FOREST FRAGMENTATION AND ANTHROPOGENIC DISTURBANCE: IMPLICATIONS ON PLANT FOODS AND BEHAVIOR OF THE TANA RIVER MANGABEY (*Cercocebus galeritus* Peters, 1879), TANA RIVER COUNTY, KENYA

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REG. NO. I56/67414/2013

A THESIS SUBMITTED IN PARTIAL FULFILMENT FOR THE AWARD OF THE DEGREE OF MASTER OF SCIENCE (BIOLOGY OF CONSERVATION) IN THE SCHOOL OF BIOLOGICAL SCIENCES UNIVERSITY OF NAIROBI

2019.

DECLARATION

I, Charles Kivasu Maingi, hereby declare that this research thesis is my own, original work and has not been submitted elsewhere either in part or in its entirety and has not been published earlier in its present form to the best of my knowledge.

Sign…………………………………… Date…………………………………………

Reg. No: **156/67414/2013**

SUPEVISORS' APPROVAL

This thesis has been submitted for examination with my approval as the university supervisors.

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DEDICATION

This research thesis is dedicated to my dear parents and brothers; Mr. and Mrs. Nicholas Maingi Makau, Patrick, David and Kennedy my source of inspiration and motivation. And to my family Alice Kananu and daughter Ramona Mueni for their love.

And finally, to all the primatologist who tirelessly work in the field to conserve non-human primates.

ACKNOWLEDGEMENT

I am grateful to my supervisors; Dr. J. I. Kanya, Dr. J. M. Githaiga and Dr. S. M. Kivai for their unconditional support, valuable guidance and encouragement during field work and thesis writing. I do wish to thank the East African Wild Life Society (EAWLS) for their financial support during coursework and field study. Also, I thank the Institute of Primate Research-National Museums of Kenya for accepting me as an intern to undertake the study in TRNPR under the Tana River mangabey project led by my supervisor Dr. Stan Kivai. I would like to acknowledge the support from Said Rhova Hiribae, Komora Said, Dhadho Omar, Abio Gafo, Galana Hussein, Abeid Said, Janesera Mukundi, John Lenguya, Aisha Mohamed, Ndera Community Conservancy and foremost Mwalimu Omar Bahatisha for his hospitality and field facilitation in Mkomani forest study site.

Special thanks to my father, mother and my brothers (Patrick, David, and Kennedy) and my wife Alice Kananu for their unconditional love and support during the whole study. Thanks to Simon Wachiuri, KWS Warden at the Tana River National Primate Reserve for his warm welcome and taking care of us during my field work at the reserve. Special thanks to the people of the Wenje, Maroni, Baomo and Mkomani villages.

Special thanks to my friends Nicole Mwende, Nyawira Gitaka, for their love, guidance, and support during my study.

Most of all, special thanks to the Almighty God for seeing me through to this far.

To all, I say thank you again.

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LIST OF ABBREVIATIONS

AJE	African Journal of Ecology
ANOVA	Analysis of Variance
BA	Basal Area
CITES	Convention on International Trade in Endangered Species
DBH	Diameter at Breast Height
DF	Degrees of freedom
EAWLS	East African Wild Life Society
FAO	United Nations Food and Agriculture Organization
IPR	Institute of Primate Research
IUCN	International Union for Conservation of Nature
JRC	Joint Research Centre
KWS	Kenya Wildlife Service
NCC	Ndera Community Conservancy
NMK	National Museums of Kenya
SPSS	Statistical Package for Social Science
TRNPR	Tana River National Primate Reserve

ABSTRACT

Tana River mangabey, *Cercocebus galeritus*, is an endangered monkey, endemic to lower Tana River forest fragments in Kenya. The species is restricted in its geographical distribution and is threatened by habitat fragmentation and continuous anthropogenic disturbances. This study was conducted in Mchelelo and Mkomani forests within the Tana River National Primate Reserve (TRNPR). The objectives of the study were to determine the: diversity and density of Tana River mangabey plant food species in anthropogenically disturbed Mkomani forest and less disturbed Mchelelo forest fragments; anthropogenic disturbances and their magnitude in the two forest fragments; and behavioral comparison between the two sites. In each forest, lines were systematically established at equidistance of 200m running from the river bank to the edge of the forest. Along the lines, 20 by 20m quadrats were systematically placed at intervals of 50m from each other throughout for collecting vegetation data. To collect behavior data, full day animal focal sampling was conducted and the focal subjects were rotationally selected in each group. Behavior sampling was conducted in a manner that balanced data collection within the groups and was achieved through assigning focal subjects on a rotational basis for data recording. In the event of feeding by focal animal the consumed plant part was recorded. This study focused on two groups of the Tana River mangabeys, one occupying Mchelelo forest and the other Mkomani forest. The diversity of the food plant species was higher in Mchelelo (H' = 2.32) compared to Mkomani forest (H' = 2.04). Study findings showed that there was a significant difference in mean density and basal area values in Mchelelo and Mkomani. Furthermore, this study showed *Phoenix reclinata*, *Ficus sycomorus* and *Synsepalum msolo* were the most consumed plant species in Mkomani forest by the study group. In Mchelelo forest, the group preferred *P. reclinata*, *F. sycomorus* and *Pavetta sphaerobotrys* plant foods species. The study groups preferred fruits and seeds compared to leaves, young stem, gums and stem bark. The major anthropogenic disturbances were logging and palm leaf harvesting in both study sites. The most targeted plant food species for exploitation by community were *P. reclinata*, *Polysphaeria multiflora* and *Lecaniodiscus fraxinifolius* in Mchelelo forest whereas in Mkomani forest they preferred *L. fraxinifolius*, *P. reclinata* and *Thespesia danis*. Both study groups spent most of their time feeding compared to resting, moving and social interaction behaviour activities. In conclusion, Mkomani forest had less diversity, basal area, and density of plant species consumed by the Tana River mangabey compared to Mchelelo forest. *P. reclinata* and *F. sycomorous* were

the most utilized plant food species by the community in both sites. This suggests that there is need to protect plant species consumed by the endangered Tana River mangabeys to provide the necessary food resources and improve diversity and density of vegetation in the forest especially in Mkomani forest. And also there is a need to replicate this study in other forest fragments along the Tana River which have varying anthropogenic activities and compare the results.

CHAPTER ONE

INTRODUCTION AND LITERATURE REVIEW

1.0 Background information

Habitat disturbance may positively or negatively affect vegetation distribution and also the behavioral activities of primate in their natural habitats (Oates, 1996; Wieczkowski, 2004; Lung, 2009). The increase of anthropogenic disturbances in tropical forests directly affects the flora and fauna especially primates, which primarily depend on the forest habitats. Thus, these disturbances affect the size of forest patches leading to decline of available food resources for primate species in forested areas (Arroyo-Rodríguez & Dias, 2010). Conversion of primate habitats to agricultural lands has posed a threat to already declining primate populations within fragmented forest habitats, (Chapman & Lambert, 2000). Globally, Forest Reserves and National Parks cover approximately 3.7 percent of the land area (McNeely, 2003).

In Africa particularly, the influence of human population explosion combined with high levels of poverty have been suggested as the major contributing factors responsible for approximately 1.6 million hectares of forest loss annually (FAO & JRC, 2012). Although data is scanty, previous studies suggest that there is a positive correlation between high human densities and forest disturbances particularly in areas of high endemism and species richness in Sub-Sahara Africa (Peres, 2001). Increased forest disturbance and rapid habitat fragmentation and loss have been linked to the sharp decline of forest-dwelling primate populations (Chapman & Lambert, 2000; Cowlishaw & Dunbar, 2000; Farwig *et al.*, 2006; Coughenour, 2007). The frequency and level of disturbance whether intermediate or continual may affect the diversity of species (Svensson *et al.*, 2012). Reduced habitat size and isolation of forests lead to the decline in populations of species and changes in variability of genes, whose fitness reduction ultimately results to extinctions of species (Bennett, 2003). Forest alterations can also result in the decline in diversity of species, which is associated with the small sizes and more isolated fragments (MacArthur & Wilson, 2001; Lung, 2009) leading to loss of biological resources (Uhl *et al.,* 1982; Anderson *et al.,* 2007). According to Mittermeier & Cheney, (1987), anthropogenic disturbances are the leading cause of biodiversity collapse in diverse wildlife habitats. For instance, cutting down of trees and clear felling of primate's plant foods, not only affect primate populations but also their vital interactions such as seed dispersal and other crucial interactions especially with plants that form their (primate) primary food source (Oates, 1996; Muoria *et al.,* 2003; Farwig *et al.*, 2006; Lehouck *et al.,* 2009; Kimaro & Lulandala, 2013). The effects of such anthropogenic disturbances to primate habitats potentially have far-reaching results, which include migration or extinction of the endangered species such as the Tana River mangabey and other species.

Previous studies have focused on the general behavior of the Tana River mangabey within the lower Tana River forest patches with few on harvesting of forest products by the community (Kinnaird, 1992; Moinde *et al.*, 2007). Overall, primate studies focusing on the effects of anthropogenic activities on primate behavioral ecology, particularly in Africa are still limited. In Kenya, data on the implication of habitat fragmentation and anthropogenic disturbances on the dietary composition and behavior of the Tana River mangabey is yet to be availed.

1.2 Literature review

1.2.1 Human disturbance and habitat fragmentation

Food resource availability and distribution has been found to be an important factor influencing primate socioecology (Wrangham, 1980). In addition, the optimal foraging theory indicates that reduction in food patch impairs the foraging benefits from such food patch (Schoener, 1977). This affects the search time of food by the primate. Evidence from the blue monkey, *Cercopithecus mitis*, study suggest that availability of food resources, particular density of fruiting trees in the habitat affects the behavior of primates (Farwig *et. al.*, 2006).

In Africa, forest loss has led to the decline of primate populations in most of the forests (Chapman & Onderdonk, 1998; McLennan & Plumptre, 2012). According to Teelen, (2007), the decline in colobus monkey density in Kakamega forest was directly linked to the declining abundance of tree species especially important fruit trees like *Prunus africana*. This species experienced a high mortality rate and low recruitment rate resulting in a negative effect on the colobus monkey (*Colobus guereza*) populations (Fashing, 2004). Similar results linking forest clearance to primate habitat fragmentation and primate population decline have been experienced in the lower Tana River primate habitat (Wieczkowski, 2004; Kimuyu *et al.*, 2012). Although reduction of food resources has been suggested as a key factor leading to population decline in primates, some species have expressed high flexibility and adaptability to such perturbations (Cowlishaw & Dunbar, 2000). Thus, understanding how disturbance influence food resources and the subsequent impact on species behavior may provide details on species coping mechanisms and ability. This thesis makes rigorous effort to achieve this objective.

Previous studies in Tana River riverine forests suggested that with the increase in demand for forest products particularly the palm leaves could have a tremendous effect on the availability of resources. This may affect the day to day activities of the Tana River mangabeys as they rely on these forest food resources such as fruits and seeds of key plant species within the riverine forests (Kinnaird, 1992; Wieczkowski, 2004; Kimuyu *et al.*, 2012). Human population increase and the increasing demand to cater for basic needs such as food and shelter imply enormous pressure on the Tana River forest fragments. This is mainly mediated through forest clearance to pave way for agriculture and unsustainable exploitation of raw domestic consumption materials for local artisan industry (Moinde *et al.*, 2007; Ndang'ang'a *et al.*, 2016). These activities have led to either discriminative or indiscriminative cutting down of key mangabey plant food resources, thus reducing the availability of food for the primates (Kinnaird, 1992; Chapman &

Onderdonk, 1998; Wieczkowski, 2004). Subsequently, with the decline in food resources, behavioral responses to cope with such habitat changes inevitably emerge as potential counter strategies of the associated adverse effects. Therefore, understanding the response of Tana River mangabeys to the presence of humans and their shift in feeding and other behavioral activities is critical for conservation and management practices.

