ABUNDANCE AND ACTIVITY PATTERNS FOR THE ANGOLAN BLACK AND WHITE COLOBUS MONKEY (*Colobus angolensis palliatus*) IN UDZUNGWA MOUNTAINS NATIONAL PARK, TANZANIA

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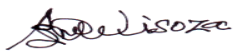
CERTIFICATION

The undersigned certifies that he has read and hereby recommends for acceptance by The Open University of Tanzania a dissertation entitled, **Assessing Abundance and Activity Patterns for the Angolan Black and White Colobus Monkey *(Colobus angolensis palliatus)* in Udzungwa Mountains National Park** in partial fulfilment of the requirements for the award of Degree of Masters in Environmental Management of the Open University of Tanzania.



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Dr James Kisoza
(Supervisor)

29th October, 2023

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Date

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DECLARATION

I, **Gabriel Joseph,** declare that the work presented in this dissertation is original and has never been presented to any other University or Institution. Where other people's works have been used, references have been provided. It is in this regard that I declare this work as originally mine. It is hereby presented in partial fulfilment of the requirement for the Degree of Master in Environmental Management.

Signature

October 28th, 2023

Date

DEDICATION

To GOD the Creator, JESUS the Saviour, and HOLY GHOST the Leader.

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ABSTRACT

This study investigated the abundance and activity patterns of *Colobus angolensis palliatus* in Udzungwa Mountains National Park (UMNP). Seven one-kilometre point-transects were set at the study area, three in disturbed and four in undisturbed sites. A group of *C.a. palliatus* at Sonjo transect, intermingled between disturbed and undisturbed areas, was selected to study activity patterns across age and sex groups. The *C.a. palliatus* were significantly abundant ($t=5.75$; $p=0.0135$) in undisturbed sites. Overall, *C.a. palliatus* spent the most time (30.6%) resting, feeding (28.5%), moving (26.2%), and socialising (14.7). Whereas males spent much of their time by 0.3%, 0.8% and 1.0% in feeding, resting, and moving, respectively. Females spent more time, by 5.7%, in socialising than males. The resting, moving and socialising activities differed significantly ($p<0.05$) across age groups**.** The adults spent much of their time resting (8.4%) and feeding (8.1%); sub-adults spent much of their time resting (7.8%) and feeding (7.0%). Juveniles spent much of their time resting (7.0%) and moving (6.6%); infants much of their time was spent socialising (6.2%), resting (6.2%) and moving (6.1%). The ANOVA results for activities across age groups differed significantly: Feeding ($F=53.88$, $p<0.05$); Resting ($F=43.47$, $p<0.05$); Moving ($F=53.39$, $p<0.05$); Socializing ($F=118.2$, $p<0.05$. The lower *C. a. palliatus* abundance in disturbed sites was attributable to low food availability and habitat degradation. The overall variations in activity patterns across age and sex groups were attributable to energy conservation strategies and body size. Increasing conservation efforts in disturbed areas in UMNP was recommended to improve *C.a. palliatus* population sustainability.

Keywords: *C. a. palliatus, disturbance, Habitat, Udzungwa Mountain National Park.*

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LIST OF ABBREVIATION

ANOVA	Analysis of Variance
CITES	Convention on International Trade in Endangered Species of Wild Fauna and Flora
COSTECH	Commission for Science and Technology
EAM	Eastern Arc Mountains
GIS	Geographical Information System
GMP	General Management Plan
GPS	Geographical Positioning System
ITCZ	Inter-tropical convergence zone
IUCN	International Union for Conservation of Nature
NHP	Non-human primates
PA	Protected Area
PAST	Paleontological Statistics
TANAPA	Tanzania National Parks
TAWIRI	Tanzania Wildlife Research Institute
UEMC	Udzungwa Ecological Monitoring Centre
UMNP	Udzungwa Mountains National Park
WBH	World Biodiversity Hotspots

CHAPTER ONE

INTRODUCTION

1.1 Background of the Study

The Angolan Black and White Colobus Monkey (*C.a. palliatus*) is a medium-sized black-coloured monkey with white hairs on the throat and cheek, a white brow band, long-haired white epaulettes on the shoulders, and white hairs on the tail. The species is characterised by a reduced or absent thumb and prominent ischial callosities (a callus or piece of skin thickened due to repeated contact and friction occurring on the animal's buttocks). Like all black-and-white colobus, the Angolan colobus has black fur and a black face, surrounded by long, white locks of hair. It also has a mantle of white hair on the shoulders. The long, thin tail can be either black or white, but the tip is always white. There is a significant regional variation in the total amount of white on the body and the length of the fur (Groves, 2007).

The Angolan colobus animals are said to live in the mountains. Generally, they have longer, thicker fur than animals from the lowlands, which are used to protect them against the cold. The Angolan colobus has a head-body length of 50 to 70 cm, with the males usually larger than the females. The tail is about 75 cm long, and the body weight varies between 9 and 20 kg. All *Colobus* species are very sociable and live in groups of up to several hundred animals, although most groups are much smaller. Their diet consists mainly of leaves and lesser amounts of fruit and seeds (Briggs and Booth, 2010).

The *C.a. palliatus* is distinguished from its closest relative, *C. guereza,* by possessing a u-shaped cape of white hairs flaring out only at the shoulders. In

contrast, the latter has white hair running from the shoulder to the lower back (Kim, 2002). The Black and White Colobus Monkeys are social animals that live in troops of six (6) to ten (10) individuals. The group is led by a female or matriarch (Estes, 1992). The troops' home range ranges from 5 ha to 25 ha (Kingdom, 2008).

The Colobus Monkeys are widely distributed in Africa's tropical and montane forests. They occur in dense rainforests in the lowlands and coastal mountains, particularly in the Congo Basin and to the south and northeast of the Congo River, as far as Ruwenzori, Burundi and south-western Uganda. They can also be found in East Africa, especially in Kenya and Tanzania's interior and coastal forests and isolated mountain areas. Although the species is named after Angola, it is quite rare in that country. The Angolan colobus is most abundant in the southernmost latitudes of all *Colobus* species. They can also be spotted up to 2,415 m above sea level in Kenya (Anderson et al., 2007; Cowlishaw and Dunbar, 2000).

The monkeys are also notable in the riparian forests, where they live and feed in the closed and open canopies high above the ground but come to the ground occasionally to pick the fruits (Groves, 2007). In Africa, there are two groups of *Colobus* species: Black and White Colobus Monkeys and Abyssinian Colobus. The first group includes King Colobus (*Colobus polykomos*), Angolan Colobus (*Colobus angolensis palliatus*), and guereza (*Colobus guereza*). The second group comprises Black Colobus (*Colobus satanas*), Red Colobus (*Colobus badius*), and Kirk's Colobus (*Colobus kirkii*) (Napier and Napier, 1985). In Tanzania, Angolan Black and White Colobus (*Colobus angolensis palliatus*) is widely distributed in the south-western areas, specifically in Rungwe Mountains and Lake Rukwa and in the

montane forests of the southern and eastern highlands of Tanzania, namely Uluguru, Nguru, Usambara, and some coastal and riverine lowland forests.

The growing human population and demand for forest resources and agricultural land have put colobus monkeys under pressure (Anderson et al., 2007). Colobus Monkeys provide meat and skin and also attract ecotourism (Von Hippel et al., 2000). These benefits jeopardise colobus monkeys and their habitat, and they are on the verge of extinction. The major threats to the colobus monkey, specifically the Angolan Black-and-White Colobus are habitat loss and forest fragmentation caused by forest logging for agriculture, settlements, mining, infrastructure, and tourism development (Anderson et al., 2007). Deforestation results in a mosaic of forests at varying stages of succession. Habitat fragmentation serves as an ecological barrier as the species need large home range for their abundance (Kanga and Heidi, 2000).

With the continuance of the habitat fragmentations, there is a need for understanding the primates' activity pattern and home range as this is very contingent on conserving the remaining habitats. Many scholars (see, for example, Lopez et al., 2016; Starr, 2019; Perkin, 2019 and Kitegile et al., 2021) have studied the activity pattern of monkeys in the locality, but their focus has been on specific issues only. Few studies (if any) have had wide coverage regarding the primate abundance, activity patterns and home range in Udzungwa Mountains National Park. Thus, there is a need to address these issues by using the locality as a case in question. It should be understood that the UMNP is one of the ecologically isolated habitats suitable for this study, and the results can inform conservation policies in Tanzania.

1.3 Statement of the Problem

The Angolan black-and-white colobus evolution and survival are associated with dense rainforests found in lowlands and coastal mountains (Anderson et al., 2007). Their abundance and richness are associated with dense forests. Food availability in these forests has decidedly influenced their abundance and richness. These conditions are readily available in the Udzungwa Mountains as the continuity in the canopy coverage in the locality provides primate excellent-ranging sites. However, recently, the Udzungwa Mountains have witnessed increased immigration of humans and establishments of permanent settlements in its vicinities.

There have also been increased farming encroachments on the locality that have induced habitat fragmentations. These activities have far-reaching impacts on the *C.a. Palliatus* abundance, richness, and range patterns. Although the problem is evident, there have not been enough empirical studies explicitly addressing the impact of the resulting habitat fragmentation on the species diversities, activities and ranging patterns. Understanding the species abundance and activity patterns under the current continued habitat fragmentation is paramount for conservation and tourism promotion.

1.4 Objectives of the Study

1.4.1 General Objective

The study aims at understanding the abundance and activity patterns of the Angolan Black and White Colobus Monkey (*Colobus angolensis palliatus*) in Udzungwa Mountains National Park in Tanzania, so as to bring about concern in conservation strategies.

1.4.2 Specific Objectives

i. To determine the abundance of *C.a. palliatus* in Udzungwa Mountains National Park.

ii. To analyse the activity patterns across sex groups of *C.a. palliatus* in disturbed and undisturbed areas in the Udzungwa Mountains National Park.

iii. To analyse the activity patterns across age groups of *C.a. palliatus* in disturbed and undisturbed areas in the Udzungwa Mountains National Park.

1.5 Hypotheses

i. The abundance of *C.a. palliatus* differs in disturbed and undisturbed areas in the UMNP

ii. The activity patterns of *C.a. palliatus* differs across sex groups in disturbed and undisturbed areas in UMNP.

iii. The activity patterns of *C.a. palliatus* differ across age groups in disturbed and undisturbed areas in UMNP.

1.6 Significance of the Study

The outcome of this study was intended to contribute to the body of knowledge on how habitat fragmentation impacts the Angolan Black and White Colobus monkey abundance, diversity and activity patterns. It also would inspire policymakers to increase efforts on the natural habitat protection for the said primates. Proper protection of the primate environment is economically viable as it assures the nation's economic growth. Since independence, Tanzania's tourism sector has enjoyed sustained growth, with a significant contribution to the Gross Domestic Product (GDP) and the Gross National Product (GNP).

The Angolan Black and White Colobus monkey is among the tourist attractions that demand the attention of the state due to the threats they experience from the continuance of its habitat degradation. The assessment of changes in abundance and activity pattern of the primate using targeted key species (*C.a. palliatus*) is likely to inform the park managers equally to conserve the area despite tourism being the primary source of income for conservation. The study was timely to contribute to the ongoing review of 2012 -2022 General Management Planning for sustainable, integrative tourism-conservation strategies.

1.7 Scope of the Study

This study compares the Angolan black and white Colobus abundance and activity patterns in two localities of the UMNP high-use zone and low zones to determine the primate activity pattern and abundance. The UMNP high zone is highly disturbed by anthropogenic activities, while the UMNP low zone is least disturbed. The aim was thus to deduce the impact of habitat fragmentation on the species abundance and diversity to inform policymakers on the extent to which habitat fragmentation affects the species biodiversity. UMNP covers a large tract of land with different microclimates that influence the existence of various primates' habitats.

For that much, the outcomes of this investigation do not necessarily reflect the reality existing in and around the UMNP but rather concentrate on assessing the abundance of *C. a. palliatus* at the UMNP high-use zone, while the UMNP low zone was used for the comparative purpose. Thus, the study assessed only one group of C.a. palliatus for its activity patterns, and results were envisaged to apply to the targeted species.

1.8 Organization of the Dissertation

The dissertation is presented in four chapters. The first introduction chapter includes the background of the study, a statement of the problem, the research objectives and hypotheses. It also presents the rationale and scope of the study that defines the boundaries to which the study results apply. The literature review presented in the second chapter includes a definition of key terms, a theoretical and empirical review, the research gap, and the conceptual framework. The research methodology forms part of chapter three, covering the study area descriptions, research approach, sampling design, methods of data collection, and analysis. Chapter four presents the study's findings and a discussion in chapter five. The sixth chapter provides the conclusion and recommendations.

CHAPTER TWO

LITERATURE REVIEW

2.1 Conceptual Definition of Terms

2.1.1 Activity Pattern

Activities patterns are determined by the habitat types in which the primates live (Cristobal-Azkarate, et al., 2007). Such patterns and actions are influenced by the availability of food, water, cover, breeding sites and other environmental factors (Riley, 2007, Wijtten, 2012). Because primates live in various habitats, their activity pattern depends on group size, site, time, individual variation, and time of the year (Fashing, 2001; Teichroeb, et al., 2003). Such activities include feeding, grooming, playing, and moving (Fashing, 2001). In this study, the primate activity pattern is defined by Cristobal-Azkarate et al. (2007).

