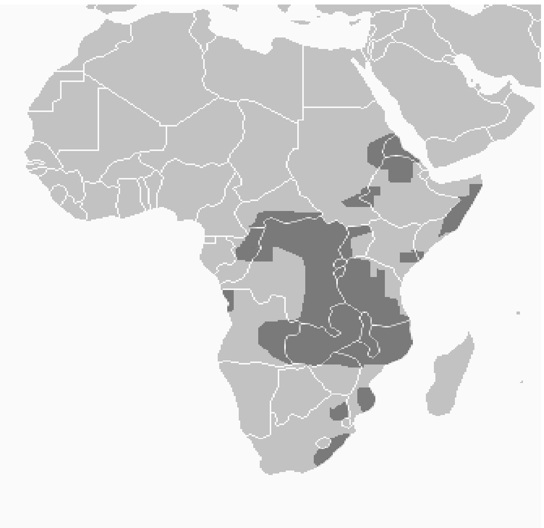


Figure 3: Geographical range of Blue Monkey © Jonathan Hornung

2.7.2 Food and Feeding Habits of Blue Monkey, Black and White Colobus and Red-tailed Monkeys

Red tailed monkeys are primarily frugivorous, but supplement their diet with leaves, insects, flowers, buds, and gum (Chapman and Chapman, 2000). It is common for adults to store fruit in their large cheek pouches in order to take their meal to an area free from the threat of theft by other monkeys (Torstar, 1984).

Blue Monkey mainly consume fruits and figs. They also will eat insects, leaves, twigs, and flowers. If they are unable to find enough food they may consume bark from the trees. It is generally threatened to some degree by deforestation and habitat fragmentation (Kingdon *et al*.,2013).

Leaves and fruit are the main foods of the Black and White Colobus but the diet is quite variable as would be expected in a species with such a wide distribution and range of habitat types. While the species has historically been believed to be exclusively leaf-eaters, they are not obligate folivores (Oates, 1994; Fashing, 2001). The proportions of these types of food relative to one another varies by study site and time of year, often with leaves making up more than half to most of the diet, but with fruit sometimes predominating (Dunbar and Dunbar, 1974; Bocian, 1997 cited in Kirkpatrick, 1999; Fashing, 1999; Harris and Chapman, 2007).

2.8 Legal Frameworks and Primate Conservation initiatives

Although governments have designated networks of protected areas where whole communities of primates may be preserved, human settlement, farming, development and exploitation continue to encroach upon the remaining regions of primate habitat (Dobson and Lyles, 1989). Considering the ecological and the socio-economic importance of primates, their conservation is necessary. Loss of species is an issue of global mutual interest. Concerted efforts to combat the trade in wild species crisis have been devoted towards legislation and mobilizing countries to not only become signatories to relevant international conventions but also to ensure compliance to their policies. One of the mechanisms to protect primate species has been through designation of protected areas. However, there is need to improve on the management effectiveness of protected areas to safeguard populations of primates and other species. Another approach is the IUCN Red listing. IUCN has five categories for conservation status (IUCN, 2016), three threatened categories (Critically Endangered, Endangered, Vulnerable) and two lower risk categories (Near-threatened and Least Concern) as well as data deficient. Most primates that are affected in this trade fall in any of the mentioned categories. The focal species in this study are all listed as Least Concern (LC) according to the IUCN Red List category. Within the IUCN exists the IUCN Species Survival Commission. Under this, there exists the IUCN – SSC Primate Specialist Group; a network of scientists and conservationists who stand against the tide of extinction which threatens primates. The up-listing or down-listing of species from the various threat categories is based on available data and can be at national, regional or global level.

Policy and legislative efforts have been initiated at various levels. At global level, the Convention on International Trade in Endangered Species (CITES) in Wild Fauna and Flora was adopted in 1973 though it became operational in 1975 as a principal international instrument for controlling trade in wild species. The principal purpose of this convention is to "To protect certain plants and animals by regulating and monitoring their international trade to prevent it reaching unsustainable levels". CITES establishes lists (known as Appendices) of species for which international trade is to be controlled or monitored. Appendix I species include Species, which are threatened with extinction, which are or may be affected by trade. Under this category, trade in these species is strictly regulated and excludes commercial activities. Appendix II species include species which although not currently threatened with extinction may become so unless trade is regulated, and other species which look similar to Appendix I species. Appendix III species include species which a party state nominates as subject to regulation by that party state and for which it wishes the cooperation of other Parties in the control of trade.

CITES has contributed to a considerable reduction in the traffic of a number of wildlife products, the fact that not all nations enforce the regulations with the same vigor notwithstanding. All the focal species in this study are listed on Appendix II of CITES and on Class B of the African Convention on the Conservation of Nature and Natural Resources (ACCNN). Lusaka Agreement on Co-operative Enforcement Operations Directed at Illegal Trade in Wild Fauna and Flora is also another conservation mechanism. After realizing the emerging need to combat trade in wild species, an agreement was signed and came into force in 1994 with the primary objective being to reduce and ultimately eliminate illegal trade in wild fauna and fauna and to establish a permanent Task Force for this purpose. The Lusaka Agreement Task Force (LATF) was established under Article 5 of this agreement. Parties to this agreement agree to be "conscious that the conservation of wild flora and fauna is essential to the overall maintenance of Africa's biological diversity and that the world fauna and flora are essential to the sustainable development of Africa.

Convention on Biological Diversity (CBD) was inspired by the world community's growing commitment to sustainable development. It represents a dramatic step forward in the conservation of biological diversity, the sustainable use of its components, and the fair and equitable sharing of benefits arising from the use of genetic resources. The Forests Act 2015, in the context of its general principles, provides for the establishment, development and sustainable management, including conservation and rational utilization of forest resources for the socio-economic development of the country. The Act recognizes the importance of forests for the benefits of soil and ground water regulation, agriculture and their role in absorbing greenhouse gases.Wildlife Management and Conservation Act (2013) govern wildlife conservation and management in Kenya. The Act recognizes the importance of publishing areas zoned to have wildlife conservation and management as their land use priority. This ensures no encroachment to wildlife-sensitive areas. This law is enforced primarily by the Kenya Wildlife Service with support from the police and other government agencies.

2.9 Research gaps

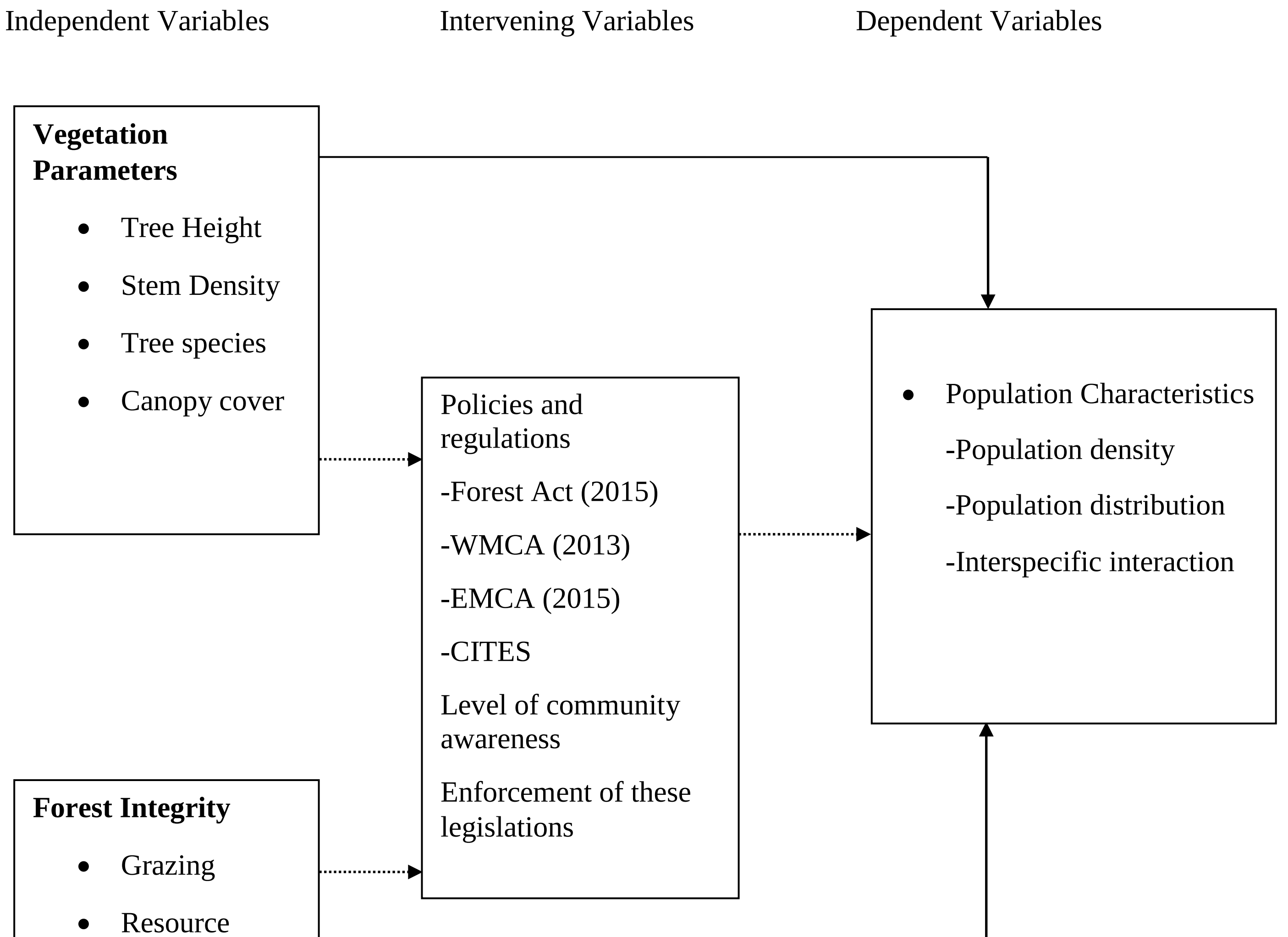
Previous research on primates has focused on factors affecting the distribution and abundance of primate species (Butynski, 1990; Peres, 1997; Anzures-Dadda and Manson, 2007; Pyritz *et al*., 2010). Mammides *et al*. (2008) investigated the effects of disturbance on distribution of Black and White Colobus and Blue Monkey at the neighboring Kakamega Forest but no such of research has been done in South Nandi Forest. Other research on disturbance on Chimpanzees includes (Chapman *et al*., 2000; Chapman and Peres, 2001). Considerable research on population status and distribution of different primate species has been done on different tropical forests in Africa (e.g. Chapman *et al*., 2003; Baranga, 2004; Isabirye-Basuta, 2004).