1.2.2 Importance of lower Tana River Forest fragments

The lower Tana River forests occur on the floodplains along the river bank as it meanders, providing a unique habitat for the different fauna species (Marsh, 1978; Butynski & Mwangi, 1994). The forest fragments provide home for the Tana River mangabey (*C. galeritus*) and other monkeys such as the Tana River red colobus (*Piliocolobus rufomitratus*), Yellow Baboon (*Papio cynocephalus*), Sykes' monkey (*Cercopithecus mitis albotorquatus*), Vervet monkey (*Cholocerbus aethiops*), Zanzibar galago (*Galago zanzibaricus*) and Garnett's galago (*Otolemur garnettii*) (Butynski & Mwangi, 1994; Butynski *et al.*, 2008). The forest galleries are characterized by emergent tree species with heights over 30m such as *Vachellia robusta*, *Sterculia appendiculata, Albizia gummifera,* canopy tree species such as *Sorindeia madagascariensis, Synsepalum msolo, Diospyros mespiliformis, Ficus sycomorus*, sub-canopy tree species such as *Oncoba spinosa*, *Phoenix reclinata* and *Pavetta sphaerobotrys* and understory species such as *Cadaba farinosa* (Maingi & Marsh, 2006). They also have some endemic tree species such as Tana River poplar (*Populus ilicifolia*) (Maingi & Marsh, 2006), which is classified as vulnerable by the IUCN Red list (World Conservation Monitoring Centre, 1998). These forest fragments constitute the support base of the local livelihoods, and provide services and products such as firewood, palm leaves (for mat making from *Phoenix reclinata* and thatching from *Hyphaene compressa*) and tree poles, (Kinnaird, 1992; Medley, 1993; Muoria *et al.*, 2003) and grazing refuge zones (Personal observation. 2015). The lower Tana River primate habitat comprised approximately 80 forest fragments as of 2000 (Wieczkowski, 2003), which differed in the assemblages of species, structural characteristics of the forest, fragment size and the extent of human disturbance. Unfortunately, unsustainable extraction of forest products by the local population has resulted in complete loss of some of these forests such as Kanjonja (Kivai, 2010) or severe modification shrinking the available habitat of the threatened Tana primate species (Kinnaird, 1992; Moinde *et al.,* 2007; Kimuyu *et al.,* 2012).

According to Wieczkowski, (2005), the Tana River mangabeys inhabit 40 forest fragments at different group sizes compared to those occupied by the Tana River red colobus which share the same habitat. The Tana River mangabeys rely on different species of plants which are found in these fragments as key food sources (Kinnaird, 1992). Some of them have being listed as top diet plant species in the list of top 15 plants consumed by Tana River mangabey generated by Wieczkowski, (2004) in the lower Tana forest fragments. The abundance and distribution of *P. reclinata* determine the distribution of mangabeys suggesting that the level of fragment utilization is potentially determined by food availability besides anthropogenic disturbances (Wieczkowski, 2003). Consequently, as earlier reported these two factors (abundance and distribution of plant food species) serve as a good indicator of the Tana River mangabey habitat quality (Muoria *et al.,* 2003; Karere *et al.,* 2004).

1.2.3 Ecology of Tana River mangabey

i) Species Biology:

The Tana River mangabey is a monkey species from the family Cercopithecidae (Butynski *et al.,* 2008). It is a medium sized primate with a prehensile tail, cheek pouch and yellow brown coat. An adult female has an average gestation period of 180 days and show post-conception sexual swellings at the end of second month of pregnancy (Kinnaird, 1990). The monkeys aggregate in groups of an average size of 26 - 27 individuals (Homewood, 1976). Most of the studies done on the mangabey have shown that the groups in areas of high disturbance have a low reproductive performance (Mbora *et al.,* 2009) while Karere *et al.,* (2004) found that the mean group sizes were found to decrease with declining forest fragment area. The population is estimated to be about 2,070 individuals in 59 groups occupying 30 forest patches according to a population survey in 2001, (Karere *et al.*, 2004).

ii) Behavior:

The Tana River mangabeys forage on the lower forest canopy level and spent about 56 percent of their time foraging on the floor of the forest (Wieczkowski, 2003). They predominantly feed on fruits (Plate 1) but also seeds constitute a larger percentage of their diet (Wahungu, 1998; Kimuyu *et al*., 2012) hence considered as a frugivorous-granivorous species. Although, they are considered as seed consumers they also disperse seeds for most of the plants in the forest (Kinnaird, 1992; Kimuyu *et al.*, 2012). Tana River mangabeys show flexibility in their diet, which helps them adapt to habitat change (Wieczkowski, 2005). They predominantly use the riverine forests as their habitat (Homewood, 1976; Kimberly, 1994; Wieczkowski, 2003; Hamerlynck *et al.,* 2012).

iii). Habitat suitability:

The Tana River mangabey was listed as one of the 25 endangered world monkeys and currently its population is on a declining trend with threat of extinction in the near future (Butynski *et al.*, 2008). Thus, conservation efforts for this monkey will be very crucial to meet the target of increasing its population in the wild. The lower Tana River riverine forests are globally significant for conservation for two reasons: firstly, as a section of the Eastern Arc and coastal forests of Kenya and Tanzania, that are listed as one of the earth's richest biodiversity hotspot, (Myers *et al.,* 2000), and secondly, it is the only remaining habitat for the endemic and highly endangered TRM and TRC monkeys (Moinde *et al.*, 2007).

The Tana River mangabey groups have over years increased their home range from 18.75 hectares within 1988 - 1989 to 46.75 hectares in 2000 - 2001 (Kinnaird 1990; Wieczkowski, 2005). Their group size increased from 17 individuals in 1988 - 1989 (Kinnaird, 1990) to 50 individuals as was estimated by Wieczkowski (2005). She also recorded the Tana River mangabey use of the scrubland and adjacent forest areas for feeding. According to Kinnaird, (1992) the Tana River mangabeys aggressively defend their resources within their territories when availability of fruit reduce, however, intergroup interactions are common when food resources are abundant. Intergroup interactions and resource defending by the Tana River mangabey is dependent on the seasonal variability of food and distribution. The riverine forests are influenced by the underground reach of the river water and the frequent flooding of the river (Andrews *et al.*, 1975). This may have restricted the growth of most trees consumed by this monkey and other monkeys along the river channel.

In addition, Tana River mangabeys prefer trees with either emergent crown or canopy level. According to Wahungu, (2001), the choice of sleeping sites is determined by their day ranging pattern, the forest area they have been feeding in the afternoon, the morphological characteristic of the available tree and the risk of attack from predators. The selection of these sleeping sites is limited during the rainy season when most of the trees have increased leaf cover which may hinder on time spotting of predators.

iv). Conservation importance of the species and its habitat:

Tana River mangabey monkey is classified by the IUCN red list as an endangered monkey with its population and habitat declining. The Convention on International Trade on Endangered Species (CITES) of wild fauna and flora puts it in the Appendix 1 list of the most endangered species. Their habitat is part of the coastal forests of Eastern Afromontane which has a high diversity of flora and fauna. Some of the riverine forest habitats of the Tana River mangabeys are within the Tana River Delta which is classified as an important wetland hence a Ramsar site due to its rich biodiversity. Detailed habitat evaluation of 73 riverine forests by Moinde *et al.,* 2007 showed that 34.5 percent of forest area was lost within a span of 21 years from 1979 to 2000. The change has been attributed to the increased human activities from the communities adjacent to the forest fragment along the Tana River as in Mkomani forest. This raises the need for strategies to conserve the species and the habitat which will benefit other species such as the endangered red colobus (Kimberly, 1994). The Tana River mangabeys depends entirely on these riverine habitats hence the decline may have adverse impact on the behavioral activities and their role in the ecosystem. It is due to these threats to the habitat which have resulted to the declining trend in population of the Tana River mangabey and it has become one of the threatened and endangered primate's species in the world.

Plate 1: Tana River mangabey (*Cercocebus galeritus*) feeding on *Ficus sycomorus* fruits.

1.3 Justification

Human disturbances and forest fragmentation may result in changes in habitat quality affecting the survival of the Tana River mangabey. This is because deterioration of forest fragments affects both the nutritional and mechanical properties of foods that not only influence reproductive fitness but also modify foraging behavior (Vogel *et al.*, 2017; Kivai *et al.*, 2017). Such effects are inevitable by the Tana River mangabey given their habitat profile. For instance, Moinde *et al.,* (2007) showed that increased human activities in the riverine forest may have augmented fragmentation of habitats. The negative changes associated with habitat disturbances may result in changes in resource quality, species richness, seed dispersal and distribution in the forest, (Schwitzer *et al*., 2011; McLennan & Plumptre, 2012). As highlighted already, past research on the Tana River mangabey has largely addressed aspects of population surveys and their general behavior, (Wahungu, 1998; Wieczkowski, 2003; Karere *et al.,* 2004; Wieczkowski, 2004). However, human disturbance effects on the behavior patterns (such as feeding) and diversity of plant foods available has been ignored, despite the dire need of such data on practical conservation efforts. Thus, highlighting the impact of human disturbances on diversity plant foods and behavior of Tana River mangabey is critical in enlightening us on the behavioral and dietary adaptations of the primates to the ever-changing habitat. Such data not only make key intellectual contributions but also provide fundamental information for practical application in making informed conservation and management decisions. This is particularly paramount in the awakening alarm of extinction that beckons primates in their natural habitats. Moreover, the information generated will particularly be useful in the formulation of policies and implementation of conservation strategies that will enhance protection of Tana River mangabeys and can be replicated to other threatened primates living in fragmented habitats all over the world.

1.4 Objectives

1.4.1 Overall objective

To determine the effects of forest fragmentation and anthropogenic disturbances on food resource dynamics and behavior of the Tana River mangabey (*Cercocebus galeritus*) in two forest fragments of the lower Tana River galleries.

1.4.2 Specific objectives

The specific objectives were to determine the:

1. Diversity and density of Tana River mangabey plant food species in anthropogenically disturbed Mkomani forest and less disturbed Mchelelo forest fragments.
2. Anthropogenic disturbances and their magnitude in the two forest fragments.
3. Behavioral comparison between the two sites

1.5 Research hypotheses

To address the study objectives, the following hypotheses were tested;

1. The diversity and density of mangabey plant foods in Mchelelo differs from Mkomani.
2. The human disturbance affects food resources and behavior of Tana River mangabey in the two primate forest habitats (Mchelelo and Mkomani).

CHAPTER TWO

STUDY AREA, MATERIALS AND METHODS

2.0 Study Area

The study was conducted in Tana River Primate National Reserve (TRPNR), which is within Tana River County in the coastal region of Kenya. The reserve was gazetted in 1976 to protect the riverine forest and the endangered primates (Tana River mangabey and Tana River red colobus) and covers approximately 171 hectares (Butynski & Mwangi, 1994). The reserve lies between 1°40' to 2°15' South 40°07' to 40' East, (Fig.1). The area is an arid and semi-arid which gets an average annual rainfall of 493 mm, ranging from 500 mm to 600 mm (Andrews *et al*., 1975). The daily temperatures range between 30-38°C for maximum and 17-25°C for the minimum temperatures (Medley, 1992). January and February are the hottest months while March to April and November to December are the wettest months (Butynski & Mwangi, 1994; Karere *et al.*, 2004).