2.1.2 Abundance

In ecology, abundance is defined as the relative representation of a species in a particular ecosystem (Preston, 2002). It is measured as the number of individuals found per sample. The abundance ratio of one species to one or multiple other species living in an ecosystem is referred to as relative species abundance. Both indicators are relevant for computing biological diversity. This study applied the term primate abundance following the above definition.

2.1.3 Ranging Patterns

In this study, the term ranging pattern is understood as the behaviours among primates, including home range, size and daily travel distances as conceived by Clutton-Brock and Harvey, (1977) and Milton and May (1976). Many factors,

including food resource quality and quantity and their associated distribution patterns (Ceccarelli et al., 2019; Erinjery et al., 2015; Reyna-Hurtado et al., 2018), predation risks (Gorini et al., 2012; Stephens et al., 2007), and climatic factors (Wong et al., 2013; Zhao et al., 2019). influence this behaviour (Albert et al., 2013; Richard, 1985). In this study, the term has been used in line with the above definition.

2.1.4 Habitat Fragmentation

Habitat fragmentation hereby refers to the emergence of discontinuities in a primate-preferred habitat, which in turn causes primate population decrease and ecosystem decay. Such phenomena could be attributed to geological processes, anthropogenic and climate change impacts that slowly alter the layout of the physical environment (Sahney et al., 2010) and human activity, such as land conversion, which transforms the environment of many species. More specifically, habitat fragmentation is the process by which large and continuous habitats get divided into smaller isolated patches of habitats (Fahrig, 2019).

2.2 Theoretical Literature Review and Theoretical Framework

2.2.1 Classification of *C.a. palliatus*

The primate under this study is among the old-world monkeys, in subfamily Colobinae, genera *Colobus* and a sub species of *Colobus angolensis* known as Angolan Black and White Colobus Monkey (*Colobus angolensis palliatus*). The classification of primates can be divided into the New and Old-World Monkeys. The New World Monkey is the common name for infraorder Platyrrhini, whilst Old World Monkey is the common name for superfamily Cercopithecoidea (family

Cercopithecidae), which is limited to living species. The taxon including Old World Monkey at the same taxonomic level as New World Monkey is infraorder Catarrhini. Catarrhini includes Hominoidea (humans and apes), as well as Cercopithecoide (Benefit, 1999; Fleagle, 1999). Cercopithecoidea encompasses the families Victoriapithecidae and Cercopithecidae.

The Old-World Monkey is defined as possessing synapomorphy, which is a derived character shared by two or more groups; it is a monophyletic taxon characteristic (Benedict, 1999; Fleagle, 1999). The family of the living Old World Monkeys Cercopithecidae includes the subfamilies Cercopithecinae and Colobinae. Subfamily Colobinae is normally divided into African colobines (subtribe Colobina) and Asian colobines (subtribe Presbytina). Included in African colobines are genera *Colobus* (Black-and-white Colobus monkey), *Procolobus*, and *Piliocolobus*. The genus *Colobus* comprises of five species, the *Colobus satanas* (black colobus), *Colobus guereza* (Guereza colobus), *Colobus polykomos* (King colobus), *Colobus vellerosus* (white thighed colobus) and *Colobus angolensis* (Angolan colobus).

2.2.2 Characteristics of *C.a. palliatus*

Colobus monkeys are medium-sized, arboreal monkeys with slender bodies and long tails. The five recognized species of Colobus share the following characteristics: a reduced thumb, prominent rump callosities, and a complex stomach, which aids in the digestion of cellulose. Angolan colobus monkeys have long, silky hair. They are black with a white brow band, cheeks, and throat. They have long-haired white epaulettes on the shoulders, and the lower half of the tail is white. The tail length is

706 mm for females and 829 mm for males, and the head and body length ranges from 490 to 680 mm. Mass varies between 6 and 11.4 kg, with males slightly larger than females. Young are born completely white and begin changing to their adult pelage at about three months of age (Rowe, 1996; Wisconsin Primate Research Center, 2000). The *C.a. palliatus* is distinguished from its closest relative, *C. guereza*, by possessing a U-shaped cape of white hairs flaring out only at the shoulders. In contrast, the latter has white hair running from the shoulder to the lower back (Kim, 2002).

Figure 2.1: Physical appearance of *C.a. palliatus* and *C. guereza*

2.2.3 Ecological Range of *C.a. palliatus*

The Colobus Monkeys have a wide distribution in tropical and mountain in Africa. They can be found in forests from Senegal to Ethiopia and from Angola through Zaire to Tanzania and Malawi. They are also found in riparian forests where they live and feed in the closed and open canopies high above the ground but come to the ground occasionally to pick the fruit (Groves, 2007). In Africa, there are two groups

of Colobus species, which are Black and White Colobus Monkeys and Abyssinian Colobus. The first group includes King Colobus (*Colobus polykomos*), Angolan Colobus (*Colobus angolensis palliatus*) and guereza (*Colobus guereza*) and the second group comprises Black Colobus (*Colobus satanas*), Red Colobus (*Colobus badius*) and Kirk's Colobus (*Colobus kirkii*) (Napier and Napier, 1985).

The Angolan Black and White Colobus (*Colobus angolensis palliatus*) is found in a broad swath from Angola across central Africa to Tanzania and the Kenya coast, mainly south of the Congo River but extending north east to the Ituri forest (Groves, 2007). In East African parts of the range, they are discontinuously distributed wherever there is sufficient forest cover. In Kenya, they are extremely distributed in south eastern part, the Diani Beach, Shimba Hills and Mrima Hill (Groves, 2007). In Tanzania, the south western localities are the Rungwe Mountains and Lake Rukwa; they also occur in the montane forests of the Southern and Eastern Highlands of Tanzania, Ulugurus, Ngurus, Usambaras and some coastal and riverine lowland forests (Groves, 2007).

2.2.4 Behavior of *C.a. palliatus*

The *C.a. pallaitus* are diurnal and arboreal monkeys (Anderson et al., 2007). They occasionally come to the ground near streams to eat herbaceous vegetation but prefer to remain higher in the canopy. They are the most arboreal of all African monkeys. They typically live in relatively small social groups of one adult male and normally two to six females with their young (Kanga & Heidi, 2000; Anderson et al., 2007). Larger troops generally have more than one resident male. The dominant male controls reproductive access to the females within his troop and defends the troop

from predators whereas the dominant female leads the troop. When a troop is threatened by a predator, the male jumps and roars until the rest of the troop has fled (Rowe 1996, Fimbel 2001). Young males in the group are forced to leave before they reach breeding age but may also challenge the dominant male for control of the females. Groups defend a relatively small core home range from other troops of Colobus monkeys. Morning roaring contests between dominant males may help to maintain group spacing (Nowak, 1999).

The Colobus monkeys reproduce throughout the year, and a single offspring is born, but twins are also possible. The young are cared for by their mothers and other members of the troop and are weaned at the age of about 15 months (Rovero et al., 2006). A comparison study of dietary diversity and behavioural plasticity for *C.a. palliatus* was conducted in the East Usagara Forest, Tanzania. The study suggested that *C.a palliatus* exhibits remarkable dietary diversity and may alter its behaviour to cope with food availability (Dunham, 2011). The study conducted by Griffith (1999) in Mount Meru National Park on the behavioural ecology of *C.a. palliatus,* particularly on resting, feeding and moving, revealed that a small size group was seen to spend more time foraging, related to the proportion of adult females within the group who foraged longer than any other age/sex class (Griffith, 1999).

The *C.a. palliatus* has no cheek pouches, but the stomach is enlarged and divided into compartments (Estes, 1992). In turn enables them to digest large quantities of mature leaves by fermentation (Estes, 1992). The species is termed folivorous, meaning that the diet consists of both young and mature leaves, fruit, flowers and woody twigs. They concentrate on a few tree species and are capable of surviving

on a diet consisting almost entirely of mature leaves (Napier and Napier, 1985).

2.2.5 Abundance of *C.a. palliatus*

Literature has shown that the Angola Colobus are still found in most of the Congo Basin, to the south and northeast of the Congo River, as far as Ruwenzori (Uganda), Burundi and south-western Uganda. The species is also located in East Africa, especially in Kenya, Tanzania, and isolated mountain areas. Although the species is named after Angola, it is rare in that country. Angola colobuses live in dense rainforests in the lowlands and coastal mountains. These monkeys are found in various habitats, including lowland rainforests, upland montane and bamboo forests, and sometimes in savannas and swamplands. The African continent harbours approximately 30 per cent of primate species (IUCN, 1996), of which the majority can be found in Cameroon, the Democratic Republic of Congo, Nigeria, the Peoples' Republic of Congo, Equatorial Guinea, and the Central African Republic.

In Kenya, the primates were estimated to be between 3,100 and 5,000 individuals (560–900 groups). Angola colobuses are classified as Least Concern (LC) on the IUCN Red List. The habitat of primates is mainly forested, and African forests have been highly dynamic, experiencing several cycles of expansion and in many regions, forests have persisted in fragmented form (Hamilton and Taylor (1991). As a result, large-scale, historical processes such as speciation, extinction, and dispersal have been critical in shaping the current patterns of primate distribution on the continent (Lawes and Eeley, 2000). Primate habitats span a range of altitudes. For example, the *Rhinopithecus bieti* has been found living in the Hengduan Mountains at altitudes of 4,700 m. The Gorilla beringei beringei can be found at 4,200 m crossing the

Virunga Mountains. The *Eropithecus gelada* is found at up to 5,000 m in the Ethiopian Highlands (Long, et al., 1994).

The conditions at the origin largely influence species diversification and during the subsequent history of the clade (Romdal, et al., 2013). The conditions are currently associated with higher levels of species richness provided the main environmental factors determining that clade's distribution and diversification. Additionally, current conditions and events such as anthropogenic changes in habitat and climate continue to influence species diversity by removing species from some areas and adding them to others (Vitousek, et al, 1997). Accounting for 25 per cent and 40 per cent of the fruit-eating animals (by weight) within tropical rainforests, the primates play an important ecological role by dispersing seeds of many tree species (Chapman and Russo, 2007).

The abundance of *C.a. palliates* has been studied in different parts of Africa. Anderson, et al (2007) assessed the occurrence and abundance patterns of *C.a. palliatus* in 46 coastal forests in the Kwale District, Kenya. The study concluded that the occurrence of colobus is positively associated with canopy cover. Marshall et al. (2005) studied monkeys' abundance and social structure in two high-elevation forest reserves in the Udzungwa Mountains of Tanzania. The study showed that the abundance of *C.a. palliatus* and *Cercopithecus mitis* had no relationship with elevation. Globally, primate populations are dramatically impacted by logging, deforestation, hunting, and other such factors. As a result, wild populations of most non-human primates (NHPs) are decreasing worldwide, and many thousands of primates are killed yearly for different purposes (Mittermeier, et al, 1986).

2.2.6 Primate Activity Patterns

Primates' activities are determined by the habitat types in which they live (Cristobal-Azkarate, et al, 2007; Fashing, et al. 2007; Riley, 2007; Wijtten, 2012). Activity pattern is influenced by the availability of food, water, covers, and other environmental factors, such as climate, competition, and safety (Cristobal-Azkarate, et al., 2007; Riley, 2007 Fernandez-Duque, 2003). Because primates live in various habitats, their activity patterns depend on group size, site, time, and individual variation (Wijtten, 2012; Fashing, 2001). The activity patterns of the primates also vary based on age, group size and sex, as some time is spent on feeding, grooming, playing, and moving (Teichroeb, 2007).

Mountain forest colobus monkeys spend up to twice as much time feeding and six times moving, but less time resting, compared to colobus monkeys in coastal areas (Fashing, et al., 2007 and Wijtten, 2012). Feeding activities tend to increase from morning to evening, major movements occur in the late afternoon, and resting stays constant throughout the day (Teichroeb, 2003). Sexes differ in activity. For example, females spend much time grooming and moving, while aggression is much more common in males than females (Fashing, et al., 2007; Teichroeb, 2003 Fashing, 2001). Infants tend to spend more time playing and less time grooming than adults. Adult male colobus monkeys spend more time defending the territory (Fashing, 2001).

Variation in activities is thus related to the strategies primates employ to budget their energy (Kingdon, 2008; Stanford, 1991; Dasilva, 1992; Milton, 1998). Similarly, the activities of black-and-white colobus monkeys and energy conservation strategies

differ from one group to another, even within the same site (Teichroeb, *et al*., 2003; Isbell and Young, 1993; Harris and Chapman, 2008). Also, energy management can vary between seasons and sexes (Fashing, et al. 2007; Teichroeb, *et al.*, 2003; Dasilva, 1992). The diversity in activities of black-and-white colobus monkeys might be due to energy conservation (Wijtten, et al., 2012; Dasilva, 1992).

A study conducted in the East African coast forests revealed that the black-and-white colobus monkeys tend to move short distances and spend much of their time resting and feeding on available abundant food materials (Wijtten, *et al*., 2012; Fashing, 2001; Oates, 1977). Results obtained from various studies show that activities like grooming, vigilance, greeting, and playing take less time for black-and-white colobus monkey than resting and feeding (Fashing, et al, 2007; Wijtten, et al., 2012 and Fashing, 2001). The number of individuals present in the group of primates can also influence activities. Individual vigilance declines with group size (Isbell and Young, 1993).