However, the population status, abundance and distribution of Black and White Colobus, Blue Monkey and the Red-tailed monkey in South Nandi Forest have not been established.

Chapman and Chapman (1996; 2000) investigated mixed-species interaction between primates at Kibale Forest, Uganda, Cords (1986; 1987; 1990) focused on a similar research at Kakamega Forest but no such research has been done in South Nandi forest. Some studies on seasonality in habitat utilization by primates have been done (e.g. Chimpanzees and Cercopithecines, Wrangham *et al*., 1998; Prosimian Primates, Overdorff, 1996; Baboons, Muruthi *et al*., 1991 and Barton*et al*., 1992), but such studies have not been conducted at South Nandi Forest Reserve. The effect of the vegetation structure on the distribution of the primates in South Nandi Forest has also not been studied. These research gaps necessitated this study to help fill gaps in biological knowledge that would ensure better management and decision making to ensure future survival of the three different primate species.

2.10 Conceptual Framework

The population, distribution, relative abundance and the interspecific interactions of the Black and White Colobus, Blue Monkey and Red-tail monkey species is associated with the vegetation structure found in South Nandi Forest. The level of community awareness and policies and regulations may be the driving force to disturbance factors such as logging, charcoal burning, grazing and resource extraction which take place in the forest hence affecting the vegetation which might affect population, distribution, relative abundance and the interspecific interactions of the three different primate species. Disturbance levels also affect the forests integrity.



CHAPTER THREE

MATERIALS AND METHODS

3.1 Description of Study Area

3.1.1 Geographical location and Hydrology

South Nandi Forest lies 34° 59.88' E, 0° 6.30' N in Nandi County (Fig. 3.1). It is a mid-elevation forest, lying west of Kapsabet Town and south of the main Kapsabet-Kaimosi Road. It covers an area of 18, 000 ha and lies at an altitude of 1,700–2,000 m above sea level. The forest is drained by the Kimondi and Sirua rivers, which merge to form the Yala River flowing into Lake Victoria.

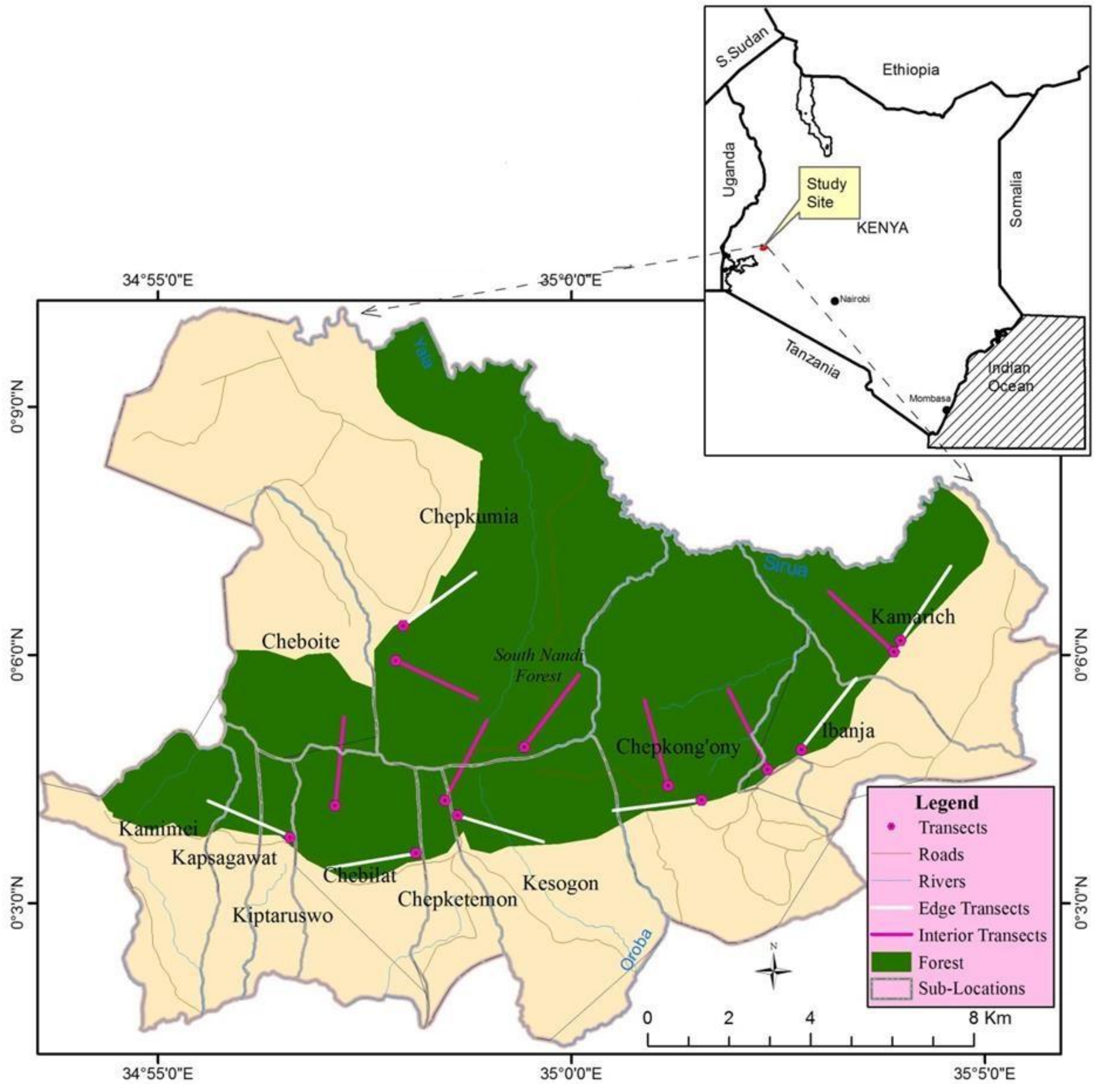


Figure 5: South Nandi Forest Reserve showing the study site and the line transects

3.1.1 Geology, Soils, Vegetation and Climate

The mean annual rainfall ranges between 1,600 to 1,900 mm per year depending on altitude. Rainfall is bimodal with peaks from late April to September and a relatively dry spell from October to March (Benum and Njoroge, 1999). The area has an average temperature of 19°C.

The landscape is gently undulating and underlined by granitic and basement complex rocks, which weather to give deep, well-drained, moderately fertile soils (Bennun and Njoroge, 1999). Common trees include *Tabernaemontana stapfiana*, *Macaranga kilimandscarica, Croton megalocarpus*, *C. macrostachyus*, *Drypetes gerrardii*, *Celtis africana*, *Prunus africana*, *Neobountonia macrocalyx* and *Albizia gummifera* (Birdlife International, 2016).

3.1.2 Biogeography

Biogeographically, South Nandi Forest is a mid-elevation forest and was once contiguous with Kakamega Forest. The two forests have same ecological affinities and are still no more than a few kilometres apart at their closest points (Bennun and Njoroge, 1999). However, it is higher in altitude than Kakamega and floristically less diverse. In effect, South Nandi Forest is transitional between the lowland forests of West and Central Africa (the easternmost outlier of which is Kakamega) and the montane forests of the central Kenya highlands (Bennun and Njoroge, 1999).

3.1.3 Conservation Status of South Nandi Forest

South Nandi was gazzetted in 1936 as a Trust Forest covering 20,200 ha and since then c.2.200 ha has been excised for settlement, c.340ha planted with tea plantations and 1,400 ha planted with exotic tree species. Of the remaining area, about.13, 000ha is closed-canopy forest, the rest being scrub, grassland or cultivation.

3.1.4 Socio-economic Profile

The forest is surrounded by a dense human population of 423.7 persons per sq.km (KNBS, 2009) with the dominant ethnic groups being Nandi and Maragoli. Both communities practice small holder farming of annual and perennial crops such as maize, beans, wheat and also livestock farming. The major cash crop grown in the area is tea with Nyayo Tea Zone surrounding most forest boundaries and providing employment opportunities for the locals (BirdLife International, 2015a and b). The tea plantation also acts as a protective barrier to the forest by reducing direct threats such as encroachment due to limited accessibility.

Communities living adjacent to the forest largely depend on the forest for fuel wood and food resources such as fruits and vegetables which grow in the forest especially during the rainy season. They also graze their livestock inside the forest especially during the dry season when there is limited fodder.

3.1.5 Species of Global Conservation Concern

The site is also an Important Bird Area[1] (IBA) as designated by BirdLife International and is a Key Biodiversity Area (KBA) as part of the Afromontane biodiversity hotspot[2] as identified under the Conservation International biodiversity hotspots. Globally threatened species of interest include birds e.g. Vulnerable Turner's eremomela (*Eremomela turneri*) and mammals e.g. Vulnerable Leopard (*Panthera pardus*). It is the most important site in the world for the Turner’s Eromomela populations (Bennun and Njoroge, 1999; BirdLife International, 2015a). Some trees of biological importance such as Prunus (*Prunus africana*) and Podo (*Podocarpus latifolius*) are also found in the forest.

3.2 Research Design

The study adopted an ecological survey design. Ecological surveys identify the species that exist within an area at the time of the survey. The study area was delineated into interior and forest edge, described by the distance from the forest boundary and a total of 14 random line transects (7 transects in the edge and 7 interior transects) were laid. The interior transects were laid at a distance of 100m from the forest boundary while the edge transects (40m from the forest boundary) were laid parallel to the forest boundary.

3.3 Methods of data collection

A reconnaissance was conducted in the South Nandi Forest for one week, which resulted in delineation of the study area into forest interior and edge, based on proximity to the surrounding matrix (farmlands and human settlements) and levels of habitat disturbance (cattle overgrazing, tree cutting, firewood collection). Transects were measuring 2 km long, 0.075km wide and at least 3km apart and were laid in the interior of the forest and along the forest edge. The line transects were maintained for both the dry and wet seasons and were

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[1] Important Bird Area (IBA) is an area identified using an internationally agreed set of criteria as being globally important for the conservation of bird populations

[2] Biodiversity hotspot is a biogeographic region that is both a significant reservoir of biodiversity and is threatened with destruction

sampled 3 times a piece during the dry and wet seasons. Navigation was by a GPS which was used to find the location of each transect, and to estimate the transect length.