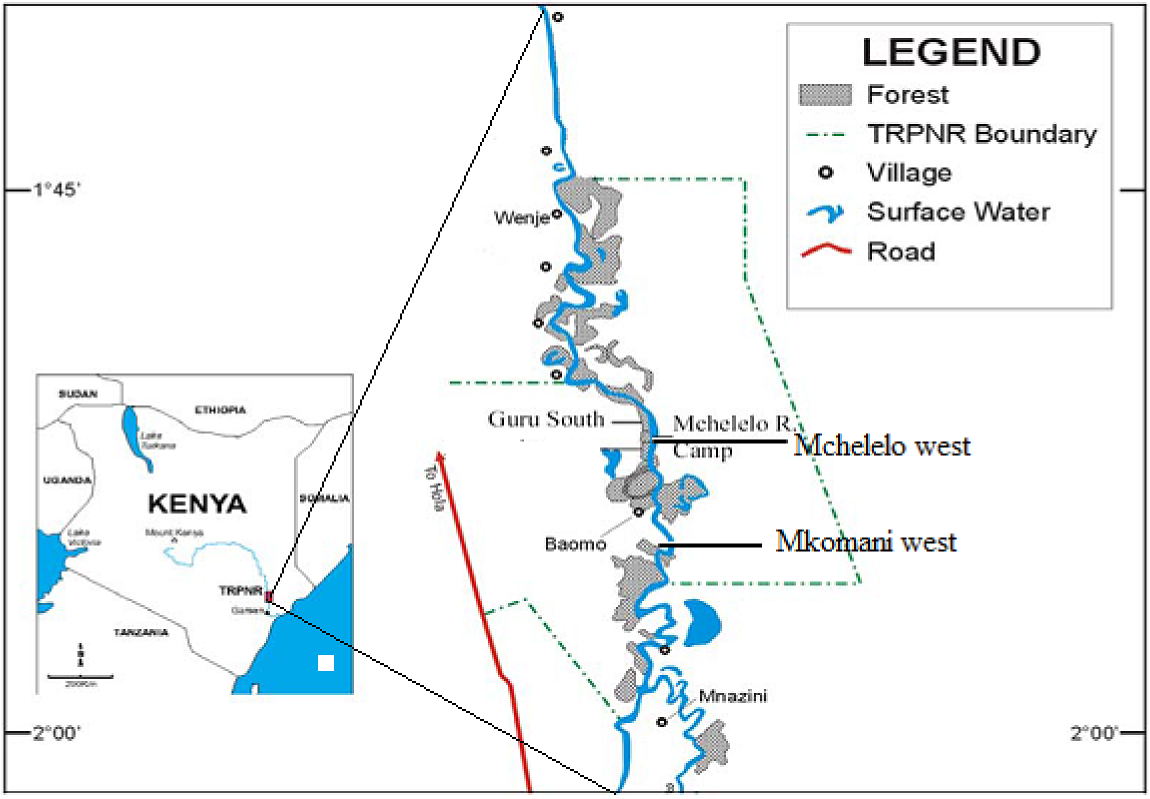

Figure 1: Map of the study area showing the two study sites (Modified from Mbora & Meikle, 2004)

2.1 Study sites

The study was carried out within two forest fragments/patches; Mchelelo and Mkomani in the west bank of the river, which are in the TRNPR. According to Butynski and Mwangi (1994) study, Mchelelo west covers an approximate area of 17 ha while Mkomani west forest covers an area of approximate 18 hectares. A research camp is situated at Mchelelo West forest hence making it easy to access while Mkomani forest is located downstream about 7 kilometers away. Mchelelo forest patch is located in between Guru South and Congolani complex and Mkomani forest fragment in the lower Tana River opposite Kitere Village.

2.2 Sampling design

To sample the density and diversity of the Tana River mangabey plant foods, both line and plot sampling methods were combined as described by Sutherland (2006). Lines were systematically established at equidistance of 200m in each forest fragment running from east to west and starting at the river bank to the edge of the forest. Along these lines, quadrats of 20 by 20m were systematically placed at intervals of 50m from each other throughout the length of the line and this was replicated in each forest. The lines began on the river-bank and ran perpendicular to the river flow towards the edge of the forest. The length of each line was dependent on the width of the each forest sampled. This enables capturing of the vegetation changes as one moved away from the river to the edge of the forest.

For behavioral data collection, this study focused on two groups of the Tana River mangabeys, one occupying Mchelelo forest and the other Mkomani forest. These groups were selected for behavioral studies because they were previously well habituated and all individuals positively identified since they were being followed for long-term studies. The Mchelelo group consisted of 68 individuals of seven adult males, 20 adult females, 28 juveniles and 13 infants, while the Mkomani group consisted of 53 individuals comprising of six adult males, 14 adult females, 26 juveniles and seven infants. Full day animal focal sampling method was used to collect behavior data on both groups and the focal subjects were rotationally selected in each group. Sampling was conducted in a manner that balanced data collection across age and sex classes and avoided over or under sampling of certain individuals. This was achieved through assigning focal subjects on a rotational basis for data recording.

2.3. Data Collection

2.2.1 Vegetation sampling

Vegetation data collection was collected within the months of June and August in 2015 since most of the plant species had not shed leaves for easy identification. With help of a research assistant sampled vegetation in plots along the Tana River in Mchelelo and later in Mkomani forest. In Mchelelo study area 21 plots were sampled and 22 plots sampled in Mkomani area. All the plots had equal area and measured 20 m by 20 m. With the help of a compass, all the plots were sampled in an east to west direction so that different vegetation layers were captured. After establishing the plots, the tree species names were recorded in a data sheet and measured their Diameter at Breast Height using a Diameter tape. Tree heights were estimated by use of a graduated pole of known height.

The obtained data was used to calculate diversity, density, and other vegetation parameters. Basal area (m^2) was calculated by use of the formula below and then divided by 10,000 to convert cm^2 to m^2.

$$\mathbf{BA = (0.5 * DBH)^2 *} \boldsymbol{pi}$$

Where: BA = basal area in meters squared,

DBH = Diameter at Breast Height in meters and *pi* =3.143.

The values were divided by the number of hectares sampled to obtain basal area/hectare and comparison done in both sites.

The species diversity was assessed using the Shannon-Weiner diversity index (*H'*) which incorporated information on the number and abundance distribution of individual species (Wolda, 1981). The diversity index (H') was calculated using the following formula and multiplied by -1;

$$\boldsymbol{H'} \mathbf{= -\sum [(pi) * \ln(}\boldsymbol{pi}\mathbf{)]}$$

Where: H' = Shannon Weiner index,

∑ = Summation of the resultant product,

ln = natural logarithm,

pi = Number of individuals of species ***i***/total number of samples S = Number of species or species richness

The Shannon Weiner equitability (E) value which assumed a value between 0 and 1 with 1 value being evenly distributed and was calculated using the following formula;

Evenness value (E) = H'/H_{max}

Where: *H'* = Shannon Weiner index and,

H_{max} = Maximum diversity possible. Calculated by getting natural logarithm of the number of species (S).

Relative derivative of density was also calculated as shown below from which the comparison between the study sites was done.

Relative density = (Number of individuals of a species/total number of individuals) × 100

2.2.2 Assessment of anthropogenic disturbances

Data on anthropogenic disturbances were recorded in the same plots, which were used to measure vegetation attributes. In each of the quadrat, presence or absence of any forms of human habitat disturbances and the number of affected individuals for each species were recorded. In addition, other trace activities of human activities in the habitat such as trails or fire occurrences were as well recorded. Because the anthropogenic disturbances were main focus detailed information was collected on the following activities as indicators of human disturbance in the habitat, logging (which in this study refers to cutting of trees for poles or building materials), palm leaves cutting, palm wine harvesting (wine tapping), tree felling for boat construction, clearing forest for cultivation, fire incidences or burning, natural honey harvesting, and plants exploitation for medicinal purposes. With the help of local research assistant, efforts were made to identify and record the intended use or services where plants were exploited or damaged as a result of human activity.

Data from each quadrat was summed up and used to compare human activities in the two sites and determine which plant species were most affected by human activities. *Adlibitum* recording of any unique anthropogenic activities observed beyond the plot boundaries was also noted to supplement the systematic collection of the disturbance data and to ensure nearly all possible human activities were captured.

2.2.3: Behavioral monitoring

Behavior monitoring of two groups of Tana River mangabey started in February to August 2015. This was done after successfully learning and positively identifying the individuals in the habituated Mchelelo and Mkomani groups for three months. In both study groups, focal animal sampling method was used to collect behavioral activity data as described by Altmann, (1974). With the help of an experienced animal observer, continuous data recording rule was used to obtain behavioral data. The behavior categories and their operational definitions adopted were as described in Table 1. Behavioral data were collected by continuous recording activities for 10 minutes for each focal individual with sampling gap of 5 minutes in between the focal individuals. Data recording started from 0700 hrs to 1800 hrs for five consecutive days every week for three months in both study sites. The behavior data recorded was used to compare the differences in the two study sites.

In order to determine the key plant foods utilized by the Tana River mangabey in the event of feeding by the focal animal, the plant species and parts eaten (fruits, seeds, leaves, young stems, tree bark, and tree gum and other parts) were recorded. This was to enable identify which plant part that is mostly consumed by Tana River mangabey during the study period.

Table 1: The behavior categories used to collect behavior data and their definitions

Behavior category	**Description**
Resting	When the focal individual was inactive or immobile
Feeding	Where focal individual was observed searching, picking, processing and orally ingesting food. In the event the focal individual was moving while feeding it was recorded as feeding
Moving	When focal individual engaged in travelling for more than five seconds either on the ground, within or between trees or food patches, and not engaged in either feeding or socializing with other individuals in the group.
Social interaction	When the focal individual was involved in either aggressive or friendly encounters with another conspecific individual, which included grooming, nursing, chasing, fighting, and copulation.

2.3 Data analysis

The collected data was entered into an MS Excel spreadsheet, sorted and edited for descriptive analysis, after which it was transferred to SPSS Statistics Version 20 for analysis. The Shapiro-Wilk (W) test was used to test for normality and the non-normal data was log transformed to achieve normal distribution for parametric tests as described by Zar, (2010). To test the difference in means of diversity, density and the basal area between the two sites the paired student t-test was used. The paired student t-test was also used to determine the difference between the independent behavior activities in both study sites. A significant level of 0.05 was used for all the statistical calculations.

CHAPTER THREE

RESULTS

3.1 Diversity and density of Tana River mangabey plant foods

3.1.1 Vegetation density, diversity and basal area in both forests

A total of 128 plant species belonging to 25 families were identified from a total of 43 plots in both Mchelelo and Mkomani forests. The overall plant species encountered during the study were 67 in Mkomani forest and 61 in Mchelelo forest. The overall Shannon Weiner species diversity index in Mchelelo was higher ($H' = 3.16$) compared to Mkomani forest ($H' = 3.11$). Similarly, the calculated Shannon Weiner diversity index for plants consumed by the Tana River mangabeys during the study period was higher in Mchelelo ($H' = 2.32$) compared to Mkomani ($H' = 2.04$) site and the species evenness in Mchelelo forest ($E = 0.77$) exceeded that of Mkomani forest ($E = 0.66$). The diversity values of the consumed plant foods in both sites showed a significant difference (t = 0.50, d.f = 126, n = 61 and 67, $P < 0.05$).

The mean density (individuals/ha) of plant food species consumed by the Tana River mangabeys in Mchelelo site (0.0034 ± 0.001 SEM) was slightly higher to that of Mkomani site (0.0031 ± 0.0006 SEM). The comparison of the mean density values of plant food species consumed by the two groups in both sites differed significantly (t = 0. 014, d.f = 126, n = 61 and 67, $P < 0.05$). The study also revealed that the overall sum basal area (m^2/ha) of the woody species was higher (BA = 3.33) in Mchelelo compared to Mkomani forest (BA = 1.32). In addition, the mean basal area of plant food species consumed by the Tana River mangabeys in Mchelelo and Mkomani were 0.093 ± 0.072 SEM and 0.035 ± 0.017 SEM (Figure 2). The mean basal area of plant food species in Mchelelo and Mkomani forest was significantly different (t = 0.77, d.f = 126, n = 61 and 67, $P < 0.05$).