Other scholars argue about the behavioural thermoregulation in colobus monkeys, that they spend much of their time resting and remain inactive for much of the day. However, many studies are needed to prove this (Fashing, 2001). Habitat loss is the primary threat facing species worldwide (Cronk and Fuller, 1995; Wong, 2010). The loss of habitats results from habitat destruction, mainly influenced by human activities and other inevitable factors such as climate change (Wade, 2003). One of the habitats which humans have degraded is tropical forests, with a loss of 1.1 per cent annually (FAO, 2000), or 9.4 million hectares per year (Wong and Sicotte, 2007), accompanied by fragmentation of remaining forest (Wong and Sicotte, 2007;

Mbora and Meikle, 2007). Loss of forest results in habitat fragmentation (Fashing, 2001; Jansson, 2011).

Despite all evidence of habitat loss, the black and white colobus is the least concerned (LC) by IUCN (Jansson, 2011). Nevertheless, numerous species of primates, including the endangered species, inhabit lower-quality forest habitats (Wong and Sicotte, 2007). Studies on primate behaviour and ecology in fragmented forests like that in UMNP can inform decision-makers on the need for quality habitats for primates (Wong and Sicotte, 2005). In high-quality habitats, primates spend less time travelling and foraging (Boyle, 2008; Onderdonk and Chapman, 2000; Jensz and Finley, 2011). Much time is likely to be spent in reproduction, thus increasing the abundance.

2.2.7 Theoretical Framework

This study was guided by two theories: the Island biogeography and the Intermediate Disturbance Hypothesis (IDH).

2.2.7.1 The Island Biogeography Theory

The island biogeography theory predicts that the number of plant and animal species on an island is related to the area of the island's landmass and the degree of isolation of the island. This study describes habitat loss as the outright destruction of natural ecosystems, an inevitable consequence of expanding human populations and human activities. As such, the theory of island biogeography advanced by MacArthur and Wilson (1967) offers a good explanation of how habitat loss affects species abundance while at the same time influencing the activity pattern and home range of

a specific species. In turn can cause species extinctions. The theory postulates that the number of plant and animal species on an island is related to the area of the island's landmass and the degree of isolation of the island. It infers that smaller, more isolated islands have fewer numbers of plant and animal species. In light of this theory, an island is more than just a piece of land surrounded by water. Ecologically, an island is an ecosystem surrounded by non-similar ecosystems. It may include mountain peaks, a lake surrounded by a desert, a patch of woodland, or even a national park. In this case, the UMNP is also an ecological island.

In this regard, the theory provides a model to explain the richness and uniqueness of species, both plants and animals, found in an isolated area. The two events that determine how many species are found in an isolated ecosystem are immigration and extinction. Research has shown that the island's size and distance from the mainland greatly influence the number (richness) of species found there. Once species have established themselves on an island, the rate at which they will go extinct depends on the size of the island, with there being less likelihood of extinction on larger islands. This is called the species-area relationship. This relationship is not just observable, but it could be predicted mathematically. By the same theory, the farther an island is from the mainland, the fewer species it tends to harbour. It is referred to as the species-distance relationship.

Island biogeographic theory has been applied to many kinds of problems, including forecasting faunal changes caused by fragmenting previously continuous habitats. It has proven to be useful in the understanding of the effects of habitat fragmentation. It is used here as a lens for the understanding of the impact of human encroachment

on the *C. a. palliatus* monkey in terms of their abundance and activity ranging in the study locality.

2.2.7.2 The Intermediate Disturbances Hypothesis

The Intermediate Disturbance Hypothesis (IDH) is the hypothesis which tries to describe disturbances in ecological phenomena. The hypothesis focuses on events of ecological succession, biodiversity, ecosystem functions and productivity of communities which occur as consequences of disturbance. It is one of the most well-known hypotheses and is widely applied, especially for managing terrestrial and marine national parks (Svenson, 2010; Connell, 1978). The origin of the IDH was the earlier works of Eggeling, Odum and Horn. The distinct underlying mechanisms of the IDH were described by Grime (1973) and Osman (1977). Mathematical modelling evaluated the hypothesis and was supported in laboratory and field studies in terrestrial, freshwater and marine communities. The hypothesis asserts that the species diversity of an ecosystem will reach its maximum at intermediate levels of disturbances.

It claims that at low levels of disturbance, species diversity of an ecosystem is low because the competitively inferior species will be overcome by strong competitors, leaving few species. At medium levels of disturbance, the mortality rates of strong competitors will also be high, and more space will be available to competitively inferior species, establishing co-existence between species. At high levels of disturbance, the mortality rates increase, and species recruitment cannot compensate for the loss; therefore, species diversity will decrease (Svenson, 2010; Willig and

Presly, 2018). Thus, the disturbance at intermediate levels results in high biodiversity, allowing both species to colonize. The IDH is primarily concerned with richness, i.e., the number of species. There is, however, another aspect of diversity: the relative abundance of species, evenness, which is also of great interest for the structure and function of biological assemblages. Even though richness and evenness are two essential aspects of diversity, it is not evident that both respond similarly to varying intensities of disturbance.

The IDH can thus be used to predict the patterns of species richness and re-colonization in the event of disturbance. Alternatively, it can be used in restoring projects to reach their maximum number of species by exposing them to intermediate levels of disturbances. In restoration projects, disturbance cycles are used to restore ecosystem functioning. But again, the hypothesis can be used to understand the role of biodiversity in highly disturbed terrestrial environments (Connell, 1978; Svenson, 2010; Wootton et al., 2009).

However, it is essential to note that although the ecosystems reach high biodiversity due to disturbances, adaptation to disturbances is only reached after a long period. There may be certain anthropogenic disturbances that may cause severe damage to ecosystems, and species diversity could behave exceptionally to the IDH-predicted pattern. Species have less adaptability to anthropogenic disturbances (Connell, 1978). Another criticism of the hypotheses is that they are too simplistic in empirical and theoretical studies (Huxham et al., 2000). Furthermore, high levels of disturbance do not negate the importance of competition (Violle et al. (2010). Miller et al. (2011) have identified co-existence regions for not only peaked but also

increasing and U-shaped relationships between diversity and increasing frequency and intensity of disturbance. Nonetheless, the IDH is still used as an important tool in ecological science and management.

This study utilised both theories to study the Angolan Black and White Colobus Monkeys' abundance, activity and ranging pattern. The Island biogeography theory addresses the issue of abundance in terms of the location and size of the habitat. At the same time, the IDH provides insights into where the individuals should be located. It also adds value to the study by addressing species co-existence. Together, they have been used to define the study's course and methodology.

2.3 Empirical Review

In accordance to a study conducted by Eustace et al (2015) on Black-and-white colobus monkeys (*Colobus guereza caudatus*) in Rau Forest Reserve showed that they spent much time resting (57.7%), followed by feeding (27.7%) and less time on moving (10.8%) and social activities contribute only (3.8%). Across age groups, adults spent 60.7% of their time resting, while juveniles and infants spent only 50% and 46.1%, respectively. Furthermore, adults spent 21% of their time feeding, followed by juveniles 27.9% and infants 16.9%. Movements were more similar across ages. Sexes differed slightly in their activities, most notably, with females spending almost twice as much time in social activities as males (8.0% vs. 4.3%). This study concluded that the difference in socialization seems to be dictated by the availability of social partners, and resting time in colobus monkeys is a strategy for energy conservation.

In the Kenyan Kakamega Forest, activity and ranging pattern of *C. guereza* was conducted on inter-group variation and implications for inter-group feeding competition investigating the activity patterns of two groups and the ranging patterns of five groups of eastern Black and White Colobus Monkey. The study confirmed that Colobus monkeys in the Kakamega forest spent more of their time resting than any other population of Colobine (Fashing et al., 2000). Likewise, at Nyungwe forest in Rwanda, activity and ranging patterns of *Colobus angolensis ruwenzori* was conducted to see whether there was a variation in activity pattern in large groups. The study showed that *Colobus angolensis ruwenzori* at Nyungwe forest spent far more time feeding and moving and less time resting than *Colobus guereza* at any other sites (Fashing *et al*, 2007).

A study conducted by Wijtten, et al., (2012) on activity budgets of *C.a. palliatus* in a coral rag forest, Mbuyu Tundu, Kenya, of a group size 5.6±2.7 observed that resting, feeding, moving and socializing took up 64%, 22%, 3% and 4% of their time, respectively. It was also found that males significantly spent more time feeding than females. In contrast, females did so in resting, and there was no significant difference in moving activity between the sex groups. This study generally concluded that activity levels and group sizes are low compared to those for other populations of *Colobus* species and suggested that *C.a. palliatus* often live under low preferred-food availability conditions and, as a result, are adapted to lower activity levels.

Yet another study on troops of *C.a. palliatus* living in the forests of Diani, a highly developed area on the Kenyan coast, was conducted by O'dwyer (2011); the study

investigated differences in behaviours between three troops inhabiting pristine forest patches and three troops occupying highly degraded forest areas. The troops in the degraded forest areas spent more time in the morning foraging than the troops in the pristine forests, which may be related to diet. The troops in the pristine forests foraged mostly from native plants, and the troops in the degraded forest areas foraged more from exotics than the troops in the pristine forests.

The troops in the degraded forest areas also had a higher dietary diversity per observation period than the troops in the pristine forests. Ranging behaviours differed between forest types, possibly reflecting home range quality. The troops in the pristine forests' home ranges were slightly bigger than the troops in the degraded forest areas' home ranges on average. Home range overlap was a lot higher for the troops in the degraded forest areas, and the troops in the degraded forest areas had to travel further each day. Overall, the troops in the pristine forests seemed to be in better shape than the troops in the degraded forest areas. It was concluded that if habitat fragmentation continues in Diani, then these highly florivorous monkeys will have a hard time adapting.

2.5 Research Gap

Africa has been rich in primates due to its geographical location close to the equator. The area provides diverse weather conditions and topography favouring different colobus Monkeys. However, the ongoing rates of forest loss, increased human population, and urbanisation have affected monkey habitats. Research that has been conducted for the past decades over the subject of the study localities (see, for example, Lopez et al., 2016; Starr, 2019; Perkin, 2019 and Kitegile, et al., 2021)

have not been able to establish the knowledge regarding changes in abundance, activity and ranging patterns for primates. Understanding how colubus monkeys are affected by habitat fragmentation is essential for conservation. It is crucial in isolated areas, like Udzungwa Mountain National Park, surrounded by humans. Despite the importance, few researchers (if any) have a focus on the subject matter raised above. Studies on related problems (Eustace, et al, 2015 Mclester et al., 2019) do not explicitly link how habitat fragmentation affects the primate's abundance, activities and ranging patterns.

2.6 The Conceptual Framework

The conceptual framework was adopted from Maarten *et al.,* (2018) to describe the impact of human activities on the primate habitat and how the same affects the primate's abundances, activities and ranging patterns. The conceptual framework (Figure 2.1) summarises the main established network and the internal interactions that can take place in either the settlement or habitat networks. These include the interactions within human settlement networks and interactions within habitat networks. The interactions and influences are significant in capturing the complexity of the dynamics within this social-ecological system, which impacts the primate's abundance, activities, and ranging patterns (Kivunja, 2018).

Figure 2.2 illustrates conceived influencing factors that determine the Angolan Black and White Colobus's abundance, activity and raging pattern. Population size and growth around the UMNP is the decisive factor in the sustainability of the primate habitat. The increasing population in rural areas, coupled with other ecological factors such as globalisation and climate change, is pushing the rural communities to

seek livelihoods in and around the area, thereby inducing resource competition with the primates. Poverty also drives people toward encroaching on the resources and establishing different livelihood activities within and around the park vicinities, resulting in the degradation and fragmentation of the primate's habitats

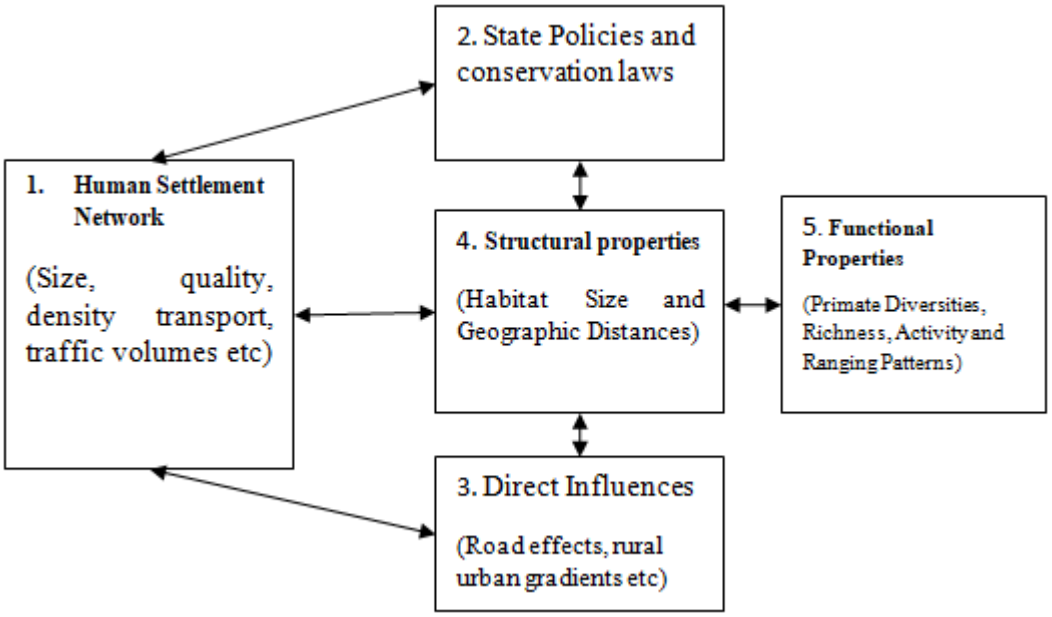

Figure 2.2: The Conceptual Framework

Source: Adopted and modified from Maarten et al, (2018)

The state policies since colonial times had functioned as the governor for the mobility of the people. They also operate to restore the primates' habitats. However, globalisation issues and poverty are pushing hard people to the Park's edge. Thus, localities where policies have successfully restricted people's entry into the park record primate abundance and high ranging pattern, while localities highly disturbed limiting the activity and ranging pattern of the primate.