Opportunistic sampling design was used for sampling the primates' population density. The species were recorded when encountered along the line transect. Habitat variables were sampled and recorded where a sighting of a mixed group or a single species group was made.

3.3.1 Estimation of primates' population size and densities

To ensure consistency in data collection procedures a 2-person survey team was constituted, trained and maintained throughout the survey. Primate census were carried out using the line transect method in accordance with Buckland *et al.* (2001). Data was collected in February to March, 2014 to represent the dry season and April to May, 2014 to represent the wet season. Censuses were carried out in early morning (8.00-11.00 am) and late afternoon (14.00-17.00pm) when monkeys are typically most active (Fashing and Cords, 2000; Mammides *et al*., 2008). During the census, the observers walked at optimal walking-pace of about 1 km/h scanning the transect area for primates. At the beginning of each transect, the location, habitat type, date, weather and starting time were recorded. When a primate group was spotted, a pair of binoculars was used to correctly identify the species and was observed up to 10 minutes. The observer remained on the census route without following the animals away from the line. The following information was recorded in data collection sheet (Appendix 1) following the guidelines of National Research Council (1981), Peres (1999) and Davis (2002):

- Identification of species and number of individuals. The group size was estimated when the group number was too large for all individuals to be counted
- Cue of detection (sight, vocalization, or sound produced by animals moving through the vegetation)
- Time of sighting
- Observer's location along transects using GPS
- Animal-observer distance (perpendicular distance) as determined by LEICA Range-master 900 rangefinder with 1 meter accuracy. The first animal to be sighted was used as the focal animal in measuring the perpendicular distance. If the monkeys started moving away, the exact point where the first monkey individual was spotted was used as the center point when measuring the perpendicular distance

- Activity of animals at first detection as described in the Table 1
- Age of individuals in each group whether adult or young (Morphologically small in size or a new born)
- Time encounter ended.

Table 1: Description of primate activities

Activity	**Definition**
Feeding	When the monkey was biting plant parts and chewing them and also turning leaves or was peeling off the tree bark searching for food
Moving	When the monkeys are jumping from one tree to the other going in a specific direction
Resting and grooming	When the monkey is sitting/sleeping motionless in a shade or when the monkey engages in fur cleaning while sitting or sleeping with fellow monkey
Basking	When the monkey is sitting/sleeping on top of a tree while facing the sun
Social Interaction	• Friendly interaction is when the species are doing the above activities together without fighting • Aggression is when the different species are physically fighting or producing warning sounds towards each other. • Vigilance is when members sit in alertness as they watch the other group feed or perform another activity

3.3.2 Assessment of the Interspecific Interaction for the Three Primate Species

During the observations for population densities, data was also collected on the different species of primates observed together with a maximum distance of 2m from each other and included;

- Names of the different species observed together
- Each groups height in the trees using the following vertical strata: ground (0-2m), lower canopy (2-8m), and higher canopy (>8m) as adopted by Ekhardt and Zuberbuhler (2004),

- Number of times observed together
- Reaction on initial detection which included; Hiding- where the monkey species would take cover in the dense canopy of same tree it was first detected on; Jumping and hiding- where the monkey species would jump from the tree it was detected on to a nearby tree and take cover in the canopy; No reaction- where the monkey would sit still in the tree detected on regardless of it being aware of human presence.
- Any behavior such as aggressiveness or friendly association.

3.3.3 Factors affecting distribution, presenceof the three primate species

Vegetation structure

Vegetation attributes were sampled at the spot where a group of monkeys was sighted. To minimize disturbance to the primates, vegetation sampling was undertaken immediately after running the entire transect. Two hundred and fifteen vegetation plots of 20m by 20m were sampled around points where monkeys were sighted along each transect and the attributes recorded included; 1) Stem density of woody plant species measuring above 5cm was recorded using a DBH metre at 1.3m above the ground (Abed, 2003); 2) Tree heights were determined using a clinometer (Suunto and Haga model) and 3) Canopy cover was measured by use of a densitometer and the overall percentage canopy cover of the plot was established. A GPS devise was used to capture the geographical coordinates for each vegetation plot. The coordinates of the plot were taken at the center of the plot.

Assessment of the level of habitat disturbance

Direct observation was used to assess the major threats within the plots along each transect where a sighting was made. Information recorded on habitat disturbance is based on Table 2

Table 2: Indicators of forest disturbance included

Threat	Measurable Indicators	Level of severity
Logging	Stumps (old and new), remaining logs, saw dust	Number of stumps of diameter >10Cm
Grazing	Presence of livestock, dung, hoof marks, browsed vegetation	Number of livestock present, number of recent dungs
Charcoal burning	Active kiln, Charcoal remains, Burnt soil	Number of kilns
Forest fire	Burnt bushes/tree barks, chars on ground,	Number of burnt bushes/trees
Resource extraction	Debarking, Pruning, uprooting, fire wood	Number of trees debarked, number of firewood cuttings

3.4 Ethical Considerations

All research permits were obtained prior to the field work by the funding organization and included Kenya Wildlife Service (KWS) permit and Kenya Forest Service (KFS) permit of research.

Research ethics was observed especially when observations of the primates were done to avoid undue disturbances on the species. During data collection, the following conduct was maintained;

- Primates were not lured for observations by being given food or fruits
- There was no direct contact with the primates. Observations were made from a considerable distance from the individuals/primate group being studied
- All the observers ensured that they made minimal noise during transect walks to minimize disturbance
- Less vegetation was cut down during establishment of vegetation plots to minimize disturbance

3.5 Data Analyses

Population data was analyzed using DISTANCE Software Package Version 6.2. The software package DISTANCE is commonly used to analyze data from line transects. However, the use of this method requires certain criteria or assumptions in order for the mathematical model to be applicable to the data (Buckland *et al.*, 2001) which were met for all species sampled. However the minimum observations for Red-tailed Monkey were <40: (1) Primates directly on the transect line were never missed; (2) Primates did not move before being detected; (3) Primates were not counted twice in a single transect walk; (4) Distances and angles were measured accurately; (5) Sightings were independent events; (6) Sufficient sightings were made for an accurate estimate of the distance; (7) Detection function (i.e. number of occasions animals were sighted) must be greater than 40 sightings.In determining the population density Black and White Colobus and Blue Monkeyin South Nandi Forest, Distance models with different adjustment factors were tried. The best model was selected based on alkaike information criterion (AIC) value. Other methods of analysis are illustrated in Table 3 below.

Table 3: Summary of data Analysis

Objective	**Variables**	**Data analysis tool**
Estimation of population density	• Count of individuals of respective species	Estimation of the absolute population density for respective species using Distance Sampling 6.2
	• Number of adults and the young per species • Reaction on detection, initial cue of detection	Descriptive statistics (presented in the form of means, StdDev)
Spatial distribution	• GPS location of each group	Arc GIS 10 Overlay of GPS points
Interspecific interaction	• Different species observed together • Activity during	Descriptive statistics (presented in the form of means, StdDev, frequency graphs)

	observation	
Factors affecting population density	Vegetation structure • Height of trees with stem density ≥ 5cm • Canopy cover • Tree species Disturbance • Logging • Grazing • Charcoal burning • Resource extraction • Forest paths	Independent samples t-test to determine if there were any differences between the factors affecting vegetation structure in the forest edge and interior

CHAPTER FOUR

RESULTS

4.1 Primate Population Densities

4.1.1 Current Population Densities of Black and White Colobus and Blue Monkey

Over the 210ha sampled, the population numbers estimates for the entire forest were projected to be 11,440 individuals for Black and White Colobus, 8,190 individuals for the Blue Monkey and 14,400 individuals for the Red-tailed Monkey. The main assumption for this projection was that the forest was homogenous and suitable for primate survival. Overall group sightings were 123 and 142 for the Blue Monkey and Black and White Colobus, respectively, with densities of 0.88±0.19 animals/ha and 0.63±0.16 animals/ha, respectively, for the two species (Figure 6). Since only 24 observations were made for the Red-tailed Monkey, the species was excluded from further analyses on population densities because observations did not attain the minimum requirement for the Distance Sampling software to be applied.

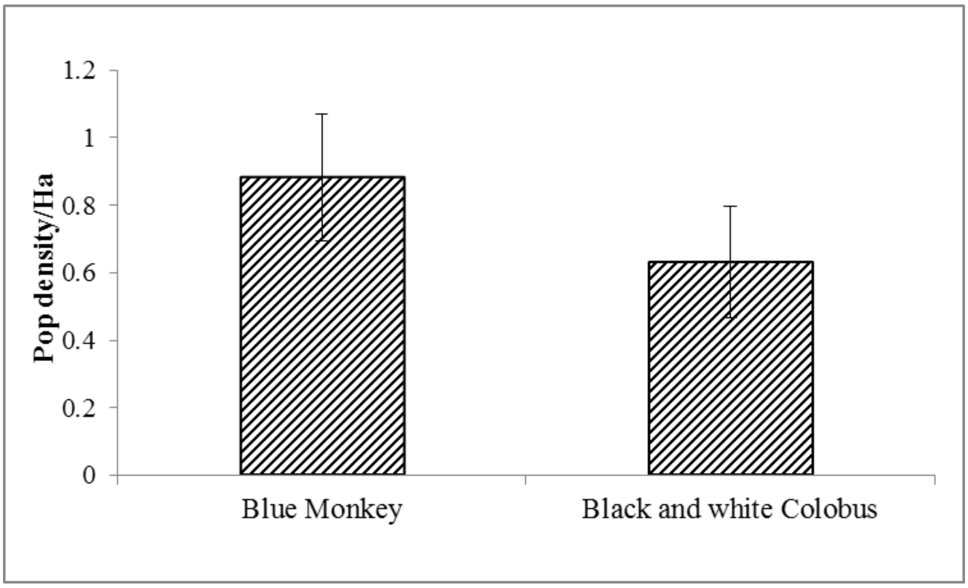


Figure 6: Overall population density/hectare of Blue Monkey and Black and White Colobus in South Nandi forest.

