Population estimate and behavioural ecology of Omo River guereza (*Colobus guereza guereza*) from Wof-Washa Natural and plantation forest, central highland Ethiopia

By

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ABSTRACT

Population estimate and behavioural ecology of Omo River guereza (*Colobus guereza guereza*) from Wof-Washa Natural and plantation forest, central highland Ethiopia

Dereje Yazezew Mammo, PhD Thesis, Addis Ababa University
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Omo River guereza (*Colobus guereza guereza*) is a subspecies of eastern black and white colobus monkeys endemic to the western Rift Valley forests of Ethiopia. No detailed published information is available on this subspecies and it remains one of the least studied primates in Africa. With the current increasing habitat loss and degradation across its geographic range, data on the current conservation status and behavioural ecology are essential to design a management plan. This study therefore aims to provide data on the population estimate and behavioural ecology of Omo River guereza. Vegetation surveys were conducted within each group's home range to quantify the overall vegetation composition. A total of 2 with 400-500 m long and 10 m wide vegetation transects were laid out and sampled the diversity of big trees ≥ 10 cm diameter at breast height (DBH= 1.3 m above ground). Phenological data were analyzed from 13 plant species: 10 trees, two shrubs and one climber. A total of 39 censuses from 1.5 to 3 km transects were conducted with a cumulative distance of 88.5 km in four different habitat types. The activity budget, feeding ecology and ranging behaviour were studied in two neighbouring groups for five minutes with 15 minutes interval scan sampling for 12 month study period. Plant species with DBH ≥ 10 cm in the range of natural forest group (N) had higher stem density (780 stems/ha) than plantation group's (P) (600 stems/ha). Plant species diversity and evenness were higher and dominance was lower in the natural forest (N) than in plantation forest (P). Young and mature leaves were the most abundant plant parts throughout the year while fruit was the least abundant. There were statistical differences in food availability indices of young leaves (Mann Whitney U; $Z=-4.16$, $P<0.001$) and mature leaves (Mann Whitney U; $Z=-4.15$, $P<0.001$) between the two guereza groups across months. Out of the total 140 Omo River guereza groups sighted, the highest encounter rate was recorded in the undisturbed natural forest (3.11 groups/km) transect while the lowest were in the *Erica-Juniperus* mixed forest and disturbed natural forest. The total population estimate of the study species was 2947 individuals. Out of the average individual number (317) of Omo River guereza sighted during the three-census period, 56.3±17.1 (71%) were adult and 17.3 ±5.6 (21.8%) were subadult of both sexes. Guerezas spent 43.1% of their time resting, 31.8% feeding 12.9% moving, 5.1% grooming and 4.8% performing other activities. Guerezas were observed feeding on 31 plant species belonging to 26 families. Overall, guerezas diet constituted 56.44% young leaves, 26.59% mature leaves, 10.8% fruits and 6.17% was from other food items. The top five species from five different families comprised 83% (group P) and 70% (group N) of Omo River guereza diet of which leaves of *Maesa lanceolata* contributed 23.2% of the overall diet. Kernel density estimate revealed that group P shared 19.1% of its home range with group N while group N shared 10.6% of its home range with group P. Further study should be carried out to work out a proper management plan and minimize human interference.

Keywords: Activity budget, feeding ecology, habitat use, population estimate, WWNSF.

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ABBREVATIONS AND ACRONYMS

AMWCDO	Agricultural Ministry of Wildlife Conservation and Development Organization
ANRS	Amhara National Regional State
BA	Basal Area
EWCA	Ethiopian Wildlife Conservation Authority
IUCN	International Union for Conservation of Nature and Natural Resources
MoNARDEP	Ministry of Natural Resource Development and Environmental Protection
NMA	National Meteorological Agency
SUNARMA	Sustainable Natural Resource Management
WWNSF	Wof-Washa Natural State Forest

1. INTRODUCTION

1.1. Background

Ethiopia is a landlocked country located in the Horn of Africa between $3^0$4´ and $14^0$53´ North latitude and $32^0$48´ and $48^0$12´ East longitude with a total area of 1.12 million km^2 (MOA [Ministry of Agriculture], 2000). It is the third largest country in Africa where agriculture is the basis of livelihood for the majority of the population and the second-most populous nation in Africa after Nigeria. It has a tropical monsoon climate with wide topographic-induced variation, high plateaus, and central mountain ranges divided by the Great Rift Valley (Selamyihun Kidanu, 2004). The country is endowed with a variety of agroecological conditions ranging from desert to rainforest and from 200 m below sea level to highlands with altitudes of over 4620 m asl (Yalden, 1983; IBC, 2008).

Ethiopia is an important regional centre for biological diversity due to its wide range of altitude, geographical diversity with high and rugged mountains, flat-topped plateaus and deep gorges, incised river valleys and rolling plains (Ensermu Kelbessa *et al.*, 1992). The diversity in physical features, climatic types, topography, habitat, vegetation types and fauna made Ethiopia to have great biodiversity resources (Friis *et al.*, 2011). Thus, Ethiopia encompasses a broad range of ecosystems with great varieties of habitats contributing for the occurrence of high faunal diversity. The variety of species and great proportion of endemicity within the groups especially in the highlands is the result of the isolation of the highland areas of the country, from other highlands within and outside the country by the surrounding lowlands. The geographical location and physical features of Ethiopia have resulted in the diversification of the wildlife (Yalden, 1983; Shibru Tedla, 1995). This is mainly reflected by altitudinal range and the diversity of climate, vegetation and landscape.

Currently, there are about 315 species of mammals in Ethiopia of which about 36 (11.4%) are endemic (Afework Bekele and Yalden, 2013). The level of endemicity in the fauna of Ethiopia can be attributed to the proportion of highland ground in the country compared to the rest of Africa (Yalden and Largen, 1992). Of the documented endemic mammals of the country, 17 live in highlands, moorland or grassland habitats whose altitudinal ranges are above 2000 m. The endemic primate subspecies Omo River guereza (*Colobus guereza guereza*) is also confined to the highland forests of Borena Sayint National Park, Wof-Washa Natural State Forest and other highland areas.

Primates are large, charismatic mammals found in many of the world's tropical forests (Fashing *et al.*, 2012). Despite the natural and anthropogenic impact, there are about 13 species of primates in Ethiopia excluding *Homo sapiens* (Afework Bekele and Yalden, 2013). The two subspecies of black and white colobus monkeys that occur in Ethiopia are Omo River guereza *(Colobus guereza guereza)* and Djaffa Mountains Guereza (*C. g. gallarum*).

Hunting, emergent diseases, habitat conversion and fragmentation are the main reasons for the global decline of primate populations (Cowlishaw and Dunbar, 2000) and as a consequence of their effects, more than half of the world's primate species are currently threatened by extinction (Chapman and Peres, 2001). Habitat fragmentation is a landscape-scale process in which continuous habitat is broken apart into smaller pieces (fragments) scattered within a matrix of nonhabitat which implies the loss of habitat and its subdivision (fragmentation) into a variable number of fragments (Fahrig, 2003; Chapman *et al.*, 2010; Chaves *et al.*, 2012).

Forest loss and fragmentation threaten many primates globally and often leads to a reduction in food resources (Bracebridge *et al.*, 2012; Campera *et al.*, 2014). Ecological factors such as forest structure, fragmentation and resource availability are critical in determining the spatial distribution of primates (Clutton-Brock, 1975b; Campera *et al.*, 2014). Degraded forest habitats typically show low fruit availability and scattered fruit tree distribution. This has been shown to force frugivorous primates either to move further in search of food, resulting in large home ranges, or to use energy saving strategies (Campera *et al.*, 2014). Estimates suggested that 50 percent of all primates are threatened by habitat loss, fragmentation, and hunting, with most species found within tropical and subtropical forest ecosystems (IUCN, 2010), where forest loss continues at a rate of approximately 13 million ha/year (FAO, 2010; Bracebridge *et al.*, 2012).

The colobines derived their name from the very reduced or absent thumbs of the African species. They are named after the Greek word *kolobos*, which means mutilated. Although their thumbs are reduced, the other phalanges are very long. The hindlimbs in colobines are longer than the forelimbs, and they have long tails (Newton and Dunbar, 1994). All species in the genus *Colobus* have long black or black and white pelage but a different coat pattern. Of the five species of *colobus*, *C. satanas* has all black pelage while the other four species have differing combinations of white or grey markings on the tail, thighs, shoulders and head. The infants of all species of *Colobus* are born pure white with the exception of *C. satanas* which are born brown. Females show a slight perineal swelling for several days in a month (Bocian, 1997). In the majority of colobus monkeys, birth occurs throughout the year without any seasonality to reproduction. Moreover, many colobine monkeys lack external signs of estrus (Newton and Dunbar, 1994).

Colobus monkeys inhabit East and Central Africa concentrating on the lowland rain, coastal, gallery, and montane forests. More specifically, populations occur from Senegal in the west to Zanzibar in the east, and from the Ethiopian Highlands to the southern edge of the Congo Basin (Oates, 1994). Colobus monkeys are among the most cold-tolerant of the African Old World monkeys.

Colobus live in highly cohesive social groups and reinforce intragroup relations through considerable amount of mutual grooming (Oates, 1977). Many guereza groups are unimale, but multimale groups also exist (Oates, 1977; Dunbar, 1987; von Hippel, 1996). Subadult or adult males may associate themselves on the peripheries of existing groups and may eventually join or take over these groups (Dunbar and Dunbar, 1976; Oates, 1977). Though slightly larger all-male groups are common, adult males not belonging to mixed-sex groups are typically observed as lone males or pairs of males (Fashing, 2001c).

Colobus monkeys exhibit seasonal variation in consumption based on food availability (Fashing, 2011). The predominantly folivorous diet of *C guereza* and *C angolensis* provides a good source of most nutrients. Some studies have suggested that wild colobus prefers leaves that have high protein to fibre ratios (Chapman *et al.*, 2002). The protein content of young and mature leaves (20-30%) appears to exceed the suggested protein requirements for nonhuman primates (15-22%) (NRC, 2003). Fashing *et al.* (2007a) suggested that colobus look for swamp plants, bark, and drink water from mud puddles to ingest adequate levels of minerals that are lacking in their primary food components.

Historical documents indicate that Ethiopia had experienced substantial deforestation, habitat change, biodiversity loss, soil degradation and an increase in the area of bare land over many years. The forest resources of the country have been continuously declining over time significantly and steadily both in size and quality (Alemnew Alelign *et al.*, 2007). Particularly, deforestation in the highlands of dates back many hundreds of years resulting in patches of forests mainly around religious centres, inaccessible and protected areas (Alemaheyu Wassie, 2007). Most of the forests in the country have disappeared and fragmented into small patches due to continuous deforestation, which is going on at a very alarming rate with an annual loss of about 141,000 ha (FAO, 2007).

According to EFAP (1994), statistical figures regarding Ethiopian forests indicate that there is a continuous decline of the original 16% of the forest cover in 1950 to 3.1% in 1982, 2.7% in 1989 and less than 2.3% in 1990. Deforestation rate has long been estimated at 150,000 – 200,000 ha per annuum (EFAP, 1994) which results in many climatic hazards emerging today. If this trend of forest devastation continues persistently, there is a great danger of serious decline or loss of the biodiversity resources (Abyot Dibaba *et al.*, 2014)

In the past, forests were managed by the government without the participation of local communities who have rich indigenous knowledge and appreciation of their natural and cultural heritages. Pressure for rapid economic development, however, can alienate people from their heritage and degrade the local environment. For example, lack of public awareness, negative attitudes, and absence of an economic benefit-sharing mechanism from the forest resources to the local people have contributed much to the loss of forests in Ethiopia (Aklilu Ameha *et al.*, 2014). Moreover, past and present efforts on land resources management seem to be inadequate as land degradation, climate change, and demographic pressure continue unabated and land productivity continues to decline at an alarming rate, which is symptomatic of our failure to mitigate the problems. Accordingly, the current rate of land resource degradation worldwide is sending a shockwave to mankind. The major reason for forest degradation, biodiversity loss and an increase in the area of bare land are the conversion of forests to farm land, fire wood, charcoal production, overgrazing, inappropriate investments and lack of viable land use policy (Ramírez-Marcial *et al.*, 2001). Such a reduction in forest cover has a number of consequences including soil erosion, loss of biodiversity, reduction capacity for carbon sequestration, and instability of ecosystem and reduced availability of various wood and non-wood forest products and services (Alemu Mekonnen and Bluffstone, 2007).

Management programme for National Parks, wildlife sanctuaries and other forest areas necessitates a thorough knowledge of the habitat preference of the wildlife of the area (Balakrishnan and Easa, 1986). Protection and management given by the Ethiopian Wildlife Conservation Authority (EWCA) during the 1980's was restricted only to a limited number of protected areas. As a result, many of the protected areas had major long-term calamities of poaching and occupation by the local people and their livestock. To this end, Wof-Washa Natural State Forest (WWNSF) can be mentioned as a tangible example. Habitat loss represents a significant threat to biodiversity and many ecological processes though habitat fragmentation leading to highly variable effects, which are either positive or negative depending on the species and the way in which fragmentation is measured (Fahrig, 2003).

1.2. Statement of the Problem

Natural populations change in structure, size, age, distribution and genetic composition over time. Variation in the density depends on the magnitude of fluctuation in its environment and on its inherent stability of population; whereas the change in age structure can affect the rate of population growth (Ricklefs and Miller, 2000). Accordingly, Wildlife population monitoring and inventory of an area is essential from time to time for effective conservation endeavor. Nevertheless, no recent data on colobus monkey population of Ethiopia since the notable decline from forest clearance ca. 30-40 years ago (Yalden, 1977; Dunbar, 1987). Historically the forest area covered a large area of land but currently it is being shrunk into inaccessible corridor due to anthropogenic factors. This undoubtedly also forces the wildlife population including colobus monkeys to decline in size or congregate within the remaining fragment of the forest.

Thus, census surveys of non-human primate populations are an integral part of primate field studies for two reasons. Firstly, to estimate population density to consider conservation priorities and develop management plans for primate populations and secondly, to understand socioecological differences between primate populations based on population estimates (Butynski, 1990; Ganzhorn *et al*., 1997). Although the black and white colobus monkeys have been studied for decades with issues related to their behavior and ecology in other countries, the parameters to be dealt in this issue will open up new avenues for researchers in colobine biology in Ethiopia.

1.3. Study objectives, hypotheses and research questions

1.3.1. General objective

The general objective of the study is to provide baseline data on Population estimate and behavioural ecology of Omo River guereza (*C. g. guereza*) from Wof-Washa Natural and plantation forest, central highland Ethiopia and ensure its long-term survival.

1.3.2. Specific objectives

- ☞ To determine population size and density of Omo River guereza at WWNSF,
- ☞ To determine effects of habitat modification on habitat use, feeding ecology and activity budget,

- To gather information on the activity budget of Omo River guerezas at Wof Washa natural and plantation forest,
- To determine the feeding behaviour of Omo River guerezas at Wof Washa natural and plantation forest,
- To determine the ranging pattern of Omo River guereza at Wof Washa natural and plantation forest.

1.3.3. Research hypotheses

- The population density of Omo River guereza is lower in WWNSF than guerezas in other countries.
- Habitat modification has negative impact on habitat use, feeding ecology and activity budget of Omo River guereza WWNSF.
- The natural forest has a higher forage availability compared to the plantation forest, and this difference will be reflected in the travel distance and activity pattern.
- Omo River guereza spend more time feeding in the natural forest than in the plantation forest.
- Omo River guereza use relatively small home range sizes and travel short distances per day in the natural forest than in the plantation forest.

1.3.4. Research questions

- How is the population density of Omo River guereza in the study area?
- What is the effect of habitat modification on habitat use, feeding ecology and activity budget?
- Which habitat type has more forage availability?

- How is the activity budget of Omo River guereza in the natural and plantation forest habitat?
- In which habitat type does Omo River guereza use small home range size and travel short distances per day?

2. LITERATURE REVIEW

2.1. Distribution and biology of colobus monkeys

The primate order is one of the most diverse and successful group of mammals with more than 630 taxa currently described (Groves, 2004; Mittermeier *et al.*, 2009; Rowe and Myers, 2011). Over the course of their evolutionary history, nonhuman primates display great diversity of behavioural and morphological traits. Nonhuman primates have been documented in every continent colonized by placental mammals with the exception of Antarctica (Rowe and Myers, 2011).

A number of primate societies have been subject to observational studies for many decades. These studies have focused on the behaviour, ecology and social organization of primates in their natural environment and have transformed our understanding of their social systems and evolution (Rodrigues, 2012). Recent studies have shown that both environmental and historical factors influence community structure (Harcourt, 2000; Chase, 2003; Reed and Bidner, 2004). However, primate ecology research has been conducted from either an ecological or an evolutionary perspective (Kamilar, 2009). The most common studies have focused on the role of abiotic factors such as rainfall and temperature in shaping various aspects of communities, including local species richness (Reed and Fleagle, 1995; Kay *et al.*, 1997), often without explicitly accounting for the particular species in the community. Concerning animal communities, climatic factors shape the abundance and diversity of vegetation in the environment (Kamilar, 2009), and this in turn sets the stage for the possible animal taxa inhabiting a particular area based on the niches available (Kay *et al.*, 1997) which is crucial for colobine distribution. The role of environmental factors on the composition of primate communities is more complex. Different abiotic factors are important for predicting the taxonomic structure of primate communities in different regions. The effects of climatic factors demonstrate that ecological filtering influences the presence or absence of many species, independent of their evolutionary history (Kamilar, 2009).

The vast majority of colobine species are strictly arboreal, whilst only a few species live semi-terrestrially. They are found in a relatively great variety of habitats and climatic zones. African colobines show a wide distribution in tropical African forests from the Atlantic coast of the far west to the coasts of the Indian Ocean in Kenya and Tanzania (Pemba Island). The majority of species live in moist lowland forests, but some members of these primate taxa live in deciduous forests, savanna woodlands and montane forest zones (Oates *et al.*, 1994). Asian colobines inhabit a wide variety of forest types, from tropical rain forest to montane, mangrove, temperate and highly seasonal forests. Hence, they are distributed over a wide geographic range, from China to Java and from India to Borneo (Bennett and Davies, 1994). Presently, colobine monkeys are almost absent in open habitats where considerable terrestrial locomotion is required (Hadi, 2012). However, fossil evidence suggests that during the Miocene and Pliocene, colobines were distributed over larger geographical areas, and many of these earlier colobines lived in relatively open woodlands and were at least partly terrestrial (Oates and Davies, 1994). For instance, Angola black-and-white colobus (*Colobus angolensis*) lives in the forests of northeast Angola, Democratic Republic of Congo, Rwanda, Tanzania, and Kenya (Kingdon, 1997). Whereas, Asian colobines extend from mainland of Asia to islands of Borneo (*Nasalis*) and Mentawai (*Simias*) (Miller *et al.*, 2005).

The black and white colobus monkey (*Colobus guereza*) is one of the five recognized species in the genus *Colobus* which inhabits a wide range of forest types in tropical Africa from Ethiopia to Nigeria (Dunbar and Dunbar, 1974). The species is folivorous and often, though not always, exhibits a preference for young leaves (Fashing, 2001b). According to Kingdon *et al.* (2008), the species, *Colobus guereza*, contains eight subspecies, of which, two are endemic to Ethiopia: *C. g. guereza* and *C .g. gallarum*.

The Omo River guereza (*C. g. guereza*, *Rüppel, 1835*) is found in the highlands west of the Great Rift Valley down to the reaches of the Awash River, the Omo River and in the Blue Nile gorge. The Djaffa Mountains guereza (*C .g. gallarum*, *Newmann 1902*) is found east of the Great Rift Valley in Ethiopia (Groves, 2007; Jensz and Finley, 2011). The subspecies status is based on differences in morphological features according to Fashing and Oates (2013). In *C. g. guereza,* mantle hair is relatively long, covering about 20% of the tail. Tail is much longer than head-body length (HB) and proximal part of the tail is grey while the distal part is silvery white. Whereas, in *C. g. gallarum*, the proximal part of the tail is black with scattered grey hairs increasing distally and the distal part is white and bushy. Both of the subspecies occur at altitudes ranging from 400-3300 m asl (Yalden, 1977).

However, the taxonomic status of many of East African primates is still under debate and the geographical distribution and conservation status of many of the primate taxa remain poorly understood (De Jong and Butynski, 2012). Even though most other subspecies of colobus monkeys have been a subject of study for decades (Oates, 1977; Bocian, 1997; Krüger *et al.*, 1998; Von Hippel, 1998; Von Hippel *et al.*, 2000; Fashing, 2001a; 2001b; 2002; Chapman *et al.*, 2007; Fashing *et al.*, 2007a), little is known about the behaviour, ecology and genetics of these two subspecies of colobus monkeys in Ethiopia (Dunbar and Dunbar, 1974; Dunbar, 1987; Jensz and Finley, 2011). Thus, understanding the basic quantitative natural history of primate species is vital to their conservation (Fashing, 2007;

Addisu Mekonnen *et al.*, 2010b). For instance, data on feeding ecology provide not only information on the individual food species necessary to the primate's survival but also insight into its level of dietary specialization.

2.2. Special adaptations of the Colobinae subfamily

A number of derived morphological traits distinguish the colobines from their sister group, the cercopithecines (subfamily Cercopithecinae), including dental, skeletal and physiological characters (Strasser and Delson, 1987). Many of the derived morphological traits found in the colobines including molar teeth with high cusps and ridges for breaking down leaf cellulose, extensive salivary glands and large, multi-chambered stomachs that contain a variety of microbes. These derived features are adaptations to diets that are more folivorous than the diets of other Old World monkeys (Kay and Davies, 1994; Disotell, 2000; Sterner *et al.*, 2006). Within the family Cercopithecidae and subfamily Colobinae, both sister clades, the Asian leaf monkeys or langurs and African colobus monkeys, have an adaptation to demonstrate a unique fermentation system for primates (Arnold and Meyer, 2006).

Langurs and African colobus monkeys possess both a complex foregut, where bacteria ferment leaf material, and a true stomach in which large levels of bacteriolytic lysozyme are expressed (Chivers and Hladik, 1980; Messier and Stewart, 1997). Ruminant artiodactyls and colobine monkeys mainly eat leaves. According to Kay and Davies (1994), a foregut-fermenting alimentary system independently originated in these organisms to facilitate the digestion of the cellulose-rich food. The parallelism of foregut fermentation in ruminants and colobines is a fascinating physiological phenomenon, that needs detailed molecular genetics and evolutionary analyses (Zhang, 2003). Moreover, many Asian colobines demonstrate a behavioural adaptation towards selecting young leaves, which are lower in plant fibre. Therefore, young leaves are easier to break down in the mouth and stomach, and have fewer plant secondary compounds, making them easier to digest (Yeager and Kool, 2000).

Additionally, it has been found that Zanzibar red colobus monkeys eat charcoal from tree bases and stumps that are charred after pastures are burned, charcoal furnaces, bits accidentally dropped by people along paths, and near houses. This behaviour enables them counteracting toxicity due to phenolic and similar compounds in their diet leaves that could potentially be deleterious to them and produce symptoms of toxicity, or at least interfere with digestive efficiency (Struhsaker *et al.*, 1997). There is an exceptional aquatic behaviour in colobines where the Asian sister clad, proboscis monkey (*Nasalis larvatus*) swims using a powerful dog paddle, with the head held well above the water (Brandon-Jones, 1996).

2.3. Phylogeny and phylogeography of the Colobinae Subfamily

Biologists have been debating whether the true centre of origin of primates was in Africa, Asia or America for more than a century and the argument has never been resolved (Heads, 2010). The problem of primates' origin in space is related to the question of their origin in time. While fossil-based dates give an origin for primates in the Paleocene, at ∼56 Ma, fossil-calibrated molecular clocks give Cretaceous dates, at ∼90 Ma (Janečka *et al.*, 2007). The single most puzzling aspect of primate evolution remained unreciprocated is the one which was asked by Masters *et al.* (2006); where did primates originate? and how did they come to occupy their current distribution? However, paleontological investigations over the past century have demonstrated conclusively that the major clades of catarrhines (where

Colobinae are a part) originated and diversified in Afro-Arabia during the Paleogene and were restricted to this zoogeographic province until the early Miocene (Harrison, 2005).