Increasing human encroachment to the National Park is also influenced by the recent recorded development in the area, accompanied by infrastructural improvements.

The construction of tarmac roads across the national Park has facilitated easy movement and settlements of the rural communities from other regions. It has also increased the rural-urban gradients. Urban demands for wildlife materials such as timber, poles, charcoal and the like increase further human encroachments. It is resulting in the increased degradation of wildlife resources and further habitat fragmentation. Such actions negatively impact the primate abundance, activity and ranging pattern.

The habitat size and geographical distances determine the structural properties. As per island biography theory, species abundance is a function of the size of the habitat and its relative location. In this study, species abundance declines will be experienced in areas that are more disturbed compared to the least disturbed areas. Similarly, the activity and ranging pattern will be determined by the size and condition of the habitat. The functional properties are thus the state of the habitat. Diversity, richness, activities and ranging patterns are determined by the state of the habitat. In less disturbed areas, species richness will be high, provided the habitat is still intact or not much fragmented by human interference.

CHAPTER THREE

RESEARCH METHODOLOGY

3.1 Overview

This chapter addresses the study area and the methodology employed to accomplish the same. It starts with the presentation of the research design used by the study. Then, describe the area in which the study area. A data collection procedure follows the target population and sampling procedure. It ends with a description of data analysis and tools and reasons behind the use of the same.

3.2 Research Approach

This study employed field ecological surveys to determine the abundance and activity patterns of *C. a. palliatus* monkeys. The inferential statistical tests were used to determine the cross-age and sex group differences in activities as well as between sites abundance (Kothari, 2004). Furthermore, this is field survey research where a population sample is studied to determine its characteristics (Kothari, 2004).

3.3 Description of Study Area

The study was conducted in Udzungwa Mountains National Park (UMNP) in the high-use zone. The park is a part of the Eastern Arc Mountains (EAM) of Tanzania and Kenya, known for their exceptional biodiversity of plants and animals, including endemic species. Udzungwa Mountain National Park (UMNP), established in 1992, covers an area of 1990 km^2 (GMP, (2014) and extends into the Kilombero and Kilosa Districts in the Morogoro Region and Kilolo District in the Iringa Region. The Udzungwa Mountains undoubtedly contain the biologically most important area of forest in East Africa and the most critical site for primates in Tanzania (Butynski

et al., 1998). Among the ten primate species, two are of conservation concern. These include the endemic Udzungwa red colobus (*Procolobus gordonorum*) IUCN vulnerable (Hilton-Taylor, 2000), which lives only in lowland forests. Two other species in the Udzungwa Mountains forests are the Angolan Black-and-White Colobus (*Colobus angolensis palliatus*; IUCN data deficient-least concern and Sykes monkey (*Cercopithecus mitis* ssp.). The UMNP is divided into three ecological zones, namely the High Use Zone (27,686.15 ha), Low Use Zone (54,925.71 ha) and the Wilderness Zone (107,842.08 ha) (GMP, 2014).

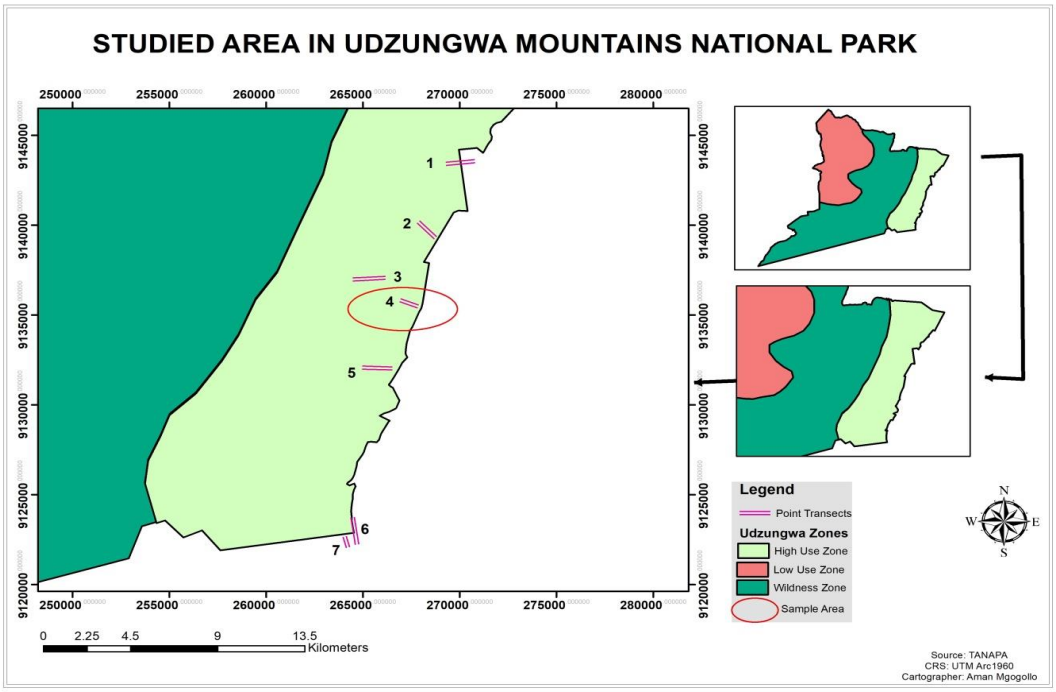

Figure 3.1: A Map of Udzungwa Mountains National Park locating point transects 1-Mkasu, 2-Tazara, 3-Campsite, 4-Sonjo, 5-Mwanihana, 6-Sanje, 7-Msolwa

Udzungwa Mountains are dominated by the forest that extends from the lowland acacia, miombo forest, and Great Ruaha Valley to high montane forests and grasslands (GMP, 2014). The park includes the former Forest Reserves of

Mwanihana, Iwonde, Nyanganje and parts of Matundu and the West Kilombero Forest Reserves. UMNP has a tropical climate with a mean annual temperature of 26.10˚C with bi-modal annual rains produced by the movements of the Inter-tropical Convergence Zone (ITCZ) (GMP, 2014).

Rainfall is seasonal, variable, and relatively abundant compared to the country. The mountain ranges facing the Indian Ocean influence the amount of rainfall received. The short rains start from the end of October to December, and the long rains period is from March to May (GMP, 2014). The mean annual rainfall in the southeast of the park, often covered by mist, is around 2000mm per year. The north-western areas, which lie on the leeward side of the mountain ranges, get only 600mm of rainfall per year (Nyundo, et al., 2006).

3.4 Sampling Procedure

The study was conducted by using point transects. A transect walk is a systematic walk along a defined path (transect) across the study site to observe the species in question by seeing and listening to the vocals or droppings. It can also employ the use of GPS to geo-code the location. Seventeen (17) groups of Angolan Black and White Colobus within the High Use Zone of the UMNP were identified during the reconnaissance survey. Seven-point transects were laid out after simple random sampling; four transects were laid within an undisturbed area, and three transects were laid in the disturbed area.

Counting individuals found within lay transects was done four times monthly to maintain consistency, and an average per transect was computed. The group

determined at Sonjo transect intermingled both in the undisturbed and disturbed area and hence was selected and monitored for one month to achieve the objectives of the activity patterns of *C.a. palliatus* across sex and age groups in disturbed and undisturbed sites. Activity patterns of Colobus Monkey under study were monitored and recorded using a stopwatch. The time spent on each activity was recorded in minutes.

Differentiating age groups of *C. a. palliatus*, typically involves observing various physical, behavioral, and external body developmental characteristics. This study used the criteria described by Estes, 1992 and Eustace et al., 2015 to differentiate age groups in this species:

a) **Infants (Newborn to 1 year):**
    i. **Size:** Infants are the smallest in the group.
    ii. **Coat Color:** Infants usually have a distinct white coat.
    iii. **Attachment to Mother:** Infants cling tightly to their mother's belly or back.
    iv. **Limited mobility:** They have limited locomotor skills and are unable to move around independently.

b) **Juveniles (1-3 years):**
    i. **Growth:** Juveniles grow rapidly and become larger than infants.
    ii. **Coat Color:** Their coat starts to darken, transitioning from white to the characteristic black fur of adults.
    iii. **More Independence:** They become more independent, spending less time attached to their mother.

c) **Subadults (3-5 years)**

i. **Size and Maturity:** Subadults continue to grow and develop physically.

ii. **Coat:** Their coat is mostly black, resembling that of adults.

iii. **Increased Independence:** They become more self-sufficient and may start exploring on their own.

d) **Adults (5 years and older):**

i. **Full Maturity:** Adults reach full physical and sexual maturity.

ii. **Coat:** Their coat is entirely black, with a white or silver beard-like mane, which is more pronounced in males.

iii. **Reproductive Behavior:** Adults are sexually active and engage in mating and parenting behaviour.

On the other hand, *C. a. palliatus* can be differentiated into sex groups primarily based on physical characteristics and sometimes behavioral differences. Here are the criteria used to distinguish between males and females in this species as described by Groves, 2007 and Willig and Presley, 2018:

a) Physical Characteristics

i. **Size:** In most Colobus monkey species, males tend to be larger than females. However, this size difference is not as pronounced as in some other primate species.

ii. **Body Mass:** Males often have slightly greater body mass than females.

iii. **Sexual Dimorphism:** There may be some sexual dimorphism, with males having more developed musculature, including stronger forelimbs.

b. Coloration

Coat Color: In some Colobus monkey species, males and females have similar coat Colours, typically a black body with white fur on their face, hands, and sometimes a white tail. However, the male's white fur on the face (mane) may be more extensive and pronounced than that of females.

c. Behavioral Differences

i. **Social Behavior:** Males may exhibit different social behaviours, such as engaging in more territorial or protective activities and participating in mate competition.
ii. **Mating Behavior:** Males are typically more active in mating behaviour, such as pursuing females and engaging in copulation.
iii. **Parenting Behavior:** Females are primarily responsible for parenting, including carrying and nursing infants.

d. Genitalia

In some cases, the presence of male genitalia, including the scrotum and the testes, can be used to confirm the sex of the individual. This is a reliable method but requires close observation.

When conducting this study, the researcher faced some limitations and challenges associated with sampling methods. These limitations and challenges were limited visibility; whereby the colobus monkeys often inhabit dense forests and canopy areas, making them challenging to observe. This may lead to sampling and detection bias. Strategies to validate data despite limitations involved cross-referencing results

from different methods and using statistical techniques to account for biases and uncertainties. Additionally, peer review and consultation with experts in the field aided in ensuring the accuracy and reliability of the data and findings.

3.5 Data Collection

3.5.1 Abundance of *C.a. palliatus*

The animal counts of *C.a. palliatus* in the disturbed area were carried out at the Tazara campsite and Sanje sites. In contrast, the undisturbed site consisted of four transects, namely Sonjo, Mwanihana, Msolwa and Mkasu. The abundance was assessed by counting individuals observed in each point-transect for four days within the month and the interval between the days in which counting was done seven days break. The activity of counting each day started from 0700 hours to 1200 hours and again from 1400 hours to 1800 hours. The procedure was repeated at all point-transects, and finally, the total number of individuals and group size were computed and recorded.

3.5.2 Activity Patterns of *C.a. palliatus*

One group in the Sonjo area intermingled between disturbed and undisturbed sites. It was selected for focal scanning when studying activity patterns of *C.a palliatus* activity patterns in undisturbed and disturbed areas (Martin, 1998). The activity patterns in this study were categorised into four types: feeding, resting, socialising and moving. Masticating and ingesting plants or prey were considered to fall under the feeding category. At the same time, any activities associated with changing spatial position by walking, running or jumping were referred to as the moving category. Moreover, the type of resting included all activities when the individuals

were physically inactive, either sitting or sleeping. Other activities like playing, grooming, mating, greeting and aggression were included in the social category. Through this method, the group of Angolan Black and White Colobus identified was observed from 0700 to 1200 hours and from 1400 to 1800 hours for group and focal (individual) scanning. This method involved tracking an animal through the trees and recording the activity performed and the time spent in minutes for the particular action (Kangwana, 1996).

3.6 Data Analysis

3.6.1 Abundance of *C.a. palliatus*

The animals' field data were analysed using inferential and descriptive statistics. The abundance data were cleaned and entered in Microsoft Excel 2013. Then, data were analysed using the Paleontological Statistics version 3 (PAST 3) statistical software package. In descriptive statistics, mean, standard deviation, group size and range were computed and presented as tables. Also, relative abundance was calculated and presented on a graph. The Paleontological Statistics software was employed to compare the abundance data between the undisturbed and disturbed areas by using two sampled t-tests. This parametric test was used after the F-test, homogeneity of variance test, revealed no significant difference in variances between the two samples. Also three normality tests (Shapiro-Wilk, Anderson-Darling and Jarque-Bera tests), tested the null hypothesis that the samples have been drawn from a normally distributed population.