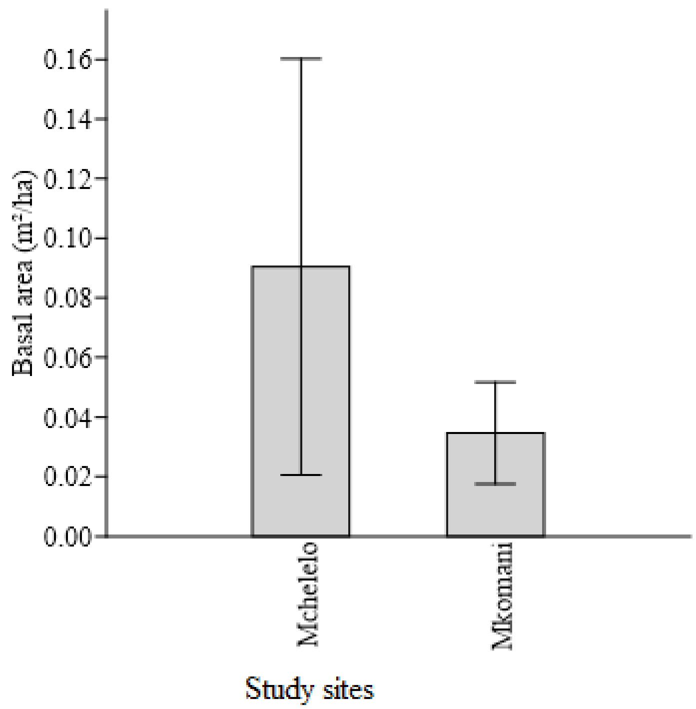

Figure 2: Mean basal area (m²/ha) of the plant food species in both forests.

The error bars represent Standard deviation.

3.1.2 Tana River mangabey diet selection and composition

During the study period 29 plant species were consumed by the Tana River mangabeys in Mkomani while 31 plant food species in Mchelelo. The plant food species in Mkomani forest were utilized by the group at varying levels (Table 2). *Phoenix reclinata* (36.94%) was the most utilized species while the second was *Ficus sycomorus*, (16.16%) and the third was *Synsepalum msolo* (7.85%). The least targeted plant species in Mkomani forest by the group were *Saba comorensis* (0.19%), *Borassus aethiopum* (0.41%) and *Cassia abbreviata* (0.49%). In addition, the Mkomani group utilized non-plant foods such as insects (13.97%) as part of their diet (Table 2).

Table 2: Feeding records (%) of plant food species fed on by the Mkomani group.

Species	Total feeding records (%)
Phoenix reclinata	36.94
Ficus sycomorus	16.16
Synsepalum msolo	7.85
Vachellia robusta	5.45
Oncoba spinosa	3.42
Brichaeria spp	2.25
Polysphaeria multiflora	2.07
Lecaniodiscus fraxinifolius	2.03
Antidesma venosum	1.99
Alangium salviifolium	1.77
Mangifera indica	1.5
Mimusops fruticosa	1.47
Harrisonia abyssinica	1.13
Cissus rotundifolia	0.94
Grewia densa	0.71
Cordia sinensis	0.64
Garcinia livingstonei	0.56
Cassia abbreviata	0.49
Borassus aethiopum	0.41
Saba comorensis	0.19
Insect	1.5

Note: N = 20 plant food species, 2263 feeding observations and an arthropod

Similarly, the Mchelelo group utilized the top twenty plant food species at varying levels (Table 3). *Phoenix reclinata* (22.67%) was the most utilized while *F. sycomorus* (11.89%) and *P. sphaerobotrys* (10.17%) were the second and the third most targeted food species. The Tana River mangabeys as well consumed non-plant food materials that included insects (13.97%), mushrooms (5.17%), and unidentified food items (1.62%). However, this Mchelelo group showed the lowest dietary selection for *A. salviifolium* (0.35%), *F. bubu* (0.35%) and *C. rotundifolia* (0.35%), (Table 3).

Table 3: Total feeding records (percentage) for the top plant foods in the Mchelelo forest.

Species	**Total feeding records (%)**
Phoenix reclinata	22.67
Ficus sycomorus	11.89
Pavetta sphaerobotrys	10.17
Vachellia robusta	8.5
Hyphaene compressa	6.02
Sorindeia madagascarensis	4.3
Brichaeria spp	2.58
Garcinia livingstonei	1.32
Diospyros mespiliformis	1.21
Ficus natalensis	1.21
Oncoba spinosa	1.06
Saba comorensis	1.01
Polysphaeria multiflora	0.96

Borassus aethiopum	0.86
Grewia densa	0.71
Keetia zanzibaricus	0.66
Antidesma venosum	0.4
Alangium salviifolium	0.35
Ficus bubu	0.35
Cissus rotundifolia	0.35
Insect	13.97
Mushroom	5.77
Unknown	1.62

Note: N = 20 food plant species, 1936 feeding observations and three non-plant items.

Tana River mangabeys consumed different parts of plant foods during the study period in varying proportions (Figure 3). These plant's parts included; fruits, seeds, leaves, young stems, gum, flowers, stem bark and other unidentified food items. Fruits were the most consumed plant parts (56.40% ± 2.6 SEM) followed by seeds (14.36% ± 4.5 SEM), leaves (4.49% ± 3.3 SEM), gum (3.1% ± 6.6 SEM), young stems (1.03% ± 5.7 SEM), flowers (0.21% ± 0.1 SEM). However, tree bark was avoided by this group while unidentified food material constituted 20.40% of the Tana River mangabey diet (Figure 3).

In the Mkomani group the most utilized plant food part was fruits (50.32% ± 27.16 SEM) followed by seeds (35.92% ± 41.85 SEM), leaves (2.02% ± 2.01 SEM), gum (0.99% ± 0.92 SEM), young stems (0.99%), stem bark (0.46%) and 0.04% comprised of flowers (Figure 3). Also, the groups consumed other food items which were not identified during the study period and accounted for 1.46% of their diet, (Figure 3).

The findings show that the Mchelelo group spent more time feeding on fruits compared to the Mkomani group (Figure 3). The Mkomani group, however, consumed more seeds, leaves, young stems and barks compared to the Mchelelo group during the study period.

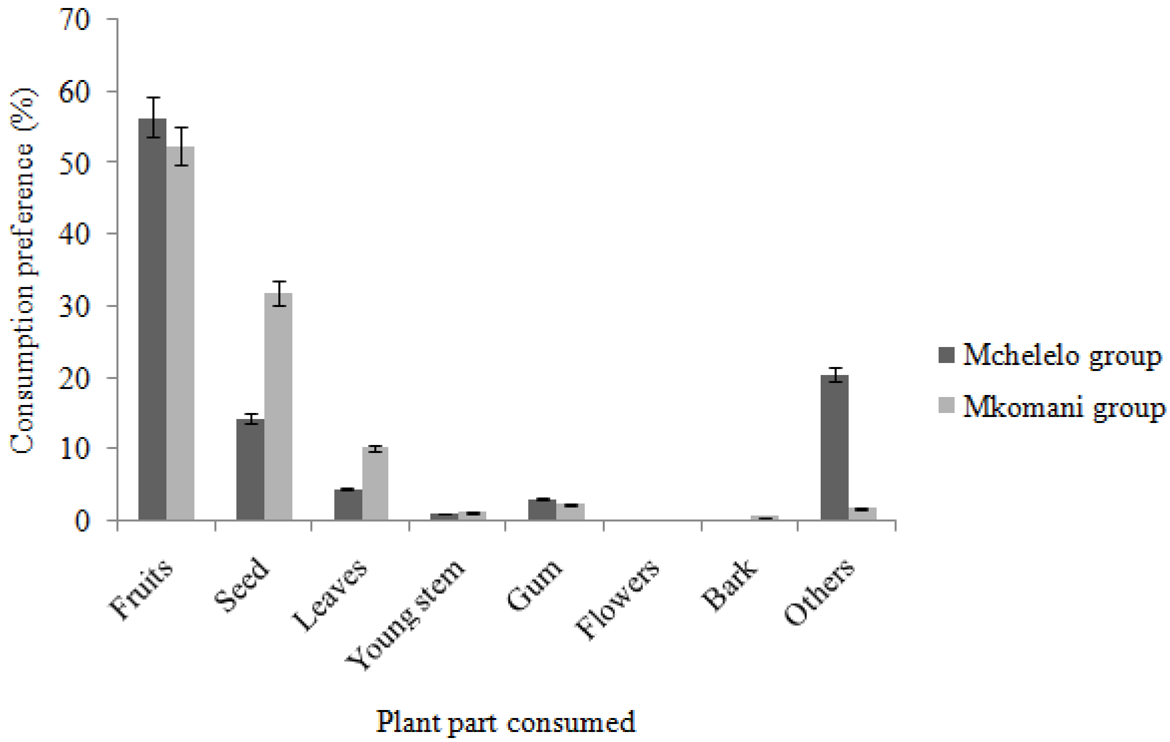

Figure 3: Plant parts fed on by *Cercocebus galeritus* in Mchelelo and Mkomani forests.

Others include the plant part which could not be identified, insects and mushrooms

3.2 Main anthropogenic activities and their magnitude in the two forest fragments

The study findings in Mkomani forest showed that logging was the leading human activity (78.98%) followed by palm leaf harvesting (16.76%) and trees affected by fire burning (3.13%), (Table 4). In the same study site, stumps of cut trees were observed such as those of *F. sycomorus* (Plate 2) and *L. fraxinifolius*. However, in Mchelelo forest harvesting of leaves from palm trees such as *P. reclinata* (Plate 3), *H. compressa* and *Borassus aethiopum* was the main source of disturbance representing 51.89% while logging and palm wine tapping represented 33.02% and 15.09% respectively (Table 4). Palm leaf harvesting was higher in Mchelelo compared to Mkomani while palm wine tapping was recorded in Mchelelo but not in Mkomani. The rest of the disturbances in the two study sites showed least percentages compared with the rest of the activities (Table 4).

Plate 2: Stumps of *Ficus sycomorus* in Mkomani forest

a b

Plate 3: a) Harvested *P. reclinata* leaves bundled together and (b) a mature *P. reclinata* cut down and the top edible shoot removed in Mchelelo forest.

Table 4: The frequency and percentages of anthropogenic activities in both study sites

	Frequency Scores			
Human activity	**Mkomani**	**%**	**Mchelelo**	**%**
Logging	556	78.98%	35	33.02%
Palm leaf harvesting	118	16.76%	55	51.89%
Palm Wine tapping	0	0.00%	16	15.09%
Boat construction	3	0.43%	0	0.00%
Cultivation	1	0.14%	0	0.00%
Fire burning	22	3.13%	0	0.00%
Honey harvesting	1	0.14%	0	0.00%
Medicine extraction	3	0.43%	0	0.00%

Based on the frequency of the plant species, *Phoenix reclinata* was the most exploited plant species in Mchelelo at 61.74%, followed by *Polysphaeria multiflora* (11.30%) and *Lecaniodiscus fraxinifolius* (8.70%) (Figure 4). On the other hand, *L. fraxinifolius* (17.01%) was the most exploited plant species in Mkomani forest, followed by *P. reclinata* (16.87%) and *Thespesia danis* at 10.61% as shown in Figure 4.