Furthermore, catarrhines have repeatedly expanded their geographic range into Eurasia. Additionally, the collision of the Afro-Arabian plate with Eurasia during the early Orleanian (at ~17–20 mya) established a land bridge between Arabia and Southwest Asia that permitted a major entry of endemic African mammals into Eurasia, including the first catarrhines (Thomas, 1985). Subsequent immigrations into Eurasia brought the first colobines (possibly as early as ~10–11 mya) (Fig. 1). Thus, Catarrhine evolution has been very much an 'Out of Africa' story (Harrison, 2005). Moreover, Fleagle and Gilbert (2006) concluded the origin of Old World monkeys in general to be in Africa. The most parsimonious explanation for colobine origins is that they first evolved in Africa, and then

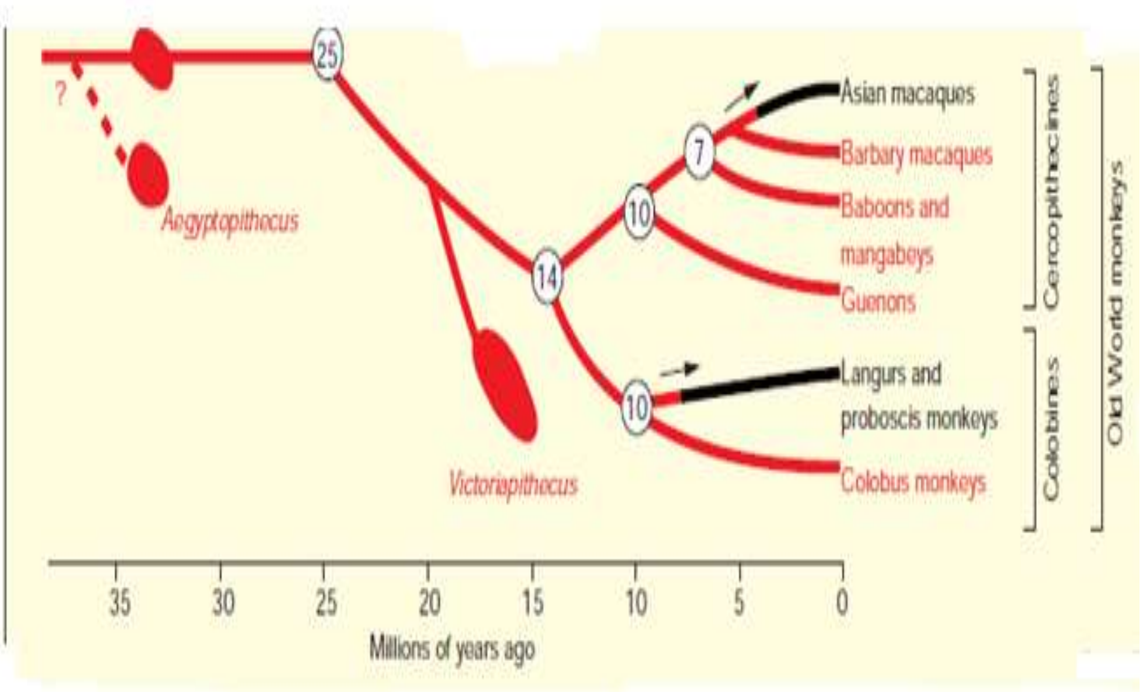

Figure 1. A synthetic hypothesis of Colobine evolution as part of Old World monkey evolution (Stewart and Disotell, 1998).

dispersed into Asia (Zhang and Ryder, 1998), less than 10 million years ago (Fig. 1) (Stewart and Disotell, 1998).

Accordingly, the origin of the subfamily Colobinae is most likely in Africa, which is in agreement with suggestions given by Delson (1994) and Stewart and Disotell (1998). On the African continent, *Colobus* split off first from the main stem ∼10.93 mya, followed shortly afterwards by the progenitor of *Piliocolobus* and *Procolobus* (Fig. 2). Presumably, respective splitting and hybridization events took place in western Africa, because all three genera occur there in sympatry (Oates, 1994; Groves, 2001), and the most ancient splits among *Pilio-colobus* and *Colobus* species are also found there (Ting, 2008). The Asian colobine ancestor most likely invaded Eurasia via an emerging land bridge connecting Africa and the Arabian Peninsula in the late Miocene (Thomas, 1985; Stewart

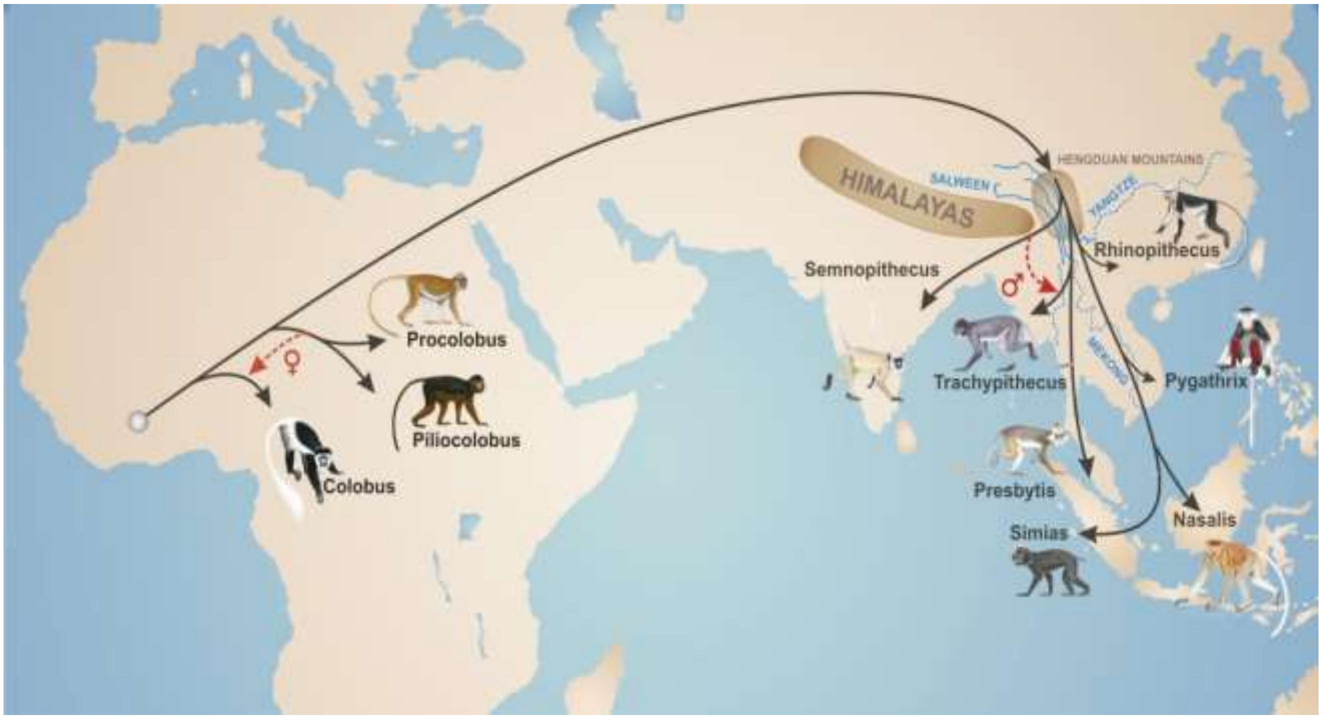

Figure 2. Origin and dispersal scenario for colobine monkeys (Source: Meyer, 2011).

and Disotell, 1998). Phylogenetic hypotheses concerning the living African colobines have been developed using analyses of morphology, pelage, and vocalizations (Ting, 2008).

The living Old World monkeys (family Cercopithecidae) have long been divided into two subfamilies, Colobinae and the cheek-pouched Cercopithecinae (Oates *et al.*, 1994; Morales *et al.*, 1999; Disotell, 2000; Groves, 2001; 2007; Wang *et al.*, 2012) (Fig. 3).

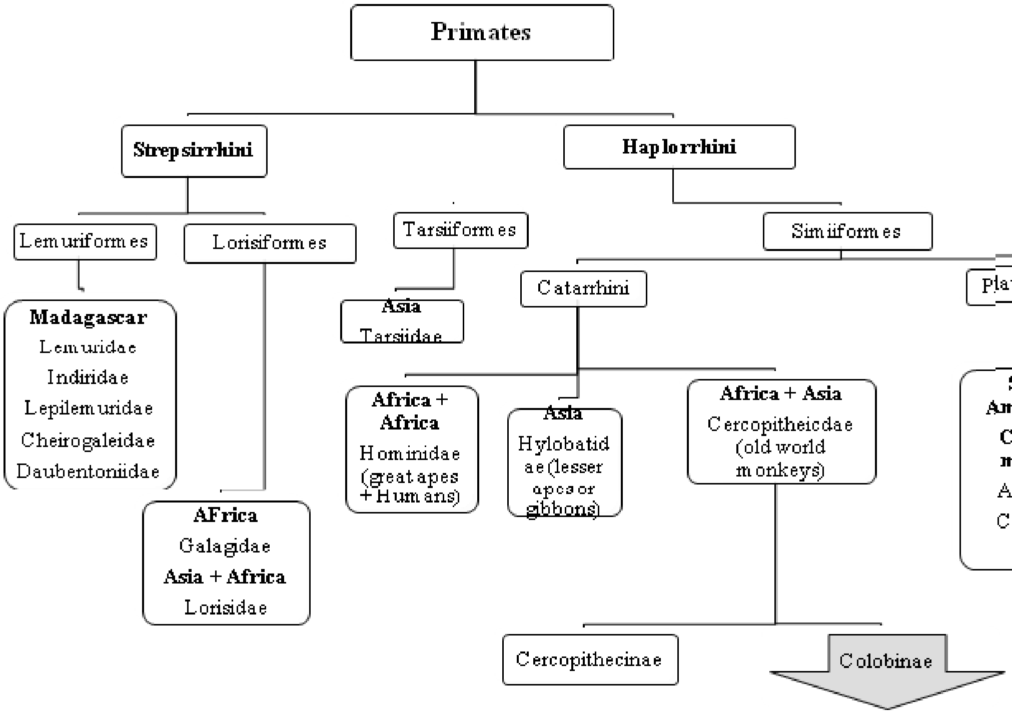

Figure 3. Taxonomic position of colobinae in the Order Primate.

Within the cercopithecinae, there are two groups: the cercopithecins (guenons, vervets, patas and swamp monkeys, and talapoins) and the papionins (macaques, mandrills, mangabeys, and baboons) (Morales *et al.*, 1999). Compared to the Cercopithecinae, Colobine monkeys differ in several morphological aspects. Colobines are easily distinguished from cercopithecines by their sharp-cusped cheek teeth and relatively narrow incisors. Their skulls have relatively short snouts, narrow nasal openings, broad interorbital areas, and deep mandibles. They have complex, sacculated stomachs similar to those of cattle that enable them to maintain bacterial colonies for digesting cellulose. Their skeletons are characterized by relatively long legs, long tails, and thumbs that are usually short or even absent (Greek Kolobos means mutilated; (Oates and Davies, 1994; Fleagle, 2013).

The living colobines have been grouped between four and nine genera, which often are categorized into two clusters, the African and Asian clades (Oates *et al.*, 1994; Fleagle, 2013). However, recent studies revealed that Colobine monkeys are a diverse group of Old-World primates with 59–78 species grouped in up to 10 genera (Groves, 2001; 2007; Zinner *et al.*, 2013) (Fig. 4). The genetic and phylogenetic relationships within and between the African and Asian colobines are very complex. As the relationships among cercopithecines, they probably reflect a complex history of hybridization (Wang *et al.*, 2012).

The African colobines appear to be a monophyletic assemblage based on some shared morphological characteristics such as a vestigial thumb, mid-tarsal shortening, and some other postcranial and dental features (Delson, 1975; Strasser and Delson, 1987; Oates *et al.*, 1994; Morales *et al.*, 1999). They were grouped into two genera, *Colobus* and *Procolobus* (Oates *et al.*, 1994; Morales *et al.*, 1999). The African colobus monkeys come in three color schemes: black and white, red, and olive. The three groups are quite distinct behaviourally and ecologically.

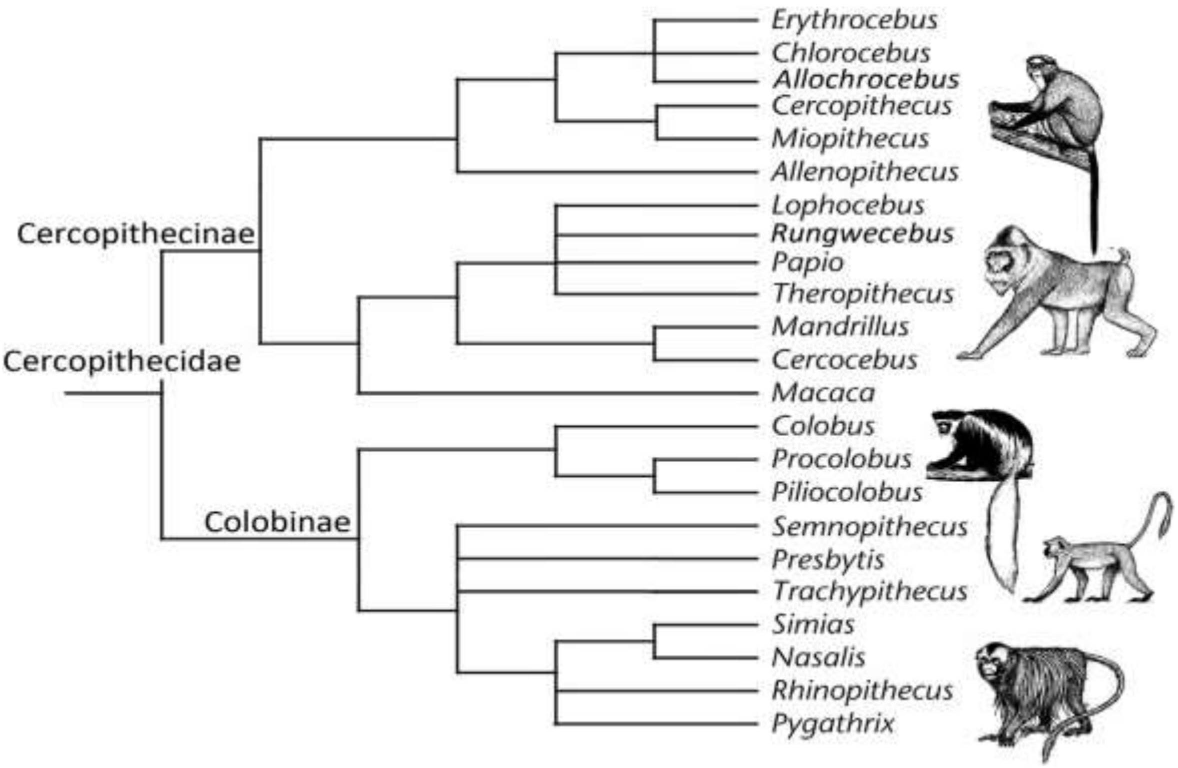

Figure 4. Phylogenetic position of Colobus monkeys in the phylogeny of Old World monkeys (Fleagle, 2013).

The black and white colobus monkeys are the largest and most spectacular of the African colobines. These are quite robust monkeys, with considerable sexual dimorphism in size (Fleagle, 2013). The black-and-white *Colobus* include five recognized species including *Colobus guereza, C. satanas, C. polykomos, C. vellerosus* and *C. angolensis* (Oates and Trocco, 1983; Grubb *et al.*, 2003). The genus *Procolobus* includes two major groups: red (subgenus *Piliocolobus)* and olive (subgenus *Procolobus)* colobus monkeys which are united by a set of anatomical characteristics that distinguish them from the members of the black and which colobus group (Oates *et al.*, 1994; Morales *et al.*, 1999). Among the red colobus, up to fourteen different taxa are recognized based on pelage, vocalization and cranial morphology, which some authors consider either different species or a single species with different local forms (subspecies) (Morales *et al.*, 1999; Ting, 2008).

However, later Groves (2007) grouped the African colobines into three distinct genera namely *Colobus*, *Procolobus* and *Piliocolobus* as illustrated in Fig. 4.

2.4. Population estimate and habitat use

Censusing non-human primates over time, is necessary for monitoring population trends, which is an important component for designing and evaluating management practices (Kremen *et al.*, 1994; Gibbs *et al.*, 1998). An understanding of population dynamics is critical to the development of effective conservation management plans and realistic models of population and behavioural ecology (Lwanga *et al.*, 2011). According to Chapman *et al.* (2010) and Struhsaker (2008), the long-term studies indicate that some and perhaps most primate populations are in non-equilibrium states. Both ecology and conservation programmes, habitat management and assessment of ecosystem status require the determination of the richness and the abundance of target species, as baseline data for calculation of biomass, productivity, and as an estimate for population trends (de Thoisy *et al.*, 2008).

The density of primates can be estimated by several methods, such as complete count of individuals, home range monitoring, playback and estimates using line transect surveys (Fashing and Cords, 2000; Chiarello and de Melo, 2001; Strier *et al.*, 2006; Marshall *et al.*, 2008; Ferrari *et al.*, 2010; Buckland *et al.*, 2010a; 2010b). Ecological determinants of primate density are manifold and include food quantity and quality, habitat diversity, parasites/diseases, and predators, (Chapman *et al.*, 1999), as well as forest type, rainfall, elevation, and latitude on a larger scale (Peres and Janson, 1999).

The colobus monkey population of Ethiopia is steadily declining with forest clearance (Yalden *et al.*, 1984) although the eastern black and white colobus monkeys, or guerezas, have traditionally been considered as one of the few species adapted to habitat degradation (Fashing, 2002). This fact is in contrary to researches stated that guereza population is reach extraordinarily high densities in small East African forest fragments where few other primate species exist or are absent (Dunbar, 1987). These studies suggest that guerezas are particularly well adapted to life in disturbed forests, though the ecological factors that allow guerezas to flourish in these forests are not entirely clear (Oates, 1977). This traditional view that guerezas flourish in disturbed areas, however, has been challenged by von Hippel *et al*. (2000) who provided evidence that a guereza population in the Kakamega Forest, Kenya, declined in density over a six-year period when the forest was degraded by human activities.

2.5. Activity budget and ranging ecology

Identifying how animals divide their activities throughout the day offers clear perception into their interaction with the environment and their strategies for maximizing energetic and reproductive success (Defler, 1995). Knowledge of a species' home-range size and ranging and activity patterns is vital for understanding its behavioural ecology, habitat requirements, and vulnerability to extinction (Singleton and van Schaik, 2001; Nkurunungi and Stanford, 2006). Studies on the behaviour and ranging patterns of species in fragments in comparison to larger forest blocks can give an indication of habitat quality such as food availability, density and distribution at least in the short term (Zanette *et al.*, 2000; Wong and Sicotte, 2007).

Primates display wide interspecific variation in activity and ranging patterns (Fashing, 2007). Activity budgets of primates are commonly associated with strategies of energy conservation (Oates, 1977; Milton, 1998) and are affected by predator or human pressure;

social structure; season; or availability, distribution and quality of food resources (Clutton-Brock, 1975a; Milton, 1980; Bennett, 1986; Boinski, 1987; Zhang, 1995; Watts, 1998; Twinomugisha and Chapman, 2008; Wijtten *et al.*, 2012). Many factors are known to influence primate activity budgets in natural habitats, most of which are linked to the challenges of food energy acquisition. Activity budgets are directly related to metabolism and to energetic needs that will change over the course of the seasons or in relation to reproductive stage (Halle and Stenseth, 2012). The availability and spatial patterning of food resources affect the activity and ranging patterns of many primates (Clutton-Brock, 1975b; Boinski, 1987; Olupot *et al.*, 1997; Wijtten *et al.*, 2012; Smith *et al.*, 2013).

Researchers observe animal ranging behaviour and habitat use to investigate the interaction between ecological influences and individual patterns of behaviour (Zhou *et al.*, 2013). Primate Ranging patterns are thought to be influenced by a variety of ecological and behavioural factors, including food availability, distribution and quality (Clutton-Brock, 1975a; Bennett, 1986; Boinski, 1987; Zhang, 1995; Olupot *et al.*, 1997), rainfall patterns (Isbell, 1983; Olupot *et al.*, 1997), distribution of water (Scholz and Kappeler, 2004), group size (Waser, 1977; Van Schaik *et al.*, 1983; Gillespie and Chapman, 2001), reproductive situation (Rasmussen, 1979; Overdorff, 1993), location of sleeping site (Zhou *et al.*, 2011), intergroup relationships and social interaction (Isbell, 1983; Benadi *et al.*, 2008), forest structure (Fan and Jiang, 2008), and parasite avoidance (Nunn and Dokey, 2006). Of these varieties of factors, primate ranging patterns are influenced primarily by the availability, distribution, and quality of food (Di Fiore, 2003; Buzzard, 2006; Zhou *et al.*, 2011).

Home range size within a species tends to increase with increasing group size and a similar relationship between group biomass and range size has also been found to hold at the interspecific level (Clutton-Brock and Harvey, 1977; Dunbar, 1988). Folivorous species tend to have smaller home ranges and travel shorter distances each day than frugivorous primates do (Zhou *et al.*, 2013). The relatively poor quality yet increased ubiquity of the forage consumed by folivorous may account for these trends (Clutton-Brock and Harvey, 1977; Chapman and Chapman, 2000). Moreover, primates can regulate their ranging behaviour in response to seasonal changes in food availability as some primates reduce the length of daily travel when high-quality food is scarce (Bartlett, 1999), while others show the opposite response, travelling further in search of high-quality food (Bocian, 1997).

2.6. Feeding ecology and resource availability

Revealing how environmental factors determine animal abundance is one of the primary goals in animal ecology in which the effect of food has paramount importance among the various factors. This concern has recently reserved a heightened weight as many animal populations are declining under increasing human pressure which deteriorate animals' habitat. Thus, understanding the factors affecting animal populations is necessary for conservation and management (Hanya and Chapman, 2013). For instance, forest loss and fragmentation often lead to a reduction in food resources and threaten many primates globally (Chapman *et al.*, 2007; Wong and Sicotte, 2007; Bracebridge *et al.*, 2012; Kibaja, 2014). Primates are ideal subjects to study both animal abundance and feeding ecology (Hanya and Chapman, 2013). As most primates are diurnal and have large body sizes, detailed behavioural observation is feasible and there have been many studies of their feeding ecology (Clutton-Brock, 1977; Hohmann *et al.*, 2012; Hanya and Chapman, 2013; Kibaja, 2014). Food abundance and distribution has great influence on primate ranging behaviour (Clutton-Brock, 1977).

Primates are generalist consumers and are dependent on a diverse array of resources, such as leaves, fruits/seeds, flowers, gum/sap, barks, and insects. These food resources vary in their nutritional and distributional properties, where comparative primate research can clarify various mechanisms concerning how food affects abundance. For instance, folivorous monkeys such as guerezas, select the most nutritive and easily digestible items, rich in proteins, such as young leaves and leaf buds though they also eat other plant parts and arthropods to supplement their diet (Chapman and Chapman, 2002; Hanya and Chapman, 2013; Kibaja, 2014).

Researchers have strived to find out how diet varies in nonhuman primates with spatiotemporal differences in food availability through long-term field studies nearly for half of a century (Oates, 1977; Milton, 1980; Fashing, 2001b; Xiang *et al.*, 2007; Felton *et al.*, 2008b). Colobinae is a large subfamily of leaf-eating, Old World monkeys represented in Africa by species of 3 genera, *Colobus*, *Procolobus*, and *Piliocolobus* (Grubb *et al.*, 2002). This subfamily in which Omo River guereza is a member, grip the focus of primatologists investigating primate feeding ecology (Clutton-Brock, 1975a; Oates, 1977; Fashing, 2001b; Fashing *et al.*, 2007a; Wong and Sicotte, 2007; Xiang *et al.*, 2007; Kibaja, 2014). These folivorous monkeys are forest-dependent and live in groups of highly variable size, often forming mixed-species associations with other primates (Clutton-Brock, 1975a; Oates, 1977). Guerezas highly depend on leaves and their special adaptation to exploit foliage attributed to life in gallery and dry forests (Oates, 1977; Bocian, 1997). However, descriptions of the diets of frugivorous primates have traditionally contrasted the relative importance of different food items by the time spent feeding on them (Felton *et al.*, 2008b).

Members of the subfamily reveal various anatomical structures that can be considered as adaptations for ingesting leaves (Xiang *et al.*, 2007). Some of these structures are high, sharp cusps and long lophs molars and enlarged, sacculate forestomach that permits the breakdown of cellulose by microbial fermentation (Chivers, 1994; Kay and Davies, 1994). These morphological traits of Colobinae indicate to folivory (Xiang *et al.*, 2007). Researchers initially assumed that this dietary specialization arose to allow colobines to feed on these indigestible leaves for other primates (Andrews and Aiello, 1984). However, further work suggests that this adaptation may have primarily served to cope with the indigestible compounds and toxins in seeds (Chivers, 1994; Lambert, 1998).