3.6.2 Activity Patterns of *C.a. palliatus*

The primary data obtained from the field was analysed by using both descriptive and

inferential statistics. The data were entered and cleaned using Microsoft Excel 2013 and then analysed using the Paleontological Statistics version 3 (PAST 3) software package. In descriptive statistics, the numbers of observations were transformed into percentages and then presented on tables and bar graphs. While inferential statistics employed statistical null hypotheses testing at a significant level $p \leq 0.05$.

The activity patterns data across age and sex groups in the disturbed and undisturbed sites was checked for homogeneity using Levene's (F-test) and three normality tests (Sharpiro-Wilk, Anderson-darling and Jarque-Bera tets) were employed. A t-test and ANOVA were employed to test for variance across different group categories. The Kruskal-Wallis, and Manny-Whitney U test were employed to test for variance for non-parametric data. Afterwards, a Tukey's pairwise post hoc test was used where significant differences occurred between different age groups within a particular activity.

CHAPTER FOUR

RESULTS

4.1 Overview

This chapter presents the findings of the study. Areas addressed in detail include the primate's abundance and their observed field activity pattern.

4.2 The abundance of *C.a. palliatus* in Udzungwa Mountains National Park

Three point-transects in disturbed and four point-transects in undisturbed sites within the UMNP were surveyed, and *C.a. palliaus* data were recorded within 17 social groups. A total of 176 individuals were recorded. The mean of Colobus group size was 47±1.21 (with a range between 9 to 13 individuals) (Table 4.1).

Table 4.1: Abundance of *C.a. palliatus* in disturbed and undisturbed sites *in* Udzungwa Mountains National Park,

Study sites	Point transects	Total	Group size (Mean±SD)	Range
Disturbed	Campsite	20	10	9-11
	Sanje	18	9	8-10
	Tazara	9	9	8-10
Undisturbed	Msolwa	33	11	10-12
	Mwanihana	36	12	11-13
	Sonjo	32	10.67	10-11
	Mkasu	28	9.3	9-10
Overall Disturbed		47	9.4±0.89	9-11
Overall Undisturbed		129	10.75±1.22	10-13
Overall		176	10.47±1.21	9-13

Source: Field Data July-August, 2021

The total individuals comprised of: 26, 44, 35 and 71 infants, juveniles, sub-adults and adults, respectively. Also, there were 19 males and 52 females (Table 4.2). *C.a. palliatus* were most abundant in the undisturbed site, totalling 129 individuals with a mean group size of 10.75±1.22; as opposed to the disturbed site where only 47

individuals were recorded with a mean group size of 9.4±0.89 (Table 4.1). High abundance of *C.a. palliaus* was recorded at Mwanihana in the undisturbed site, with 36 individuals and a group size of 12 individuals per group (Table 4.1). But, the Colobus were least abundant at the Tazara point transect in the disturbed site, where only one group with 9 individuals was observed (Table 4.1).

The Mwanihana point-transect had a higher relative abundance of 22.5% (Figure 4.1). The F-test for homogeneity of variance (homoscedasticity) revealed no significant variances (F=3.149; p=0.023). Also, the three normality tests Shapiro-Wilk (W=0.9225, p=0.4136), Anderson-Darling (A=0.2989, p=0.5114) and Jarque-Bera (JB=0.7814, p=0.6 766) rejected the null hypothesis that population, was not normally distributed.

Table 4.2: Abundance of *C.a. palliatus across* sex and age group categories *in* Udzungwa Mountains National Park

Group Type	Category	Number of Individuals
Sex Groups	Males	19
	Females	52
	Total	71
Age Groups	Infants	26
	Juveniles	44
	Sub-Adults	35
	Adults	71
	Total	176

Source: Field Data June-July,2021

The t-test revealed significant differences in the abundance of *C.a. palliatus* between disturbed and undisturbed sites (t=5.75; p=0.0135).

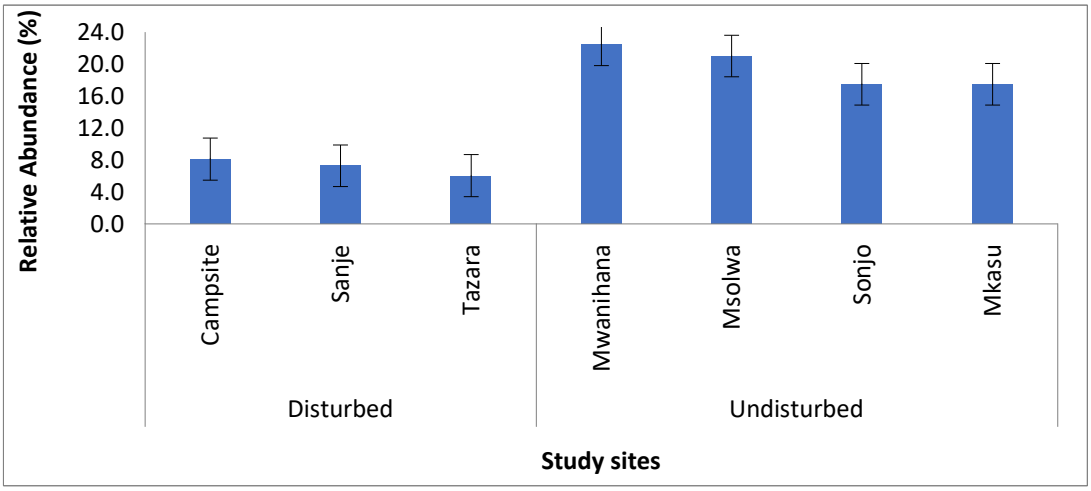

Figure 4.1: The Relative Abundance of *C.a. palliatus* in the Disturbed and Undisturbed Sites in Udzungwa Mountains National Park

4.3 The activity pattern of *C.a.palliatus* across sex and age groups in UMNP

The activities across sex and age groups were tested for normality, all of the three normality tests, Shapiro-Wilk (W=0.9791, p=0.8013), Anderson-Darling (A=0.2623, p=0.6793) and Jarque-Bera (JB=0.6442, p=0.7246) rejected the null hypothesis that the samples were not drawn from a normally distributed population. The Levene's test of homogeneity shown no significant deference among groups (F =3. 207, P = 0.031)

4.3.1 Overall Activity Patterns of *C.a.palliatus* across Sex Groups

The study results show variations in activity patterns among males and females. Amongst the activities observed, *C.a. palliatus* spent most time resting (30.6%), feeding (28.5%) and moving (26.2%), contrasted to the least time spent on socialising (14.7%). Males spent much of their time feeding (0.3%), resting (0.8%) and moving (1.0%) activities in contrast to females, respectively (Figure 4.2). On the other hand, females spent much of their time in social activities, 5.7% more than males (Figure 4.2).

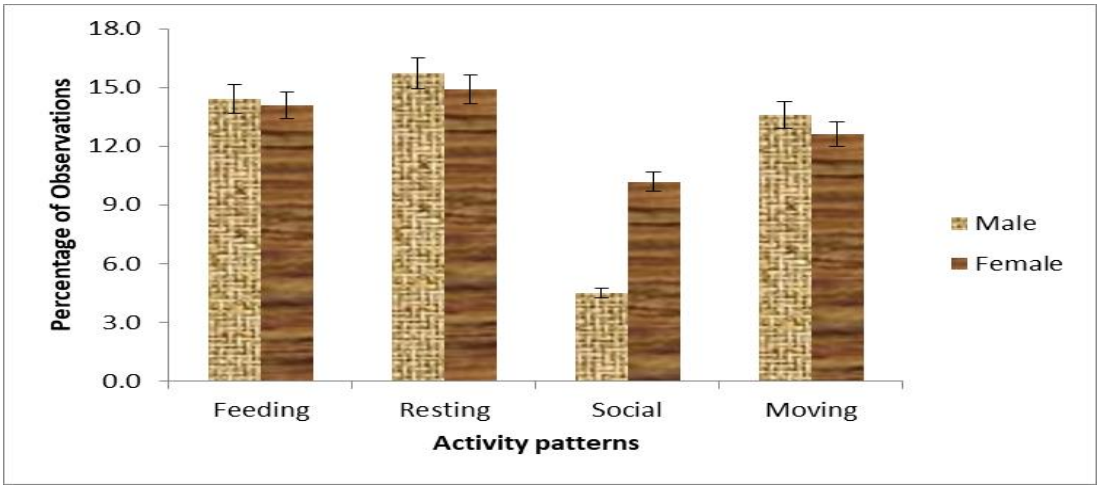

Figure 4.2: Overall Activity Patterns of *C.a. palliatus* Across Sex Groups in Udzungwa Mountains National Park
Source: Field Data, (2021).

The observed activities across sex groups and the time spent by the *C.a. palliatus* were tested for homogeneity by F-test and revealed that there were no significant differences ($p>0.05$) for all activities (Table 4.3), and a Shapiro-Wilk ($W=0.8681$, $p=0.7002$), shows that the population was normally population . Hence, a parametric test, a two-sample t-test, was used to compare the time spent in the different activities by males and females. Two sample t-test revealed no significant difference in feeding ($t=0.8284$, $p=0.3942$) between males and females (Table 4.3). On the contrary, two-sample t-test shows a significant difference in resting ($t=2.146$, $p=0.0361$), socialising ($t=15.022$, $p=1.187E-21$) and moving ($t=0.5752$, $p=0.0126$) between males and females *C.a. palliatus* (Table 4.3).

Table 4.3: Statistical Tests' Summary for Activity Patterns of *C.a. palliatus* across Sex Groups in UMNP

Activity	F-test	Two sample t-test
Feeding	F=2.101, p>0.05	t=0.8284, p=0.3942
Resting	F=2.101, p>0.05	t=2.146, p=0.0361
Social	F=1, p>0.05	t=15.022, p=1.187E-21
Moving	F=1, p>0.05	t=2.5752, p=0.0126

Source: Field Data, (2021).

4.3.2 Overall Activity Patterns of *C.a.palliatus* Across Age Groups

The results show variations in activity patterns among age groups. Amongst the activities observed, *C.a. palliatus* adults spent much of their time resting (8.4%) and feeding (8.1%) while spending less time in moving (4.2%) and socialising (3.7%) (Figure 4.3). The sub-adults spent much of their time resting (7.8%) and feeding (7.0%) while spending less time in moving (5.6%) and social (4.1%) activities (Figure 4.3). Not only did juveniles and infants show minimal differences in time spent in their different activities, but activity patterns also differed from those of adults and sub-adults (Figure 4.3).

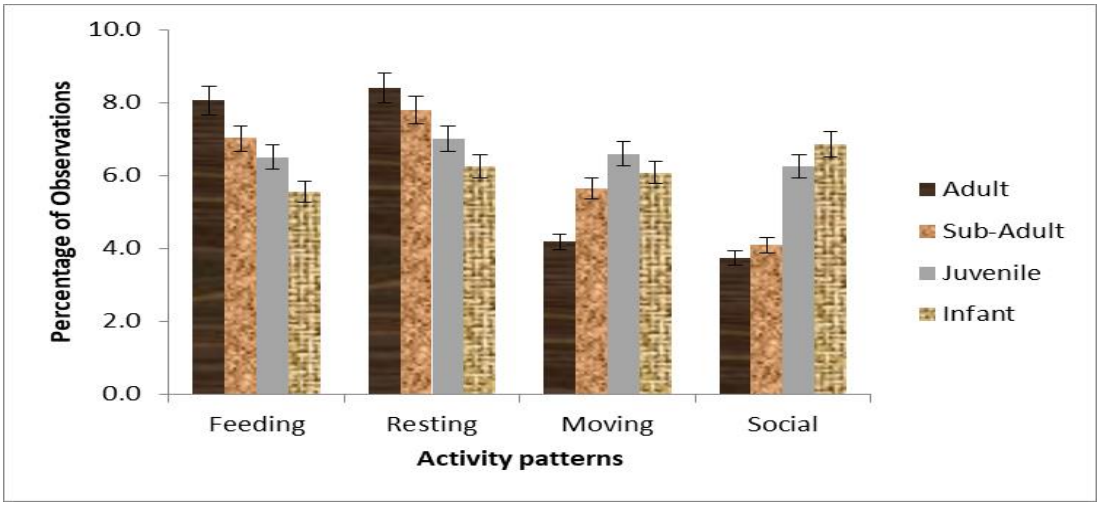

Figure 4.3: **Overall Activity Patterns of *C.a. palliatus* across Age Groups in Udzungwa Mountains National Park**

Juveniles spent much of their time resting (7.0%) and moving (6.6%), while spending less time in socialising (6.2%) and feeding (6.5%) activities (Figure 4.3). In infants, much of their time was spent socialising (6.2%) and resting (6.2%), while spending less time on feeding (5.6%) and moving (6.1%) activities (Figure 4.3). For each activity observed per groups, the time spent by the *C.a. palliatus* was tested for homogeneity of variance by Levene's test, and it revealed that there were no significant differences in variance ($p>0.05$) for all activities (Table 4.4). A One-way

ANOVA test showed the significant difference in feeding ($F=53.88$, $p<0.05$), resting ($F=43.47$, $p<0.05$), social ($F=118.2$, $p<0.05$) and moving ($F=53.39$, $p<0.05$) among age groups of *C.a. palliatus* (Table 4.4).