The population densities per hectare and number of observations (*n*)of Black and White Colobus and Blue Monkey in the dry and wet Seasons and also in the forest edge and forest interior as calculated using the DISTANCE software across the area sampled (210 ha) are shown in Table 4 and 5.

Table 4: Population densities for the *C.mitis* and *C. guereza* in the forest edge and interior

Species / Location	*C.mitis*			*Guereza*		
	n	**MER**	**DHa**	**n**	**MER**	**DHa**
Forest Edge	59	0.32	0.75	55	0.66	0.42
Forest Interior	64	0.17	0.99	87	0.15	0.89
Total	123	0.49	1.74	142	0.47	1.31

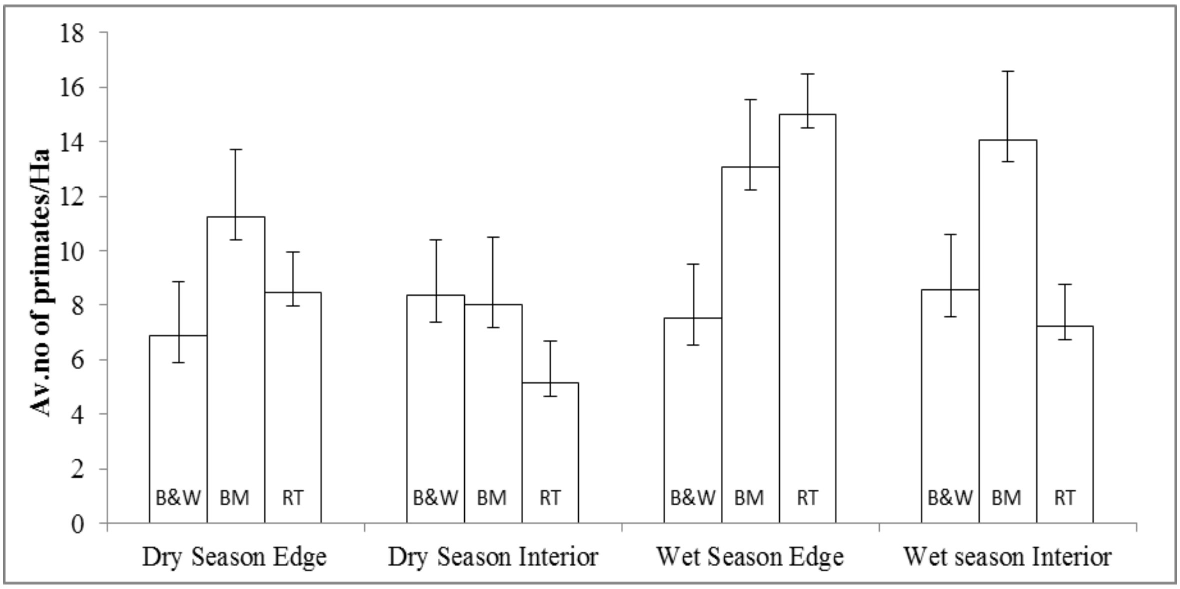
N.B: n = observations; MER = mean encounter rate (n/km^{-1}); D = primate density/ha

Table 5: Population densities for the *C.mitis* and *guereza* in the dry and wet seasons

Species / Seasons	*C.mitis*			*Guereza*		
	n	**MER**	**DHa**	**n**	**MER**	**DHa**
Dry Season	64	0.23	0.72	64	0.75	0.49
Wet Season	59	0.22	1.13	78	0.28	0.81
Total	123	0.45	1.85	142	1.03	1.30

N.B: n = observations; MER = mean encounter rate (n/km^{-1}); D = primate density/ha

The population numbers of the three primate species showed a high number of observations along a gradient of forest location and seasons (Dry and wet seasons). Black and White Colobus were mostly recorded in the forest interior regardless of the season. Blue Monkey groups were recorded in the forest edge during the dry season and in the forest interior during the wet season. Red-tailed Monkey was mostly recorded in the forest edge in the dry and wet season (Figure 7).



*RT= Red-tailed Monkey; BM=Blue Monkey B&W= Black and White Colobus

Figure 7: Average number of primate species in the forest edge and interior during the dry and wet seasons.

4.1.2 Initial Cue of Detection

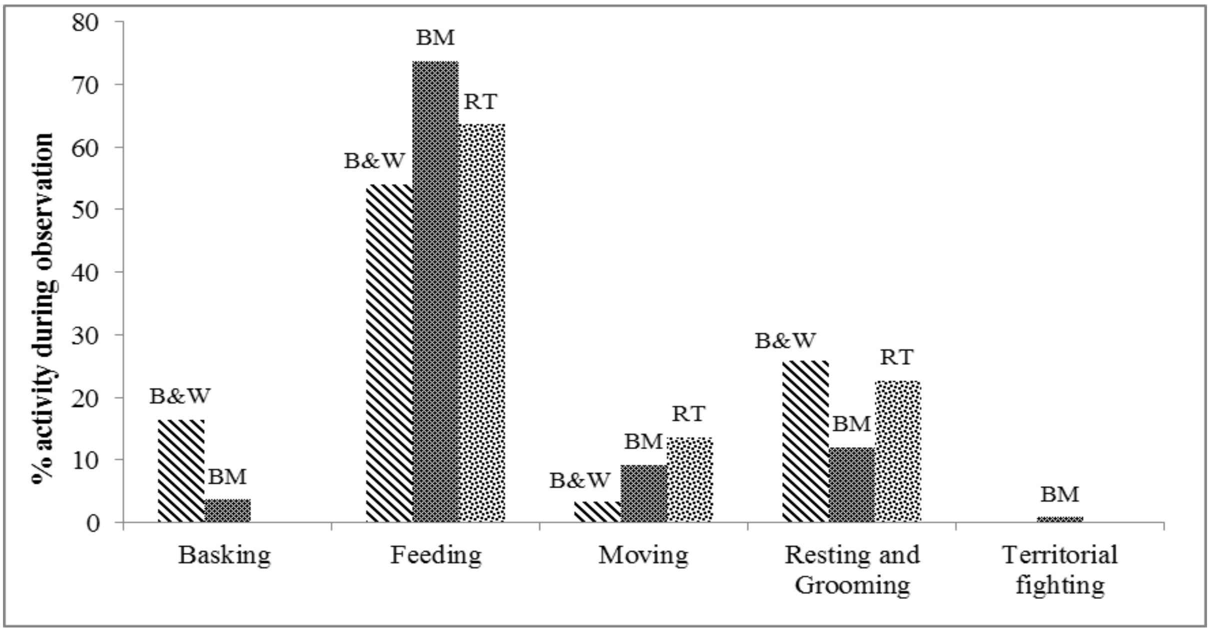
The average number of groups of primates detected per transect walk was 6.54.± 5.17 for Black and White Colobus, 7.71 ± 6.63 for Blue Monkey and 3.67 ± 4.08) for Red-tailed Monkey (*n*=14 transects). Individuals of all the species were detected mostly by visual cues (73%) rather than auditory cues 27%. During the dry season the percentage detection by auditory cues was higher in the forest edge 49% as compared to forest interior. Percentage detection in the wet season was higher in forest edge by 51%. Visual detection in the dry season was high in the forest edge by 54% (Table 6).

Table 6: Percentage Initial Cue of Detection of Primate Species in South Nandi Forest

Initial cue of detection	**Forest Edge**		**Forest Interior**	
	Dry Season	**Wet Season**	**Dry Season**	**Wet Season**
Auditory	49%	51%	28%	72%
Visual	54%	46%	53%	47%

4.1.3 Activity during Initial detection

With most diurnal primates being active in the early morning and late afternoon, their daily activities varied. The common activities observed during this study included feeding, basking, moving, resting and grooming, territorial fighting. All the species differed in performing these activities with aggression being observed only in Blue Monkey, basking time was only utilized by the Black and White Colobus and Blue Monkey. The three primate species utilized a significant percentage of their time (65%) on feeding (Figure 8 and Table 7; 8) followed by resting and grooming which was 19%, Basking 8%, moving 7% and aggression was the least 0.9%.



***RT= Red-tailed Monkey; BM=Blue Monkey B&W= Black and White Colobus

Figure 8: Activities of the three primate species during the initial detection

Table 7 below shows how forest locality affected the activities of the different species of monkeys with most of the activities being recorded in the forest interior.

Table 7: Forest edge and interior and primates activities

Forest Locality	Basking	Feeding	Moving	Resting and grooming	Territorial fighting	Totals
Edge	10	67	1	17	2	**97**
Interior	8	72	15	23	0	**118**

The activities of the primates were also affected by the seasonal variation with 47% of all the counts of activities being recorded in the dry season and 53% in the wet season. Only basking and resting and grooming were highest during the wet season (Table 4.5).

Table 8: Primate Activities in the dry and wet seasons

Seasons	Basking	Feeding	Moving	Resting and grooming	Territorial fighting	Grand Total	Percentages
Dry	6	72	10	14	0	**102**	47
Wet	12	67	6	26	2	**113**	53
Grand Total	**18**	**139**	**16**	**40**	**2**	**215**	**100**

The activities of the primates were also influenced by the time of day with most activities taking place during the morning hours (8.00-10.00 am) as presented in (Table 4.6).

Table 9: Activities of the primates and time of the day

Time of Day	Basking	Feeding	Moving	Resting and grooming	Territorial fighting	Grand Total
Evening	0	32	2	24	0	58
Morning	18	107	14	16	2	157
Grand Total	**18**	**139**	**16**	**40**	**2**	**215**

4.1.4 Spatial distribution of primates in South Nandi Forest

The mapping of primate sightings across the areas sampled in South Nandi Forest for each species are presented in Figures 11, 12 and 13. Figures 9 and 10 represent the overlayed distribution of the three different primate species in the dry and wet season over the area studied.