2.7. Conservation of colobus monkey

World mammal status analysis on global scale shows that primates are the most threatened (Schipper *et al.*, 2008) making them indicators for investigating vulnerability to threats. Habitat loss and destruction are often considered to be the most serious threat to many tropical primate populations because of agricultural expansion, logging, and human settlement (Cowlishaw and Dunbar, 2000). Deforestation and forest fragmentation have marched together with the expansion of agricultural frontiers, resulting in both habitat loss and subdivision of the remaining habitat (Michalski and Peres, 2005). This forest degradation results in reduction in size or fragmentation of the original forest habitat (Fahrig, 2003).

Forest primates are thought to be particularly vulnerable to local extinction in fragmented landscapes (Cowlishaw and Dunbar, 2000). Arboreal primates are often unable to cross non-forest areas, which results in low population densities, and are often subjected to direct human persecution (Chiarello and de Melo, 2001). Likewise, the main threats of colobus monkeys are ongoing habitat loss and degradation for agriculture, grazing land expansion, plantation and the removal of forest products for fuel wood and charcoal production (Kingdon *et al.*, 2008) due to the ever-increasing human population growth in Ethiopia. Consequently, species that are unable to adapt to altered habitats are being forced into small, marginal habitat patches. In small and fragmented populations, genetic diversity may be reduced owing to increased levels of drift and inbreeding. This reduced diversity is often associated with decreased fitness and a higher threat of extinction (Bergl *et al.*, 2008). As a result, the long-term survival of many of these animals is questionable (IUCN, 2000). Largely because of this habitat loss, 50% of African colobine species are endangered, and additional 20% are rare (Grubb *et al.*, 2002). In addition, colobus monkeys are also killed for their skin in Ethiopia (Yalden, 1977).

3. DESCRIPTION OF THE STUDY AREA

3.1. The study site location

The study on population and behavioural ecology of Omo River guereza was conducted in Wof Washa Natural State Forest (WWNSF) which is located in North Shoa Zonal administration, Amhara National Regional State, central highlands of Ethiopia. The escarpment forms part of the catchment of the Awash River system which drains into the Danakil Plains in the northern section of the Rift Valley (Tamirat Bekele, 1993). It extends approximately between 9º42′- 9º47′ N latitude and 39 º 43′- 39 º 49′E longitude (Fig. 5).

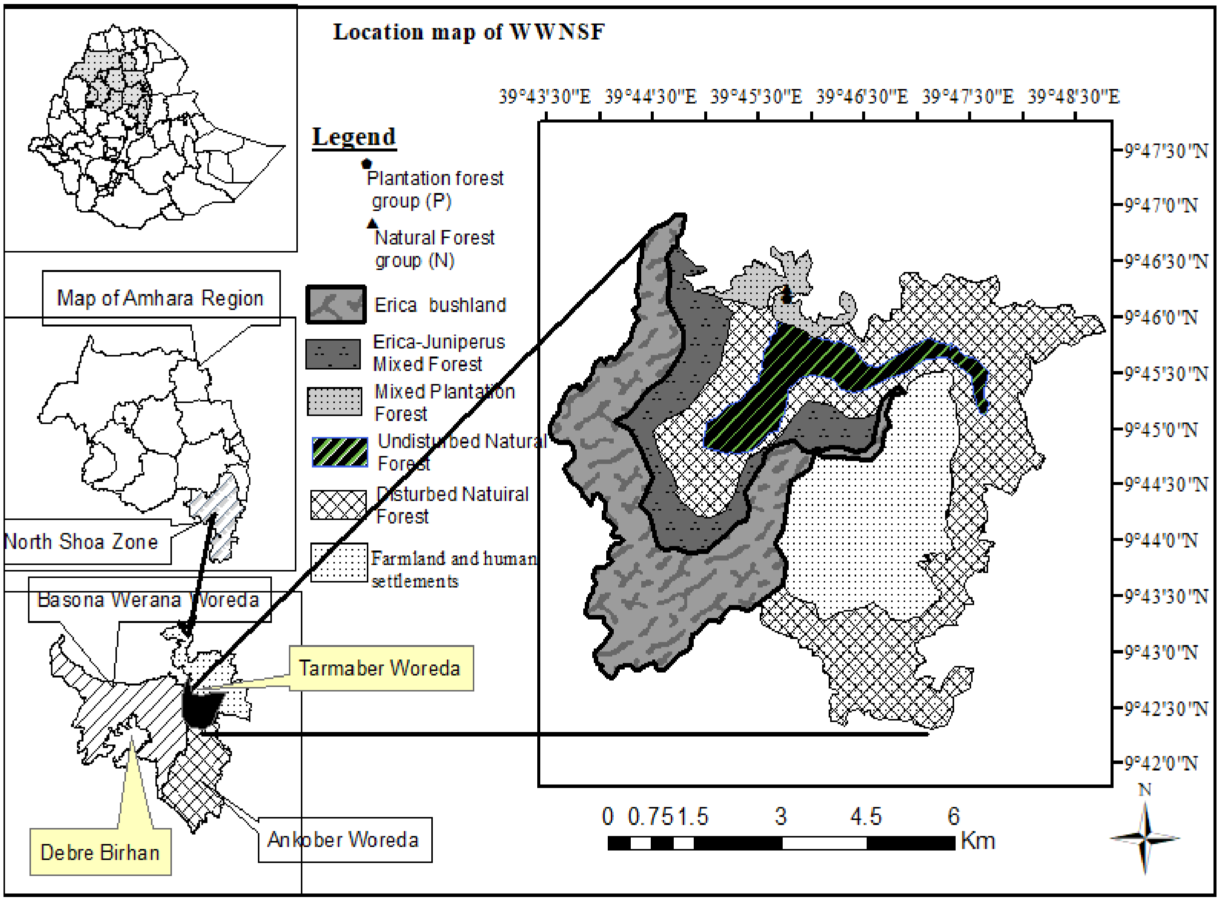

Figure 5. Map of the study area

WWNSF is one of the very few remaining dry Afromontane forest and oldest natural state forests of the central highlands in Ethiopia. It is the only stretch of forest left in the surrounding. The terrain that makes it nearly impossible to build roads down into the lowlands cutting through the forested area because of the rough cliffs and steep slopes. Thus, the inaccessibility of the area even on foot, enables most of the original tree population to survive. During the rule of Emperor Zara Yaqob in the 15th century, the forest was mentioned as the *King's forest*. This denomination kept the farmers out of the forest and left the timber and other forest products for the king's sole use.

Before being cleared for agriculture, it was, a dense continuous forest throughout the region, but most land outside WWNSF has been deforested and small holder subsistence agriculture dominates the landscape nowadays. The extent of WWNSF is estimated by the Ministry of Natural Resource Development and Environmental Protection (MoNARDEP, 1994) to be 167 km^2. According to this report, 92 km^{2}of the area is covered with disturbed natural forest while about 42.7 km^2 by artificial forest. The remaining 33.9 km^2 is open and bushland as well as agricultural land and settlements. Recently, the forest covers 7850 ha but it has about 400 ha additional area which is completely degraded with very few *Juniperus procera* trees on the forest border and cliffy bare areas on the higher region of the forest, which has shrunk from 9200 ha since 1994 (Action Aid Ethiopia, 2010). Additionally, the forest is still under human and livestock pressures which are believed to reduce the area of the WWNSF as time goes on (Demel Teketay and Tamrat Bekele, 1995).

For this study, the forest is classified into five habitat types based on the dominant vegetation types (plantation, *Erica* bushland, *Erica-Juniperus* mixed forest and natural forest) and the intensity of human encroachment (disturbed and undisturbed natural or relatively intact forest). These habitats are Mixed Plantation Forest (MPF= 130 ha), Disturbed Natural Forest (DNF=1628 ha), Undisturbed Natural Forest (UDNF= 317 ha), Erica-Juniperus Mixed Forest (EJMF= 485 ha) and Erica bush land (EBL= 1139 ha) which altogether cover 3699 ha (Fig. 5). The area of each habitat type is obtained by digitizing from google Earth programme and excludes the area covered by cliffy bare land and human settlements within the forest.

The study area is bordered by three Woredas, namely: Tarmaber in the northeast, Ankober in the south and southwest and Basona-Worena in the north and northwest (Action Aid Ethiopia, 2010). Concerning the topography, the forest is situated along the altitudinal gradient between 1,650 m asl near Gift Michael where it merges into *Acacia* scrubland on the valley floor to 3,700 m asl at the top of the Rift Valley escarpment near Kundi on the plateau. The area is steep and dissected by ravines and gorges through which rivers and streams tumble down the eastern escarpment of the Great Rift Valley. The forest is on very steep slopes in narrow valleys mostly facing to the East (Plate 1).

Plate 1. The east facing view of WWNSF.

3.2. Physical and biological settings of the area

There are no climatic data available for the forest area. Accordingly, the data used for the description of the climate was collected from Debre Berhan Station, at 2750 m asl (9° 40' N, 39 °30' E) and 30 - 35 km west of the forest, obtained from the National Meteorological Agency (NMA, 2016).

Based on 32 years of climate data (1985-2016) obtained from NMA, the mean annual rainfall of the study area is 906 mm (NMA, 2016). The distribution of rainfall in the area is bimodal, characterized by small rain from March-May with a peak in April (Daniel Gamachu, 1977) and a prolonged wet season from July to September (big rain) with high concentrations in July and August, which was reduced since the 1960s (Magin, 2001). The highest amount of rainfall is recorded in July followed by August. The small rainy season is unpredictable and highly variable. As in many tropical rain forests, there is considerable month-to-month variation in rainfall in the region.

Cloud persistence is common in this forest which is a phenomenon not observed elsewhere on the Central Plateau. A cloud belt is formed at the altitude of the forest belt and stays for the most part of the day. This cloud formation is the result of orographic condensation and forced convective raising (Tamrat Bekele, 1993). There are often dry winds during the day; frosts may occur at night, and snow sometimes settles on the summit of Eme-mihret, Kundi and Wuti. The mean annual temperature of the study area is 12.6 ^{0}C ranging from the mean annual minimum temperature of 2.3 ^{0}C to the mean annual maximum temperature of 22 ^{0}C (Fig. 6). The study area falls into different climatic zone as Weina Dega, Dega and Wurch.

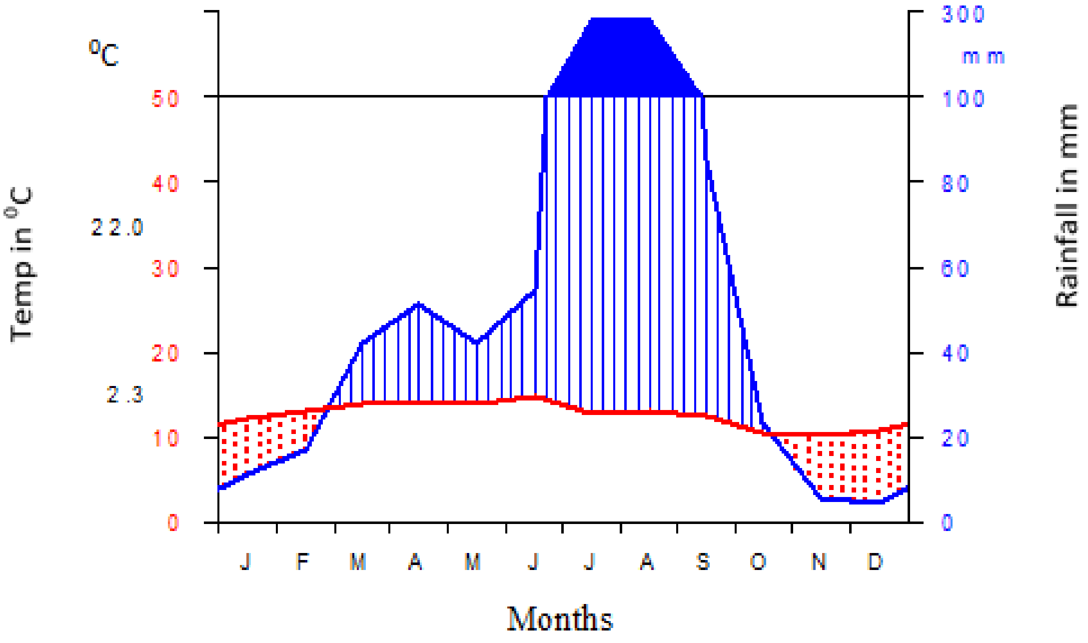

Figure 6. Climate diagram for Wof-Washa Natural State Forest (1985-2016) (Source: NMA, 2016).

In addition to the meteroeological data obtained from NMA, rainfall and temperature data have been recorded in the study area using Oregon wireless rain gauge and Taylor digital waterproof maximum/minimum thermometer (Plate 2) for a year from May 2015 to April 2016. Average mean monthly rainfall and maximum and minimum temperatures have been summarized for comparison with the data obtained from NMA. Accordingly, the annual rainfall of the study area is 1401 mm for the year 2015-2016 and the mean annual temperature of the study area is 16.1 ^{0}C ranging from the mean annual minimum temperature of 8.5 ^{0}C to the mean annual maximum temperature of 24 ^{0}C (Fig. 7).

Plate 2. Photos of field equipment and installation of Oregon wireless rain gauge and Taylor digital water proof maximum/minimum thermometer (Source: Dereje Yazezew, 2015).

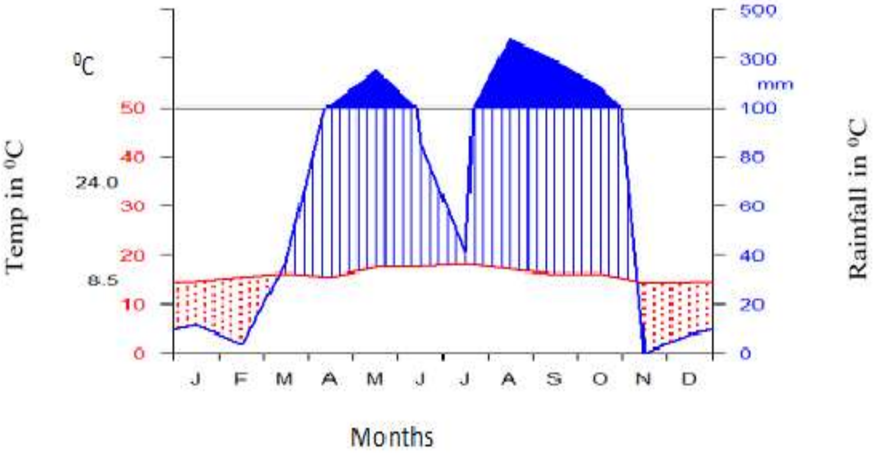

Figure 7. Weather diagram for WWNSF during the study period (May 2015 – April 2016).

Geologically, the bed rocks are volcanic and consist of Termaber basalts, which constitute the major rock type of the region, which are named after the Termaber Pass near Debresina (Tamrat Bekele, 1993). Most parts of the area are covered by volcanic rocks mainly basalts of Tertiary age. Precambrian rocks that underlie the whole of Ethiopia consist of complex metamorphic and igneous rocks of many different grades and types (Mohr, 1971). The lithology of the forest is very heteroginous, comprising ferric basalts, fine-grained basalts, zeolitised basalts, phonolites, alkali trachytes and subordinate alkaline and per alkaline rhyolites. The basaltic assemblage is reported to be alkaline. The termaber basalts differ from the typically fissured ones of the plateau, owing to markedly lower SiO_2 and much higher Al_2O_3 and alkali contents. It is worth nothing that the alkaline character of the Termaber rock is essentially due to the high level of Na_2O (Marla *et al*., 1979). Reddish-brown soils are predominant on slopes, while black soils are prevalent in valley bottoms and on the surrounding highland plains. The soils are very shallow and mostly rocky, especially on the slopes. Soil erosion is very serious problem in these highlands (Tamrat Bekele, 1993).

The vegetation of northwestern highland forests of Ethiopia broadly belongs to the Afromontane archipelago-like centre of endemism mostly found in the tropics (White, 1983). According to Friis (1992) and Tamrat Bekele (1993), the vegetation in northwestern highland Ethiopia are categorized under the dry evergreen montane forest which is characterized by one or more closed strata of evergreen trees. This dry evergreen vegetation type is further divided into two: the Afromontane rainforest which occurs above 2000 m asl in the tropics that characteristically contain a mixture of *Podocarpus falcatus* and broadleaved species. The second type includes the Transitional Rainforest, which occurs in the northwestern highlands of Ethiopia. The altitudinal location of the study area reveals that the vegetation under study can be categorized in Dry Evergreen Afromontane Forest ecosystem. The vegetation of WWNSF is a montane moist to dry Afro-alpine mixed with both broadleaved and conifers. There are both indigenous and exotic tree species in WWNSF.

The main characteristic species at the higher altitudes are *Hagenia abyssinica*, *Olea europaea cuspidata* and *Juniperus procera*. *Podocarpus falcatus*, *Allophylus abyssinicus*, *Haleria lucida*, *Euphorbia abyssinica*, *Polyscias fulva* and *Olinia rochetiana* at the middle. Above 3,000 m asl *Erica arborea*, *Hypericum revolutum* and giant *Lobelia* spp. are the most dominant species with few *Hagenia abyssinica* and *Pittosporium viridiflorum* below inaccessible cliffy and steep slope areas. In the open areas, over rocks and on the cliffs, there are also extensive patches of the endemic *Kniphofia foliosa*, Clumps of *Helichrysum* spp. and *Festuca* grass which adapt the extreme climate. The natural vegetation of the study area is broadly classified as *Juniperus procera* forest or “dry evergreen montane forest” with *J. procera* as the dominant species in most of the forest area. *Arundinaria alpina* is found only at the deepest gorge at the centre of the forest along the source of Awadi River. *Dovyalis abyssinica* and *Maytenus arbutifolia* are the most dominant shrubby trees under the canopy of *Juniperus procera* and *podocarpus falcatus* in most part of the forest. Generally, there are over 252 species of plants, of which, 29 species (12%) are endemic to Ethiopia while 7 (3%) are nearly endemic (Demel Teketay and Tamrat Bekele, 1995).

In addition to Omo River guereza (*C. g. guereza*), the study area also supports a variety of wildlife populations including large troops of *Theropithecus gelada* which is more numerous at the top of the cliffs near Woti, Kundi, Eme-mihret, Gosh meda, Zeno Ber and

Metatekiya. The endemic Menelik's bushbuck (*Tragelaphus scriptus meneliki*) is also found to populate on the lower and central part of the forest in association with Colobus vigilance. Grivet monkey (*Cercopithecus aethiops*), Klipspringer (*Oreotragus oreotragus*), common duiker (*Sylvicapra grimmia*), crested porcupine (*Hystrix cristata*), Abyssinian hare (*Lepus habessinicus*), bush hyrax (*Hetrohyrax brucei*) and others (Appendix 1) are among the commonest. Carnivorous mammals in the area include leopard (*Panthera pardus*), hyaena (*Crocuta crocuta*), common jackal (*Canis aureus*), Serval (*Felis serval*) and Abyssinian genet (G*enetta abyssinica*).

The area also harbours rodent species including Ethiopian White-footed Mouse (*Myomys albipes*), white-tailed Rat (*Stenocephalemys albicuadata*), Dega rat (Harrington's scrub rat) (*Pelomys harringtoni*), harsh-(brush)-furred mouse (*Lophuromys flavopunctatus*), groove-toothed (swamp) rat (*Otomys typus*), natal multimammate mouse (*Mastomys natalensis*) and gray-tailed rat (*Stenocephalemys griseicauda*) (Mulu Negesse, 2017), and different bird species including the endemic vulnerable Ankober serin (*Serinus ankoberensis*). *Serinus ankoberensis* is a species confined to areas between 2,800 m and 3,750 m along the escarpment rim from Ankober to Tarmaber.

In the highlands of Ethiopia, settled agriculture is the dominant form of supporting livelihood in ancient times and the country is still predominantly agricultural. Though agricultural practices and human settlements have a long history in the highlands of Ethiopia, recently there are high population pressures with unsustainable practices leading to depletion of the natural resources. In addition to the overall dependence on agriculture, ox-ploughing has remained almost the same over the centuries (Berekete Kebede, 2002). Agriculture in the country is predominantly subsistent in nature with small holder farmers with an average holding of less than one-hectare (Bayush Tsegaye, 1997). Moreover, agricultural production system is mainly rainfed and traditional, which is characterized by low input of fertilizer and pesticides.

Currently, the country's agricultural sector is increasingly being confronted with the pressure from a rapidly growing population and diminishing natural resources. These problems endanger biophysical land degradation and hamper sustainable agricultural development in the country (Herweg and Stillhardt, 1999). Land use system change has important impacts on the functioning of socioeconomic and environmental systems with tradeoffs for sustainability, food security, biodiversity and the vulnerability of people and global ecosystem impacts (Lesschen *et al.*, 2005). According to Woldeamlak Bewket and Solomon Abebe (2013), similar to developing countries across the globe significant land-cover changes have been observed in Ethiopia since the last century. These changes are caused primarily by anthropogenic activities, because increasing population has forced people to clear forest for cultivation and for forest products (Girmay Gebresamuel *et al.*, 2010).

The central plateau of Ethiopia is characterized by mixed cereal and livestock agriculture. Nutrient deficient soils, high stocking rates and shortage of animal feeds are common features in the highlands. The economy is based on agriculture which accounts for almost half of the gross domestic product, 60% of exports, and 80% of total employment (The World Bank, 2006). Accordingly, agriculture is the mainstay of the Ethiopian economy and of the people at large. The poor are overwhelmingly concentrated depending on the natural resource base for their livelihoods. It is characterized by low productivity per unit of input and high risk. Farmers manage multiple crops, livestock species, and production practices to manage risks and to meet their multiple objectives.

Livestock provide essential commodities and services to much of the world's population and serve as a strategic reserve that reduces risk and adds stability to farming system (Benin and Pender, 2006). Livestock in the highlands account for 80% of the total population and about 20% of the agricultural gross domestic product of the country (Mengistu Alemayehu, 1997). Livestock are herded together and grazed on communal pastures, private land and stables depending on the time and season of the year. Cattle are the most important livestock species in the Ethiopian agriculture and they are kept mainly for traction and milk production. Grazing is being expanded to very steep slopes and marginal lands, as more land is cultivated to compensate for the diminishing soil fertility and to meet the ever-increasing food demands (Zerihun Woldu and Mohammed Saleem, 2000).

The study area is located in a region which is one of the most intensively cultivated areas in the country. The long history of settlement and cultivation coupled with deforestation and cattle grazing has led to intensive pressure on the land, decreased soil quality, soil erosion and deforestation (Sustainable Natural Resource Management (SUNARMA, 2006). The hillsides are mostly very steep and hard to cultivate, plot sizes are commonly very small.

According to Sustainable Natural Resource Management (SUNARMA, 2005) report, the total house holders of the three Districts (Tarmaber, Ankober and Basona Werana) are directly or indirectly dependent on the forest. Like any other parts of the highlands of the country, mixed cultivation of livestock rearing and crop production, are the main economic development of the community. Honey bee production is also practiced in the forest area.

The traditional farming systems enforce the population to exploit the forest, particularly at the marginal areas for agricultural expansion and settlement. Ethnically, the population is not diverse and they are the Amhara people. To a large extent, most human settlements are concentrated along the periphery of the WWNSF. The study area is surrounded by agricultural land up to its boundary (Plate 3).