The Tukey's pairwise post hoc test was employed to reveal further where the differences occurred between different age groups within a particular activity. The Tukey's pairwise post hoc test showed that all age groups had significant differences in resting ($p<0.05$). Also there was significant difference In feeding, across age groups ($p<0.05$). The exception was between sub-adults and juveniles, which had no significant differences ($p>0.05$) (Table 4.4).

Table 4.4: Statistical Tests' Summary for Activity Patterns of *C.a. palliatus* across Age Groups

Activity	Levene's test	ANOVA (df=119)	Tukey's pairwise post hoc test (p>0.05)
Feeding	p>0.05	F=53.88, p<0.05	Sub-adults and Juvenile
Resting	p>0.05	F=43.47, p<0.05	NA (p<0.05)
Moving	p>0.05	F=53.39, p<0.05	Sub-adults and Infants; Juvenile and Infants
Social	p>0.05	F=118.2, p<0.05	Sub-adults and Adults; Juvenile and Infants

Source: Field Data, (2021).

Furthermore, the sub-adults and infants, juveniles and infants, had no significant differences ($p>0.05$) in moving. Otherwise, all other groups differed significantly ($p<0.05$). In the case of social activities, all age groups had significant differences ($p<0.05$) except for the groups between adults and sub-adults, juveniles and infants, which show no any significant differences ($p>0.05$) in socialising (Table 4.4).

4.3.3 Activity Patterns of *C.a.palliatus* across Sex Groups between Disturbed And Undisturbed Sites

This study compared activity patterns of *C.a. palliatus* between disturbed and undisturbed sites across sex groups. The results show that *C.a. palliatus* spend more

time in undisturbed areas than disturbed ones. In the undisturbed sites, they spent most of their time feeding (20.3%), resting (22.7%) and social (5.5%), whereas in the disturbed sites, they spent much of their time moving (20.7%) (Figure 4.4). Furthermore, the activity patterns varied among the sex groups between the two sites. In the disturbed sites, females spent much of their time resting by 1.1% compared to males, while males rested by 1.9% more than females (Figure 4.4). On the other hand, in the disturbed site, males moved by 1.3% ahead of females as opposed to the undisturbed site, whereby females moved more than males by 0.3% (Figure 4.4).

The time spent by the *C.a. palliatus* in different activities between the selected sites was tested for homogeneity of variance by F-test. There were no significant differences in variance (F= 1.4594, p>0.05) for all activities. Hence a parametric test, a two-sample t-test, was used to compare the time spent in the different activities by *C.a. palliatus* between the two selected sites. A two sample t-test results show a significant difference in time spent by *C.a. palliatus* sex groups between disturbed and undisturbed sites (t=1.311, p=0.0278).

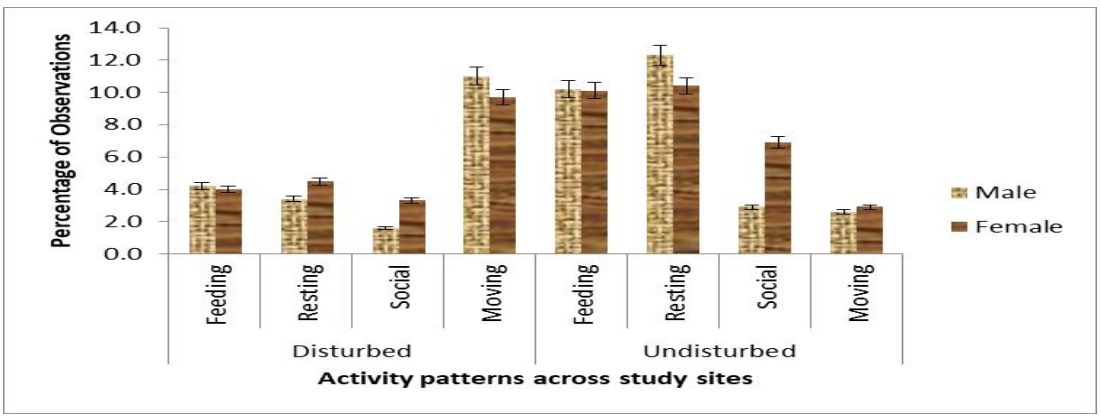

Figure 4.4: Activity Patterns of *C.a. palliatus* across Sex Groups between Disturbed and Undisturbed Sites in Udzungwa Mountains National
Source: Field Data July-August, (2021).

4.3.4 Activity Patterns of *C.a.palliatus* across Age Groups between Disturbed and Undisturbed Sites

The study results show different *C.a. palliatus' age groups* spend much of their time in undisturbed sites than disturbed sites. In the undisturbed site, most time was spent on feeding (21.6%), resting (23.2%) and social activities (13.0%), whereas in the disturbed site, they spent much of their time moving (16.8%) (Figure, 4.5). Furthermore, the activity patterns varied in the age groups between the two sites. The variations were seen in feeding and moving, whereby in disturbed site, infants spent much of their time feeding (1.8%) than juveniles (1.2%) and sub-adults (1.5%); while in the undisturbed site, infants spent less time feeding (4.8%) than juveniles (5.3%) and sub-adults (5.5%) (Figure 4.6). On the other hand, in undisturbed site, juveniles moved more (2.0%) ahead of the other age groups as opposed to the disturbed site, where they came second only after infants with 4.6% time spent in moving (Figure 4.5).

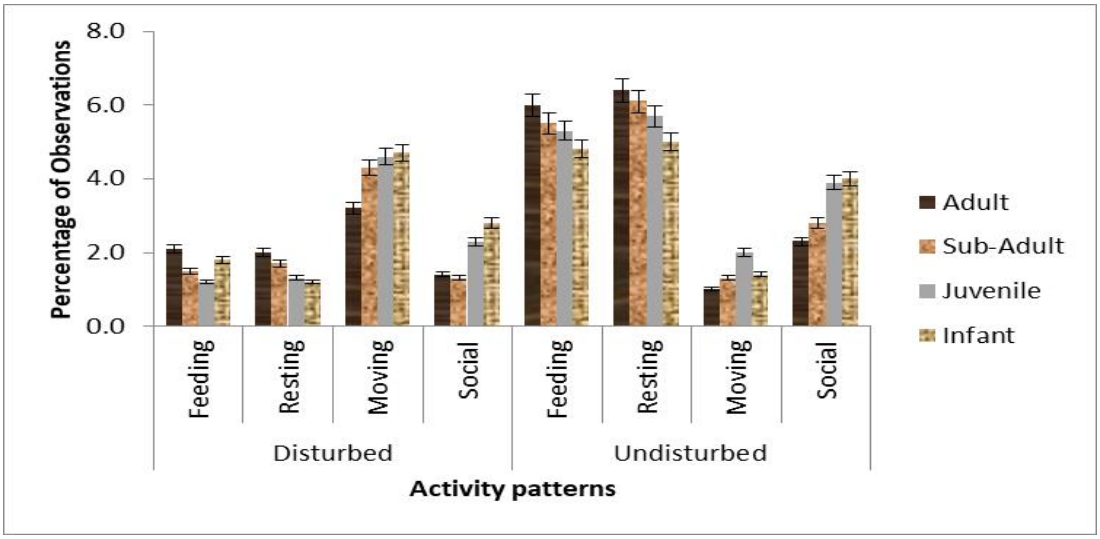

Figure 4.5: Activity Patterns of *C.a. palliatus* across Age Groups between Disturbed and undisturbed Sites in Udzungwa Mountains National Park

Source: Field Data, (2021).

The homogeneity F-test was applied to test time spent on different activities by *C.a. palliatus* age groups in two sites. The results revealed no significant differences in feeding (F= 1.6442, p>0.05) and social activities (F=11.934, p>0.05) (Table 4.5). Hence a parametric test, two sample t-test, was used to compare the time spent in the different activities by *C.a. palliatus* between the selected sites. Two sample t-test revealed that C.a. *palliatus* age groups spent significantly different time between disturbed and undisturbed sites in feeding (t=1.6442, p=0.0357).

Also, a significant difference in social activities (t= 2.939, p=0.026) between the disturbed and undisturbed sites (Table 4.5). On the other hand, the F-test show moving (F=22.711, p<0.05) and resting (F=16.358, p<0.05) had no significant differences in variance. Then a non-parametric test, Mann-Whitney, was used to compare the selected sites. Mann-Whitney revealed that there was a significant difference in time spent by *C.a. palliatus* age groups between disturbed and undisturbed sites in both resting (U=0, p=0.03) and moving (U=0, p=1E-5) (Table 4.5).

Table 4.5: Statistical Tests' Summary of *C.a. palliatus'* Activity Patterns across Age Groups between disturbed and undisturbed Sites in UMNP

Activity	F-test	Two sample t-test	Mann-Whitney
Feeding	F=1.6442, p=0.3574	t=6.9029, p=0.0005	
Resting	F=16.358, p=0.0411		U=66, p=0.0303
Moving	F=22.711, p=0.029		U=23, p=1E-6
Social	F=11.132, p=0.0713	t=2.9386, p=0.0026	

Source: Field Data, (2021).

CHAPTER FIVE

DISCUSSION OF THE FINDINGS

5.1 Overview

This chapter discusses the findings concerning the specific objectives addressed by this study. The empirical results were cross-referenced with similar studies and literature. Then, implications of the study were drawn, and some generalisations were made. The group size found in this study was unusually low for colobines in Africa. The ecological constraints model proposes that constrained group size and abundance are associated with feeding competition and necessitating increased moving. Small group size and low abundance suggest high competition induced by low food availability, degradation, hunting or inadequate habitat suitability

5.2 The abundance of *C.a. palliatus*

A total of 17 social groups of *C.a. palliatus* comprising 176 individuals were present in the study area. A mean colobus group size was estimated to be 10.47±1.21, ranging between 9-13 individuals. The *C.a. palliatus* was significantly abundant in undisturbed sites, accounting for 129 individuals, with a group size of 10.75±1.22. In comparison, the disturbed area had only 47 individuals, with a group size of 9.4±0.89. The record is unusually low for colobines in Africa. The ecological constraints model proposes that constrained group size and abundance are associated with feeding competition and necessitating increased moving.

Small group size and low abundance indicate high competition induced by low food availability, degradation, hunting or inadequate habitat suitability (Fimbel *et al.*, 2001; Teichroeb *et al.*, 2003) in Nyungwe, Rwanda. The essential habitat for *C.a.*

palliatus in UMNP, the high-use zone, is being degraded and decreasing in extent. Rapidly decreasing and remnant *C.a. palliatus* populations might drastically alter their behaviour and exploit a wider range of food sources, including cultivated and non-indigenous plants (Anderson, 2005).

5.3 The Activity Patterns of C.a.*palliatus*

This study showed variability in activity patterns of *C.a. palliatus* both generally and across sex groups. The *C.a. palliatus* spent most time resting, then feeding, and moving. In contrast, less time was spent on social activities. Spending much time resting, as disputed by other authors, might be due to behavioural thermoregulation of colobus monkeys, whereby they tend to rest under shaded tree canopies during the afternoon and in sunny canopies during the morning and evening (Eustace et al., 2015: Fashinget *al*.,2007; Fashing,2001). In addition to that, spending much time resting might be needed to assist food digestion as a related *C angolensis* sub. species feed on cellulose-rich food materials requiring long gut passage times (Matsuda *et al*., 2009).

Furthermore, vegetation quality has been linked to increased levels of resting among colobine monkeys (Wijtten, *et al*., 2012). During food scarcity, *C. angolensis* often rely heavily on mature leaves, which contain higher toxin levels, as backup foods, more so than any other African colobines (Fashing, 2007). It is supposed that Colobus's unique foregut anatomy is adapted to reduce leaf toxin levels prior to absorption by allowing fatty acid fermentation (Wijtten, *et al*., 2012). Thus, the induced need to reduce toxin levels may explain the increase in resting activity.

The study's results of C.*a. palliatus* spending much time resting, feeding and moving corresponded with several studies carried out at East Sagara Forest in Tanzania (Preston,2002; Fox,2004; Heinen,2006; Olsen,2007; Dunham,2009). However, the study by Wijtten *et al*., (2012) at East African coastal forest, corresponded to the findings of this study except for moving activity which seemed to be consistently lower in the mentioned study. But again, the closest cousin of *C.a. palliatus*, *C.a.ruwenzorii* subspecies in Nyungwe forest, Rwanda and Ituri forest, DRC, appeared to spend much more time feeding and moving but resting approximately half as much as *C. a. palliatus* (Bocian, 1997; Fashing, *et al*., 2007).

The movement activity of *C.angolensis* sub-species in East African coastal forest, Nyungwe and Ituri forests may have differed from those from this study due to inland location with plenty of food and low forest encroachment by humans. The sex groups varied in activities at UMNP. Males significantly spent more time resting than females, as also corroborated by (Fashing, 2001; Teichroeb, 2003; Fashing *et al*., 2007; O'Dwyer, 2011; Wijten *et al*., 2012). Other activities, such as vigilance, are common for resting males but is less practised by females (Fashing *et al*., 2007). According to Eustace (2015), body size has a positive relationship with resting time in African colobines, as males are larger than females, hence resting more.