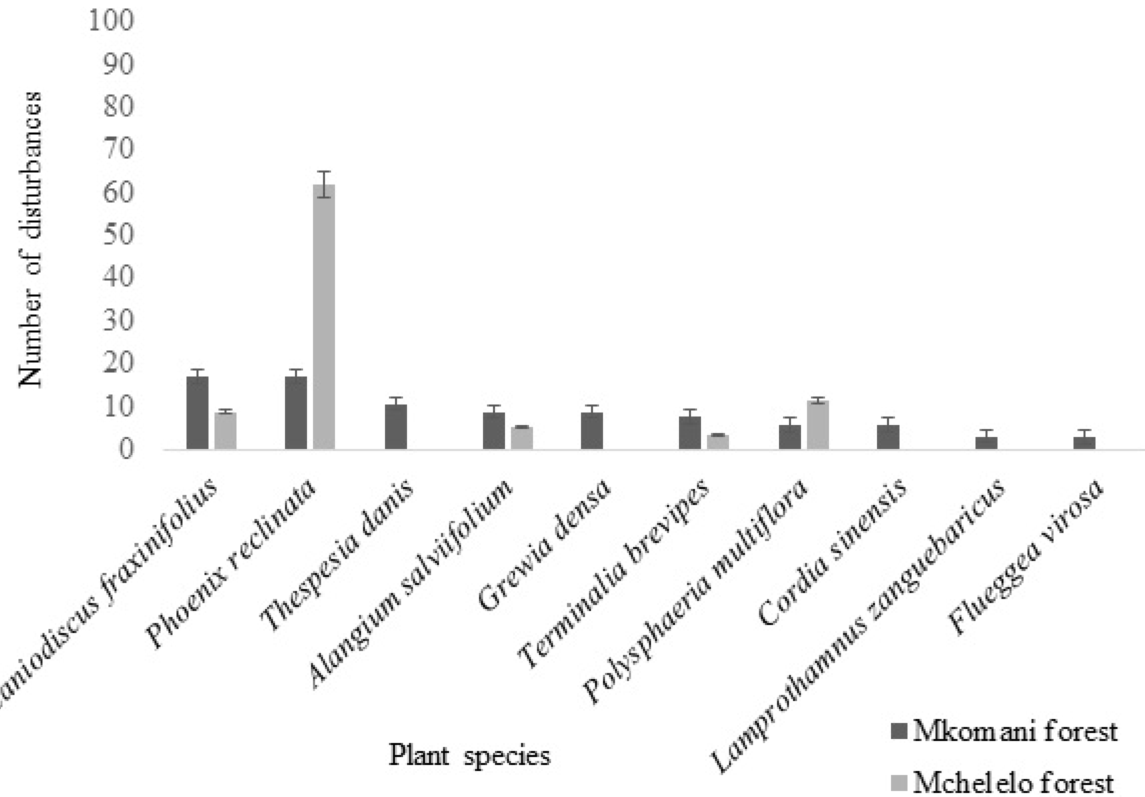

Figure 4: Number of disturbance (%) by humans for the plant food species in both sites.

The error bars represent SEM.

Furthermore, the least disturbed plant food species by the Tana River mangabey groups in Mkomani and Mchelelo was at varying levels, (Figure 5). The least disturbed plant food species in Mkomani had the same percentage value of 0.14% and were; *Spirostachys venenifera*, *Pavetta sphaerobotrys*, *Antidesma venosum*, *Keetia zanzibarica*, *Salacia erecta*, *Hunteria zeylanica*, *Citrus limon* and *Ficus sycomorus* (Figure 5).

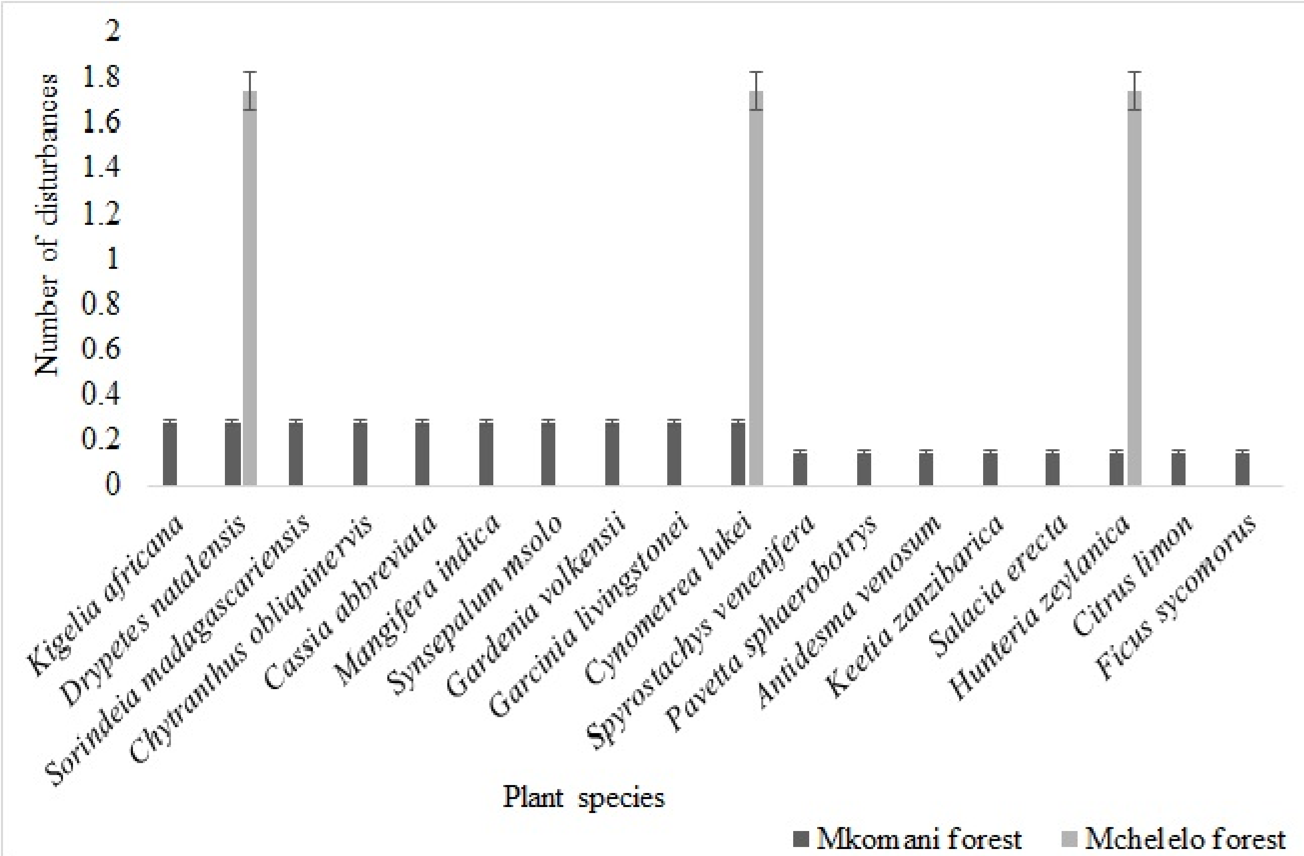

Figure 5: Frequency of disturbance by humans for the least disturbed plant food species in the study sites.

In Mkomani forest, the *Mimusops fruticosa* tree been one of the trees with least disturbance records of 1.09%. However, its trunk has been mostly used for making boats by the local community members (Plate 4). Within Mkomani study site *M. fruticosa* was among the top 20 trees with a 1.47% feeding record compared to other plant foods. In Mchelelo forest *M. fruticosa* was not disturbed or used by the community, Appendix 3.

Plate 4: A log of *Mimusops fruticosa* used for making boat in Mkomani forest

3.3 Behavioral patterns of the Tana River mangabey in the two forest fragments.

The average time spent by the two groups on each behavior activity varied within the two forest patches. For instance, in Mchelelo group the average time (Seconds ± SEM) spent by the Tana River mangabey group was higher in feeding (297.80 ± 4.8), followed by moving (109.59 ± 1.9), social interaction (92.81 ± 1.7) and the groups allocated less time resting (77.05 ± 1.7). While in Mkomani forest, the mean time spent by the Tana River mangabey group in feeding was higher (238.38 ± 1.8) compared to the rest of activities; moving (156.88 ± 2.2); resting (76.02 ± 1.9), and social interaction (37.36 ± 1.7) (Figure 6).

The comparison of the feeding data showed there was a significant difference between feeding in the two study sites ($t = 2.47$, d.f = 239, n = 129 and 112, $P < 0.05$). The two groups showed that there was a significant difference in time allocated to moving behavior between the two study sites ($t = 8.22$, d.f = 239, n = 129 and 112, $P < 0.05$). However, the comparison of time allocated to resting behavior between the two groups showed that there was no significant difference (t =

0.65, d. f = 239, n = 129 and 112, P > 0.05), and the same trend was exhibited by the time allocated to social interaction data in the two sites ($t = 8.78$, d.f = 239, n = 129 and 112, $P < 0.05$).

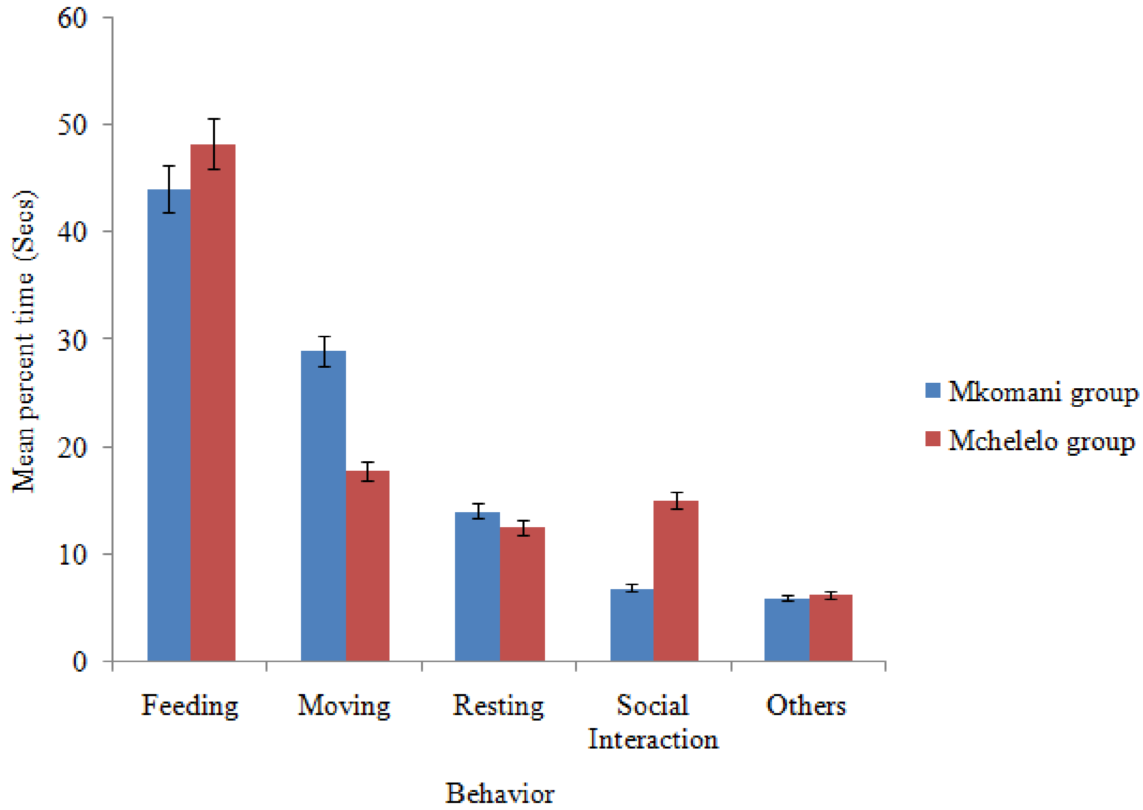

Figure 6: Percent mean time spent per behavioral activity (in seconds) in both groups. The error bars represent the Standard Error of the Mean (SEM).