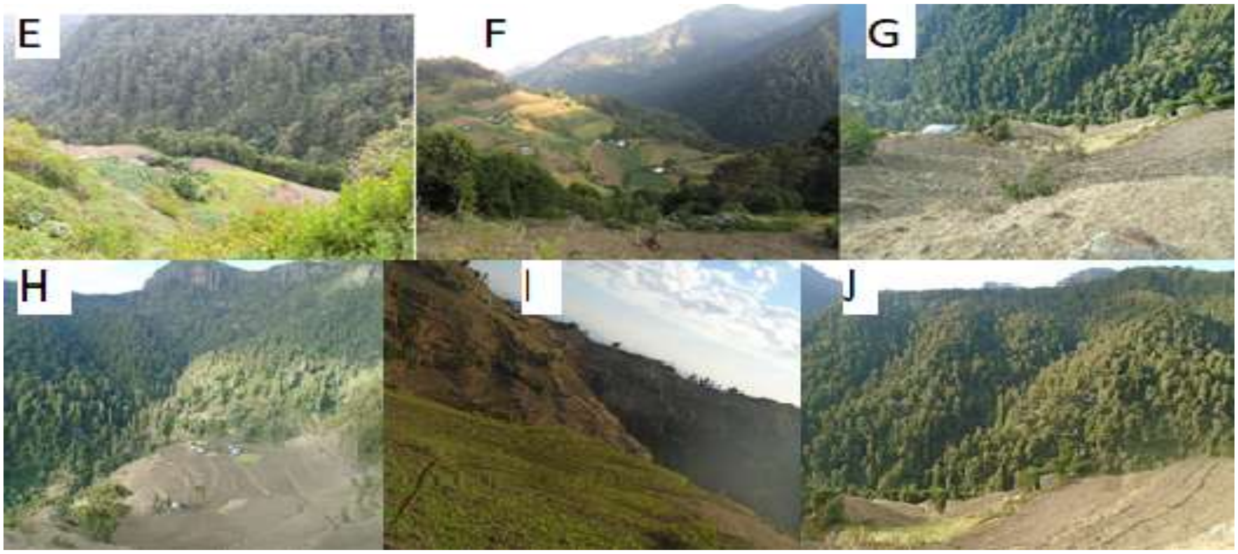

Plate 3. View of human settlement and agricultural expansion in and around WWNSF at different sites (Source: Dereje Yazezew, 2015).

The main agricultural product is cereal crops such as barley, maize, wheat, beans, peas, which are grown for subsistence and very little or nothing is commercialized.

Rhamnus prinoides is important cash earning plant mostly in Ankober Wereda Kebeles. Cattle are the most important livestock species and they are kept mainly for ox-plough, traction and milk production. There are illegal logging and timber production as a main source of economy. Contrary to ancient times when forest patches were cleared to gain farmland, this is not practiced anymore in WWNSF. The trees are cut at night and taken out one by one. In most cases, it is not the whole trunk carried out but only planks (Plate 4). The guards have no authority to stop the timber men anymore, once these timber men

Plate 4. Evidence of cut timber inside WWNSF. A) Timber prepared to be picked up for market, B) Cutting out-timber from *Podocarpus falcatus* and C) Finished timber products collected by scouts and stored in scout manager office (Source: Dereje Yazezew, 2014-2016).

are outside the forest. There is some uncertainty about the role of the farmers in using forest products. There is no feeling of responsibility by the farmers in the area due to a weak forest guard system and a de facto use-right they have.

Due to the de facto protection, residents are frequently disturbing the forest and disturb wild animals in the area for different reasons. Population expansion resulted in the encroachment of the forest to collect firewood, construction and utensil materials, farm tools, and to graze livestock (Plate 5) and to collect grass both for domestic usage and market. The majority of the farmers in the study area have neither private nor communal grazing land. Generally, nutrient deficient soils, high stocking rates and shortage of animal feeds are common features in the surroundings of WWNSF. Accordingly, the large number of livestock and scarcity of grazing land had made the local people highly dependent on the forest for grazing as well as grass harvesting. Scouts always encounter local people in the forest at the time of timbering, firewood collection and harvesting of grasses, causing serious disturbances to the wildlife. Moreover, honey is an important non-timber forest product in the area, suggesting that it is the major off-farm source of income. During the flowering season of the tree, they install beehives. *Erica arborea*, *Olinia rochetiana*, *Dombeya torrida* are some of the most important plant species for the honeybees which might cause a great disturbance to the wild animals as the bees sting them while the animals forage nearby the hives.

Plate 5. Fire wood collected from the forest and transported to market (A), installation of the beehives (B) and livestock grazing (C) (Source: Dereje Yazezew, 2015).

Participatory Forest Management (PFM) and Community Based Tourism (CBT) have been established nearly a decade ago in WWNSF. PFM is a practice allowing communities to get involved in the management of the forest close to them whereby the benefits generated by sustainable use of forest products flow back to the community. Community based tourism (CBT) is an approach to enable communities to generate income besides farming. Depending on this approach, the number of forest guards is reduced highly that they might not be necessary anymore. However, communities that have been excluded from forest resources, have been perceived as, and often were, destructive towards forest resources.

Stakeholders of WWNSF organized the community to construct lodges and manage the forest by themselves via aforementioned approaches to make the communities beneficiary and conserve the forest sustainably. However, what the mass of the community invested their time, effort and finance for more than a year changed into ash overnight (plate 6). This indicated that the forest became a *de facto* open-access resource and liable to over-exploitation although it cannot be said rapid laminar deforestation. According to FARM-Africa (2003), this is a recent situation in many countries today (including Ethiopia), and is the reason that rapid deforestation continues despite growing awareness amongst all stakeholders of the need and advantage of sustainable forest management.

Plate 6. Lodge construction under PFM and CBT approach, in WWNSF (Source: Dereje Yazezew, 2016).

The WWNSF area has various topographic land forms which is endowed with numerous streams and rivers such as Awadi, Mehal Wenz, Shema Matebia which are permanently flowing throughout the year. These rivers provide the surrounding people with drinking water and small-scale irrigation in their lower course towards Afar region.

3.3.Subject of the study

The guereza is a large black and white monkey with a white mantle and tuft of tail. *C. g. guereza* has a tail which is longer than the head and body combined length, with the anterior half being gray and the tuft taking up about half of its length (Groves, 2001). The body is mostly black, with the white mantle extending from the shoulder to the hip, connecting around the lower torso. Thus, the smooth black fur covers much of the body contrasting with short, white hair surrounding the face, and a U-shaped, cape-like mantle of long white hair that extends down the shoulders and across the lower back (Groves, 2001; Gron, 2009). The age of full sexual maturity in the guerezas is at least 6 years in males and 4 years in females. The lifespan of *Colobus guereza* is thought to be over 30 years in captivity and about 20 years in the wild. Each adult female produces one young every 20 months after a gestation period of about 6 months (Gron, 2009). The average gestation length in colobus monkey is 158 days and female colobus often solicits copulations from males (Harris and Monfort, 2006). At birth, the hair of infant guerezas is completely white except the pink to red skin at the area of ear and face, in striking contrast with the predominately black fur of the adult guereza (Gron, 2009). The face is surrounded by white and bushy cheek hairs in adults (Plate 7).

Plate 7. Female Omo River guereza with two month old white infant (A) and male Omo River guereza (B) (Source: Dereje Yazezew, 2015).

Guerezas are slightly sexually dimorphic, with males weighing up to 1.19 times more than females (Gron, 2009). The mean weight of male colobus ranges from 9.3 and 13.5 kg while female colobus ranges from 7.8 and 9.2 kg. Head and body length averages 61.5 cm males and 57.6 cm in females (Oates *et al.*, 1994; Gron, 2009). Guerezas inhabit in areas that have trees and are occur in both deciduous and evergreen forests (Oates *et al.*, 1994; Lwanga, 2006). The conservation status of *C. g. guereza* is considered as Least Concern on the IUCN Red List (Gron, 2009).

3.4. Threats to the forest and wild animals of the study area

The local communities were not friendly with the researcher during the commencement of the preliminary survey. Especially they were pessimists with regard to the issues concerning forest protection as their livelihood is highly dependent on the forest. This was signified by their destructive action on trees labelled for phenological study (Plate 8) assuming that the researcher could give up conducting the research. Accordingly, they used to destruct what researchers and/or forest experts do in the forest. They utilize the forest for timber, charcoal production, construction materials, animal fodder, grazing land and apiculture, which definitely affect the long-term survival of Omo River Guereza. To overcome this unanticipated problem, the researcher recognized awareness creation among local people as the first-hand tool not only for short term solution to conduct the current research but also to integrate the communities' resource use pattern from the forest and survival of the Omo River guereza and other wildlife in the forest. However, the researcher did not succeed as such in changing their attitudes.

Plate 8. Dislodged tag of tree selected for phenological study (Source: Dereje Yazezew, 2015).

The attempt carried out by SUNARMA and other stakeholders to rehabilitate indigenous tree species in particular and the forest in general seemed unaccepted by the local people involved in the project. Although there is a well established nursery in the forest to rehabilitate indigenous trees such as *Podocarpus falcatus*, *Hagenea abyssinica* and *Olea europea*, the seedlings are not planted properly (Plate 9). The local people planted seedlings in mass haphazardly and/or thrown into ravine. Even planted saplings are trampled by livestock grazing in the forest which could affect regeneration status of different tree species of the forest. Agricultural activity is also being expanded in all sides of the forest causing a serious contraction and fragmentation of the forest habitat into smaller homogenous habitat types.

Plate 9. Seedlings of *Olea europea* planted in mass (M) and dumped into ravines (N) (Source: Dereje Yazezew, 2015).

The carcasses of Omo River guereza (Plate 10) found during the study period depicted that death of this endemic subspecies of colobus monkey is common though the cause was obscure. This situation could be considered as threat for the population of the subspecies and warrants further investigation to determine the source of the problem.

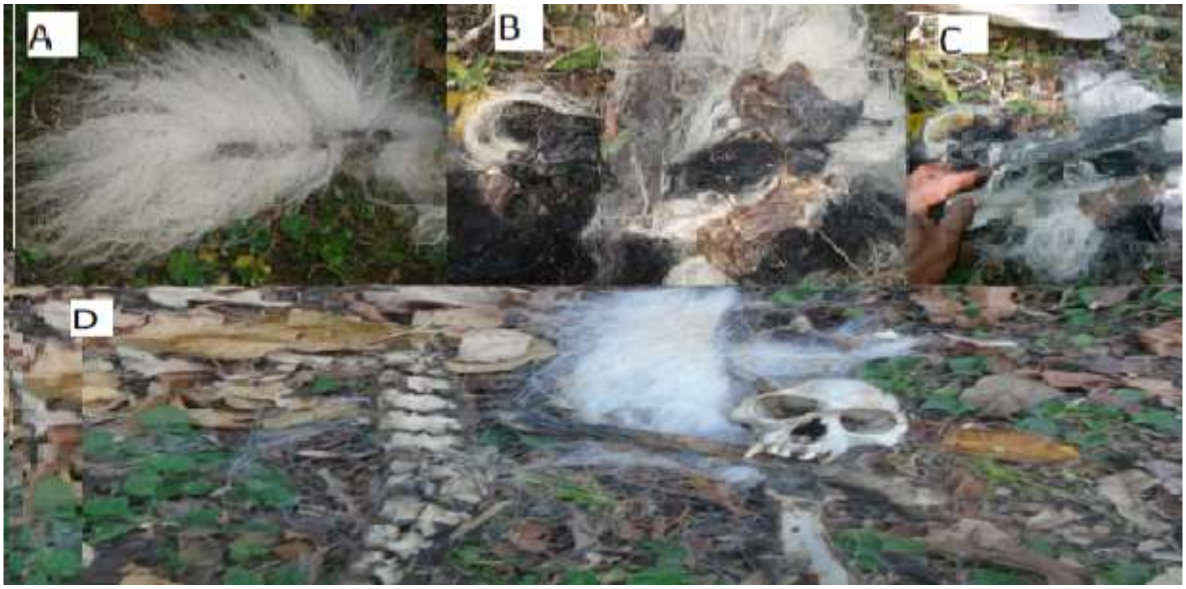

Plate 10. Carcasses of Omo River guereza from different localities (Source: Dereje Yazezew, 2015/16).

4. MATERIALS AND METHODS

4.1. Preliminary survey

During the reconnaissance survey, habitat types were identified based on the dominant vegetation cover. Transects were established based on a stratified random sampling approach within different habitat types to collect population census data. Two Omo River guereza groups were selected; one (group P) from the plantation forest and the other one (group N) from the relatively intact natural forest for scan sampling to record diet, activity and ranging patterns. The study groups were identified by some individual members that have unique natural markings, coat colour, other identifiable features and group size. Group P consisted of 7 individuals (two adult males, two adult females, one sub-adult male and two juveniles) at the start of this study, increasing to nine individuals after two infants were born in September and October 2015. Group N had six individuals (three adult males, two adult females and one sub-adult male) at the start of this study, also adding two infants (born in October and November 2015) which enhanced the group size to eight.

The study groups were habituated to human observer for three months by following the groups throughout the day by the researcher and trained local field assistants. Both groups of colobus monkeys were shy and elusive during the start of habituation period and flee from observers and hide themselves especially in the upper canopy of the tallest trees of *Juniperus* and *Podocarpus*. Accordingly, it was not possible to see colobus monkeys at a distance greater than 50 m. After being habituated, colobus monkeys were approached up to 5 m animal observer distance whereby they perform their natural behaviour ignoring human presence in their vicinity. They were observed to forage on a 5 m tall tree where the observer could easily record their behaviour. We often followed and collected data on one group (group P) at a time followed by the other group (group N) or vice versa. To minimize seasonality effects, we distributed observation time for each group approximately equally over each month.

4.2.Data collection

Vegetation surveys were conducted within each group's home range from randomly selected vegetation transects. These surveys were conducted at the completion of the behavioural study, when the boundaries of each group's home range were known. A total of 2 with 400-500 m long and 10 m wide vegetation transects were laid out within each of the study group's (P and N) home ranges and adequately sampled the diversity of big trees ≥ 10 cm DBH (diameter at breast height = 1.3 to 1.4 m above ground) (Teelen, 2007; Wong *et al*., 2006). In some instances, DBH was measured below the branching point when the trunk of a tree was branching below 1.3 m. DBH was calculated as circumference (in cm at a height of 1.3 to 1.4m)/π.

All big trees with DBH ≥ 10 cm and all climbers with DBH ≥ 5 cm (Suarez, 2013) were recorded, identified and measured along with species identity, number, DBH (in cm) using caliper or tape measure (for big trees with DBH>50cm), height (m), canopy size/ diameter (m) (using tape measure) and percentage of canopy cover. Visual inspection was made to estimate plant height after certain tree measurements were taken for some trees as standing estimators (Plate 11). To sample all plant species ≥10 cm DBH, a total of six 50 x 10 m vegetation enumeration quadrats were sampled from the vegetation transects in the home range of each of the study groups. Data were not recorded on dead trees as they were not used for any calculations of habitat variables. Plant species were identified and recorded in the in situ if known while unidentified species were collected, named by their local name, pressed and taken to Addis Ababa University National Herbarium for further taxonomic identification.

Plate 11. Height measurement taken as standing measurement for plant height inspection.

The vegetation quadrats and transects were used to quantify the overall vegetation composition of the study areas and differences in forest composition between the study group home ranges and habitat types. The density of each plant species of ≥ 10 m DBH was calculated by dividing the total number of individuals of a certain species recorded per unit area. Accordingly, density was computed by converting the count from the total quadrats in the home range of each group in the hectare basis. Plant species diversity of big trees ≥ 10 cm DBH in the study areas was calculated using the Shannon-Wiener index of diversity, H’, Simpson’s Dominance index, D, and evenness index, J (Krebs, 1999) to determine whether the dietary species are evenly distributed or not in the home ranges of the study groups. Shannon’s index accounts for both abundance and evenness of species present. Species diversity is quantified by the formula:

$$H' = -S\sum_{i=1}^{s} \text{pi} \log \text{pi}$$

Where S is the number of species, and pi is the proportion of the total number of individuals represented by i^{th} species to total abundance value; pi=ni/Ni. Plant species evenness index is computed by the formula: $J = H^I / H^{max}$, where; $H^{max} = \ln S$, H^I is Shannon-Wiener's diversity index, H^{max} is the maximum value of H^I and S is Species richness. Simpson's Index (D) measures the probability that two individuals randomly selected from a sample will belong to the same species. It is an index of dominance and hence inversely related to evenness and richness. Simpson's dominance index was calculated by the formula $D=\sum ni\ (ni-1)/\ N\ (N-1)$.

Where, ni= the total number of individual trees of each plant species and N = the total number of individual trees of all plant species. The value of D ranges between 0 and 1. With this index, 0 represents infinite diversity and 1, no diversity. Using transects quadrate data, basic habitat variables were calculated for each group's home range (Table. 1).

Plant species richness and similarity were also assessed between the home ranges of the two groups. Sørensen (Ss coefficient) indices used to quantify tree species similarity between pairs of home ranges and are used as indices of habitat similarity. These indices are calculated using the following formulas (Krebs, 1999):

$$S_s = \frac{2a}{(2a+b+c)}$$

where *a* is number of species occurring at both sites, *b* is the number of species occurring only at site 1, and *c* is the number of species occurring only at site 2 (Kent and Coker, 1992). Coefficients ranged from 0 to 1 with zero representing no species shared (no similarity) and one representing all species shared (complete similarity). The basal area

(BA) of each tree species was calculated to estimate the biomass of each tree within the home range of colobus (Fashing, 2001b; Felton *et al.*, 2008b; Chaves *et al.*, 2012). Basal area (BA) calculations were made on the diameter measurements of the stem with DBH of ≥10 cm using the formula: $BA = ([0.5 \times DBH]^2 \pi)$ (Fashing, 2001a).

Table 1. Summary of habitat variables quantified for each group home range.

Habitat Variables	Description or Equation
DBH of large tree species surveyed ≥ 10cm DBH	Circumference (in cm, measured at a height of 1.3m)/ π
BA (cm^2/ha) of large trees ≥ 10cm DBH	BA/ha
Habitat similarity across the home ranges of the study groups	Sorenson (S_s) indices (Krebs, 1999)
Large tree species richness ≥ 10 cm DBH	Number of tree species/area
Large tree species density ≥ 10 cm DBH	Number of trees/ area
Large tree species diversity ≥ 10 cm DBH	Shannon-Wiener (H') Index using (ln) (Brower and Zar, 1977)
Large tree species evenness ≥ 10 cm DBH	Based on Shannon-Wiener Index (J')
Large tree stem density per ha ≥ 10 cm DBH	
Canopy size of large trees (m) ≥ 10 cm DBH	
Height of large trees (m) ≥ 10 cm DBH	
Large tree species dominance index, D ≥ 10 cm DBH	Simpson's Dominance Index (D), $D=\sum ni\ (ni-1)/\ N\ (N-1)$
Large tree species important value index (IVI) ≥ 10 cm DBH	Importance Value Index (IVI) = RD + RF + RDO of a species
Food plant species density	
Food plant species richness	
Food plant species diversity	
Food plant species evenness	

There is direct relationship between DBH and BA as BA = π (d / 2)^2, where d =DBH. BA is expressed in cm^2/ha (Hutchings, 1986). BA per hectare was used to estimate the biomass of each tree species in the home range of each study group (Kool, 1989) and to determine dominant tree species in the home range.

Important Value Index (IVI) of big trees $\geq$10 cm (DBH) was determined to quantify the extent of dominance, occurrence and abundance of a given plant species in relation to other associated species in an area (Kent and Coker, 1992). Importance Value Index (IVI) = RD + RF + RDO, where RD is relative density, RF relative frequency and RDO relative dominance of the corresponding species *i* in the group's home range.

A phenological assessment was carried out in the home range of the two groups (P and N) over an annual cycle for selected food plant species. Tree species selected for phenology assessments were determined after approximately two months of habituation of each group. After habituation period of the group, 10 individuals of the food plant species/trees ($\geq$ 10 cm DBH) were marked and identified which included trees and shrubs (DBH ≥ 10 cm), and climbers (DBH ≥ 5 cm). Phenological data of the marked trees in the home range of the study groups were collected monthly for 1 or 2 days after the field observation. Each marked tree was assessed for the relative abundance of young leaves, mature leaves, flowers, whole fruits, and seeds using visual inspection or binoculars (Fashing, 2001b; Xiang *et al.*, 2007; Suarez, 2013). Each plant part was assigned to a relative abundance value (score) ranged from 0 to 8 at intervals of 1 (Addisu Mekonnen *et al.*, 2017). An abundance score of 0 indicates that a tree exhibited 0% (item absent from plant) of its potential abundance of that phytophase during the assessment and 8 indicates 87.5-100% (plant fully laden with the item).

Phenological data were analyzed from 13 species: 10 trees (*Olinia Rochitiana, Cupresus lusitanica, Podocarpus falcatus, Allophylus abyssinicus, Galiniera saxifraga, Ilex mitis, Juniperus procera, Maesa lanceolate, Pittosporum viridiflorum* and *Bersama abyssinica*), two shrubs (*Vernonia leopoldi* and *Disopodium penninervium*) and one Climber (*Embelia schimperi*). Food availability was analysed from the average availability scores of food item categories of each marked tree species.

The monthly phenology scores of young leaves, mature leaves, fruits, flowers and others were averaged for each plant species as well as for all plant species in each study group. Monthly food availability index (FAI) for each plant part was calculated by multiplying the mean phenology scores of species *i* with the mean basal area of species *i* or density of the corresponding species *i* per ha (Fashing, 2001b). Density is defined as the number of plants of a certain species per unit area. Thus, both the phenological and vegetation survey data were used to calculate monthly indices of availability for young leaves, mature leaves and fruits. A monthly Food Availability Index (FAI) was obtained for each plant species using the following formula.

$$\text{FAIi} = \text{BAi} \times \text{PISpi}$$

where FAIi is the food availability index of species i, BAi is the basal area (cm2/ha) of species i obtained by the vegetation survey data, and PISpi is the monthly phenological index for the species i (Zunino *et al.*, 2001). The monthly total FAI for each phenophase was calculated by adding FAIi indices across plant food species, as follows:

$$\text{Total FAI} = \sum_{i=1}^{S} \text{FAIi}$$

Population census of Omo River guereza was conducted in WWNSF three times from February 2015 to April 2016 using line transect method (Struhsaker, 1981; Peres, 1999; Plumptre, 2000; Buckland *et al*., 2010a; 2010b; Thomas *et al*., 2010). Survey sites were selected to cover accessible altitudinal ranges and vegetation types of the area (Baumgarten, 2006). Transects were established based on a stratified random sampling approach within different habitat types and marked every 50 m interval using flagging tape (Chapman *et al.*, 1988; Peres, 1999; Plumptre, 2000; Rovero *et al.*, 2006; Mammides *et al.*, 2009; Buckland *et al.*, 2010a; 2010b).

A total of 14 transects ranging from 1.5 to 3.0 km length and 0.08 km (in undisturbed forest) to 0.2km (*Erica* bushland) sighting distance were censused across mixed plantation forest, *Erica* bushland, *Erica-Juniperus* mixed forest, disturbed natural forest and relatively intact (undisturbed) natural forest habitat types. Censuses were conducted on transects from 06:30-06:45 to 10:30-10:45 in the morning and from 14:00 to 18:00 in the afternoon (Peres, 1999; Addisu Mekonnen *et al.*, 2010b; Chagas and Ferrari, 2011) when the monkeys are typically active, although data collection was interrupted whenever atmospheric conditions (wind, rain) reduced visibility significantly. Transects walked at an average speed of 1 km/hr pausing at regular intervals to scan the forest and listen for calls and movements in the canopy in an attempt to locate colobus monkeys and other mammals (Wallace *et al.*, 1998; Peres, 1999; Ciani *et al.*, 2001).

During transect walks, once Omo River guerezas were encountered, a standard set of data was collected, including group size or estimated number of individuals, which is the number of individuals counted during a maximum of 10–15 min observation on each group (Rovero *et al.*, 2006; Lwanga *et al.*, 2011), group spread, estimated animal-observer distance, sighting angle (angle to trail using compass), perpendicular distance from the transect to the first animal seen, the height of animal on the tree when first detected, and habitat type where the group is spotted (Rovero *et al.,* 2006; Marshall *et al.,* 2008; Mammides *et al.*, 2009; Chagas and Ferrari, 2011; Lwanga *et al.*, 2011; Rovero *et al.*, 2012). The distances were estimated visually and a compass was used to measure the angle.

Habitat use by Omo River guereza in WWNSF was assessed by a combination of transect sampling in different habitat types and instantaneous sampling methods of focal groups (Addisu Mekonnen *et al.*, 2010b; Addisu Mekonnen *et al.*, 2017). Encounter rates of groups per km were calculated for each habitat type (Wallace *et al.*, 1998; Bobadilla and Ferrari, 2000), and sightings were summarized as the total number of groups and individuals observed in each habitat type (Anderson *et al.*, 2007). Data collected for population density estimate were used to determine habitat use by Omo River Guereza. Moreover, information on the two groups of colobus monkeys home range and distribution of habitats within each groups home range were used to determine the amount of each habitat type in the home range of each groups (Raboy *et al.*, 2004). Thus, each group was followed and its location and habitat types were recorded (Gómez-Posada *et al.*, 2007; Zhou *et al.*, 2013). Then, ArcView 3.2 GIS software was used to merge the home range and habitat maps to determine the amount of each habitat type in each groups range (Raboy *et al.*, 2004; Williams-Guillén *et al.*, 2006; Gómez-Posada *et al.*, 2007).