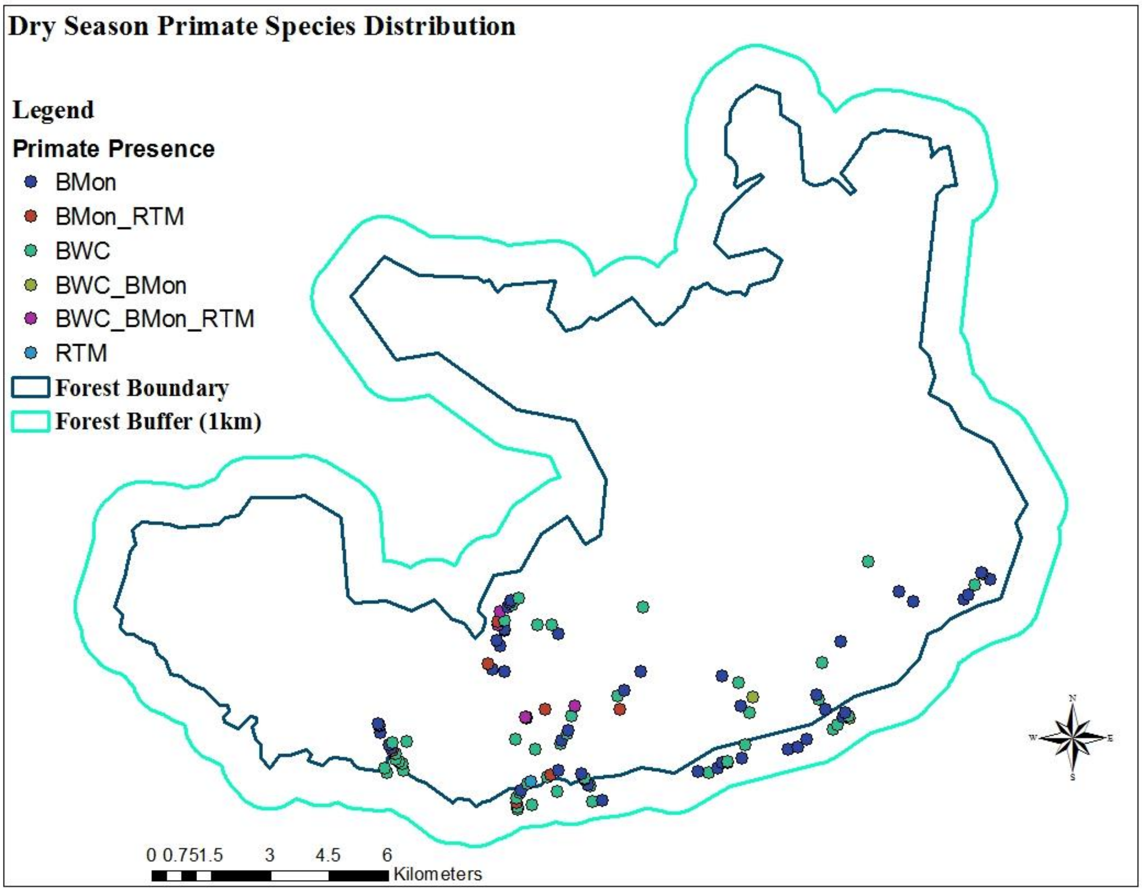


Figure 9: Spatial distribution of the three primate species during the dry season