Moving and social activities are the other activities which showed a significant difference between the sex groups. Females seemed to be more involved in social activities than males. The availability of social partners is likely to influence social activities in females as most groups of colobus monkeys are dominated by a single male (Kutsukake, 2006; Eustace, et al., 2015). Females showed more grooming,

meeting and playing than males, while males mostly showed aggression. The aggression in males was mainly inter-group rather than intra-group. On several occasions, males were observed chasing away other males from other groups approaching their home range and different kinds of animals, such as birds and small mammals. Fashing, *et al*. (2007) reported a similar phenomenon that adult male colobus monkeys often defend the territory more than females. Suggesting that competition in male colobus monkeys is mostly over access to females rather than food.

Although males rested more than females, they moved more extensively than females. Probably, it is due to the territoriality behaviour of *C. a.palliatus*, whereby males engage in surveillance movements and chase other animals for group protection. Again, the males moved more extensively in the disturbed site than in the undisturbed area; a similar observation was reported by Wijtten, *et a*l. (2012). The overshoot of males' movement in disturbed sites compared to females resulted in the overall significant difference of *C.a. palliates* movement across sex groups in UMNP.

Feeding in this study was not significantly different between the sex groups, and males tended to feed more than females. Contrary to other studies, females feed more to cover their increased nutritional requirements resulting from suckling infants (Fashing, 2001; Teichroeb, 2003; Fashing, *et al*., 2007; Wijten *et al*., 2012). The difference might be attributed to the study site location, where the present study was conducted in disturbed sites as opposed to the other studies in inland forests. In disturbed site, males spent a lot of energy moving. Hence, this might be the case

that males fed more than females to regain the energy utilised in the disturbed site.

Activity patterns by age groups generally varied significantly. All age groups exhibited a significant difference in resting activity, although adults and sub-adults rested more than juveniles and infants. While resting, males often remained vigilant, while females socialised with infants (Grimes, 2000; Fashing, 2001). Also, as observed by Grimes (2000), animals become less active when they are old and thus tend to rest more. All groups except for sub-adults and juveniles showed significant feeding differences, where adults spent more time feeding than the other groups. Fashing (2001) made similar observations in one group of colobus monkeys at Kakamega Forest. Movements across the age groups tend to be more or less similar, probably because colobus monkeys move as a group (Jansson, 2011; Public Broadcasting Services, 2014).

All groups except sub-adults and adults, juveniles and infants showed significant differences in social activities. Juveniles and infants spend much of time in social activities than adults and sub-adults, possibly due to their involvement in a wide range of activities, including playing, which is rare at other ages (Fashing, 2001). Juveniles and infants spend more time playing while adults are resting. The results of feeding and moving across age groups do conform to the results by Fashing (2001) in two groups of black-and-white colobus monkeys in Kakamega Forest, Kenya, Grimes (2000) in Entebe Botanical Gardens, Uganda and O'Dwyer (2001) in Diani Forest, Kenya.

CHAPTER SIX

CONCLUSIONS AND RECOMMENDATIONS

6.1 Overview

This chapter presents the conclusion and recommendations. The conclusion is based on the study's specific objectives, while recommendations include further research and policy action suggestions.

6.2 Conclusion

The results show that the abundance and group size of *C. a. palliatus* in UMNP was higher in the undisturbed sites compared to the disturbed sites. The Food quantity and quality had a greater influence on the *C. a. palliatus* activities, whereby time for resting was relatively higher than the time spent on other activities. Plentiful and quality food in the undisturbed areas allowed *C. a. palliatus to* spend less time feeding and more time resting. While in the disturbed areas, the consumption of poor-quality food compelled the primates to spend much time resting - as feeding on mature leaves that may contain higher toxins levels compels longer resting time to allow fermentation of fatty acids.

The results suggest that the disturbed site at UMNP had significantly lower abundance and group size than the undisturbed site. Small group size and abundance indicate high competition induced by low food availability, degradation, hunting or inadequate habitat suitability. The overall activity of black-and-white colobus monkeys does vary. They spend more than 50 per cent of their time resting and feeding while spending less time in social activities. Variations also occur between age and sex groups. Adults rest more than juveniles and infants, while juveniles feed

more than adults and infants. Infants spend much of their time in social activities. Males rest more than adult females, and females socialise more than males.

The variations in overall activity may be due to energy conservation strategies and more time for digesting cellulose food materials, hence more resting time. Body size is a factor for much resting time across age and sex groups. Availability of social partners was the factor for females to socialise much more than males. In contrast, the involvement of infants in a wide range of social activities was the factor for infants to be more involved in social activities than adults and juveniles.

6.3 Recommendations

Based on the study results and conclusion, the following were recommended

i. The increased human encroachment on UMNP is posing an increasing challenge to the diversities, activities and ranging patterns of the *C.a. palliatus*. There is a need for the state to increase measures that will control the encroachments UMNP protected areas.

ii. Human encroachments in the UMNP can be controlled by effectively enforcing existing laws. It is recommended that the government employ sufficient manpower in the protection section and allocate more funds to purchase equipment and other materials required for law enforcement purposes.

iii. Protection of *C.a. palliatus* is of paramount importance due to increasing threat of their extinction. There is a need for the policy change to sensitise UMNP adjacent communities to participate fully in the protection of the species, including refraining from establishing farms and settlements in the

protection area.

iv. The recommended areas for further research. The results of this study were based on a single group studied for a short period. It is recommended that other studies be conducted on the activities and foraging behaviour of colobus monkeys, involving more groups in different localities that will provide a clear extent of the impacts of fragmentation on Blank and White Angolan Colobus monkey abundance as an indicator species.

REFERENCES

Anderson, J.; Cowlishaw, G.; Rowcliffe, J. M. (2007). "Effects of forest fragmentation on the abundance of *Colobus angolensis palliatus* in Kenya's coastal forests" (PDF). *International Journal of Primatology*, 28(3), 637.

Bailey, R. P., Collins, D., Ford, P. A., MacNamara, A., Toms, M., & Pearce, G. (2010). *Participant development in sport; an academic review*. Leeds: SportsCoach UK.

Bocian, C. M. (1997). Niche Separation of Black-and-White Colobus Monkeys (Colobus angolensis and C. guereza) in the Ituri Forest. PhD thesis, City University of New York, New York, USA.

Butynski, T. M., Ehardt, C. L. & Struhsaker, T. T. (1998). Notes on two dwarf galagos (Galagoidesudzungwensis and Galagoidesorinus) in the Udzungwa Mountains, Tanzania. *Prim. Conserv.* 18: 69–75.

Chapman, C. & Russo, S., Campbell, C. J., Fuentes, A., MacKinnon, K. (2007). *Primate seed dispersal, in Primates in Perspective*. Oxford: Oxford University Press.

Clutton-Brock, T. H., and Harvey, P. H. (1977). Primate ecology and social organisation. J. *Zool. (Lond.),* 183, 1–39.

Connell, J.H. (1978). Diversity in Tropical Rain Forests and Coral Reefs. *Science*, New series: 199(4335), 1302-1310.

Cowlishaw, G. & Dunbar, R. (2000). *Primate Conservation Biology*. Chicago: The University of Chicago Press.

Cristobal-Azkarate J. & Arroyo-Rodriguez, V. (2007). Diet and Activity of Howler Monkeys (Alouatta palliata) in Los Tuxtlas, Mexico: Effects of Habitat

Fragmentation and Implications for Conservation. *American Journal of Primatology*, 69, 1013– 1029.

Cronk, Q. C. B. & Fuller, J. C. (1995). *Plant invaders: The threat to natural ecosystems.* London: Chapman & Hall.

Estes, R. D. (1992). *The behaviour guide to African mammals including hooved, carnivores and primates.* Vermont: Chelsea Green Publishing.

Eustace, A., Kisingo, A. W., Kahana, L. W. & Lyimo, E. H. (2015). Activity Patterns of Black-and-White Colobus Monkey (Colobus guereza caudatus) in Rau Forest Reserve, Tanzania. *Research & Reviews: Journal of Ecology and Environmental Sciences,* 3(4), 17-24.

Fahrig, L. (2019). Habitat fragmentation: A long and tangled tale". Global Ecology and Biogeography, 28(1), 33–41.

FAO, (2000). Global forest resources assessment: 2000 main report, FAO, Rome 2000.

Fashing, P. J, Gakima, J. B., Masozera, M., Manunura, I., Nguyen, N. & Plumptre, A. J. (2007). Activity and Ranging patterns of Colobus angolensisruwenzonrii in Nyungwe Forest, Rwanda. *International Journal of Primatology,* 39, 83-92.

Fashing, P.J. (2001). Activity and Ranging s of Guerezas in the Kakamega Forest: Intergroup Variation and Implications for Intragroup Feeding Competition. *International Journal of Primatology,* 22, 549–577.

Fernandez-Duque, E. (2003). Influences of moonlight, ambient temperature, and food availability on the diurnal and nocturnal activity of owl monkeys (Aotus azarai). *Behavioural Ecology and Sociobiology,* 54, 431–440.

First, B. (2022). Exploration of Preventive Measures of unwanted Pregnancies among teenage Girls in selected Chunya District Rural Secondary Schools Tanzania. Unpublished MA Dissertation. The Open University of Tanzania, Dar es Salaam, Tanzania.

Fox, M. (2004). The crushing mbega: A follow-up study of black and white colobus in the Usambara Mountains. The unpublished independent study project, School for International Training, Arusha, Tanzania.

Grimes, K. H. (2000). Guereza dietary and behavioural patterns at the Entebbe Botanical Gardens. PhD. Thesis, The University of Calgary, Alberta, Canada.

Groves, C.P. (2007). The taxonomic diversity of the Colobinae of Africa. *Journal of Anthropological Sciences.* 85, 7-34.

Grubb, P., Butynski, T.M., Oates, J.F., Bearder, S.K., Disotell, T.R., Groves, C.P. and Struhsaker, T.T. (2003). Assessment of the diversity of African primates. *International Journal of Primatology,* 24(6), 1301-1357.

Hamilton A. C. & Taylor, D. (1991). History of climate and forests in tropical Africa during the last 8 million years, *Tropical Forests and Climate*, 19, 65–78.

Hammer, Ø, Harper, D. A. T. & Ryan, P. D. (2001). PAST: Paleontological Statistics Software Package for Education and Data Analysis. Paleontological Association.

Heinen, L. (2006). Mbega and the rainforest: A study of *Colobus angolensis palliatus* in the Sagara Village Forest. Unpublished independent study project, School for International Training, Arusha, Tanzania.

Hilton-Taylor, C. (Compiler) (2000). 2000 IUCN Red List of Threatened Species, IUCN, Gland, Switzerland and Cambridge, UK.

Isbell, L. A. & Young, T. P. (1993). Social and ecological influences on activity budgets of vervet monkeys, and their implications for group living. *Behavioural Ecology and Sociobiology*, 32, 377–385.

IUCN, (1996). African Primates: Status Survey and Conservation Action Plan, Revised edition. IUCN, Gland, Switzerland,

Jansson, C. (2011). The major food trees of the Angola black-and-white colobus (Colobus angolensis palliatus).

Jensz, K. & Finley, L. (2011). Species profile for Colobus guereza. Hobart, Tasmania: Latitude 42 Environmental Consultants Pty Ltd.

Kanga, E. M. & Heidi, C. M. (2000). Survey of the Angolan black-and-white colobus monkey Colobus angolensis palliatus in the Diani forests, Kenya. *African Primates*, 4, 50–54.

Kangwana, K. (1996). *Studying Elephants.* Nairobi: African wildlife foundation.

Kim, K. (2002). Colobus guereza, Animal Diversity Web 2002.

Kingdon, J. (2008). Colobus guereza: IUCN Red List of Threatened Species 2008.

Kivunja, C. (2018). Distinguishing between theory, theoretical framework and conceptual framework: A systematic review of lesson from the field. *International Journal of higher education*, 7(6), 44-53.

Kothari, C. R. (2004). *Research Methodology; Methods and Techniques*, 2nd Revised Ed., New Delhi: New age International.

Kutsukake, N. (2006). Pattern, distribution, and function of greeting behaviour among black-and-white colobus. *International Journal of Primatology*, 27, 1271- 1291.

Lawes M. J. & Eeley, H. A. C. (2000). Are local patterns of anthropoid primate

diversity related to patterns of diversity at a large scale? *Journal of Biogeography,* 27(6), 1421-1435.

Linder, J.M., Cronin, D.T., Ting, N., Abwe, …. Oates, J.F., Struhsaker, T.T. (2021). Red colobus (Piliocolobus) conservation action plan 2021–2026. Gland, Switzerland: IUCN.

Long, Y., C. R. Kirkpatrick, T. Zhongtai, and L. Xiaolin (1994). Population, and ecology of the Yunnan snub-nosed monkey (Rhinopithecus bieti). *Primates*, 35(2), 241–250.

Mahale Ecosystem, Western Tanzania. International Journal of Primatology.

Marshall, A. R., Topp-Jorgensen, J. E., Brink, H. & Fanning, E. (2005). Monkey abundance and social structure in two high-elevation forest reserves in the Udzungwa Mountains of Tanzania. *International Journal of Primatology*, 26, 127-145.

Martin, C. (1998). The Rainforests of West Africa. Conservation, Borkhauser Verlag, Basel.

Matsuda, I., Tuuga, A. & Higashi, S. (2009). The feeding ecology and activity budget of proboscis monkeys. *American Journal of Primatology,* 71, 478-492.