Activity time budget data were collected using instantaneous scan sampling method (Altmann, 1974) at 15-minute intervals. Activity budget data from the members of the two neighbouring focal groups (P and N) were collected on an average of two-five consecutive study days each (Fashing, 2001a; Di Fiore, 2003; Addisu Mekonnen *et al.*, 2010a; Addisu

Mekonnen *et al.*, 2017). During the 5-day samples, activity scan samples were collected for up to five minutes duration every 15 min sampling gap between 06:00 to 18:00 (Fashing, 2001a; Teichroeb *et al.*, 2003; Wong and Sicotte, 2007; Twinomugisha and Chapman, 2008; Wijtten *et al.*, 2012; Hussein Ibrahim *et al.*, 2017). During each sample, the activities were recorded by scanning the group from left to right or vice versa depending on the position of the observer to avoid possible bias (over-representing) towards eye-catching activities such as grooming, fighting, moving, and mating (Fashing, 2001a; Teichroeb *et al.*, 2003; Wong and Sicotte, 2007; Pinheiro and Mendes, 2015).

The identity of the scanned individual was recorded (Di Fiore, 2003; Wong and Sicotte, 2007; Zewdu Kifle *et al.*, 2013) and assigned to one of the following age/sex classes: adult male, adult female, sub-adult male, sub-adult female, juvenile male and juvenile female but not infants (Fashing, 2001a; Harris and Chapman, 2007). In addition to the differences in body morphology and genital materials, a large continuous line of white hairs presents across the perineum of only male Omo River guereza (Fashing, 2001a; Eustace *et al.*, 2015). Five minutes were allocated to record the activities of 3-6 guerezas, excluding white infants as they are dependent for everything on their mother. Each individual Omo River guereza was observed for five seconds after it was first detected and its predominant behaviour in the scan period was recorded (Di Fiore, 2003). Although the same individuals could be sampled in consecutive scans, care was taken to avoid sampling the same individual more than once in a given scan.

During scan sampling, individuals were approached at a distance of 5-25 m and their activities were recorded as one of the following behavioural records: feeding, moving, resting, playing, aggression, grooming, sexual activity, and others such as drinking, defecation, urination, looking at the observer (vigilant) and vocalization that does not fit in the aforementioned categories (Fashing, 2001a; Addisu Mekonnen *et al.*, 2010a; Addisu Mekonnen *et al.*, 2017).

Moving includes any locomotor behaviour, including walking or running, leaping or bridging, climbing or descending that resulted in an individual changing its spatial position and when guereza was not engaged in feeding, resting or any form of social activity (Fashing, 2001a; Teichroeb *et al.*, 2003; Addisu Mekonnen *et al.*, 2017). For instance, it excluded young animals moving during play (Oates, 1977). The locomotor behaviour of colobus monkey categorized as quadrupedalism, when all four limbs move in a regular pattern above the support or on the ground including, walking, running and leaping where the hind limbs propel an animal across a gap when to communicate and avoid predator (Estes, 1991). Vertical locomotion- movement up or down a vertical or steeply inclined support, and others: including quadrupedal suspensory movements in which the body is progressing below a support using three or four limbs; bridging- where spatial gaps are crossed by body stretching; bimanualism-where the hands grasp a support and are used to pull the body up to a support from below; bipedalism-in which only the hind feet used to walk a short distance; vertical bounding-where a succession of short jump-clings up a vertical support.

Resting was recorded when the animal was inactive and either lying down (lying on belly, side or back body), sitting, immobile in a quadrupedal stance or self-grooming. Playing included hitting, biting, chasing and other vigorous activities accompanied with movements and gestures by more than one individual that were clearly interacting with each other in a non-aggressive behaviour (Fashing, 2001a). Aggression was recorded when a colobus monkey is chased, bit, grabbed, displaced and threatened with vocal and gesture another colobus monkey. Grooming includes instances in which one monkey used its hands to discover or to clean the body of another monkey. Sexual activity was recorded when a monkey groomed the sexual organs, presenting, embracing, copulating or engaged in mating activity. Vigilant includes instances when a monkey sat and peered intensely in a certain direction (Fashing, 2001a; Teichroeb *et al.*, 2003; Addisu Mekonnen *et al.*, 2017).

The study groups were first habituated to the constant presence of the observer within the forest for more than two months. Prior to recording feeding activities, each study group was followed from 06:00 h in the morning to 18:00 h in the afternoon. Each group was studied during five consecutive days per month from May 2015 to April 2016. Feeding incidents of each sighted individual in each of the studied groups were systematically recorded using Instantaneous Scan Sampling method (Altmann, 1974) with sampling units of 5-minutes duration in every 15-minutes interval (Fashing, 2001b; Matsuda *et al.*, 2009; De Oliveira *et al.*, 2014; Kibaja, 2014; Eustace *et al.*, 2015; Pinheiro and Mendes, 2015).

Each day observations commenced by arriving at each group’s sleeping site that was located the previous evening. Accordingly, when an individual Omo River guereza was feeding on plant material during a scan sample, data were collected on species consumed, plant part, and maturity of the item. However, when an individual is observed feeding on rare plat species, the incidence was recorded in the next scan so as not to avoid the species from the food list, which was not a case for common food plants as this causes bias on actual data. The types of food items were recorded as young leaves, mature leaves, root, stem, flower, fruit, seeds, shoot, bark, bud or animal preys. Feeding was recorded when an individual Omo River guereza manipulated food items such as plucked food items, passing food items towards the mouth, masticated and swallowed (De Oliveira *et al.*, 2014; Eustace *et al.*, 2015; Pinheiro and Mendes, 2015).

Species of plants consumed by members of Omo River guereza were identified and recorded in situ if known while unidentified species were collected, named by their local name, pressed and taken to the Addis Ababa University National Herbarium for further taxonomic identification. Dietary composition was evaluated by determining the proportion of different dietary items and plant species based on the total amount of time spent feeding by focal groups (Felton *et al.*, 2008b; Addisu Mekonnen *et al.*, 2010a). Daily food items and species consumed were summed up by the group within each month to construct a monthly proportion of food items and food species consumed.

To determine the dietary preference or selection ratio of guerezas on specific tree species, the percentage of a specific species in the diet was divided by the percentage of that species in the transect sample enumerated. Ratios above one indicates selectivity, ratios of approximately one indicates no selection (i.e. feeding as expected based on the species' relative abundance within the home range), and ratios below one indicates avoidance (Fashing *et al.*, 2014; Addisu Mekonnen *et al.*, 2018).

Ranging data on the two study groups were collected during two 5 focal full-day follows of each group each month from 0630 to 1800 hr (Di Fiore, 2003; Addisu Mekonnen *et al.*, 2017). During instantaneous scan sampling, the locations of the geographic centre of the study group were recorded at 15-minute intervals using a Handheld Garmin GPS Map 62s and Garmin etrex 10. The GPS locations of the group recorded used to estimate the average daily travelled distances (DTD) and the home range utilized by the groups each month as well as the average travel rate were calculated as average daily distance traveled each month divided by time spent moving (Di Fiore, 2003).

4.3. Data analyses

Group density was calculated as the total number of groups sighted within the fall-off sighting distance divided by the total transect length sampled multiplied by both sides of the transect width (Fashing and Cords, 2000). Sightings of solitary individuals were excluded from the analysis to calculate group density estimates and encounter rates (Rovero *et al.*, 2006; Mammides *et al.*, 2009; Chagas and Ferrari, 2011).

Total population was estimated by multiplying the average group density estimates with the mean group size and the total area of suitable habitat in the study site (Chiarello, 2000; Addisu Mekonnen *et al.*, 2010b). Moreover, population estimate data analyses were carried out using Distance 6.2 Release 1 (Ferrari *et al.*, 2010; Thomas *et al.*, 2010; Buckland *et al.*; 2010b; Fashing *et al.*, 2012). The calculated density estimates of Omo River guereza were made from 140 group encounters recorded along 13 transect lines walked in a total distance of 88.5k m surveyed. On average, 47 sightings were used for accurate density estimation (Marshall *et al.*, 2008; Buckland *et al.*, 2010b). The data from all the three sampling months within each transect were pooled to estimate the density of Omo River guereza in the study area.

Habitat use was expressed as the percentage of monthly location records occurring in each habitat and the annual habitat use was obtained by averaging the monthly percentages (Zhou *et al.*, 2013). Patterns of habitat use were quantified as the percentage of the total location records that fell into each habitat type for each group of Omo River guereza (Gómez-Posada *et al.*, 2007; Zhou *et al.*, 2013). Kruskal-Wallis H test was used to examine whether there are significant differences in use intensity of different habitats. Additionally, chi-square test was used to compare the frequency of use of each habitat with its area within the home range to test whether groups used habitat types in proportion to their availability

The monthly activity budgets were compared using Pearson chi-square test and One-way ANOVA. Diet selection by each study group was determined from the relative proportions of the number of scans spent feeding on different food items and plant species in the diet. Dietary preference for different food species by the study group was also calculated as the proportion of annual feeding time spent feeding on a certain species *i* divided by the density of that species *i* in the study group's home range (Fashing, 2001b; Xiang *et al.*, 2007; Addisu Mekonnen *et al.*, 2010a; Ryan *et al.*, 2013). Dietary diversity and evenness were calculated using the Shannon-Wiener index, H' and the evenness index, J (Krebs, 1999), respectively. The daily travel distance (DTD) was determined by measuring the straight-line distances between consecutive GPS locations scored during group follows and averaged the values on a monthly basis. The mean hourly movement rates (MVR) was estimated by dividing the mean monthly DTD by the mean monthly number of hours of observation per day (Fashing *et al.*, 2007b). The minimum convex polygon (MCP) and the best home range estimator technique (Fixed Kernel) methods were used to determine the home range sizes and daily travel distance via GIS software ArcGIS version 10.0 (Fashing *et al.*, 2007a; Addisu Mekonnen *et al.*, 2010a).

5. RESULTS

5.1.Habitat description and resource availability

Plant species richness was lower in the plantation forest (12 species) than in the natural forest (21 species). A total of 24 plant species grouped in 20 families were found to exist in the quadrats of the transects. Plantation forest group (P) had 12 species grouped in 10 families (8 trees, 1 liana/climber, 1 tree/shrub and 2 shrubs). Natural forest group (N) had 21 species grouped in 18 families (12 trees, 6 shrubs and 3 tree/shrubs) (Table 2). The plant species with DBH ≥ 10 cm in the range of natural forest group (N) had high stem density (780 stems/ha) than plantation group's (P) range (600 stems/ha). *Allophylus abyssinicus*, *Erica arborea*, *Pittosporium viridiflorum*, *Galineira saxifrage*, *Osyris quadripartite* and *Myrica salicifolia* were very common in the ranges of N group but did not occur in the ranges of P group. Regarding basal area, *Juniperus procera*, *Podocarpus falcatus*, *Myrica salicifolia*, *Maesa lanceolata*, *Pittosporium viridiflorum* and *Nuxia congesta* were the highest ranking in N group while *Ficus sur*, *Ilex mites*, *Erythrina brucei*, *Olinia rochitiana*, *Juniperus procera*, *Cupresus lusitanica* and *Maesa lanceolata* were the highest ranking in P group's range.

Though P group in the plantation forest and N group in the natural forest of WWNSF are neighbouring groups with slight overlapping home ranges, the plant species similarity index is much lower (9 of 24 species). Moreover, the vegetation in the ranges of Omo River guereza group (N) inhabiting natural forest was more diverse (21 species) than in the ranges of group (P) in plantation forest (12 species). Plant species diversity (both Shannon-Wiener and Simpson's diversity index) and species evenness were higher and dominance was lower in the natural forest (N) than in plantation forest (P) (Table 3).

Table 2. Results of enumeration of plants ≥ 10 cm DBH in the quadrats of transects within the home ranges of natural and plantation forest groups.

Natural forest (N)						Plantation forest (P)					
Rank of abundance	Species	No. of trees	No. per hectare	% of total trees	Basal area/ha (cm2/ha)	Rank of abundance	Species	No. of trees	No. per hectare	% of total trees	Basal area/ha (cm2/ha)
	Oliniaceae						Myrsinaceae				
1	*Olinia Rochitiana*	45	150.0	19.2	801.4	1	*Maesa lanceolata*	80	266.7	44.4	1099.7
	Ericaceae						Cupressaceae				
2	*Erica Arborea*	39	130.0	16.7	565.4	2	*Juniperus procera*	50	166.7	27.8	1755.3
	Sapindaceae						Cupressaceae				
3	*Allophylus abyssinicus*	34	113.3	14.5	995.0	3	*Cupresus lusitanica*	15	50.0	8.3	1519.8
	Cupressaceae						Podocarpaceae				
3	*Juniperus procera*	34	113.3	14.5	4228.6	3	*Podocarpus falcatus*	15	50.0	8.3	462.9
	Myrsinaceae						Solanaceae				
5	*Maesa lanceolata*	30	100.0	12.8	1728.3	5	*Discopodium penninervium*	4	13.3	2.2	277.6
	Solanaceae						Fabaceae				
6	*Discopodium penninervium*	8	26.7	3.4	402.3	5	*Erythrina brucei*	4	13.3	2.2	4906.0
	Rubiaceae						Asteraceae				
7	*Galineira saxifraga*	6	20.0	2.6	305.2	7	*Vernonia leopoldi*	3	10.0	1.7	462.9
	Loganiaceae						Melianthaceae				
7	*Nuxia congesta*	6	20.0	2.6	1015.5	8	*Bersama abyssinica*	2	6.7	1.1	261.7
	Oleaceae						Myrsinaceae				
7	*Olea europaea*	6	20.0	2.6	738.5	8	*Embelia schimperi*	2	6.7	1.1	167.5
	Pittosporaceae						Aquifoliaceae				
10	*Pittosporum viridiflorum*	5	16.7	2.1	1557.9	8	*Ilex mites*	2	6.7	1.1	18463.2
	Podocarpaceae						*Oliniaceae*				
11	*Podocarpus falcatus*	4	13.3	1.7	3024.9	8	*Olinia Rochitiana*	2	6.7	1.1	3168.9

	Asteraceae						Moraceae				
11	*Vernonia leopoldi*	4	13.3	1.7	847.8	9	*Ficus Sur*	1	3.3	0.6	49112.2
	Santalaceae										
13	*Osyris quadripartita*	3	10.0	1.3	277.6			-	-	-	-
	Melianthaceae										
14	*Bersama abyssinica*	2	6.7	0.9	376.8			-	-	-	-
	Scrophulariaceae										
14	*Halleria lucida*	2	6.7	0.9	364.3			-	-	-	-
	Cupressaceae										
16	*Cupresus lusitanica*	1	3.3	0.4	588.8						
	Flacourtiaceae										
16	*Dovyalis abyssinica*	1	3.3	0.4	261.7						
	Aquifoliaceae										
16	*Ilex mites*	1	3.3	0.4	669.9						
	Celastraceae										
16	*Maytenus arbutifolia*	1	3.3	0.4	376.8						
	Myricaceae										
16	*Myrica salicifolia*	1	3.3	0.4	2936.6						
	Myrsinaceae										
16	*Myrsine africana*	1	3.3	0.4	550.2			-	-	-	-
		234	780.0	100	22613.3			180	600	100.0	81657.5

Table 3. Characteristics of the Omo River guereza study sites, groups, habitats and home ranges.

Characteristics of study sites and groups	Plantation forest (Group P)	Natural forest (Group N)
Group size	7	6
Mean elevation (m asl) (Range)	2757 (2714-2798)	2775 (2628-3058)
Total area surveyed for vegetation composition analysis	0.3 ha	0.3 ha
Habitat variables		
Large tree stem density per ha ≥10 cm DBH	600	780
Large tree species richness ≥10 cm DBH	40	70
Simpson's species diversity index [N(N-1)/sumn(n-1)]	3.49	8.05
Large tree species evenness ≥10 cm DBH	0.64	0.77
Large tree species dominance index ≥10 cm DBH (Simpson's dominance index)	0.29	0.12
Habitat similarity across the home ranges of the study groups (Sorenson coefficient (S_s) indices	0.55	
Characteristics of home ranges (large trees ≥10cm DBH, mean		
Number of live trees counted ≥ 10cm DBH	180	234
DBH of large tree species surveyed ≥10cm DBH	35.38	18.51
Basal area (cm^2/ha) of large trees ≥10cm DBH	2041.44 ± 1235.43	323.05 ±70.02

The Shannon-Wiener diversity index (H’) of large tree species with DBH ≥10 cm was 1.6 in plantation forest while it was 2.34 in the natural forest habitat. However, Mann Whitney U test revealed that there was no significant difference in the diversity of big trees between the two habitats types ($P>0.05$). Sørensen (S_s coefficient) index analysis (9 of 24 species; S_s =0.55) revealed that there were a greater number of plant species shared between the home ranges of Omo River guereza group.

Important value index (IVI) analysis that combines data from the three parameters such as RD, RF and RDO is useful to compare the ecological role of species. IVI analysis revealed that the species with the highest IVI are the leading dominant species in each group’s home range. Accordingly, *Maesa lanceolata, Juniperus procera, Podocarpus falcatus* and *Cupresus lusitanica* were the dominate species in plantation forest while *Olinia rochitiana, Erica arborea, Allophylus abyssinicus, Juniperus procera* and *Maesa lanceolata* were the dominant species in the Natural forest group (Table 4). The tree species with the highest IVI are tolerant species that resist high pressure of disturbances, natural and environmental factors that posed on them by the local communities.

Table 4. Important Value Index (IVI) of plant species occurring in the home ranges of P and N.

Plantation forest (P)				Natural forest (N)			
Species	R.Dominance ∑ni (ni-1)/ N (N-1)	IVI	% of IVI	Species	Relative Dominance	IVI	% of IVI
Maesa lanceolata	35.1	80.0	54.5	*Olinia rochitiana*	8.5	27.9	22.8
Juniperus procera	8.8	36.7	25.0	*Erica arborea*	3.5	20.3	16.6
Cupresus lusitanica	0.9	9.3	6.3	*Allophylus abyssinicus*	2.9	17.5	14.3
Podocarpus falcatus	1.0	9.4	6.4	*Juniperus procera*	3.2	17.8	14.6
Disopodium penninervium	0.1	2.3	1.6	*Maesa lanceolata*	2.8	15.7	12.8
Erythrina brucei	0.1	2.3	1.6	*Disopodium penninervium*	0.2	3.6	3.0
Vernonia leopoldi	0.0	1.7	1.2	*Galineira saxifraga*	0.1	2.7	2.2
Bersama abyssinica	0.0	1.1	0.8	*Nuxia congesta*	0.1	2.7	2.2
Embelia schimperi	0.0	1.1	0.8	*Olea europaea*	0.1	2.7	2.2
Ilex mites	0.0	1.1	0.8	*Pittosporum viridiflorum*	0.1	2.2	1.8
Olinia rochitiana	0.0	1.1	0.8	*Podocarpus falcatus*	0.0	1.8	1.4
Ficus Sur	0.0	0.6	0.4	*Vernonia leopoldi*	0.0	1.8	1.4
		146.8		*Osyris quadripartita*	0.0	1.3	1.1
				Bersama abyssinica	0.0	0.9	0.7
				Halleria lucida	0.0	0.9	0.7
				Cupresus lusitanica	0.0	0.4	0.4
				Dovyalis abyssinica	0.0	0.4	0.4
				Ilex mites	0.0	0.4	0.4
				Maytenus arbutifolia	0.0	0.4	0.4

	Myrica salicifolia	0.0		0.4	0.4
	Myrsine africana	0.0		0.4	0.4

5.2. Phenology

The monthly food availability index (FAI) analysis showed that there was variation in plant parts based on monthly abundance (Table 5). Young and mature leaves were the most

Table 5. Monthly food availability indices (FAI units/ha) for groups P and N.

	Young leaves		Mature leaves		Fruit	
Months	P	N	P	N	P	N
May_15	16291	32502	22342	42438	3444	3200
June_15	21970	40923	25600	51027	2886	3368
Jul_15	24390	47154	30534	57595	2700	1179
Aug_15	25787	48669	31279	59559	1862	674
Sept_15	27462	50858	33327	63152	1862	3537
Oct_15	25694	45133	33317	58942	4748	6399
Nov_15	20294	39744	33141	52206	7447	8589
Dec_15	18898	45133	32210	53890	8378	11620
Jan_16	18494	36544	33751	67699	8192	9094
Feb_16	17894	37386	32489	63994	7447	10104
Mar_16	16705	35870	25114	52206	4934	8252
Apr_16	18339	31323	19177	44796	2607	3705

abundant parts throughout the year while fruit was the least abundant. Comparatively, mature leaves were the most abundant food item in the ranges of both study groups and were available in large quantities throughout the year compared to young leaves. Fruits were relatively high from October to March in the range of both groups. Mann Whitney U test revealed that there were statistical differences in FAI of young leaves (Mann Whitney U; Z=-4.16, P<0.001) and mature leaves (Mann Whitney U; Z =-4.15, P<0.001) between the two guereza groups across months which indicates that higher FAI in the natural forest habitat than in the plantation. However, there was no statistical difference in FAI of fruits between the two groups across months (Mann Whitney U; Z =0.98, P>0.05). Fruits were at peak during December in both group ranges. Moreover, Spearman's Rank correlation coefficient revealed that there was no significant relation in the FAI between young and mature leaves (r_p=0.56, P>0.05) (Fig. 8).

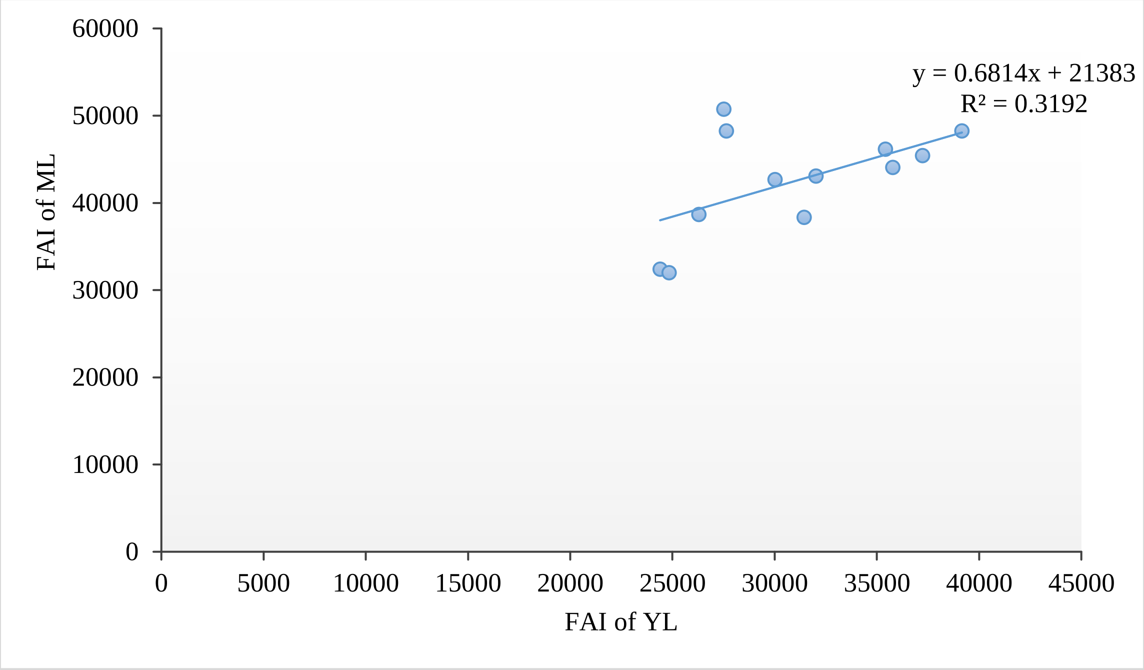

Figure 8. Comparison of total FAI between young leaves (YL) and mature leaves (ML) in the study area.

The overall annual young and mature leaves availability per hectare were 32 % and 30% higher in the range of natural forest group than in the plantation forest group, respectively. Moreover, the overall annual availability of fruit was 10% lower in planation forest group range than in natural forest habitat. The monthly patterns of food item availability within the two guereza home ranges was illustrated in Fig. 9.