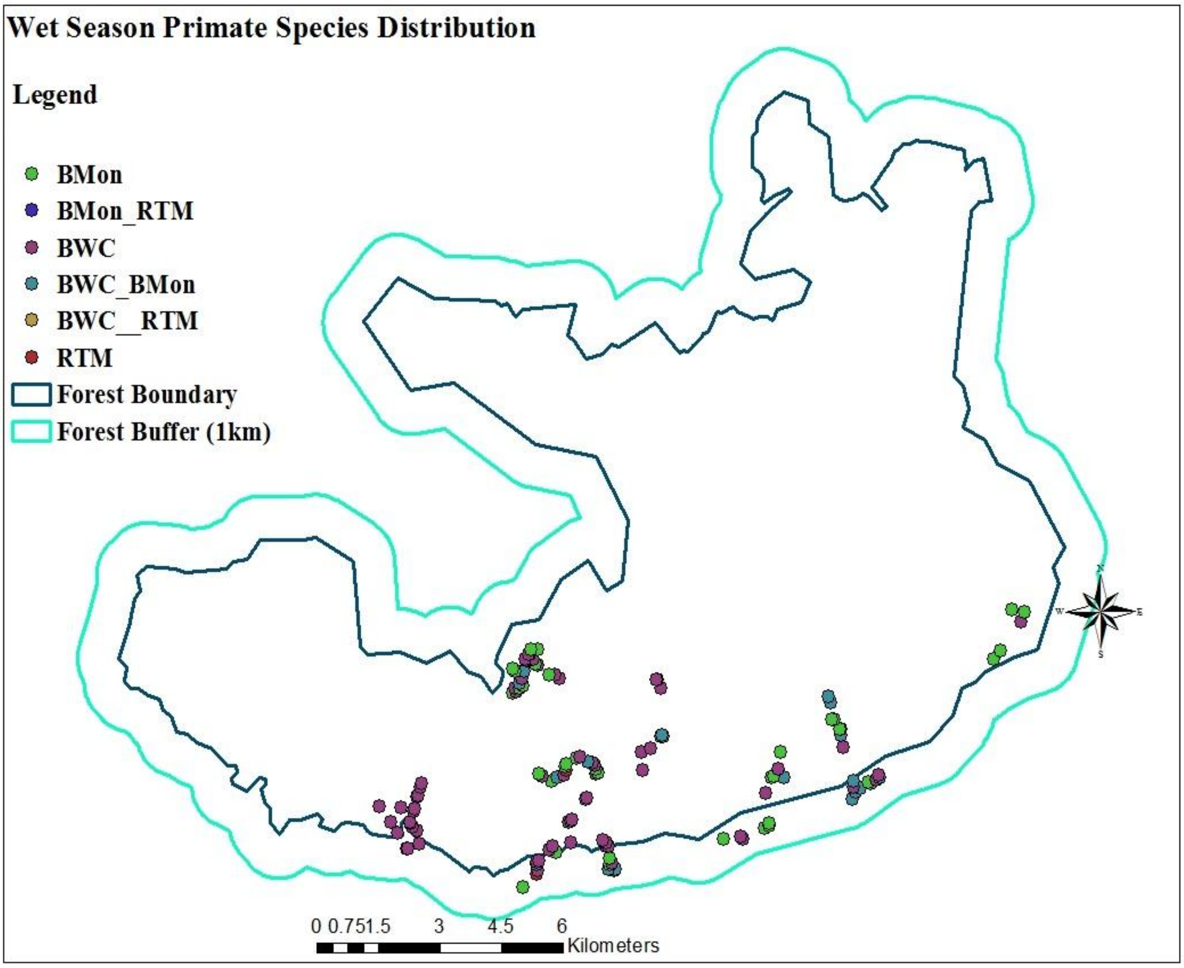


Figure 10: Spatial distribution the three primate species during the wet season

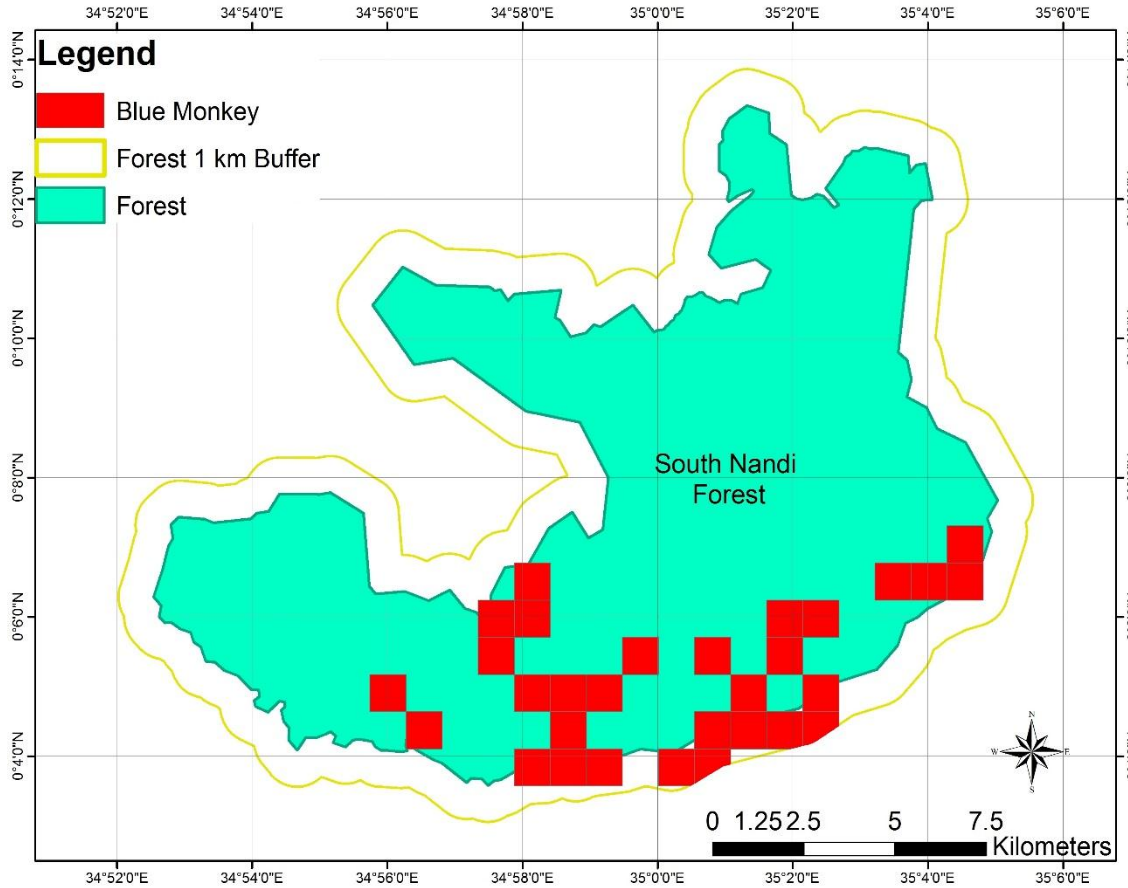


Figure 11: Spatial distribution of Blue Monkey in the studied area of the forest

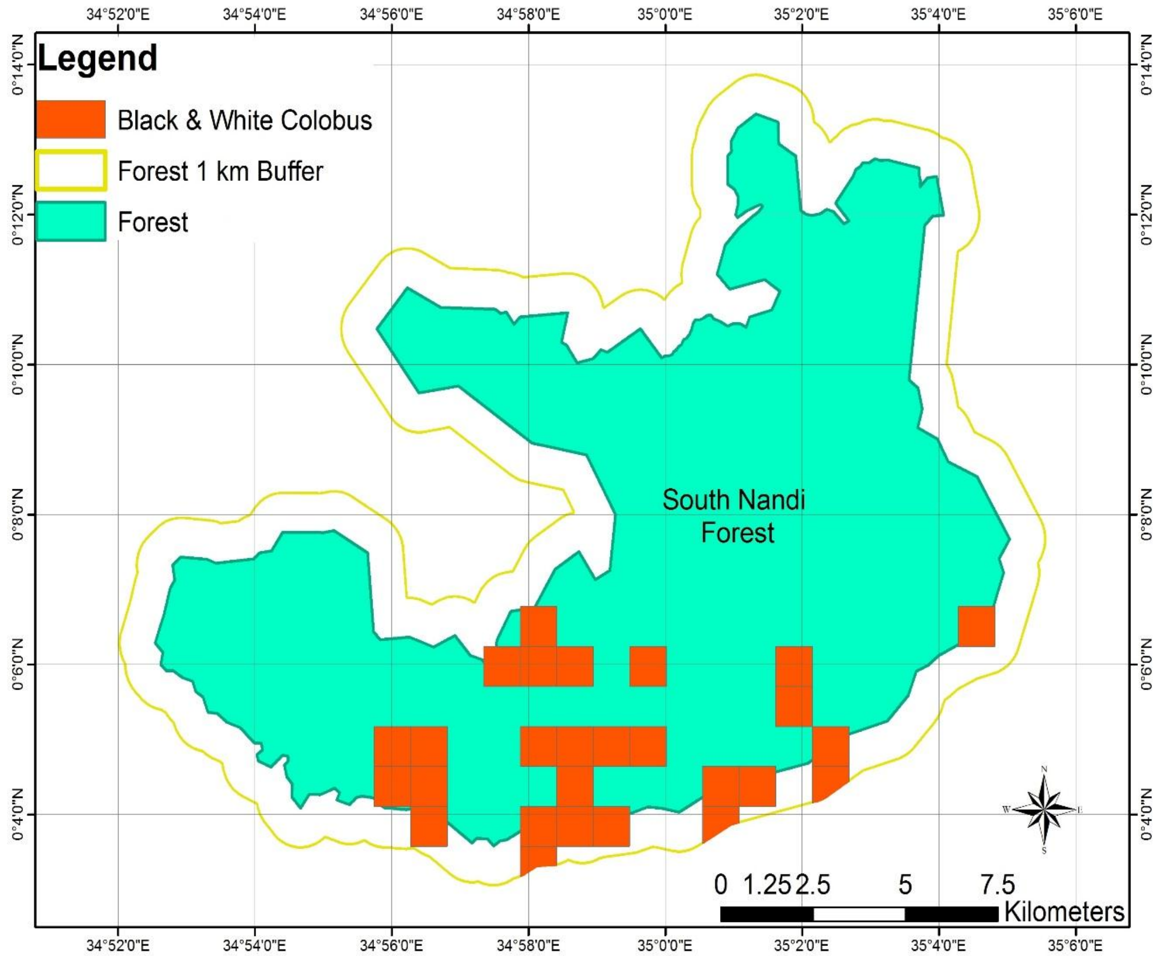


Figure 12: Spatial distribution of Black and White Colobus in the studied area of the forest

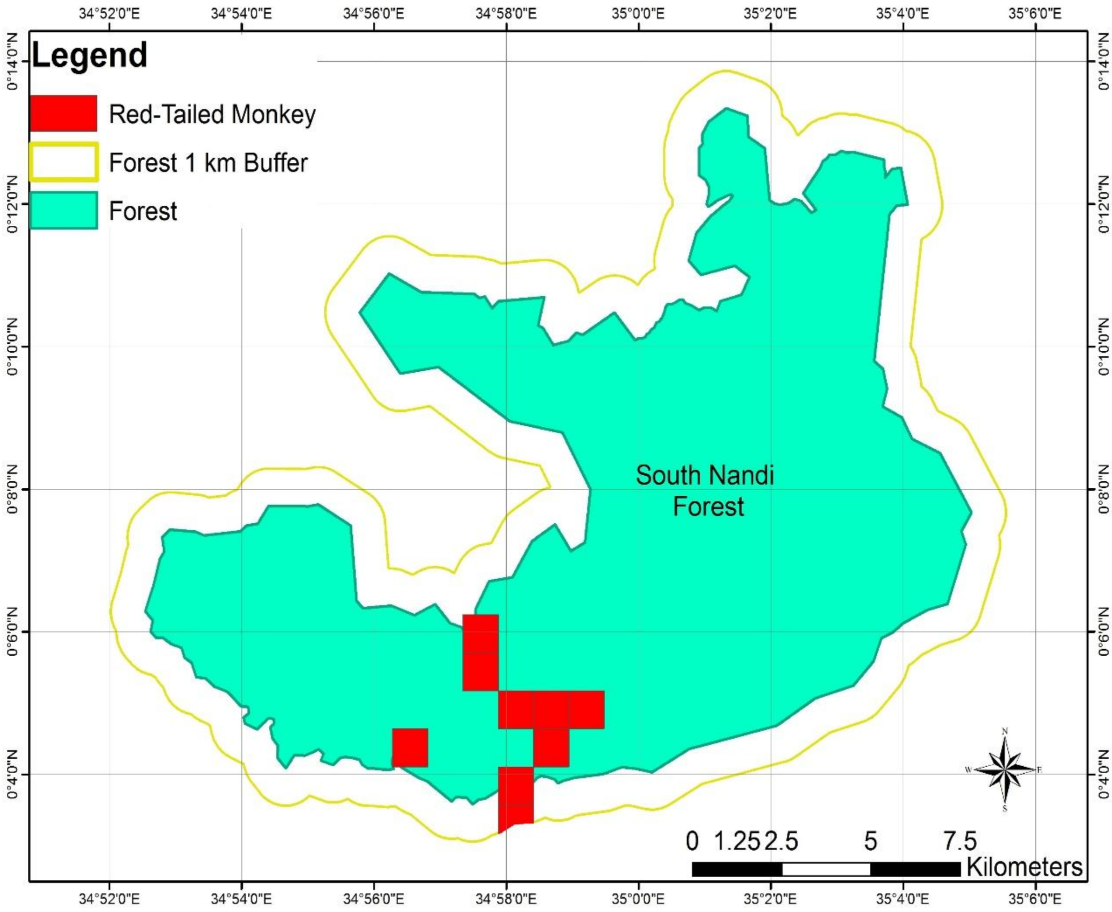


Figure 13: Spatial distribution of Red-tailed Monkey in the studied area of the forest

4.2 Assessing Interspecific Interaction between Primates

Of the many times the different species where observed together in the same space, they were sharing resources such as food trees or performing the same activity such as feeding, moving and resting and grooming activity.

4.2.1 Interaction in relation to Forest Location and Seasons

Primate interactions were high during the dry season (60%) as compared to the wet season with interaction among all species being observed only during the dry season (Table. 10).

Table 10: Observations of primate Interactions

Primate Species	**Number of Times Observed in Dry and Wet Seasons**	
	Dry	**Wet**
All primate species	4 times	0
Black and White Colobus and Blue Monkey	4 times	5 times
Black and White Colobus and Red-tailed Monkey	0	Twice
Blue Monkey and Red-tailed Monkey	4 times	Once
Total	**12**	**8**
Percentages	**60**	**40**

The forest interior had 70% of the primate interactions with Blue Monkey being observed more times with the Black and White Colobus than with the Red-tailed monkey. Only 30% of the interactions were observed in the forest edge. Of all the observations made during the survey, all species were observed together only 20% of the time in the entire survey (Figure 14). When all the primates were sharing a space, they were performing same or different activities. During the observation of all the species together, 75% of the time they were observed was utilized on feeding, 17% resting and 8% resting.

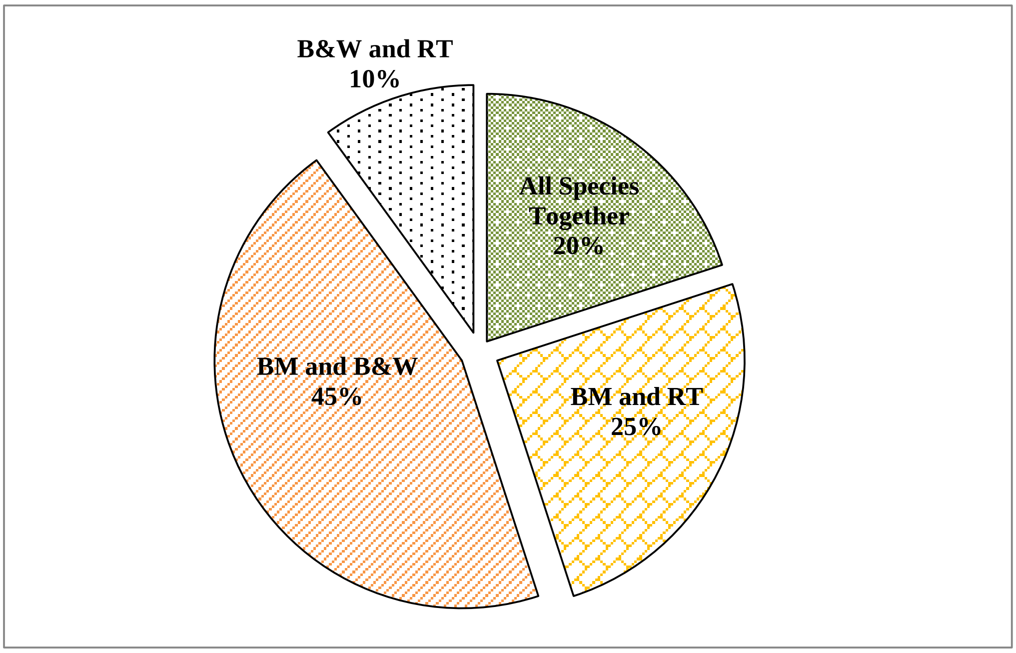


Figure 14: Interactions of the different primate species observed

4.2.2 Major Tree Species Utilized by the Primate Species

The major tree species utilized by three different primate species are presented in Table 11

Table 11: Major tree species utilized by the primates

Scientific Name	Local Name	Family	IUCN Red List status
Polyscias fulva	Soiyet	Araliaceae	LC
Croton machrostachyus	Tebeswet	Euphorbiaceae	LC
Ficus sur	Mokoiwet	Moraceae	LC
Trilepisium madagascariense		Moraceae	LC
Croton megalocarpus	Masineitet	Euphorbiaceae	LC
Prunus africana	Tendwet	Rosaceae	VU, Appendix II
Albizia gummifera	Seet	Fabaceae	LC
Allophylus abyssinicus		Sapindaceae	LC
Casearia battiscombei	Siksiket	Flacourtiaceae	LC
Celtis africana	Chepkeleliet	Cannabaceae	LC
Drypetes gerrardii		Euphorbiaceae	LC
Macaranga kilimandscharica	Sebesebet	Euphorbiaceae	LC

Diospyros abyssinica	Kenduiwet	Ebenaceae	LC
Tabernaemontana stapfiana	Mobondet	Apocynaceae	LC
Strombosia scheffleri	Chepkorkoriet	Olacaceae	LC
Celtis mildbraedii	Psertet	Cannabaceae	LC
Oxyanthus speciosus		Rubiaceae	LC
Solanum mauritianum	Chepsese	Solanaceae	LC
Schefflera volkensii		Araliaceae	LC
Syzygium guineese	Lamaiywet	Myrtaceae	LC
Ficus lutea		Moraceae	LC

*LC= Least Concern, VU= Vulnerable

4.3 Factors affecting population density, spatial distribution of the three primate species

A total of 215 vegetation plots in relation to forest location and season were sampled. The most common factors observed included grazing, firewood collection, paths. Their frequencies and means are represented in Table 12 below.