CHAPTER FOUR

DISCUSSION, CONCLUSION, AND RECOMMENDATION

4.1 Discussion

4.1.1 Diversity and density of Tana River mangabey plant food species

This study findings showed that the Shannon Weiner diversity index was higher in Mchelelo (H' = 2.32) compared to Mkomani (H' = 2.04). Although, Mkomani forest had more number of individual trees sampled Mchelelo forest (E = 0.77) showed evenly distribution of trees sampled compared to Mkomani (E = 0.66). From the results the comparison of diversity values in both sites showed a significant difference (t = 0.50, d.f = 126, n = 61 and 67, $P < 0.05$). Similarly, the results showed that the calculated vegetation density was higher in Mchelelo (0.0034 ± 0.001 SEM) compared to Mkomani forest (0.0031 ± 0.0006 SEM). The comparison of the mean density values of plant food species consumed by the two Tana River mangabey groups in both sites differed significantly (t = 0. 014, d.f = 126, n = 61 and 67, $P < 0.05$). The mean basal area of plant species which were consumed by Tana River mangabeys was higher in Mchelelo (BA = 3.33) compared to Mkomani forest (BA = 1.32) (Figure 2). The comparison of the mean basal area differed significantly in both sites. The mean basal area of plant food species in Mchelelo and Mkomani forest was significantly different (t = 0.77, d.f = 126, n = 61 and 67, $P < 0.05$).

4.1.2 Tana River mangabey diet selection and composition

From the results in Table 2, groups in both sites consumed different plant food species at varying levels where 29 and 31 plant species were consumed by in Mkomani and Mchelelo forest fragment respectively. In Mkomani forest, the top plant species utilized by the group were *Phoenix reclinata* (36.94%), *Ficus sycomorus* (16.16%) and *Synsepalum msolo* (7.85%). And the least fed on plants by this group were *Saba comorensis* (0.19%), *Borassus aethiopum* (0.41%) and *Cassia abbreviata* (0.49%). From the feeding records in Table 3, the most consumed plant food species by the Mchelelo group were *P. reclinata*, *F. sycomorous* and *P. sphaerobotrys* at 22.67, 11.89 and 10.17 percentages respectively. The plant food species: *Antidesma venossum* (0.40%), *Alangium salviifolium* (0.35%), *F. bubu* (0.35%) and *Cissus rotundifolia* (0.35%) were the least consumed by the Mchelelo group. Some of these plant food species recorded during the study period in both sites were also recorded as some of the top plant species consumed by Tana River mangabey by Wieczkowski, (2004) in her 2000 study. Similarly, from a study to establish the diet selection overlap between baboons and the Tana River mangabey revealed that *P. reclinata* (20%) was the most consumed plant food by the later followed by *S. madagascarensis* at 19% (Wahungu, 1998). In contrast to the Wahungu, (1998) study, the group in Mkomani forest did not consume *S. madagascarensis* while in the Mchelelo group feeding this plant species formed 4.3 percent of the diet. To supplement their diet the two groups consumed non-plant foods as shown in Tables 2 and 3, although in the Mchelelo group insects and mushrooms accounted for 13.97, 5.77 percentages respectively of the feeding records compared to 1.5 percent by the Mkomani group.

As shown in Figure 3, the groups in both sites consumed different plant parts at varying levels. The group in Mchelelo forest in their diet consumption preferred fruits (56.40% ± 2.6 SEM) and seeds (14.36% ± 4.5 SEM) while the least preferred food item was flowers (0.21% ± 0.1 SEM) and young stems (1.03% ± 5.7 SEM). In the other forest, the Mkomani group preferred fruits (50.32% ± 27.16 SEM), seeds (35.92% ± 41.85 SEM) and leaves (2.02% ± 2.01 SEM), to plant gum (0.99% ± 0.92 SEM), young stems (0.99%), stem bark (0.46%) and flowers (0.04%).Also from Figure 3, this group consumed other food items which were not identified during the study period and accounted for 1.46% of their diet. The findings of this study show that the Mchelelo group spent more time feeding on fruits compared to the Mkomani group. In addition, findings from Figure 3 show that the Mkomani group consumed more seeds, leaves, young stems and barks compared to the Mchelelo group during the study period. The results of this study conformed to those of previous studies done on food selection by the Tana River mangabeys, which showed that this monkey spent considerable time-consuming fruits and seeds compared to other plant parts (Wahungu, 1998; Wieczkowski, 2004; Kimuyu *et al.,* 2012).

Plants food species such as *S. comorensis*, *O. spinosa*, *H. compressa*, *S. madagascariensis,* and *P. reclinata* provided the much-needed fruits during the study period. *Vachellia robusta, S. madagascariensis* and *Alangium salviifolium* trees provided seeds for the Tana River mangabey groups during the study periods, while *V. robusta* provided plant gum for the monkeys which might have been used as an alternative source of food during the dry season. According to Wahungu, (1998), the tree species above play a key role in the survival of the Tana River mangabeys in the forest. The differences in consumption of different plant parts may be explained by the decline in food availability in the forest fragments which may force primates to diversify their food as observed by spider monkeys (Chaves *et al.,* 2011). The same trend may be employed by the Tana River mangabeys in opting to feed more on arthropods in order to supplement their diet. With the increased agricultural activities within their habitat, the probability of the Tana River mangabeys to engage in crop raiding in Mkomani is higher than in Mchelelo.

4.1.3 Main anthropogenic activities and their magnitude in the two forest fragments

The anthropogenic disturbances varied in both sites. As indicated in Table 3, Mkomani forest logging (78.98%) was the leading human activity followed by the palm leaf harvesting (16.76%) and burning (3.13%). This might be due to the close proximity of the Tana River mangabey habitat to human settlement and farming areas in Mkomani forest. The community members around Mkomani use slash and burn method to prepare their farms for planting before the rainy season (*Personal observation*). This could have led to the decline in vegetation cover through burning of the undergrowth and affect the growth of plants. This may also affect the availability of food resources which eventually impact on the behavior of the Tana River mangabeys as they might be forced to move further to compensate for the lost food sources. As indicated in Table 4, palm leaf harvesting was the main anthropogenic activity followed by logging and palm wine tapping in Mchelelo forest. Logging in Mkomani was higher compared to Mchelelo forest while palm leaf harvesting in Mchelelo was high than Mkomani. Although, Muoria *et al.,* 2003 study focused on primate census and evaluation of habitat in the Tana Delta region, their results were similar to this study were they recorded; cutting of poles, burning, leaf harvesting and wine tapping, as the main human activities. From Figure 6, palm wine tapping in Mchelelo forest was observed majorly targeting *Hyphaene compressa* and was one of the activity most threatening the survival of the Tana River mangabey as this plant is one of the key plant food. On the specific plant species *Phoenix reclinata*, *Polysphaeria multiflora,* and *Lecaniodiscus fraxinifolius* were the most exploited plant food species in Mchelelo while in Mkomani forest *L. fraxinifolius*, *P. reclinata* and *Thespesia danis* were the most exploited food plant species as shown in Figure 6 and Appendix 3. The poles from the *L. fraxinifolius* and *T. danis* were used for building by the villagers and the palm leaves for making mats and house thatching (Medley, 1993).

The communities in both sites relied on forest resources as shown in Table 4 and Figure 6.This was evident from the high number of tree stumps from logging recorded in both forest fragments that may have been harvested and used as poles for building houses and frequency from other recorded activities. There was also a high demand for other forest products such as *Phoenix reclinata* leaves which were used for mat making and as a source of income as shown in Table 2 & 4 and by Kinnaird, (1992) and Medley, (1993). In addition, Kinnaird, (1992) went further to categorize the different uses of *P. reclinata* by the community from commerce, construction, remedy, food among other uses. From personal observation on the impact of plant species by anthropogenic activities,, this study conforms to the findings of Kinnaird, (1992), that some of the destructive humans use such as cutting palm trunks for building, palm heart extraction, beer production, and excessive leaf removal affects the meristem preventing growth. This uncontrolled extraction of forest products by both communities could be linked to poor management and lack of policies as highlighted by Kinnaird, (1992). She also noted that harvesting *P. reclinata* and *H. compressa* in the unprotected sites was high and unsustainable thus spilling to the protected areas. However, findings of this study show that harvesting of *P. reclinata* leaves is increasingly resulting in degradation of Tana River mangabey habitats.

4.1.4 Behavioral patterns of the Tana River mangabey in the two forest fragments.

As indicated in Figure 6, the Mchelelo group spent more time feeding, followed by moving activity compared to other behavioral patterns while the Mkomani group spent more time feeding and moving compared to resting and social interaction. Further comparison of behavioral activities in both sites indicated that in Mkomani forest, moving activity was higher compared to moving activity in the Mchelelo group. The Mkomani group spent more time resting compared to socializing. This may be due to more time spent moving within the forest in search of food or avoiding human presence in the forest hence prefers saving energy while resting than wasting during social interaction. Although, Wieczkowski (2003) in her 2000 study, used different methods to collect behavior data, Tana River mangabeys allocated more time feeding, resting and socializing compared to findings in this study. In both sites, the variation of time spent per behavioral activity differed significantly as it is shown in Figure 6. From the differences in time allocated to different behavior categories and the high human activities in Mkomani forest it is clear that habitat disturbances may have impact on the behavior of the Tana River mangabeys either positively or negatively where the groups in disturbed area may experience longer feeding time, high time spent in moving and less resting time.

In this study, the findings show that trees cut for boat construction were recorded in Mkomani forest (0.43%) but not recorded in Mkomani forest as shown in Table 4. Results from a study by Moinde *et al.,* (2007) found out that trees cut for boat construction were common in forest patches which were in close proximity to the villages. Also, similar studies in the region show that there was a high demand of plant species for boat construction, land for farming activities, palm leaves and trunks for income and house construction, construction poles (Kinnaird, 1992; Medley, 1993; Moinde *et al.,* 2007). This might have been the reason for high numbers of human activities recorded in this study in Mkomani compared to Mchelelo forest as shown in Table 4. Furthermore, the targeting of the plant food species by the community may have led to decline of vegetation as shown by the low diversity and density values, and the high number of disturbance activities in Mkomani forest which may have forced the Tana River mangabey group in this forest to allocate more time moving in search of food compare to the Mchelelo group..

The decline in Tana River mangabey plant foods in Mkomani may be linked to high exploitation in the forest by the communities living adjacent to the forest (Wieczkowski, 2005; Moinde *et al.*, 2007). The unsustainable utilization of forest products in the Tana River forests is one of the major threats to the Tana River mangabey food species (Wieczkowski, 2005), which affects the diversity of plant in the forests, thus explaining the low diversity in Mkomani forest. The decline in the plant food species poses a great danger to the survival of this endangered primate species in Mkomani forest study area as compared to Mchelelo forest, although behavioral ecology studies of Tana River mangabeys show that they have a high adaptability to habitat change (Homewood, 1976; Kinnaird, 1990; Wieczkowski, 2003). Thus, with the low diversity of Tana

River mangabey plant food species within the forest patches, they tend to compensate this by increasing their foraging range (Wieczkowski, 2003) and supplementing their diet with insects and mushrooms (Homewood, 1976; Wieczkowski, 2003; Table 2 & 3). This tends to increase the area of coverage to compensate for decreased food resource availability in the forests. Hence, explaining why time allocated to moving behavior category by Mkomani group was higher than time allocated to the same behavior by Mchelelo group as shown in Figure 6. This shows that increase of human activities in the forest may deter the animals from accessing food patches within the forest.