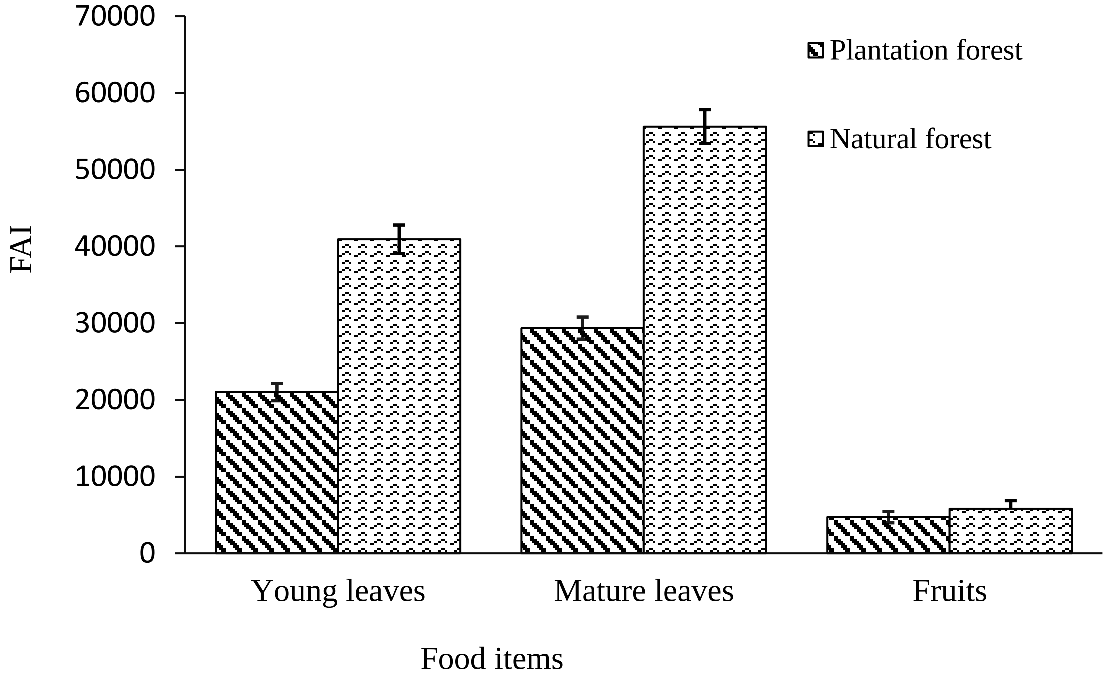

Figure 9. Comparison of total food availability index (FAI) values of food items in the ranges of plantation forest and natural forest groups.

Pearson correlation coefficient between food availability indices of plant items of phenology tree species and total feeding time scans (for all phenology species in the two groups range) revealed significant correlation only with young leaves (r=0.63, P<0.05). However, this relationship between young leaf consumption and availability existed for natural forest study group (Fig. 10). Young leaves attained their peak point in September when they cover the highest canopy percentage of most tree species.

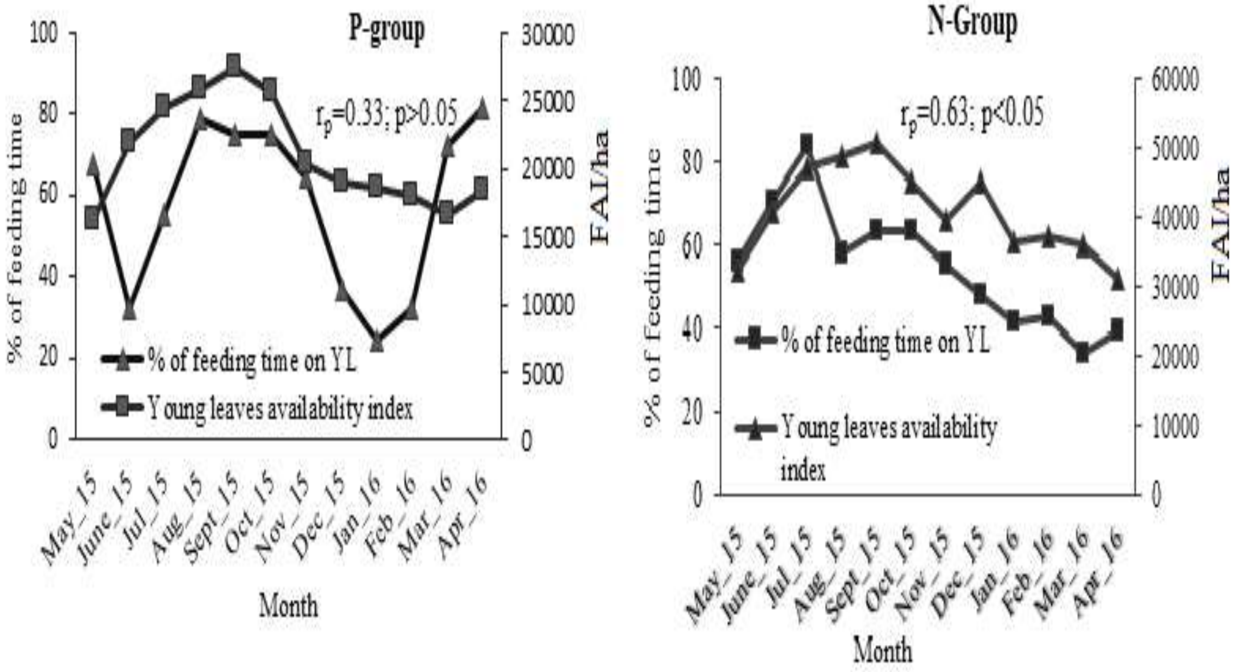

Figure 10. Comparison of the availability of young leaves and its consumption values across months (May 2015-April 2016) in the rangs of the two groups (P and N).

Juniperus procera contributed the highest abundance of both young and mature leaves in both group ranges though its consumption rank was 6th in P-group and 9th in N-group. Young leaves and mature leaves of *Maesa lanceolata* were the second food abundance in both group ranges where the species ranked first in P-group and second in N-group in consumption percentage (Fig. 11). *Vernonia leopoldi* contributed the least abundant food items even though it had the highest percentage of feeding time scans in N-group and fourth in the range of P-group.

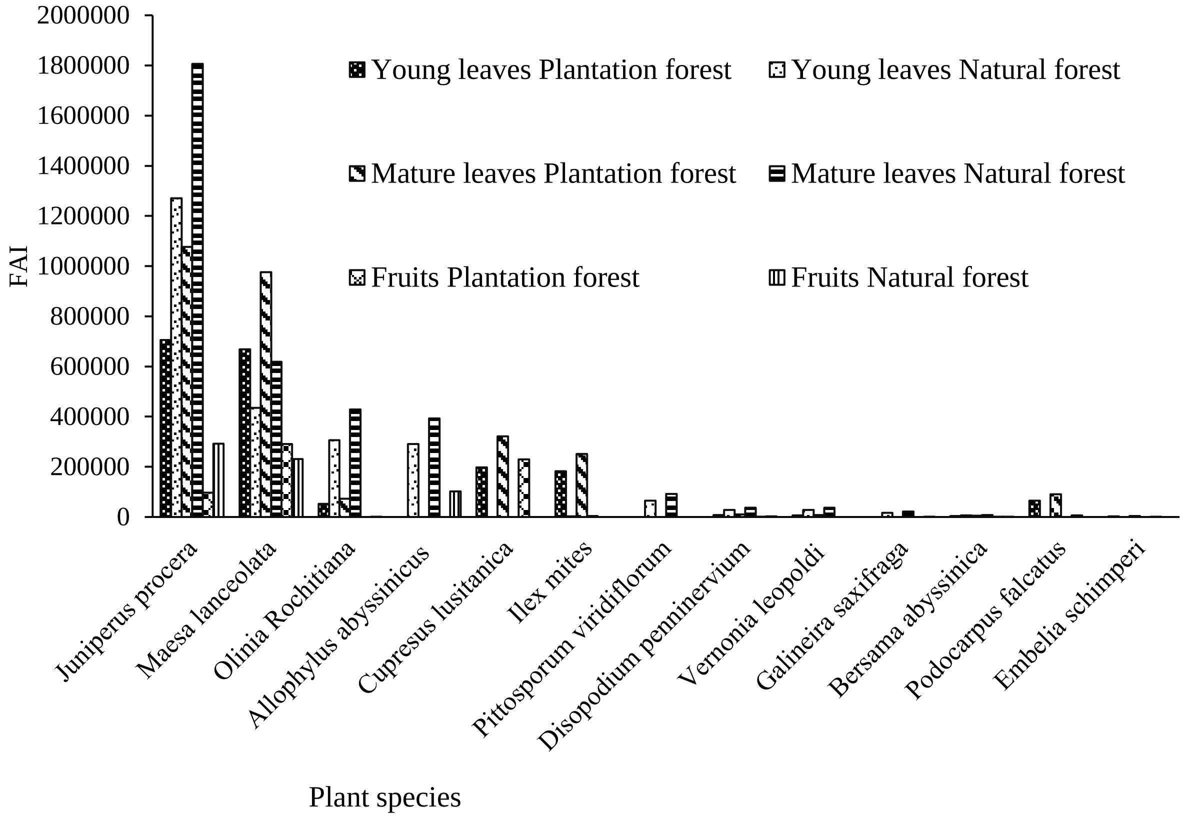

Figure 11. Comparison of food availability index (FAI) values for young leaves, mature leaves and fruits for 13 phenology tree species between plantation (P) and natural forest (N) guereza groups.

5.3. Population estimates

The number of Omo River guereza individuals per group varied from 3 to 16 with a mean group size of 6.8 individuals. The average encounter rate of Omo River guereza groups/km along transect lines walked was 1.65 (range 0.93-3.11 groups/km). The highest encounter rate was recorded in the Undisturbed Natural Forest (UDNF) (3.11 groups/km) transect with the mean of 1.96 group/km while the lowest encounter rates were recorded in the *Erica-Juniperus* Mixed Forest (EJMF) and Disturbed Natural Forest (DNF) with 0.93 groups/km in both habitats (Table 6). However, there were no statistical differences in the rates of encounter of groups across all the transect lines during the three months census periods (Kruskal Wallis H test, $P > 0.05$).

Table 6. Population estimate of Omo River guereza in WWNSF along transects based on the three months census

			Census Months												
			15-May		Sept. 2015		Jan. 2016								
T.No.	Tn.L	SW	gp. no.	T. Ind.l	gp. no.	T. Ind.l	gp. no.	T. Ind.l	Dist. Surveyed	T. G. no.	Encounter Rate	Mean gp size	Gp. Density	Popun. Density (Indl./km2)	Habitat Types
1	2.5	0.1	4	34	4	32	7	48	7.5	15	2	7.60	20.00	152.00	MPF
2	2.5	0.1	2	11	2	11	3	20	4.5	7	1.56	6.00	15.56	93.33	MPF
Mean									**12**	**22**	**1.78**	**6.80**	**17.78**	**122.67**	
3	2.5	0.16	2	16	2	15	5	24	7.5	9	0.93	6.11	7.50	45.83	EJMF
4	3	0.16	5	37	5	34	3	24	9	13	1.33	7.31	9.03	65.97	EJMF
Mean									**16.5**	**22**	**1.13**	**6.71**	**8.27**	**55.9**	
5	2.5	0.12	2	16	2	13	3	28	7.5	7	1.2	8.14	7.78	63.33	DNF
6	2	0.12	3	22	2	15	4	21	7.5	9	0.93	6.44	10.00	64.44	DNF
7	1.5	0.12	3	24	4	29	3	18	6	10	1.5	7.10	13.89	98.61	DNF
8	3	0.12	8	53	6	43	3	18	4.5	17	2.22	6.71	31.48	211.11	DNF
9	1.5	0.12	1	5	2	13	6	52	9	9	1.89	7.78	8.33	64.81	DNF
10	1.5	0.12	4	23	5	38	5	30	4.5	14	2	6.50	25.93	168.52	DNF
Mean									**39**	**66**	**1.62**	**7.11**	**16.24**	**111.80**	
11	2.5	0.08	3	17	4	26	3	18	4.5	10	3.11	6.10	27.78	169.44	UDNF
12	3	0.08	6	33	4	23	3	18	7.5	13	1.33	5.69	21.67	123.33	UDNF
13	1.5	0.08	2	15	2	18	3	17	9	7	1.44	7.14	9.72	69.44	UDNF
Mean									**21**	**30**	**1.96**	**6.31**	**19.72**	**120.74**	
Combined Total/mean	32		45	306	44	310	51	336	88.5	140	1.65	6.80	16.05	106.94	

Note: T.No.=Transect number, Tn.L=Transect length, SW=strip (sighting) width, gp.no.=group number, T. ind.l=total individuals, T.G. no.=Total group number, MPF=Mixed Plantation Forest, EJMF=*Erica-Juniperus* Mixed Forest, DNF=Disturbed Natural Forest, UDNF=Undisturbed Natural Forest.

The average group density of the species was 16.05 groups/km^2 (range 7.5-31.5 groups/km^2). The average individual density extrapolated from the calculated density was 106.05 individuals/km^2 (range 45.83-211.11 individuals/km^2). Guerezas were found in higher group density (19.72 group/km^2) and individual density (120.74 individuals/km^2) in the UDNF habitat though in lower average group size. The total area of the study sites inhabited by Omo River guereza was 25.6 km^2. Thus, the total population size of the study species in WWNSF was estimated to be 2715 individuals.

The population estimate of Omo River guereza by DISTANCE 6.2 Release 1 using perpendicular distance from the transect to the first animal seen was estimated to be 202.85 ± SE 54.06 individuals/ km^2, whereas, the mean group size was 6.67 ± SE 0.31 (Table 7). However, there were no statistical differences in the estimation of group size and individual densities obtained from the sample estimation and distance software estimation during the three months census periods (Kruskal Wallis H test, $P > 0.05$). This shows conformity between the estimation tools used in the analysis.

Table 7. Group size and population estimation by DISTANCE 6.2 Release 1.

	Months			
	May	Sept	Jan	mean
Group size	6.5±0.36	7±0.31	6.52±0.27	6.67±0.31
Population density (Ind./km^2)	213.82±37.87	210±44.44	184.73±79.88	202.85±54.06

5.4. Sex and age group composition

Out of the average individual number (317) of Omo River guereza sighted during the three-census period, 56.3±17.1 (71%) were adult and 17.3 ±5.6 (21.8%) were subadult of both sexes (Table 8). The age group of juvenile and infants accounted 4.3± 1.9 (5%) and 1.8±0.3 (2.2%), respectively. When sex values were treated independently, females constituted an average of 32 ±9.2 (52%) and males 29.5 ±9.3 (48%). The difference

Table 8**.** Age and sex classes of Omo River guereza.

Habitat type	Total	AM	AF	UA	SAM	SAF	USA	YG	Inf	M	F	Adult	Sub-adult	SA: Ad	M: F
MPF	52	15	17	5	4	3	3	2	2	19	20	37	11	1:3.4	1:1.1
EJMF	50	14	16	4	4	5	4	3	2	17	21	34	12	1:2.8	1:1.2
DNF	154	46	48	13	10	12	12	10	2	57	59	107	34	1:3.2	1:1.1
UDNF	62	20	23	4	5	5	3	2	1	25	28	47	12	1:3.9	1:1.11
Total	317	96	103	26	23	25	21	16	7	118	128	225	69	1:3.3	1:1.1
Mean with SE (Mean ± SE)		23.8 ±7.5	26 ±7.5	6.5 ±2.2	5.8 ±1.4	6.3 ±2	5.5 ±2.2	4.3 ± 1.9	1.8 ±0.3	29.5 ±9.3	32 ±9.2	56.3 ±17.1	17.3 ±5.6		
Percentage		30.3	32.5	8.2	7.3	7.9	6.6	5.0	2.2	48	52	71	21.8		

Note: AM=Adult male, AF=Adult Female, UA=Unidentified adult, SAM=Subadult male, SAF=subadult female, USA=Unidentified subadult, YG=young, Inf=Infant, M=Male, F=female, Sa-subadult, Ad=adult.

was insignificant (P>0.05). During the study period, more adult individuals were counted than sub-adults and young ones for both sexes in the study area. The overall average sex ratio of males to females was 1:1.1 and that of subadult to adults age ratio was 1:3.3. Mann Whitney U test analysis of the age structure for adults and subadults showed that there was significant difference (P< 0.05) in the age distribution in the study area. However, there was no statistical difference in sex ratio though the population is female biased. All Omo River guereza groups encountered were multimale except the four one male group incidents in January 2016. Nevertheless, all male groups were not observed during the census period.

5.5. Habitat use

A total of 140 groups were sighted in 42 censuses conducted over three months along transect lines crossing a total distance of 96 km encompassing five different habitat types. Of these five habitat types surveyed during the population census, highest group encounter rate (3.11groups/km) of Omo River guereza was recorded in the Undisturbed Natural Forest (UDNF) while the lowest in *Erica-Juniperus* Mixed Forest (EJMF) and none was observed in *Erica* bushland (EBL), which indicated some patterns of habitat use, though not confirmed significant. More time in certain area means more “use” of resources or conditions at that location. However, there was no statistically significant difference in habitat use intensity (Kruskal–Wallis H test, $\chi^2 = 5.17$, P >0.05).

Based on the GPS data records taken at each group sighted, Omo River guerezas were more abundant in the altitudinal zonation between 2510-3100 m asl which is in Dry Evergreen Afromontane Forest ecosystem (the Montane forest belt) (Fig. 12). This belt is dominated by plant species like *Olea europaea subsp. cuspidata, Juniperus procera, Podocarpus* *falcatus, Allophylus abyssinicus, Haleria lucida, Maesa lanceolate, Ilex mites* and *Olinia rochetiana* which are the major food resources for guerezas.

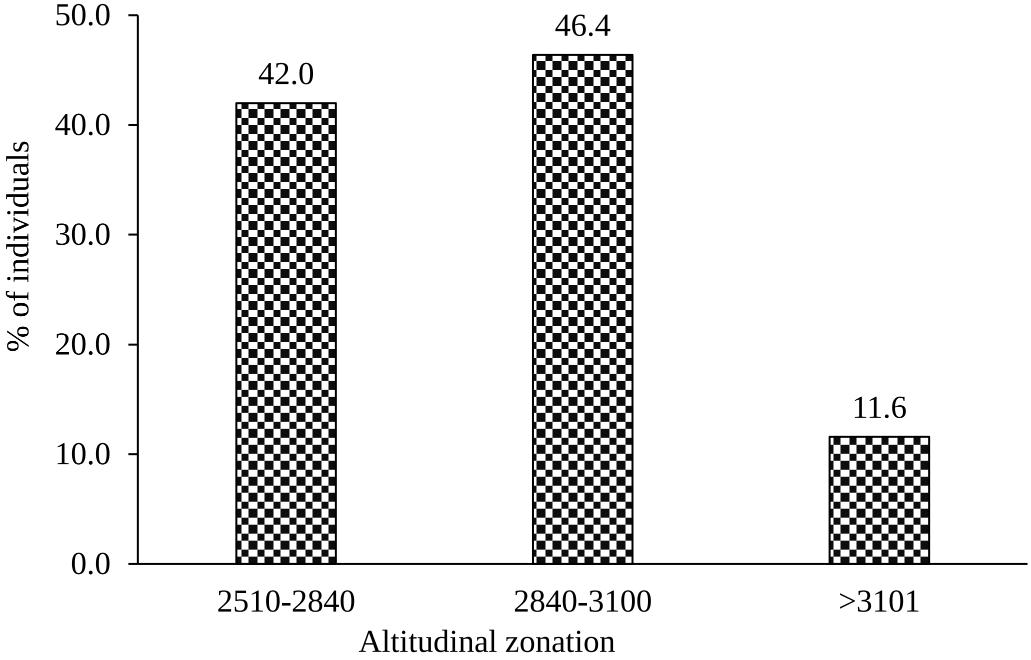

Figure 12. Distribution of Omo River guereza across altitudinal zonation.

5.6. Activity budget

A total of 22618 individual behavioural observations were recorded from 5071 instantaneous group scans during 1268 hrs in 120 total observation days (60 days for each of P and N group). From the total behavioural observations, 11990 and 10628 were in group P and N, respectively. Based on the combined study groups P and N, on average Omo River guerezas spent 43.1% (41.3-44.9%) of their time resting, 31.8% (30.4-33.1%) feeding and 12.9% (11.5-14.3%) moving (Fig. 13).

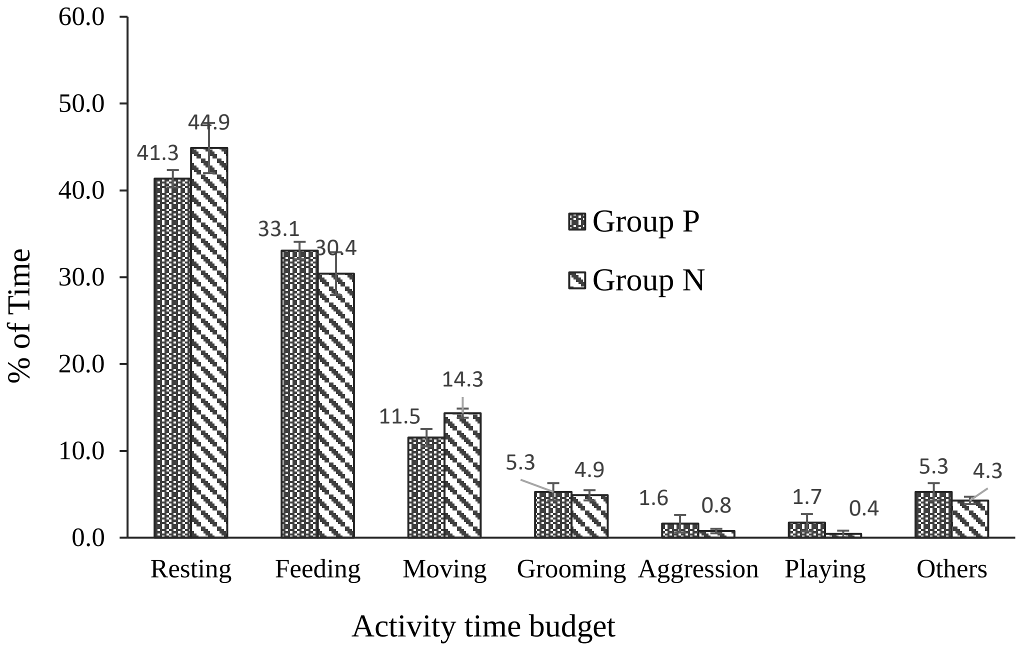

Figure 13. Comparison of annual activity time budget of the scan groups of Omo River guereza (for P, n=11990 and N, n=10628) in WWNSF.

Omo River guereza group in natural forest habitat spent significantly more time moving (5.3% vs. 4.9%; ANOVA: F = 10.72, df = 1, $p < 0.05$), and less time playing (0.4% vs. 1.7%; ANOVA: F = 10.47, df = 1, $p < 0.05$) and aggression (4.3% vs. 5.3%; ANOVA: F = 8.87, df = 1, $p < 0.05$) than the group in plantation forest. However, there were no statistically significant differences in resting (41.3% vs 44.9%; ANOVA: F = 0.79, df = 1, p =0.38), feeding (33.1% vs. 30.4%; ANOVA: F = 0.62, df = 1, p =0.44), grooming (5.3% vs. 4.9%; ANOVA: F = 0.35, df = 1, p =0.56) and other activities (5.3% vs. 4.3%; ANOVA: F = 2.23, df = 1, p =0.15) between groups in the plantation and natural forest habitat types.

Levene statistic test of homogeneity and Shapiro-Wilk test of normality revealed that the distribution of variances across months for all variables were heterogeneous and abnormal ($p<0.05$), respectively. Thus, Non-Parametric Kruskal–Wallis H test was used to compare the activity time budget of Omo River guereza across the 12 months. The monthly time budget for resting during the study period varied across months ranging from 31.89% during May to 57.5% during July. Feeding ranged from 22.67 % in February to 46.21 during May. Moreover, grooming was lower in May (0.56%) and higher during September (3.54%) (Fig 14). However, Kruskal–Wallis H test revealed that there were no statistically significant differences in percentage of time budgeted for different activities across months (P>0.05).