Mbora, D. N. & Meikle, D. (2004). Forest fragmentation and the distribution, abundance and conservation of the Tana River red colobus (Procolobus rufomitratus). *Biological Conservation,* 118, 67–77.

Milton, K. (1998). Physiological ecology of howlers (Alouatta): Energetic and digestive considerations and comparison with the Colobinae. *International Journal of Primatology*, 19, 513–547.

Mittermeier, R. A. J. F. Oates, A. E. Eudey, J. (1986). Ornback, Primate conservation: 3–72, In *Comparative Primate Biology*, G. Mitchell and J. Erwin, Eds., Alan R. New York: Liss, Inc.

Napier, J. R. & Napier, P. H. (1985). *The natural history of primates.* London: British Museum.

Nyundo, B.A., Mtui, A. & Kissaka, H. (2006). Assessment of ecological and social impacts caused by a collection of deadwood and medicinal plants and cutting of grass for thatching inUdzungwa Mountains National Park. Unpublished report to TANAPA/WWF-TPO.

O'Dwyer, R. (2011). The black-and-white colobus monkeys (Colobus angolensis palliatus) of Diani Forest, Kenya. Behavioural responses to habitat fragmentation.

Oates J. (1977). The guereza and its food. In Clutton-Brock TH, editor. Primate Ecology: Studies of Feeding and Ranging Behavior in Lemurs, Monkeys and Apes. New York: Academic Press.

Olsen, K. (2007). When you're talking about my monkeys… it doesn't matter if they're black or white: A behavioural follow-up on the black and white colobus and a study of their tree use. The unpublished independent study project, School for International Training, Arusha, Tanzania.

Onderdonk, D. A. & Chapman, C. A. (2000). Coping with forest fragmentation: the primates of Kibale National Park, Uganda. *International Journal of Primatology*, 21, 587–611.

Perkin, A., Rondo Dwarf Galago Paragalago rondoensis (Honess in Kingdon, 1997). In: C. Schwitzer, R. A. & Mittermeier, A. B. (eds.), Primates in Peril: The

World's 25 Most Endangered Primates, 24-27. IUCN SSC Primate Specialist Group.

Preston, M. (2002). An endangered monkey? A study of the Colobus angolensis. The unpublished independent study project, School for International Training, Arusha, Tanzania.

Riley, E. P. (2007). Flexibility in Diet and Activity of Macaca tonkeana in Response to Anthropogenic Habitat Alteration. *International Journal of Primatology*, 28, 107–133.

Romdal, T. S., Ara´ujo, M. B. & Rahbek, C. (2013). Life on a tropical planet: niche conservatism and the global diversity gradient. *Global Ecology and Biogeography*, 22, 344-350.

Sahney, S., Benton, M. J., Falcon-Lang, H. J. (2010). Rainforest collapse triggered Pennsylvanian tetrapod diversification in Euramerica. *Geology*, 38(12), 1079 1082.

Stanford, C. B. (1991). The capped langur in Bangladesh: Behavioral ecology and reproductive tactics. Contributions to Primatology, 26, 1–179.

Svensson, J. R. (2010). Ecological Disturbances: The Good, the Bad and the Ugly. Thesis for the Degree of Doctor of Philosophy, University of Gothenburg, Sweden.

Teichroeb, J. A., Saj, T. L., Paterson, J.D. &Sicotte, P., (2003). Effect of Group Size on Activity Budgets of Colobus vellerosus in Ghana. International Journal of Primatology, 24(4), 743- 758.

Udzungwa Mountains National Park, (2014). Udzungwa Mountains National Park, Tanzania, General Management Plan (2012-2022).

Vitousek, P. M.,. Mooney, H. A. Lubchenco, J. & Melillo, J. M. (1997). Human domination of Earth's ecosystems. *Science*, 277(5325), 494–499.

Von Hippel, F., Fredrick, H. & Cleland, E. (2000). Population declines of the black and white colobus monkey in the Kakamega Forest, Kenya. *Zoologica Africana*, 35:69-75.

Wade, (2003). Distribution and causes of global forest fragmentation. *Conservation Ecology*, 7, 7.

Wijtten, Z., Hankinson, E., Pellissier, T., Nuttall, M. & Lemarkat, R. (2012). Activity Budgets of Peters' Angola Black-and-White Colobus (Colobus angolensis palliatus) in an East African Coastal Forest. *Journal of African Primates*, 7 (2), 203-210.

Willig, M. R. & Presley, S. J. (2018). Biodiversity and Disturbance. *Encyclopedia of the Anthropocene*, 3, 45-51.

Wong, S. N. P. & Sicotte, P. (2007). Activity budget and ranging s of Colobus vellerosus in forest fragments in central Ghana. *Folia Primatologica.* 2007; 78, 245–254.

Wootton, J. T., Cusson, M., Navarette, S. & Pertraitis, P. S. (2009). *Disruption, Succession and Stochasticity, Marine Hard Bottom Communities: Patterns, Dynamics, Andand and Diversity, and Change, Ecological studies*: 206. Pg 201-211. Verlag Berlin Heidelberg: Springer.

APPENDICES

Appendix 1: An adult male Colobus angolensis palliatus on Rauvolfia caffra tree

Appendix 2: Researcher Joseph Gabriel at the field during data collection

Appendix 3: Field assistant, Mokoro during data collection

Appendix 4: Research clearance

THE OPEN UNIVERSITY OF TANZANIA

DIRECTORATE OF POSTGRADUATE STUDIES

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Our Ref: PG201802158

15th January2021

Conservation Commissioner (CC),

Tanzania National Parks (TANAPA),

P.O.Box 3134,

ARUSHA.

RE: RESEARCH CLEARANCE

The Open University of Tanzania was established by an Act of Parliament No. 17 of 1992, which became operational on the 1st March 1993 by public notice No.55 in the official Gazette. The Act was however replaced by the Open University of Tanzania Charter of 2005, which became operational on 1st January 2007.In line with the Charter, the Open University of Tanzania mission is to generate and apply knowledge through research.

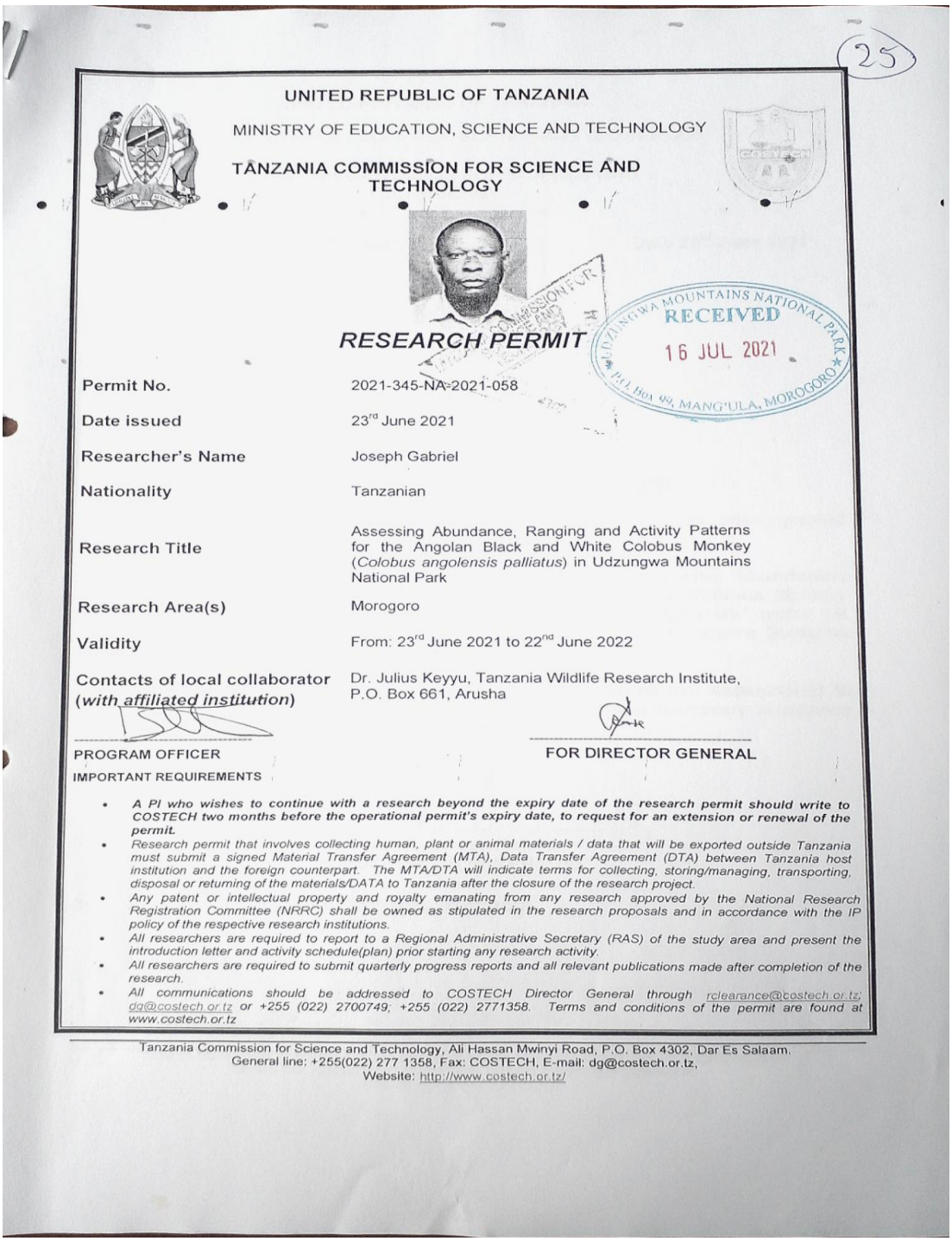
To facilitate and to simplify research process therefore, the act empowers the Vice Chancellor of the Open University of Tanzania to issue research clearance, on behalf of the Government of Tanzania and Tanzania Commission for Science and Technology, to both its staff and students who are doing research in Tanzania. With this brief background, the purpose of this letter is to introduce to you **Mr. GABRIEL, Joseph, Reg No: PG201802158** pursuing **Master of Environmental Studies (MES).**We here by grant this clearance to conduct a research titled **"Assessing Abundance, Ranging and Activity Patterns for the Angolan Black and White Colobus Monkey (Colobus angolensis palliates) in Udzungwa Mountains National Park".** He will collect his data at your area from 20th January 2021 to 26th February 2021.

In case you need any further information, kindly do not hesitate to contact the Deputy Vice Chancellor (Academic) of the Open University of Tanzania, P.O.Box 23409, Dar es Salaam.Tel: 022-2-2668820.We lastly thank you in advance for your assumed cooperation and facilitation of this research academic activity.

Yours,
THE OPEN UNIVERSITY OF TANZANIA

Prof. Magreth Bushesha
DIRECTOR OF POSTGRADUATE STUDIES.

Appendix 5: Research permit



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UNITED REPUBLIC OF TANZANIA

MINISTRY OF EDUCATION, SCIENCE AND TECHNOLOGY

TANZANIA COMMISSION FOR SCIENCE AND TECHNOLOGY

UDZUNGWA MOUNTAINS NATIONAL PARK
RECEIVED
16 JUL 2021
P.O. BOX 99, MANG'ULA, MOROGORO

RESEARCH PERMIT

Permit No.	2021-345-NA-2021-058
Date issued	23rd June 2021
Researcher's Name	Joseph Gabriel
Nationality	Tanzanian
Research Title	Assessing Abundance, Ranging and Activity Patterns for the Angolan Black and White Colobus Monkey (*Colobus angolensis palliatus*) in Udzungwa Mountains National Park
Research Area(s)	Morogoro
Validity	From: 23rd June 2021 to 22nd June 2022
Contacts of local collaborator (*with affiliated institution*)	Dr. Julius Keyyu, Tanzania Wildlife Research Institute, P.O. Box 661, Arusha

PROGRAM OFFICER

FOR DIRECTOR GENERAL

IMPORTANT REQUIREMENTS

- ***A PI who wishes to continue with a research beyond the expiry date of the research permit should write to COSTECH two months before the operational permit's expiry date, to request for an extension or renewal of the permit.***
- *Research permit that involves collecting human, plant or animal materials / data that will be exported outside Tanzania must submit a signed Material Transfer Agreement (MTA), Data Transfer Agreement (DTA) between Tanzania host institution and the foreign counterpart. The MTA/DTA will indicate terms for collecting, storing/managing, transporting, disposal or returning of the materials/DATA to Tanzania after the closure of the research project.*
- *Any patent or intellectual property and royalty emanating from any research approved by the National Research Registration Committee (NRRC) shall be owned as stipulated in the research proposals and in accordance with the IP policy of the respective research institutions.*
- *All researchers are required to report to a Regional Administrative Secretary (RAS) of the study area and present the introduction letter and activity schedule(plan) prior starting any research activity.*
- *All researchers are required to submit quarterly progress reports and all relevant publications made after completion of the research.*
- *All communications should be addressed to COSTECH Director General through rclearance@costech.or.tz; dg@costech.or.tz or +255 (022) 2700749; +255 (022) 2771358. Terms and conditions of the permit are found at www.costech.or.tz*

Tanzania Commission for Science and Technology, Ali Hassan Mwinyi Road, P.O. Box 4302, Dar Es Salaam.
General line: +255(022) 277 1358, Fax: COSTECH, E-mail: dg@costech.or.tz,
Website: http://www.costech.or.tz/