Table 12: Frequencies and means of the common factors affecting primate distribution

Activity	Frequency	Mean
Paths	164	82.4
Grazing	164	82.4
Firewood collection	100	50.3
Logging	119	59.5

(a) Comparing grazing in the forest edge and interior

In as much as grazing was recorded in the forest interior and edge (Plate 3), there was no significant difference between the grazing counts in the forest edge (Mean= 14.6, Sd= 7.8) and forest interior (Mean= 10.0, Sd= 7.0); df=12, t =1.15, p=0.27.

Plate 3: A flock of sheep grazing along the forest edge in the study area

(b) Comparing number of paths in the forest edge and interior

There was no significant difference between the counts of paths in the forest edge (Mean= 13.1, Sd= 8.4) and forest interior (Mean= 11.0, Sd= 8.8); df=12, t =0.47, p=0.65.

(c) Comparing rates of firewood collection in the forest edge and interior

In as much as firewood collection (Plate 4) was recorded in the forest, there was no significant difference between the counts of firewood collections in the forest edge (Mean= 8.7, Sd= 9.5) and forest interior (Mean= 6.6, Sd= 5.2); df=12, t =0.49, p=0.63.

Plate 4: A group of women carrying firewood from the forest in the study area

(d) Comparing logging in the forest edge and interior

Uncontrolled logging activities (Plate 5) in the forest could affect primate distributions even though there was no significant difference between the counts of logging in the forest edge (Mean= 8.7, Sd= 7.3) and forest interior (Mean= 9.0, Sd= 7.2); df=12, t (12) =0.07, p=0.95.

Plate 5: Logging activity in the forest using wood power saw in the study area

Vegetation variables sampled included tree height, canopy cover and stem density. They were compared in the forest edge and forest interior.

(e) Comparing tree heights in the forest edge and interior

There was no significant height differences between the forest edge (Mean= 19.0, Sd= 4.4) and forest interior (Mean= 20.3, Sd= 0.69); df=12, t=0.76, p=0.46. Although according to the means there was a high average of heights in the forest interior.

(f) Canopy difference in the forest edge and interior

There was no significant canopy cover differences between the forest edge (Mean= 63.4, Stdev= 5.7) and forest interior (Mean= 64.0, Sd= 7.3); df=12, t=0.16, p=0.87. Although according to the means there was a high canopy cover in the forest interior.

(g) Stem Density difference in the forest edge and interior

There was no significant stem density differences between the forest edge (Mean= 55.2, Sd= 9.1) and forest interior (Mean= 56.2, Sd= 17.0); df=12, t=0.13, p=0.90. Although according to the means there was a high average of stem density in the forest interior.

Other threats such as honey harvesting and charcoal conversion (Appendix 3 and 4) were also recorded but are not discussed in this study because only one observation was made hence not comparable.

CHAPTER FIVE

DISCUSSION

5.1 Primate Population density

The population densities of Black and White Colobus and Blue Monkeys differed based on location in the forest and season. This is probably attributable to food preference and its availability for the two species, which is in agreement with previous studies that have found primate distributions varying according to season and food availability (e.g. Stone, 2007; Pruetz, 2015; Strier, 2015). Effects of human activities such as selective logging affect the availability of food species for the two primate species. Selective logging forAfrican cherry (*Prunus africana*), has been increasing in many forests due to its unsustainable bark exploitation for international plant trade (Cunningham and Mbenkum, 1993; Hall *et al*., 2000). Blue Monkeys had the highest populations in the dry and wet seasons and also in the forest edge and forest interior. This might be attributed to their wide foraging habits and a fairly generalist diet. These monkeys are mainly frugivores and will also eat seeds, arthropods, and leaves (Cords and Rowell, 1987). They also breed throughout the year (Strawder, 2001), explaining their high populations both during the dry and wet seasons. A similar seasonal population survey on different primate species including Black and White Colobus, Blue Monkey and Red-tailed Monkey in Ngogo, Kibale National Park, Uganda found out the population of those primates were more in the wet season as compared to the dry season (Lwanga *et al*., 2011) hence supporting our findings from this study.

Black and White Colobus Monkeys were more abundant in the forest interior than at the edges. This variation is likely due to their feeding nature and physiological adaptations. The variation could also be due to the selective logging of the African Cherry for honey harvesting in the edge habitat which is more accessible. The African Cherry is an important composition in the diet of the Eastern Black and White Colobus monkey (*Colobus guereza*). According to Fashing (2001), *Prunus Africana* contributed 30-50% of the species diet at Kakamega forest. According to Gron (2009), Colobuses are able to digest plant material with a high fiber content with its specialized stomach hence it is able to access diverse habitats inaccessible to other primate species. Interior forests tend to be less susceptible to biotic and abiotic edge effects hence are able to sustain the viability of the plant and animal communities that depend on its generally stable environmental conditions (Bannerman, 1998). It is also well known that forest edges have higher temperatures due to less canopy cover and are more xeric than the interior (Burke and Nol, 1998; Didham and Lawton, 1999; Gehlhausen *et al*., 2000). These conditions could potentially affect the distribution of primates directly through their own tolerances or indirectly through the tolerances of indirect impacts on their food, predators, competitors, or disease organisms (Murcia, 1995). The forest edges are also susceptible to human disturbance affecting the distribution of primates especially if settlements and agricultural practices are taking place (Hockings and Humle, 2009).

Encroachment of the forest boundaries results to the conversion of forests to farmlands especially at the edge habitat (August *et al*., 2002). Such conversions affect the availability of food trees for different primate species (Pienkowski *et al*., 1998) and also limit primate species movements due to destruction of their travel pathways in the upper canopy. Absence of dry firewood especially in the wet season results to unplanned logging (e.g. for *Solanum mauritianum*) (Johns *et al*., 1996) which opens up resting, basking and feeding areas for primates resulting to increased primate exposure to predators (Gates, 1996). These activities affect the spatial and temporal distribution of primates in a given habitat and can significantly influence primate populations.

Farming close to protected areas has been perceived as a major disadvantage in Western Uganda as it forms a basis of HWC due to crop predation (Archabald and Naughton-Treves, 2001). In Gishwati Forest Rwanda, crop raiding has been associated with Chimpanzee and Cercopithecine monkeys. The plantation of palatable foods near the forest edge attracts the primates to the farms especially when there is limited food availability in the forest (Hockings and Sousa 2012). According to Naughton-Treves (1998), in Kibale Forest Uganda, 15% of farmers within 300 m of the forest edge respond to crop raiders with snares, traps, poison bait, and leaving land fallow, in addition to guarding. Although planting of less susceptible crops reduces HWC cases (Sitati and Walpole, 2006), it may lead to reduced dietary diversity and hence deepened food insecurity in the future, especially with a steeply increasing population (Tweheyo *et al*., 2005; Vedeld *et al*., 2012).

No previous data on population densities of the two primate species in South Nandi Forest exist as a basis to compare with the current populations from this study. According to Dela (2011), continued escalation of human-induced threats significantly affects the population densities of primate species. This study was conducted during the harvesting period of exotic plantations surrounding parts of the forest. After harvesting, the plantations are given to local farmers to do subsistence farming (PELIS program) and this could have a significant effect on the edge population for the primate species as the farmers chase the primates away from the forest edge for fear of crop raids.

5.1.1 Primate Activity during initial detection

Most diurnal primates shift their activity patterns in response to changes in seasons, ambient temperatures and rainfall patterns that affect food availability. They may also shift their daily activities based on habitat disturbances due to human interference or natural catastrophes such as forest fires and floods (Soria-Auza *et al.*, 2010).The proportion of time different primate species devote to various activities coincides with divergent suites of behavioral and anatomical traits (Strier, 2007). Some activities by the primates differed in forest location, in seasons and also in time of day. Activities such as feeding and moving were high during the dry as compared to the wet season. This may be attributed to the fact that during the dry season the food trees are sparsely distributed and the primates have to travel long distances to reach the food resources. Wijtten *et al.* (2012) conducted a similar study in an East African Coastal Forest on Angola Black and White Colobus found out that feeding time and vigilance increased during the dry season less time was spent resting. Lowe and Sturrock (1998)compared the diet of a troop of *Colobus angolenis palliatus* at the end of the dry season to their diet at the beginning of the wet season and found out that the troop rested nearly 50% longer during the wet season.

Primate activities also differ with the time of day with activities such as basking, feeding and moving being concentrated in the morning hours and resting being more in the afternoon hours. Many primate species take long rests under shaded trees during hot hours of the day and are mostly active during early morning and late afternoons. Ring-tailed Lemurs rest in shaded areas during hot afternoons and forage intensely during low temperatures (Cawthon, 2005). Blue and Red-tailed Monkeys can be classified as energy maximizers and they rest less and devote a significant amount of their time to searching and travelling to food patches. These food items such as fruits tend to be more widely dispersed than leaves but they are also higher in calories and are easy to digest (Cords, 1987). Some activities alike resting and grooming are mostly exercised in the evening (Jolly, 1966; Sussman, 1991).