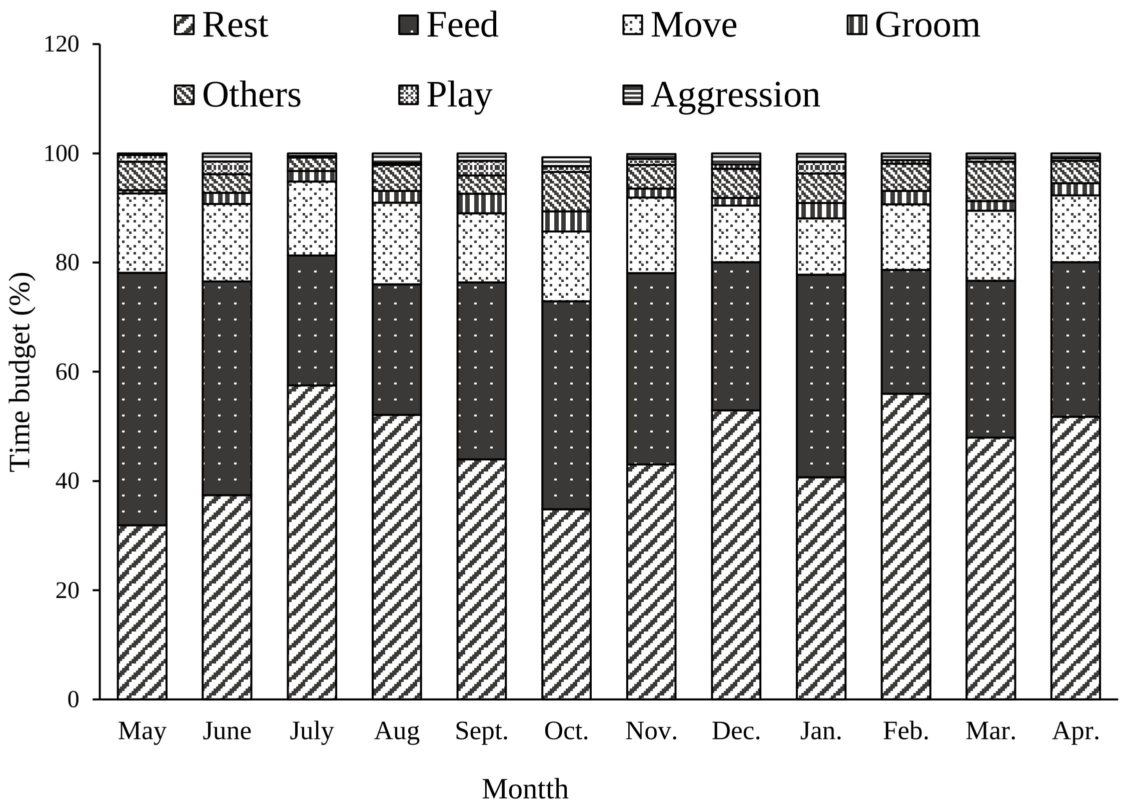

Figure 14. Percentage of time budget of Omo River guereza for different activities across months.

The mean activity budgets for females in the study area were 47.69% resting and 30.23% feeding. Whereas, males devoted 44.25% for resting and 33.18% for feeding. This revealed that females and males devoted nearly similar amounts of time to moving, other activities and playing while females devoted slightly higher time budget for resting and grooming though the differences were not significant (Fig. 15). Males devoted more time for feeding and aggression than females though the difference was not statistically significant (Mann-Whitney U test, *P* >0.05).

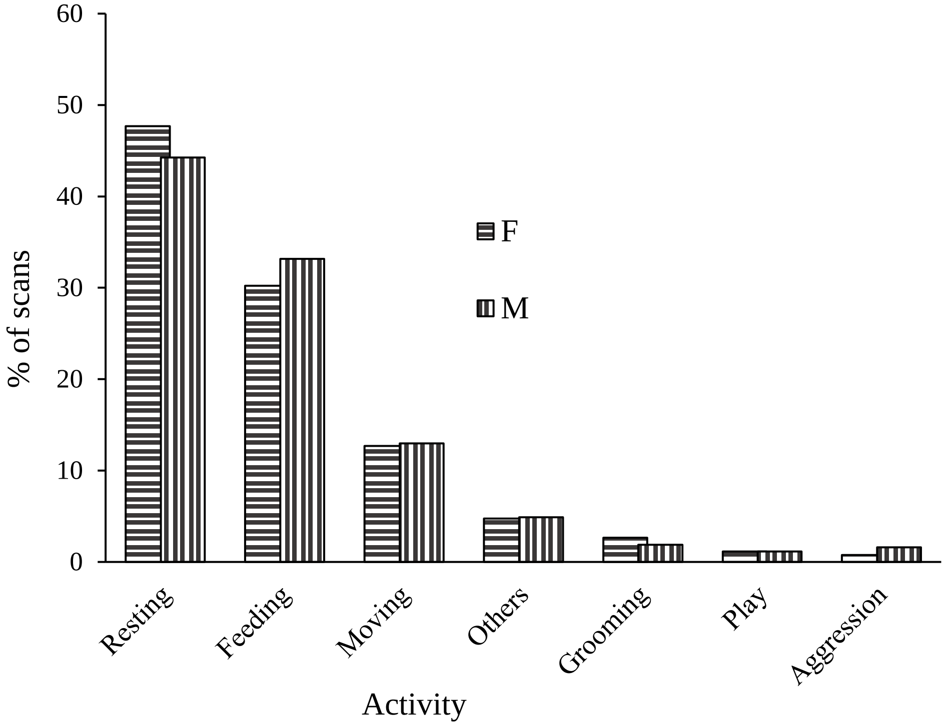

Figure 15. Comparison of activity budgets between females (*n* = 9889) and males (*n* = 12729).

Regarding the time budget of different individual age categories, adults spent about 47.3% of their time resting while subadults and juvenile spent only 44.2% and 40.3%, respectively (Fig. 16). Feeding varied with adults spending 29.9%, subadults 35.8% and juveniles 37.6% of their time budgeted for feeding. However, Kruskal–Wallis H test revealed that there was no statistical difference (p>0.05) in time budgeted for different activities across age categories.

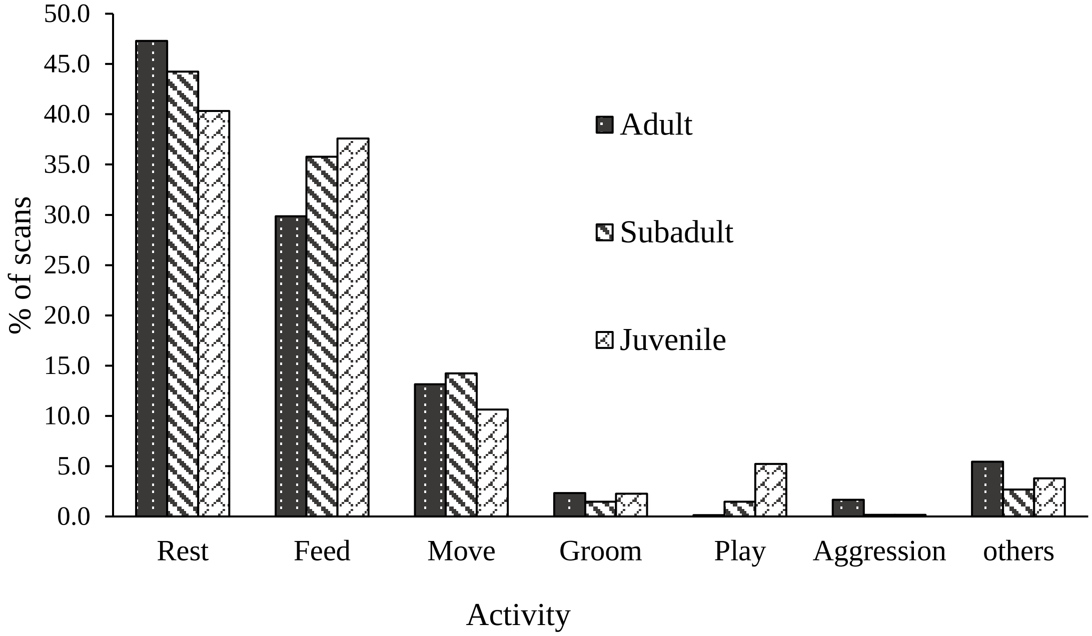

Figure 16. Comparison of activity time budgets on different activities across individual age groups.

The pattern of resting in Omo River guereza decreased from its highest peak in the morning (54.8%) to the very low peak in late afternoon (28.8%). Feeding pattern oscillated inversely (21.4%-50.4%). Moving was slightly higher early in the late afternoon in which animals were most active to forage and nourish themselves for the longer night. Grooming (0.6%-3.5%), playing (0.7%-1.8%), aggression (0.9%-1.7%) and other activities (2.7%-8.2%) were performed steadily throughout the day (Fig. 17). However, the difference was not significant (P>0.05).

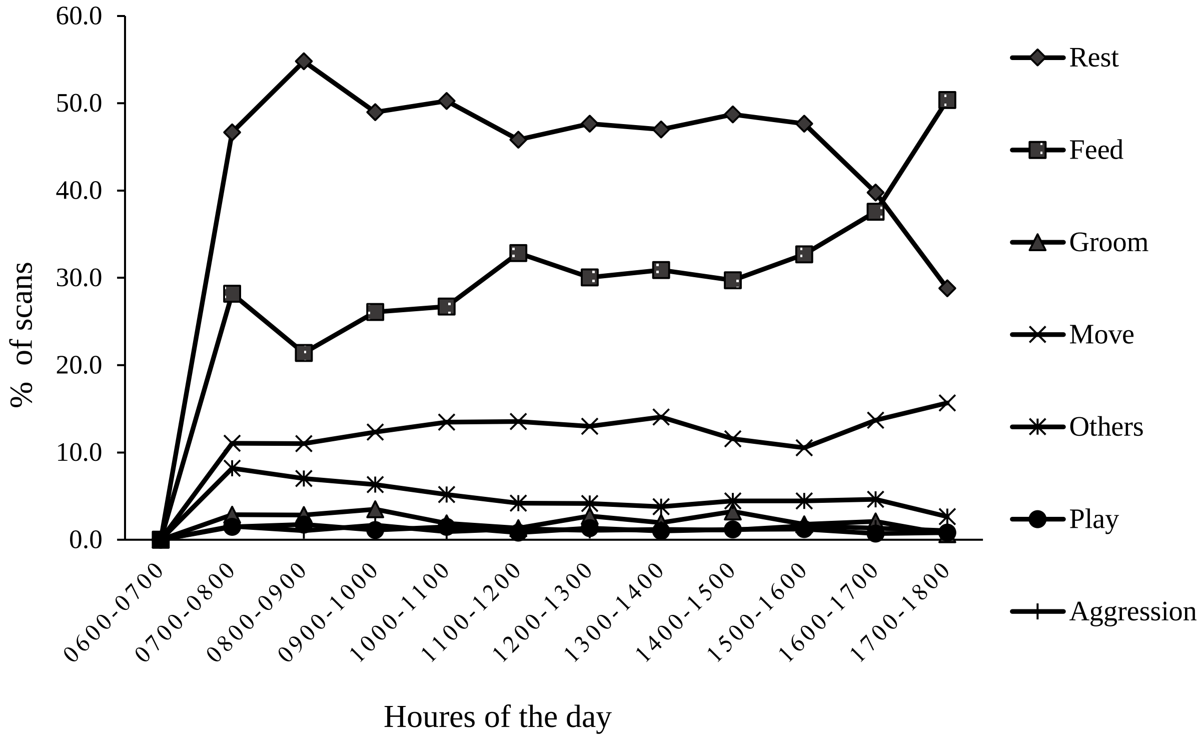

Figure 17. Average annual diurnal activity patterns of Omo River guereza in WWNSF.

5.7. Feeding Ecology

The total number of dietary plant species identified as food for guerezas in WWNSF were 31, of which 18 were in the plantation forest group and 30 in the natural forest group. Guerezas were observed feeding plant species belonging to 31 genera and 26 families (Table 9). The food sources of guerezas in the plantation forest were 8 trees, 2 trees/shrubs, 4 shrubs, 3 lianas/climbers and 1 epiphyte. However, in the natural forest, they fed on 13 trees, 4 trees/shrubs, 6 shrubs, 4 lianas/climbers, 2 herbs, and 1 epiphyte.

A few plant food resources accounted for the majority of guerezas diet. The top five species from five different families comprise over 83% (group P) and 70% (group N) of the overall diet of Omo River guereza. Nearly 10 plant species individually accounted more than 1% of the overall annual diet in the plantation forest (Table 9) whereas 15 species comprised

Table 9. Annual percentage of time spent feeding on a specific food item of a plant species (Plantation forest group, n=3972; Natural forest group, n=3228).

Family	Species	*Growth form	Fruit	Mature leaves	Shoot	Stem	Young leaves	Total spp. contribution
Plantation forest (P)								
Myrsinaceae	*Maesa lanceolata*	T	0.05	8.48	0.55	1.06	20.51	30.65
Podocarpaceae	*Podocarpus falcatus*	T	12.06	0.38	0.08	0	3.61	16.12
Aquifoliaceae	*Ilex mites*	T	0	2.77	0.28	0.45	10.62	14.13
Asteraceae	*Vernonia leopoldi*	S	0	3.96	0.13	0.48	8.98	13.55
Solanaceae	*Disopodium penninervium*	S	0	2.83	0	0.63	5.17	8.63
Cupressaceae	*Juniperus procera*	T	0.48	1.14	0.1	0.03	2.17	3.91
Oliniaceae	*Olinia Rochitiana*	T	-	0.98	0.05	0.13	2.55	3.71
Moraceae	*Ficus sur*	T	3.51	-	-	-	0.03	3.53
Melianthaceae	*Bersama abyssinica*	T/S	-	0.96	-	0.1	1.79	2.85
Cupressaceae	*Cupresus lusitanica*	T	-	0.4	0.03	-	1.11	1.54
Oleaceae	*Jasminum abyssinicum*	L/C	-	-	-	-	0.55	0.55
Ranunculaceae	*Clematis hirsuta*	L/C	-	0.03	0.03	-	0.3	0.35
	unidentified mosses	E	-	-	-	-	0.18	0.18
Myrsinaceae	*Embelia schimperi*	L/C	-	-	-	-	0.08	0.08
Rosaceae	*Rubus steudneri*	S	-	0.03	-	-	0.05	0.08
Scrophulariaceae	*Halleria lucida*	T/S	-	-	-	-	0.05	0.05
Myrsinaceae	*Myrsine africana*	S	-	-	-	0.03	0.03	0.05
Oleaceae	*Olea europaea*	T	-	-	-	-	0.03	0.03
	Total		16.12	21.95	1.24	2.90	57.80	100
Natural forest (N)								
Asteraceae	*Vernonia leopoldi*	S	0.19	11.83	0.9	0.81	16.05	29.77
Myrsinaceae	*Maesa lanceolata*	T	0.99	4.71	1.15	0.4	8.4	15.64
Pittosporaceae	*Pittosporum viridiflorum*	T	1.18	2.94	0.59	0.15	7.13	11.99
Oliniaceae	*Olinia Rochitiana*	T	0.12	2.11	0.46	0.12	4.46	7.28
Aquifoliaceae	*Ilex mites*	T	-	2.29	0.37	-	3	5.67
Rubiaceae	*Galineira saxifraga*	T	0.5	1.24	0.31	0.09	2.79	4.93

Solanaceae	*Disopodium penninervium*	S	0.19	1.49	0.46	0.28	2.04	4.46
Sapindaceae	*Allophylus abyssinicus*	T	0.09	0.9	0.22	0.03	2.51	3.75
Cupressaceae	*Juniperus procera*	T	0.25	0.65	0.15	0.03	2.29	3.38
Cupressaceae	*Cupresus lusitanica*	T	-	0.87	0.59	-	1.08	2.54
Moraceae	*Ficus sur*	T	1.89	-	-	-	-	1.89
Oleaceae	*Olea europaea*	T	0.03	0.53	0.12	-	1.02	1.7
Melianthaceae	*Bersama abyssinica*	T/S	0.06	0.37	0.22	0.06	0.81	1.52
Scrophulariaceae	*Halleria lucida*	T/S	-	0.34	0.34	0.09	0.59	1.36
Podocarpaceae	*Podocarpus falcatus*	T	-	0.09	-	0.03	0.84	0.96
Loganiaceae	*Nuxia congesta*	T	-	0.5	0.09	-	0.28	0.87
Myrsinaceae	*Myrsine africana*	S	-	0.12	0.03	-	0.43	0.59
Flacourtiaceae	*Dovyalis abyssinica*	S	0.03	0.03	-	-	0.34	0.4
Ranunculaceae	*Clematis hirsuta*	L/C	-	0.06	-	-	0.28	0.34
Meliaceae	*Turraea holstii*	S	-	0.03	-	-	0.19	0.22
	unidentified mosses	E	-	-	-	-	0.22	0.22
Myrsinaceae	*Embelia schimperi*	S	-	0.03	-	-	0.09	0.12
Ericaceae	*Erica Arborea*	T/S	-	0.03	0.03	-	0.06	0.12
Celastraceae	*Maytenus arbutifolia*	T/S	-	0.06	-	-	0	0.06
Anacardiaceae	*Rhus natalensis*	T	-	-	-	-	0.06	0.06
Balsaminaceae	*Impatiens tinctoria*	H	-	-	-	-	0.03	0.03
Oleaceae	*Jasminum abyssinicum*	L/C	-	-	0.03	-	-	0.03
Lamiaceae	*Plectranthus lactiflorus*	H	-	-	-	-	0.03	0.03
Urticaceae	*Urera hypselodendron*	L/C	-	-	-	-	0.03	0.03
Cucurbitaceae	*Zehneria scabra*	L/C	-	-	-	-	0.03	0.03
	Total		5.51	31.23	6.07	2.11	55.08	100

Note: *Growth form T=Tree, T/S= Tree /Shrub, S=Shrub, H= Herb, L/C= Liana/Climber, E= Epiphyte

more than 1% of the overall annual diet individually in the natural habitat. One of the top five food species in both groups, *Maesa lanceolata*, dominated the overall diet at 23.2% of feeding time, of which 21.05% was from young leaves in the plantation (P) group. Although the food plant species in plantation forest group were found in N group, there was a great difference in the contribution of various species to the overall diet. For instance, fruits of *Podocarpus falcatus* and *Ficus sur* accounted 12.06% and 3.51% in plantation forest while only 0% and 1.89% in natural forest habitat, respectively. Moreover, *Vernonia leopoldi* comprised the first rank (29.77%) in natural forest while fourth (13.55%) in plantation forest group. A great deal of dietary overlap occurred as the top ten food species of plantation group found within the top 15 of the group in the natural forest habitat. These differences in the utilization of food plant species between groups likely reflect variation in the availability of these plants in the groups respective home ranges. For example, while *Maesa lanceolata* was the most important food resource for plantation group, natural forest group intensively used on *Vernonia leopoldi.*

A total of 7200 feeding behavioural observations were recorded from 15 minutes instantaneous scan sampling of the two combined study groups of Omo River guerezas, 3972 (Plantation forest group) and 3228 (Natural forest group) collected in the 12 months for each group (Fig. 18). Leaves comprised the major diet composition in both plantation (79.7%) and natural forest (86.3%) groups though variation was observed in the proportion of mature and young leaves. Young leaves accounted between 55.1%-57.7% of groups' overall diets whereas mature leaves comprised between 22%-31.2%. Analysis of independent sample T test revealed that there was no statistically significant difference between groups in the time spent on food items on mature leaves (t=1.5, df=22, p>0.05), stems (t=2, df=22, p>0.05) and young leaves (t=0.5, df=22, p>0.05). However, there was a significant difference in time spent feeding on fruits (t=2.2, df=22, $p<0.05$) and shoots (t=3.6, df=22, $p<0.05$) between groups in the plantation and natural forest habitats.

Guerezas spent more of their time feeding on young leaves than mature leaves. Plantation forest (P) group spent more proportion of their time feeding on young leaves and less time feeding on mature leaves than the natural forest (N) group (Fig. 18).

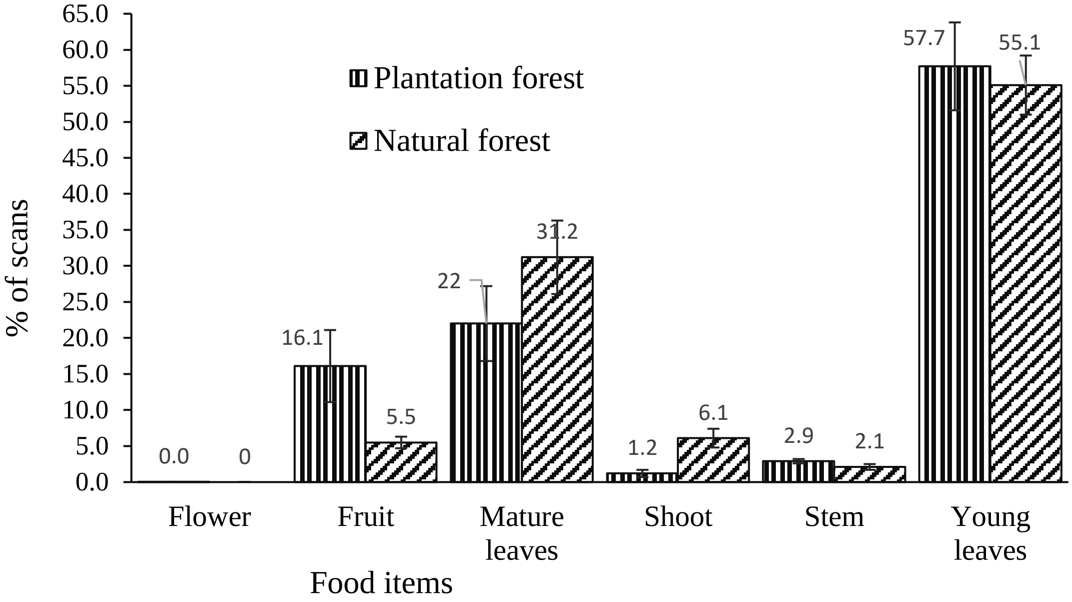

Figure 18. Annual percentage of plant part composition in the diet of two groups of Omo River guereza.

Based on the combined study groups P and N, on average, Omo River guerezas spent 11.2%, SD±9.4% (ranged 2.2%-33.4%) of their monthly time feeding on fruit. The peak of scan observation of feeding on fruit was in June while the lowest was in September. The average monthly time spent feeding on mature leaves was 26.2%, SD±15% (range 3.6% in July to 53.1% in January) while that of young leaves was 56.4%, SD±13% (range 32.9% in January to 66.7% in July) (Fig. 19).

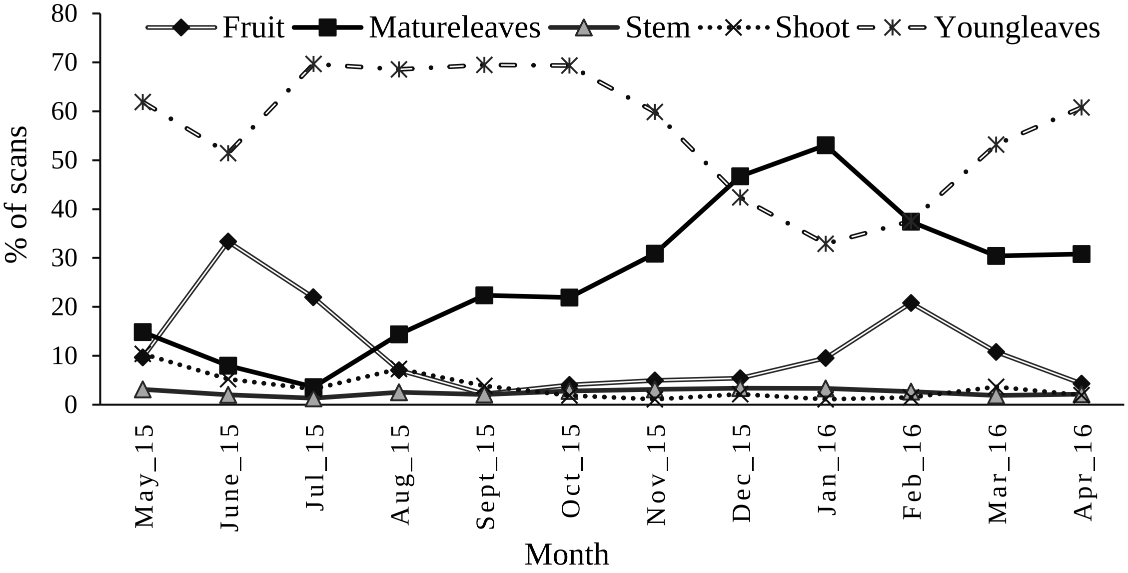

Figure 19. Monthly changes in the proportion of plant parts composition in the diet of Omo River guereza.