In addition, the frequency and intensity of human activities may also influence the distribution and behavior of mangabeys and other primates in the forests by affecting time spent feeding and other essential roles in the habitat (McCabe & Gotelli, 2000; Wieczkowski, 2004; Graham *et al.*, 2013). This can eventually result in the adoption of other behaviors such as visiting agricultural areas to raid crops to compensate for the decline in food availability as was shown by Olive baboons (*Papio anubis*) in a study by Strum, (2010). Thus, understanding the behavior of the Tana River mangabeys in forest with different levels of disturbance may help us explain the effects of anthropogenic disturbance on their behavior

4.2 Conclusion and recommendations

4.2.1 Conclusion

Mkomani forest fragment along the Tana River had low diversity, basal area, and density of plant species consumed by the Tana River mangabey compared to Mchelelo forest. This was due to more harvesting of vegetation in Mkomani forest compared to Mchelelo. The study findings showed that there was an even distribution of plants sampled in Mchelelo forest compared to Mkomani forest. In addition, anthropogenic activities such as logging and palm leaf harvesting were found to be the most common human activities in both sites. These activities were found to target the mature plant species which formed the base of food resources for the Tana River mangabeys. In Mkomani forest, logging targeting *M. fruticosa, P. reclinata, L. fraxinifolius, T. danis and F. sycomorous* was found to be the most destructive activity affecting the plant food species of the Tana River mangabey, while in Mchelelo forest human activities palm leaf harvesting and wine tapping targeting *P. reclinata* and *H. compressa* were observed as the most destructive activities.

In addition, Mchelelo group allocated more time to feeding behavior compared to Mkomani group which spend less time feeding, although the Mkomani group allocated more time in moving behavior category. The study demonstrated that fruits and seeds were the major plant parts consumed by the Tana River mangabey in Mkomani and Mchelelo sites. Cutting of plant food species for boat making and other uses directly affects the availability of these food resources in the forest habitat.

Results of this study suggest that reducing the human activities in the forest can be very crucial in minimizing their impacts on the diversity and effects on the behavior of Tana River mangabeys. The collected information adds to the existing scientific information on the vegetation, behavior and diet data of the Tana River mangabeys in the lower Tana River forests.

4.2.2 Recommendations for management and further studies.

- The plant food species consumed in both sites need to be protected from overharvesting by the community to provide the necessary food resources to the endangered Tana River mangabeys and improve diversity and density of vegetation in the forest especially in Mkomani forest fragment.
- Tana River mangabeys inhabiting forest fragments such as Mkomani which experience high anthropogenic activities needs to be protected to prevent population decline.

- There is need for a continuous study on the effects of anthropogenic activities to the behavior of the Tana River mangabey. This should be encouraged within the reserve and forest outside to help understand the change in behavior of the Tana River mangabey groups' overtime.
- There is also a need to replicate this study in other forest fragments along the Tana River which have varying anthropogenic activities and compare the results.
- There is need to minimize the cutting of matures trees, leaf harvesting of key plant species such as *Phoenix reclinata, Lecaniodiscus fraxinifolius, Hyphaene compressa, Mimusops fruticosa* which are the Tana River mangabey plant food species. This will help the Tana River mangabeys with diverse food resources.

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Appendices

Appendix 1: Vegetation parameters for Mchelelo plant species

SPECIES	No. of Ind.	Diversity H'	Cover (%)	Rel. cover	Aver. height	DBH (m)	Density	rel. density	Freq.	rel. freq.	I.V.I	BA in m²
Vachellia robusta	2	0.0099	15	0.93	28.5	0.4	0.00023	0.023	0.091	9.09	10.04	0.12572
Senegalia rovumae	3	0.0139	26	1.61	24.5	0.26	0.00034	0.034	0.136	13.64	15.28	0.05365
Acalypha echinus	5	0.0212	2	0.12	4	0	0.00057	0.057	0.182	18.18	18.36	0.00000
Afzelia quanzensis	2	0.0099	8	0.50	16.5	0.33	0.00023	0.023	0.091	9.09	9.61	0.08402
Alangium salviifolium	19	0.0611	41	2.54	11.97	0.16	0.00216	0.216	0.409	40.91	43.67	0.01890
Albizia gummifera	6	0.0246	63	3.90	25.7	0.48	0.00068	0.068	0.227	22.73	26.70	0.17893
Allophylus alnifolius	5	0.0212	1	0.06	3	0	0.00057	0.057	0.182	18.18	18.30	0.00000
Antidesma vogelianum	28	0.0820	21	1.30	3.5	0	0.00318	0.318	0.182	18.18	19.80	0.00000
Aporrhiza paniculata	2	0.0099	1	0.06	6.5	0.057	0.00023	0.023	0.091	9.09	9.18	0.00255
Capparis tomentosa	15	0.0510	6	0.37	3.5	0	0.00170	0.170	0.273	27.27	27.81	0.00000
Cassia afrofistula	1	0.0055	1	0.06	7	0	0.00011	0.011	0.045	4.55	4.62	0.00000
Catunaregam spinosa	1	0.0055	1	0.06		0	0.00011	0.011	0.045	4.55	4.62	0.00000
Celtis philippensis	13	0.0456	2	0.12	5.5	0.052	0.00148	0.148	0.364	36.36	36.64	0.00208
Chytranthus obliquinervis	46	0.1171	6	0.37	3.5	0.056	0.00523	0.523	0.500	50.00	50.89	0.00246
Cola clavata	1	0.0055	1	0.06	5	0.05	0.00011	0.011	0.045	4.55	4.62	0.00196
Cordia goetzei	5	0.0212	26	1.61	15.5	0.11	0.00057	0.057	0.136	13.64	15.30	0.00905
Cynometra lukei	1	0.0055	20	1.24	27	0.48	0.00011	0.011	0.045	4.55	5.80	0.17916
Diospyros consolatae	1	0.0055	1	0.06	5	0.05	0.00011	0.011	0.045	4.55	4.62	0.00196
Diospyros ferea	1	0.0055	1	0.06	5	0.05	0.00011	0.011	0.045	4.55	4.62	0.00196
Diospyros kabuyeana	1	0.0055	1	0.06	5	0.05	0.00011	0.011	0.045	4.55	4.62	0.00196
Diospyros mespiliformis	7	0.0279	70	4.34	20.4	0.40	0.00080	0.080	0.273	27.27	31.69	0.12447
Drypetes natalensis	83	0.1742	64	3.97	3.5	0.053	0.00943	0.943	0.864	86.36	91.27	0.00221
Erythroxylum fischeri	7	0.0279	1	0.06	5.5	0.06	0.00080	0.080	0.227	22.73	22.87	0.00283

Ficus natalensis	2	0.0099	6	0.37	19.5	0.15	0.00023	0.023	0.091	9.09	9.49	0.01733
Ficus sycomorus	2	0.0099	40	2.48	39.5	1.69	0.00023	0.023	0.091	9.09	11.59	2.24418
Flueggea virosa	5	0.0212	2	0.12	3	0	0.00057	0.057	0.136	13.64	13.82	0.00000
Garcinia livingstonei	8	0.0310	5	0.31	7	0.084	0.00091	0.091	0.227	22.73	23.13	0.00554
Grewia densa	46	0.1171	83	5.14	3	0	0.00523	0.523	0.591	59.09	64.76	0.00000
Grewia stulhmanii	2	0.0099	2	0.12	5	0	0.00023	0.023	0.091	9.09	9.24	0.00000
Harrisonia abyssinica	8	0.0310	25	1.55	8	0	0.00091	0.091	0.364	36.36	38.00	0.00000
Hibiscus micranthus	15	0.0510	2	0.12	2	0	0.00170	0.170	0.136	13.64	13.93	0.00000
Hunteria zeylanica	111	0.2085	54	3.35	5	0.063	0.01261	1.261	0.636	63.64	68.24	0.00312
Hyphaene compressa	58	0.1374	132	8.18	20	0.33	0.00659	0.659	0.500	50.00	58.84	0.08557
Keetia zanzibarica	20	0.0636	54	3.35	5	0	0.00227	0.227	0.636	63.64	67.21	0.00000
Lamprothamnus zanguebaricus	6	0.0246	1	0.06	6.4	0.059	0.00068	0.068	0.091	9.09	9.22	0.00274
Lannea schweinfurthii	4	0.0176	16	0.99	11	0.23	0.00045	0.045	0.136	13.64	14.67	0.04060
Lawsonia inermis	1	0.0055	1	0.06	8	0.073	0.00011	0.011	0.045	4.55	4.62	0.00413
Lecaniodiscus fraxinifolius	18	0.0588	21	1.30	4.9	0.06	0.00205	0.205	0.318	31.82	33.32	0.00280
Maerua triphylla	15	0.0510	8	0.50	4	0	0.00170	0.170	0.182	18.18	18.85	0.00000
Majidea zanguebarica	4	0.0176	4	0.25	9.8	0.11	0.00045	0.045	0.136	13.64	13.93	0.00880
Maytenus heterophylla	2	0.0099	1	0.06	1	0	0.00023	0.023	0.091	9.09	9.18	0.00000
Maytenus undata	15	0.0510	25	1.55	4.2	0.056	0.00170	0.170	0.273	27.27	28.99	0.00242
Mimusops fruiticosa	19	0.0611	19	1.18	5.6	0.076	0.00216	0.216	0.500	50.00	51.39	0.00454
Oncoba spinosa	72	0.1590	39	2.42	6	0.059	0.00818	0.818	0.818	81.82	85.05	0.00274
Synsepalum msolo	2	0.0099	1	0.06	4.5	0.05	0.00023	0.023	0.091	9.09	9.18	0.00196
Pavetta sphaerobotrys	17	0.0561	10	0.62	4.4	0.058	0.00193	0.193	0.091	9.09	9.90	0.00264
Phoenix reclinata	61	0.1423	108	6.69	11.6	0.13	0.00693	0.693	0.545	54.55	61.93	0.01314
Polysphaeria multiflora	117	0.2150	98	6.07	6.22	0.067	0.01330	1.330	0.636	63.64	71.04	0.00353
Rauvolfia mombasiana	5	0.0212	5	0.31	4.4	0.055	0.00057	0.057	0.227	22.73	23.09	0.00233
Rinoria elliptica	237	0.3087	86	5.33	4.1	0.06	0.02693	2.693	0.864	86.36	94.39	0.00283
Saba comorensis	1	0.0055	6	0.37	20	0	0.00011	0.011	0.045	4.55	4.93	0.00000
Salacia erecta	4	0.0176	26	1.61	8	0	0.00045	0.045	0.182	18.18	19.84	0.00000

Salacia stulhmaniana	12	0.0428	4	0.25	10.6	0	0.00136	0.136	0.227	22.73	23.11	0.00000
Sorindeia madagascarensis	109	0.2063	238	14.75	9.4	0.17	0.01239	1.239	0.727	72.73	88.71	0.02303
Spyrostachys venenifera	8	0.0310	7	0.43	15.4	0.19	0.00091	0.091	0.273	27.27	27.80	0.02957
Sureganda zanzibariensis	8	0.0310	15	0.93	10	0.094	0.00091	0.091	0.227	22.73	23.75	0.00688
Tapura fischeri	2	0.0099	1	0.06	6	0.057	0.00023	0.023	0.045	4.55	4.63	0.00255
Terminalia brevipes	11	0.0400	5	0.31	7	0.10	0.00125	0.125	0.227	22.73	23.16	0.00845
Thespesia danis	5	0.0212	6	0.37	5	0.066	0.00057	0.057	0.136	13.64	14.06	0.00342
Uvaria spp	11	0.0400	25	1.55	5.2	0	0.00125	0.125	0.409	40.91	42.58	0.00000
Zizisphus pubescens	19	0.0611	54	3.35	8.83	0.11	0.00216	0.216	0.545	54.55	58.11	0.00994
TOTAL	**1317**	**3.16196**	**1614**				**0.14966**	**14.966**	**16.136**			**3.32867**