Although the utilization of the habitat may differ between the forest edge and interior most primates often wander to the forest edge mostly in search of food especially during the dry season when food is limited. Primate activities in the forest edge and forest interior differ with some activities such as basking taking place more often in the forest edge than the forest interior. In most tropical forests the forest edge is mostly composed of open canopies due to human disturbance (Williams-Linera, 1990; Matlack, 1993) and this exposes them to direct sunlight making the edge favorable for basking especially after a cold night as compared to the forest interior. Feeding and moving were high in the forest interior probably due to the high amount of food and perhaps availability of cover for safety. Resting and grooming were also mostly done in the forest interior due to the availability of cover as compared to the forest edge which is more exposed.

5.2 Interspecific Interaction among Black and White Colobus, Blue Monkey and Red-tailed Monkey

Species can interact in the same environment when they share space, resources such as food trees or even when they are sharing an activity. There were several interspecific interactions between the three primate species. Most interactions among Black and White Colobus, Blue Monkey and Red-tailed Monkey were observed during the dry season and in the forest interior. The interaction between Blue Monkey and Black and White Colobus was higher compared to the interaction between Blue Monkey and the Red-tailed Monkey. Red-tailed Monkeys interacted more with the Blue Monkey as compared to the Black and White Colobus. Close association of Blue Monkey and Red-tailed Monkey has previously been documented where the two different species even mate to produce a viable offspring (Leland and Struhsaker, 1993). Black and White Colobus interacted with the Red-tailed Monkey only two times in the wet season. The two species form a feeding association especially when fruits are involved (Bryer *et al*., 2013). All the three species were encountered together four times in the dry season. The interaction may be attributed to increase in demand for food which becomes scarce during the dry season hence combined efforts lead to possible access to otherwise inaccessible foods (Struhsaker, 1981). Increased predator defense (Struhsaker, 1981; Chapman and Chapman, 1996) and also decreased predation risk through increased detection of predators (Struhsaker, 1981; Cords 1990; Bshary and Noe, 1997) also increases primate interactions. The three primate species are otherwise known to occur in many tropical forests (Cords, 1987; Fashing and Cords, 2000; Fashing, 2002; Mammindes *et al*., 2008) in association with other primates such as Baboons(*Papio anubis*) and Chimpanzee (*Pan troglodytes*). Although they have different feeding habits they share some food trees as described by Cords (1987).

According to Struhsaker (1981) and Cords (1990), Red-tailed Monkeys spent about 74% of their time together withBlue Monkeys at Kakamega Forest while at Kibale Forest National Park, Uganda, these species spend only 18% of their time together. However, over the period of 4.5 months during this study, these species were observed to spend only 3.4% of their time together. According to Cords (1990) mixed-species associations are affected by the particular ecological setting. This greatly influences the nature of the interaction between species through its effect on population structure, dietary overlap, food distribution, and community composition. Some monkey species share the same food items at certain times of the year. In a study conducted at Kibale forest (Uganda), Bryer *et al*. (2013) documented that Mangabeys and Red-tails interacted more often than would be predicted by chance and also that the latter formed close associations with the Mangabeys as compared to the Blue Monkeys which were also present in the area during time of study. According to Bshary and Noe (1997) high association between the Red Colobus and Diana monkeys in Tai National Park, Ivory Coast was mostly recorded during the peak of the Chimpanzee hunting season, when risk of attack especially to Red Colobus was highest.

Different ecological conditions present in geographically separated areas may alter the costs and benefits of mixed-species interactions leading to variations in their time spend together (Chapman and Chapman, 2000). Alternatively, mixed-species groups could simply involve random encounters, and changes in the abundance of species among sites could alter the chances of species encountering each other. Similar variation among populations in the tendency to form mixed species groups has also been documented in birds (Borges and Stouffer, 1999; Munn, 1985) and fish (Wolf, 1985). In some cases according to Chapman and Chapman (1996) species may compensate for the relative scarcity of one species with which they form mixed-species by changing the level of interaction with the second. For example where Red-tailed were relatively rare, Blue Monkey was mostly seen to spend more time with the Black and White Colobus.

5.3 Factors affecting population density and spatial distribution of the three primate species

Although there were no significant differences in grazing, firewood collection, establishment of paths and logging between the forest edge and interior, more of these threats were recorded at the forest edges. The characteristics of habitat edges are influenced by patterns of land use surrounding forest fragments and can have a major impact on biodiversity especially primates by affecting ecological processes such as dispersal, establishment, survival, and growth (Harper *et al*.,2005). The Nyayo Tea Zone which surrounds most forest edges at South Nandi Forest has played a significant role in minimizing the intensity of these threats to the forest edge. The edges which were not surrounded by the Nyayo Tea Zone were severely degraded and no Black and White Colobus, Blue Monkeys or Red-tailed Monkeys were found in these areas.

Although not in a significant way, some destructive practices associated with humans such as illegal selective logging, grazing, firewood collection, honey harvesting and charcoal conversion were more pronounced at the forest edges than in the forest interior. These activities probably affected the food trees used by the primates and may have also driven the studied primate species deeper in the forest where these threats are lower. Encroachment of the forest boundaries is also major threat by the local farmers neighboring the forest boundaries and this may have affected the distribution of the primate species in the forest.

The distribution of the three primate species in the forest was not affected by the distribution of these threats in the forest edge or interior. However the three species prefer secondary forests but can also be found in degraded, regenerating or logged forests and thickets (Macdonald, 2006; Kingdon *et al*., 2008; Oates *et al*., 2008; Gron, 2009), the future survival of the three primate species may be highly affected by extreme levels of habitat alteration and disturbance. Escalation of the threats recorded in the forest might significantly affect the future primate populations if not controlled.

Black and White Colobus mostly feed on leaves and unripe fruits to avoid competition from other primate species which prefer feeding on ripe fruits (Fashing, 1999; Harris and Chapman, 2007). Young leaves are mostly found on the uppermost part of different tree species and this might explain the high density of the Black and White Colobus in the forest interior where all height classes were present. Blue Monkeys also preferred the forest interior in this study. According to Strawder (2001) this species prefers tall trees which provide food resources and shelter. Their high distribution in the forest interior, therefore, could be due to the presence of all the height classes. Red-tailed monkeys' abundance has been shown to be high in the forest edge (Naughton-Treves, 1998; Baranga *et al*., 2012; Kingdon *et al*., 2013) which explains the highest numbers of the Red-tailed Monkeys in the edge during the dry and wet seasons.

Black and White Colobus, Blue Monkey and Red-tailed monkey in this study were observed to prefer dense trees for cover to act against predation especially by the Crowned hawk eagle (*Stephanoaetus coronatus*) which is the main predator for the three primate species (Kemp, 1994; Struhsaker and Leakey, 1990) and is present in South Nandi Forest (Bennun and Njoroge, 1999).The dense canopies are also utilized by the primates during travelling from one area to another. The high canopy classes were recorded in the forest interior as compared to the forest edge which is exposed to more threats. The highest tree heights were also recorded in the forest interior and these provide arboreal pathways for the primates during movement from one part of the habitat to the other.

CHAPTER SIX

CONCLUSION AND RECOMMENDATIONS

6.1 Conclusions

- There were more numbers of monkeys in the wet season as compared to the dry season. During the wet season there is more food available for the primates and the rates of movement to different parts of the habitats is high

- The highest interaction among the three different primate species wad in the dry season. Food is scarce during the dry season hence the primates form feeding associations to increase the efficiency of searching for food

- Ecological and anthropogenic factors affect primate distribution. Selective logging which affects some of the foods utilized by the primates. E.g. *Prunus africana* should be controlled. Ecological factors such as canopy cover and tree height affect the vertical stratification when the three species interact. Deforestation influences the vegetation structure and could affect the interaction the three different species when they occur together

6.2 Recommendations

6.2.1 Recommendations for Conservation Action

1. Monitoring of all the primate species populations to investigate long term human activity effects on primate populations and distributions should be initiated
2. Establishment of more Ranger Posts for effective enforcement to increase patrol efficiency which helps in reducing cases of illegal logging, unsustainable honey harvesting and charcoal burning
3. Awareness raising among the locals through the CFAs to sensitize them on impacts of illegal activities (e.g. illegal logging) as it reduces the vegetation stratification
4. Income generating activities should be diversified and up-scaled e.g. bee keeping, agroforestry to reduce human pressure on the forest

6.2.2 Recommendations for Further Research

1. Future surveys to consider other primate species (e.g. Baboons, Vervet Monkeys) as their presence might affect the distribution of the three primate species under study
2. Research to understand the effect of the Nyayo Tea Zone on the distribution of the primates
3. Research to understand people's perception attitudes and interactions with primate species

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APPENDICES

APPENDIX 1: Population Data collection Template
PRIMATES SPECIES CENSUS

Date…………….Habitat Type (Edge or interior)…....Transect Name/No......................

Time Start………..Time End…….Observer(s): ……………………………..

Data	Primate species	Time seen	Initial cue of detection	Reaction on initial detection	Number of monkeys present in the group	Distance	Adults	Young	GPS Location of the group	Activity
1										
2										
3										
4										
5										
6										
7										

APPENDIX 2: Vegetation Data Collection Template
Vegetation Survey

Date…………..Habitat Type (Edge or interior)…………...Transect Name/No..........................

GPS readings…………………………………..……Observer(s): ……………………

Date: ....

VEGETATION AND PLOT DESCRIPTION

General vegetation type...

Conservation Threats

Logging	
Grazing	
Charcoal burning	
Forest fire	
Resource extraction	

Intensity of disturbance: Low ☐ Moderate ☐ High ☐

Canopy cover:

Tree upper canopy (>20m) %............... Tree middle canopy (≥10- <20m) %..........

Tree lower canopy (≥5-<10m) %......... Cover of shrub layer (1-<5) %.................

Cover of herbaceous (<1m) %................. Cover by litter %.......................

Woody species (> 5cm Stem Density)

No.	**Species**	**Stem Density (>5cm)**	**Height (m)**
1.			
2.			
3.			
4.			
5.			
6.			

APPENDIX 3: *Prunus africana* felled for purposes of honey harvesting

APPENDIX 4: An active charcoal kiln observed in the forest