Appendix 2: Vegetation parameters for Mkomani plant species

Species	No. of Indiv.	Diversity (H)	% Cover	Rel. cover	Aver. Height (m)	DBH (m)	Density	Rel. density	Freq.	Rel. freq.	I.V.I	BA(m^2)
Abutilon mauritanum	4	0.018	10	0.67	4	0	0.00042	0.32	0.04	0.32	10.64	0.0000
Senegalia melifera	1	0.006	1	0.07	3	0.05	0.0001	0.08	0.04	0.32	1.40	0.0020
Vachellia robusta	9	0.036	88	5.86	19.77	0.338	0.00094	0.72	0.29	2.24	90.96	0.0898
Vachellia zanzibarica	1	0.006	1	0.07	5.5	0.05	0.0001	0.08	0.04	0.32	1.40	0.0020
Acalypha ekinos	7	0.029	9	0.60	4.1	0	0.00073	0.56	0.04	0.32	9.88	0.0000
Alangium salviifolium	16	0.056	22	1.46	8.7	0.1063	0.00167	1.28	0.17	1.28	24.56	0.0089
Allophylanthus reticlatus	1	0.006	1	0.07	6	0	0.0001	0.08	0.04	0.32	1.40	0.0000
Allophylus rubifolius	2	0.010	1	0.07	5.5	0	0.00021	0.16	0.08	0.64	1.80	0.0000
Antidesma venosum	2	0.010	1	0.07	5	0.1713	0.00021	0.16	0.08	0.64	1.80	0.0231
Apporhiza paniculata	4	0.018	1	0.07	3	0.05	0.00042	0.32	0.08	0.64	1.96	0.0020
Blighia unijugata	7	0.029	1	0.07	3.7	0.06	0.00073	0.56	0.04	0.32	1.88	0.0028
Bridelia micrantha	1	0.006	1	0.07		0.149	0.0001	0.08	0.04	0.32	1.40	0.0174
Capparis tormentosa	4	0.018	6	0.40	4	0	0.00042	0.32	0.17	1.28	7.60	0.0000
Capparis verminia	5	0.022	24	1.60	6.4	0	0.00052	0.40	0.21	1.60	26.00	0.0000

Carisa edulis	3	0.014	15	1.00	9	0	0.00031	0.24	0.08	0.64	15.88	0.0000
Cassia abbreviata	2	0.010	3	0.20	6.5	0.1025	0.00021	0.16	0.08	0.64	3.80	0.0083
Cassia affrofistula	3	0.014	1	0.07	4	0	0.00031	0.24	0.08	0.64	1.88	0.0000
Catunaregam spinosa	6	0.026	1	0.07	4	0	0.00063	0.48	0.17	1.28	2.76	0.0000
Chytranthus obliquinavis	19	0.063	5	0.33	3	0.052	0.00198	1.52	0.29	2.24	8.76	0.0021
Cola clavata	1	0.006	1	0.07	3	0.05	0.0001	0.08	0.04	0.32	1.40	0.0020
Cordia sinensis	11	0.042	73	4.86	9.1	0.1462	0.00115	0.88	0.38	2.88	76.76	0.0168
Cordia goetzei	21	0.069	25	1.66	8.2	0.1015	0.00219	1.68	0.38	2.88	29.56	0.0081
Croton menyharthii	30	0.090	60	3.99	3.8	0	0.00313	2.40	0.04	0.32	62.72	0.0000
Cynometrea lukei	3	0.014	1	0.07	4	0.05	0.00031	0.24	0.08	0.64	1.88	0.0020
Diospyros consolatae	1	0.006	1	0.07	6	0	0.0001	0.08	0.04	0.32	1.40	0.0000
Diospyros kabuyeana	1	0.006	2	0.13	10	0.155	0.0001	0.08	0.04	0.32	2.40	0.0189
Diospyros mespiliformis	14	0.050	12	0.80	6.6	0.125	0.00146	1.12	0.33	2.56	15.68	0.0123
Dobera loranthifolia	7	0.029	20	1.33	10.6	0.3678	0.00073	0.56	0.04	0.32	20.88	0.1063
Drypetes natalensis	21	0.069	11	0.73	4.08	0.054	0.00219	1.68	0.33	2.56	15.24	0.0023
Ficus bubu	1	0.006	1	0.07	10	0.125	0.0001	0.08	0.04	0.32	1.40	0.0123
Ficus natalensis	1	0.006	1	0.07	1	0.05	0.0001	0.08	0.04	0.32	1.40	0.0020
Ficus sycomorus	24	0.076	115	7.65	17.01	0.5252	0.0025	1.92	0.29	2.24	119.16	0.2167
Flueggea virosa	16	0.056	7	0.47	4	0	0.00167	1.28	0.21	1.60	9.88	0.0000
Garcinia livingstonei	32	0.094	107	7.12	8.08	0.2806	0.00333	2.56	0.38	2.88	112.44	0.0619
Gardenia volkensii	1	0.006	3	0.20	8	0.0743	0.0001	0.08	0.04	0.32	3.40	0.0043
Grewia densa	90	0.189	17.25	1.15	5.1	0	0.00938	7.19	0.75	5.77	30.21	0.0000
Grewia stulhmanii	6	0.026	12	0.80	6.3	0	0.00063	0.48	0.25	1.92	14.40	0.0000
Haplochoelum mombasense	4	0.018	1	0.07	5	0.0635	0.00042	0.32	0.08	0.64	1.96	0.0032
Harisonia abysinica	6	0.026	6	0.40	4	0	0.00063	0.48	0.25	1.92	8.40	0.0000
Hunteria zeylanica	6	0.026	1	0.07	3.25	0.05	0.00063	0.48	0.04	0.32	1.80	0.0020
Keetia zanzibarica	6	0.026	6	0.40	4	0	0.00063	0.48	0.25	1.92	8.40	0.0000
Kigelia africana	3	0.014	1	0.07	6	0.105	0.00031	0.24	0.04	0.32	1.56	0.0087
Lamprothamus zanguebarica	16	0.056	16	1.06	5.5	0.0709	0.00167	1.28	0.21	1.60	18.88	0.0039

Lawsonia inermis	4	0.018	7	0.47	8.2	0.0965	0.00042	0.32	0.08	0.64	7.96	0.0073
Lecaniodiscus fraxinifolius	131	0.237	106	7.05	4.7	0.0623	0.01365	10.46	0.75	5.77	122.23	0.0030
Citrus limon	1	0.006	1	0.07	1.5	0.05	0.0001	0.08	0.04	0.32	1.40	0.0020
Leosineria africana	2	0.010	5	0.33	5	0	0.00021	0.16	0.04	0.32	5.48	0.0000
Mangifera indica	3	0.014	35	2.33	11.2	0.2374	0.00031	0.24	0.08	0.64	35.88	0.0443
Meytenous heterophylla	14	0.050	1.5	0.10	1	0	0.00146	1.12	0.29	2.24	4.86	0.0000
Mimusops fruticosa	23	0.074	40	2.66	6.8	0.1382	0.0024	1.84	0.42	3.21	45.04	0.0150
Mormodica trifoliata	4	0.018	5	0.33	13	0	0.00042	0.32	0.17	1.28	6.60	0.0000
Synsepalum msolo	14	0.050	75	4.99	18.6	0.7643	0.00146	1.12	0.21	1.60	77.72	0.4590
Pavetta sphaerobotrys	5	0.022	3	0.20	5	0.057	0.00052	0.40	0.13	0.96	4.36	0.0026
Phoenix reclinata	46	0.121	30	2.00	5	0.085	0.00479	3.67	0.38	2.88	36.56	0.0057
Polysphaeria multiflora	323	0.350	250	16.64	5.6	0.071	0.03365	25.80	0.75	5.77	281.57	0.0040
Prosopis juliflora	7	0.029	1	0.07	3	0.05	0.00073	0.56	0.13	0.96	2.52	0.0020
Rinorea elliptica	50	0.129	11	0.73	3.7	0.055	0.00521	3.99	0.42	3.21	18.20	0.0024
Saba comorensis	6	0.026	18	1.20	5.6	0	0.00063	0.48	0.25	1.92	20.40	0.0000
Salacia erecta	8	0.032	10	0.67	3	0	0.00083	0.64	0.33	2.56	13.20	0.0000
Salvadora persica	2	0.010	1	0.07	3	0.05	0.00021	0.16	0.08	0.64	1.80	0.0020
Sorindeia madagascariensis	15	0.053	6	0.40	4.1	0.051	0.00156	1.20	0.33	2.56	9.76	0.0020
Spyrostachys venenifera	18	0.060	28	1.86	8.7	0.0976	0.00188	1.44	0.42	3.21	32.64	0.0075
Tamarindus indica	6	0.026	45	2.99	10.5	0.3388	0.00063	0.48	0.13	0.96	46.44	0.0902
Terminalia brevipes	67	0.158	62	4.13	6.4	0.12	0.00698	5.35	0.38	2.88	70.24	0.0113
Thespesia danis	73	0.165	64	4.26	4.4	0.105	0.0076	5.83	0.38	2.88	72.72	0.0087
Trema oreintalis	10	0.039	5	0.33	4.8	0.073	0.00104	0.80	0.13	0.96	6.76	0.0042
Trichilia emetica	1	0.006	1	0.07	1.5	0.05	0.0001	0.08	0.04	0.32	1.40	0.0020
TOTALS	**1252**	**3.106**	**1502.75**	**100**	**402.09**	**6.0752**	**0.13042**	**100**	**13**	**100**	**1702.75**	**1.31671**

Appendix 3: Percentages of human disturbances in Mchelelo and Mkomani forests

	Frequency of human disturbance on plant species			
Plant Species	**Mkomani forest**	**%**	**Mchelelo forest**	**%**
Lecaniodiscus fraxinifolius	125	17.01	10	8.7
Phoenix reclinata	124	16.87	71	61.74
Thespesia danis	78	10.61	0	0
Alangium salviifolium	64	8.71	6	5.22
Grewia densa	64	8.71	0	0
Terminalia brevipes	55	7.48	4	3.48
Polysphaeria multiflora	43	5.85	13	11.3
Cordia sinensis	41	5.58	0	0
Lamprothamnus zanguebaricus	23	3.13	0	0
Flueggea virosa	21	2.86	0	0
Lawsonia inermis	19	2.59	0	0
Cordia goetzei	15	2.04	0	0
Rinorea elliptica	11	1.5	0	0
Mimusops fruiticosa	8	1.09	0	0
Diospyros mespiliformis	7	0.95	0	0
Tamarindus indica	6	0.82	0	0
Allophylus rubifolius var. *alnifolius*	3	0.41	0	0
Kigelia africana	2	0.27	0	0
Drypetes natalensis	2	0.27	2	1.74
Sorindeia madagascariensis	2	0.27	0	0
Chytranthus obliquinervis	2	0.27	0	0
Cassia abbreviata	2	0.27	0	0
Mangifera indica	2	0.27	0	0
Synsepalum msolo	2	0.27	0	0
Gardenia volkensii	2	0.27	0	0
Garcinia livingstonei	2	0.27	0	0
Cynometrea lukei	2	0.27	2	1.74
Spyrostachys venenifera	1	0.14	0	0
Pavetta sphaerobotrys	1	0.14	0	0
Antidesma venosum	1	0.14	0	0
Keetia zanzibarica	1	0.14	0	0
Salacia erecta	1	0.14	0	0
Hunteria zeylanica	1	0.14	7	6.09
Citrus limon	1	0.14	0	0
Ficus sycomorus	1	0.14	0	0

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