The mean monthly dietary diversity over 12 months as calculated by the Shannon-Weaver index, H’, for guerezas in the plantation (P group) and natural forest (N-group) were 1.75 (range 1.18-2.19) and 2.09 (range 1.46-2.54), respectively. Mann Whitney U test revealed that there was a higher monthly dietary diversity in the natural forest group than it was in plantation forest ($P<0.05$). Dietary diversity was highest in September and October and lowest in February in P-group. It was highest in June and lowest in December for N-group (Table 10). The mean monthly dietary evenness index, J, for guerezas in the plantation (P group) and natural forest (N-group) were also 0.38 (range 0.36-0.41) and 0.46 (Range 0.42-0.49), respectively. Mann Whitney U test revealed that dietary items were significantly evenly distributed in the natural forest group than it was in plantation forest ($P<0.05$). Mean monthly dietary diversity and evenness indices were low in the study area ranging from 1.57-2.32 (H’) and from 0.39-0.44 (J) (Table 10).

Table 10. Food species diversity and evenness indices for the 12 months study period from Plantation and Natural forest.

Month	Shannon Wiener diversity index, H'			Evenness index, J		
	P-Group	N-Group	Mean	P-Group	N-Group	Mean
May_15	1.77	2.44	2.11	**0.36**	0.44	0.40
June_15	1.60	**2.54**	2.07	0.37	**0.42**	**0.39**
Jul_15	1.66	2.31	1.99	0.40	0.48	0.44
Aug_15	1.66	1.84	1.75	0.40	0.48	**0.44**
Sept_15	**2.19**	2.40	2.30	**0.36**	**0.49**	0.43
Oct_15	**2.19**	2.45	**2.32**	**0.36**	0.43	0.40
Nov_15	2.00	2.00	2.00	0.37	0.44	0.41
Dec_15	1.76	**1.46**	1.61	0.39	0.47	0.43
Jan_16	1.85	1.98	1.92	**0.36**	0.46	0.41
Feb_16	**1.18**	1.95	**1.57**	**0.41**	0.48	0.44
Mar_16	1.50	1.68	1.59	0.38	0.46	0.42
Apr_16	1.58	2.05	1.82	0.40	0.45	0.42
	1.75	2.09	1.92	0.38	0.46	0.42

Although the top 5 plant species comprised over 70% of feeding time in the overall annual diet of the combined group, this does not mean that guerezas can exist on these species alone, as these plant resources may not consistently provide the required quality and quantity of plant parts throughout the year. Indeed, their presence in the diet on a month-by-month basis is highly variable (Table 11). Only the first seven top plant species are eaten during every month of the study period while variation existed in the occurrence of feeding bouts on different plant species to the extent that some species were consumed during only one or few months sample. *Maesa lanceolata* contributed the highest percentage regularly throughout the year ranging from 13.9 % (June) to 31.6% (September). *Maesa lanceolata* was the most frequently consumed food plant species with the highest proportion from young leaves. *Vernonia leopoldi* was the second most consumed plant species followed by *Ilex mites* and *Podocarpus falcatus*. Kruskal-Wallis H tests on the comparison of plant species contribution across each month showed no significant differences in the time spent feeding on different plant species ($P > 0.05$).

Table 11. Monthly percent variation in the contribution of plant species to the diet of Omo River guerezas.

Species consumed	May	June	July	August	Sept.	Oct.	Nove.	Dece.	Jan.	Feb.	March	April	Mean
Maesa lanceolata	19.0	13.9	18.5	24.8	31.6	31.0	27.1	30.0	25.3	14.1	29.2	20.8	23.8
Vernonia leopoldi	7.4	4.8	9.5	33.6	15.0	18.5	23.0	36.6	23.3	31.4	33.8	29.5	22.2
Ilex mites	14.7	13.3	19.4	6.2	11.2	7.0	10.0	3.5	4.8	10.2	5.3	19.9	10.5
Podocarpus falcatus	13.0	20.3	16.1	2.4	4.6	4.2	3.5	4.5	9.8	20.2	9.3	3.4	9.3
Disopodium penninervium	1.7	2.1	5.5	6.8	5.6	9.5	8.4	8.3	9.6	10.2	6.8	9.0	7.0
Pittosporum viridiflorum	7.0	8.1	9.0	6.4	4.2	2.9	6.8	0.8	5.6	5.1	3.1	5.0	5.3
Olinia Rochitiana	10.8	8.7	2.4	2.6	6.3	5.6	6.9	4.3	4.8	1.2	2.4	1.3	4.8
Juniperus procera	9.9	3.8	0.5	0.2	4.9	1.8	3.1	1.9	8.3	0.5	2.6	1.2	3.2
Ficus sur	3.1	13.3	9.0	3.5	0.0	0.1	1.2	0.8	-	0.7	-	-	2.6
Bersama abyssinica	1.7	1.4	-	1.5	4.4	4.7	1.0	6.8	0.6	-	3.1	1.2	2.2
Galinera saxifraga	4.3	2.3	3.6	0.7	1.7	2.7	2.2	0.8	1.4	2.4	2.2	1.5	2.1
Cupresus lusitanica	0.3	-	-	9.2	2.9	2.6	2.2	1.0	2.9	1.7	-	2.7	2.1
Allophylus abyssinicus	2.9	4.2	1.2	0.7	1.7	2.0	2.8	-	0.8	-	-	1.3	1.5

Diet selection

Food plant species that contributed more than one percent in the diet of guerezas during the study period in the home range of the animal is presented in Table 12. Based on the dietary preference ratio, *Ilex mites* was the most selected plant species by P-group with a selection ratio (SR) of 12.7 followed by *Vernonia leopoldi* (8.1) and *Ficus Sur* (6.3). whereas, *Vernonia leopoldi*, *Ilex mites* and *Pittosporum viridiflorum* were the first, second and third selected spices with SR of 17.4, 13.3 and 5.6 in the N-group, respectively. Conversely, *Maesa lanceolata* had a low SR (0.7) despite the highest percentage contribution in the overall diet of Omo River guereza.

Table 12. Dietary selection of guerezas based on stem density (individuals/ ha) and percentage of time spent (proportion of the total number of foraging scans).

	P-Group					N-Group			
Rank	Species consumed	Annual diet%	% of stem density	SR by stem density	Rank	Species consumed	Annual diet%	% of stem density	SR by stem density
1	*Maesa lanceolata*	30.6	44.4	0.7	1	*Vernonia leopoldi*	29.8	1.7	17.4
2	*Podocarpus falcatus*	16.1	8.3	1.9	2	*Maesa lanceolata*	15.6	12.8	1.2
3	*Ilex mites*	14.1	1.1	12.7	3	*Pittosporum viridiflorum*	12	2.1	5.6
4	*Vernonia leopoldi*	13.5	1.7	8.1	4	*Olinia Rochitiana*	7.3	19.2	0.4
5	*Disopodium penninervium*	8.6	2.2	3.9	5	*Ilex mites*	5.7	0.4	13.3
6	*Juniperus procera*	3.9	27.8	0.1	6	*Galineira saxifraga*	4.9	2.6	1.9
7	*Olinia Rochitiana*	3.7	1.1	3.4	7	*Disopodium penninervium*	4.5	3.4	1.3
8	*Ficus Sur*	3.5	0.6	6.3	8	*Allophylus abyssinicus*	3.7	14.5	0.3
9	*Bersama abyssinica*	2.9	1.1	2.6	9	*Juniperus procera*	3.4	14.5	0.2
10	*Cupresus lusitanica*	1.5	8.3	0.2	10	*Cupresus lusitanica*	1.7	0.4	0.7
					11	*Olea europaea*	1.7	2.6	0.7
					12	*Bersama abyssinica*	1.5	0.9	1.8
					13	*Halleria lucida*	1.4	0.9	1.6
					14	*Podocarpus falcatus*	1	1.7	0.6

5.8. Ranging Ecology

On annual average (± S.E.), the plantation forest group travelled 658.5 ± 36.4 m, and the natural forest group moved 800.5 ± 39.9 m each day (Fig. 20). The shortest daily travel distance (DTD) made by plantation forest group was 110.7 m (August 23) and the longest was 1743.9 m (November 30). On the other hand, the shortest DTD made by the natural forest group was 331.3 (April 28) and the longest was 1733.2 m (November 24). Generally, the average DTD was significantly different between the two guereza groups (Z=-2.58, n=120, P<001).

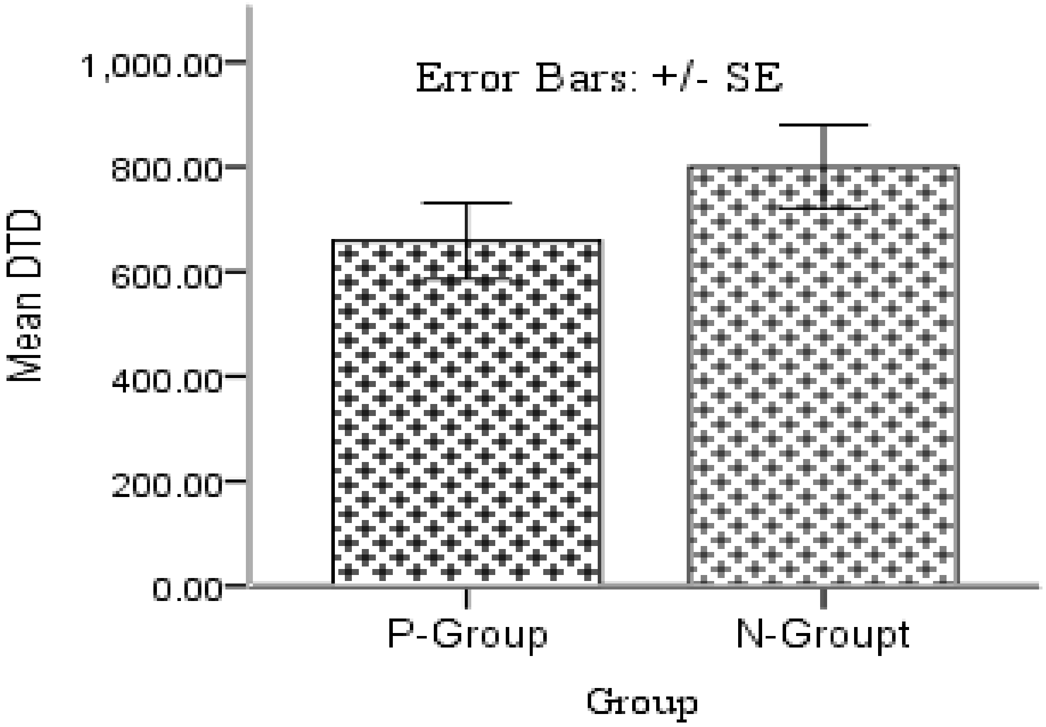

Figure 20. Comparison of daily travel distance (DTD) between the two guereza groups.

The median value (614.4) of the DTD observations was observed around the mean DTD for the plantation group. Whereas, in the natural forest group, the median (712.5) of DTD observations was below the mean and most observations were highly concentrated in the first and second quartile (Fig. 21).

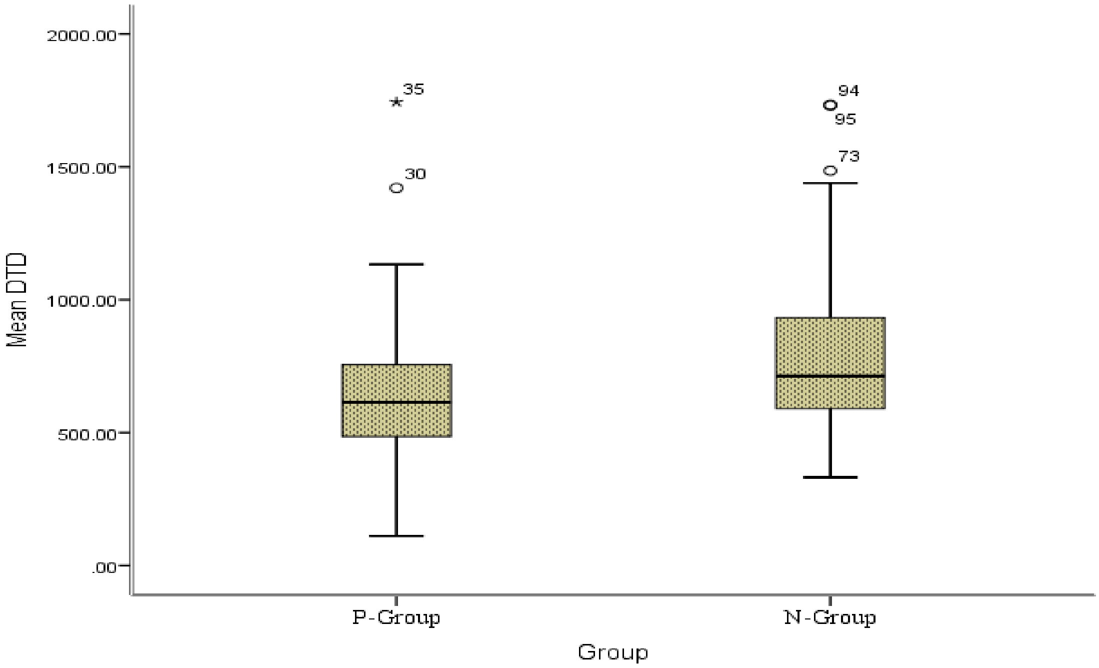

Figure 21. Comparison of the distribution of median of the DTD observations in the ranges of the two guereza groups.

Analyses of the effect of temporal variation and habitat type (independent variables) on mean monthly DTD (dependent variable) within each group revealed that guerezas in the natural forest habitat travelled near significantly (Z=-1.9, P=0.057) farther than plantation forest group (Fig. 22).

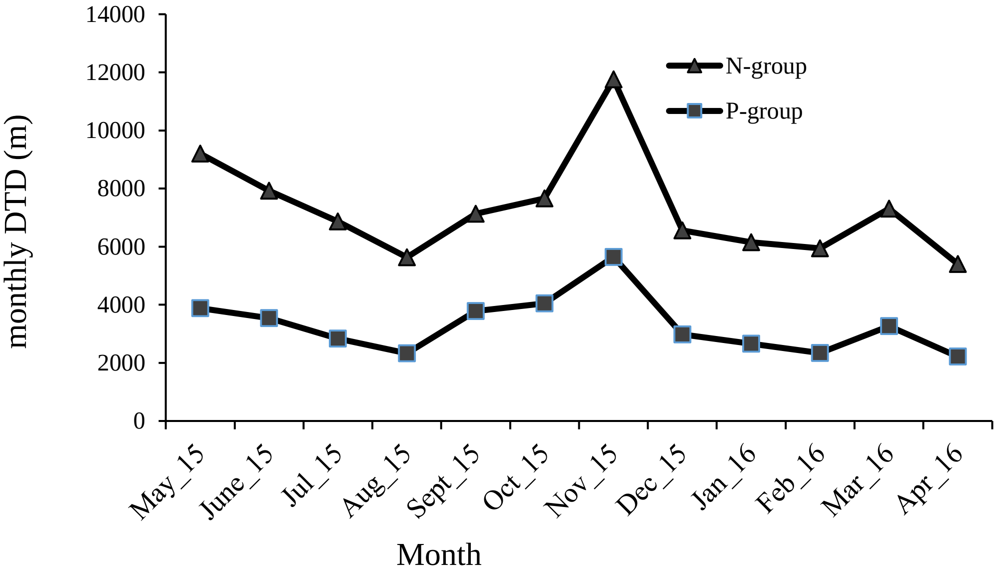

Figure 22. Monthly variation in the DTD between the two groups.

Although, the group size in N group was lower (6 members) than the P group (7 members), guerezas had significantly higher movement rate (MVR) in the natural forest habitat (Mean =76.3 ± 5.2 m/hr) than in plantation forest (Mean =62 ±5.2 m/hr) (Mann Whitney U test; Z=2.02, P<0.05). Overall, the monthly MVR ranged from 42.4 to 115.7 m/h between groups (Table 13). There was a statistically significant difference in MVR across months in both plantation forest group (t=11.96, df=11, P<001) and in natural forest group (t=14.6, df=11, P<001), where the highest and lowest MVR were recorded in November and April, respectively, in both groups.

Table 13. Group size, annual and monthly mean (± SE) and range values of daily travel distance (DTD) and monthly mean (± SE) movement rates (MVR) for the two study groups.

Group	Study period	Group size	Months (Days)	Monthly mean ± SE DTD (m)	Range of DTD	Monthly Mean ± SE MVR(m/hr)	Range of MVR
P	May_2015 -Apr_2016	7	12 (60)	658.5 ± 36.4	110.7-1743.9	62±5.2	42.4-105.1
N	May_2015 -Apr_2016	6	12 (60)	800.5 ±39.9	331.3-1733.2	76.3±5.2	59.9-115.7

When data from the two groups were pooled, there was no relationship between young leaves availability and DTD (regression, F = 0.09, p = 0.769; R = -0.095, R^2 = 0.009, R2 adj. = -0.09), mature leaves availability and DTD (regression, F = 0.43, p = 0.52; R = 0.204, R^2 = 0.042, R2 adj. = -0.054). Similarly, there was no relationship observed between food availability and DTD for both groups.

Based on 95% fixed Kernel Density estimate (KDE), the home range size of plantation forest group was smaller (2.98 ha) than the natural forest group (5.40 ha) (Table 14; Fig. 23). However, the difference was not statistically significant (Mann Whitney U test, p>0.05). Moreover, there was no extensive home range overlap despite the groups occupying adjacent habitats. Home range areas of plantation group and natural forest group in WWNSF overlapped, accounting 0.57 ha according to KDE. Based on 95% KDE, group P shared 19.1% of its home range with group N while group N shared 10.6% of its home range with group P (Fig. 23; Table 15).

Table 14. Comparison of annual home range size (ha) estimated by MCP (100%, 95% and 90%) and 95% fixed kernel analysis, and core area size estimated as 50% fixed kernel analysis for the two groups.

			Annual home range (ha)				Core area (ha)
Group	No. of days	No. GPS pts	100% MCP	95% MCP	90% MCP	95% KDE	50% KDE
Plantation forest (P)	60	2539	11.32	3.92	3.00	2.98	0.18
Natural forest (N)	60	2666	9.48	6.29	4.87	5.40	0.67

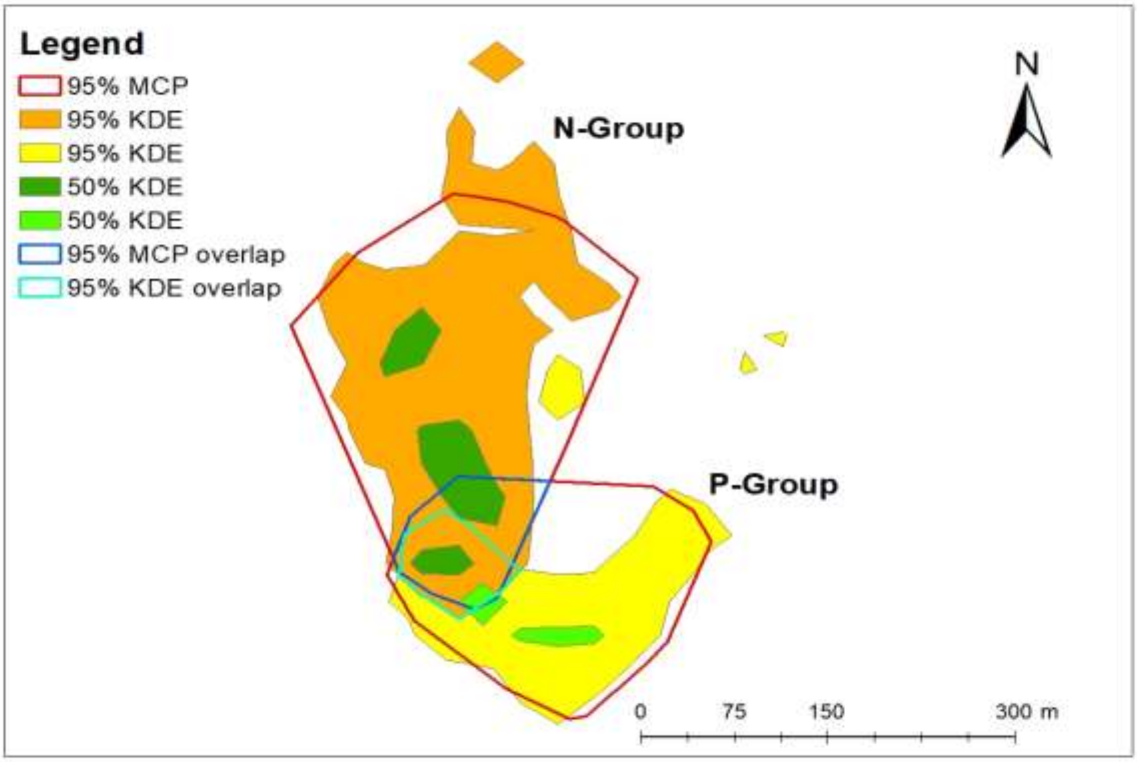

Figure 23. Annual home ranges (ha) and core areas (ha) of Omo River guereza groups in plantation and natural forests [red open line (95% MCP), orange (95 % KDE of group N), yellow (95 % KDE of group P), dark green (50% KDE core area of group N), light green (50% KDE core area of group P), dark blue open line (50% MCP overlap between group P and N), and light blue open line (95% % KDE overlap between group P and N)].

Table 15. Home range area overlap comparison between group P and N, based on areas calculated using 95% MCP method and 95% KDE method.

Group	Home range size (ha) 95% MCP	Home range overlap (ha) 95% MCP	% of range shared 95% MCP	Home range size (ha) 95% KDE	Home range overlap (ha) 95% KDE	% of range shared 95% KDE
Plantation forest	3.92	0.96	24.4	2.98	0.57	19.10
Natural forest	6.29	0.96	15.2	5.40	0.57	10.60

6. DISCUSSION

6.1. Habitat description and resource availability

Plants that had DBH ≥ 10 cm occurred in greater stem density (780 stems/ha) in the range of natural forest group (N) than in plantation group's (P) range (600 stems/ha). Moreover, large tree species like *Allophylus abyssinicus, Pittosporium viridiflorum, Galineira saxifrage* and *Myrica salicifolia* were very common in the ranges of N group but did not occur in the ranges of P group. This is in line with the report of Gebremicael Fisaha *et al.* (2013) that stated that there is a declining trend of the basal area of big trees from 100.3 m^2/ha in 1993 to 64.32 m^2/ha in 2013. This is possibly due to selective cutting of large-sized plant species for timber by illegal loggers and for other construction purposes resulting in the domination of the forest by small sized trees/shrubs in plantation forest as this habitat is close to villages. According to their findings, large-sized trees which are in turn food resources for guerezas are facing high deforestation, and the forest is dominated by shrubs and small trees, which will have effect on the sustainability of the forest.

The Shannon-Wiener species diversity of plant species in the plantation and natural forest guereza groups home range was found to be 1.60 and 2.34, respectively. This indicated that the availability of diversified resource plant species in the home range of natural forest guereza group is more than that of the plantation one. Conversely, the value of Simpson's dominance index was higher for plantation forest (0.29) than that of natural forest (0.12) proving the lower biodiversity hence the value inversely related to evenness and richness. This finding is contrary to those reported by Addisu Mekonnen *et al.* (2018) for Bale monkey where dietary plant species are more diversified in fragments than in continuous forest habitats. The possible reason for these differences might be due to guerezas dependency on taller large tree species rather than fast growing pioneer species like fast growing graminoids and forbs.

Important value index (IVI) is useful to compare the ecological significance of species (Lamprecht, 1989). Shibru and Balcha (2004) stated that species with the greatest importance value are the leading dominant species of specified vegetation. Priority for conservation of plant species must be given based on their IVI values (first priority for species with highest IVI value and the last priority of conservation for species with least IVI values). In the current study area, plant species like *Maesa lanceolata, Juniperus procera, Podocarpus falcatus* and *Cupresus lusitanica* in plantation group's home range; and *Olinia rochitiana, Erica arborea, Allophylus abyssinicus, Juniperus procera* and *Maesa lanceolata* had highest IVI values and require immediate conservation and protection programme.

6.2. Phenology

Although guerezas were adapted to folivore feeding (Bocian, 1997), the feeding time on young leaves is affected by the abundance level of this food item on the tree species. The progressive changes in resource abundance and availability have fundamental effects on the behaviour and ecology of primates (Dunbar, 1988). In the present study, food abundance was significantly higher in the natural forest habitat than in the plantation forest. This might possibly be due to the intensive human encroachment and habitat degradation in the plantation forest habitat that affects plant species richness, diversity and structure in the plantation forest. This ultimately reduces the availability of food resources for many primate species (Boyle *et al.*, 2012). Guerezas spent more time feeding on plant species like *Maesa lanceolata*, *Vernonia leopoldi* and *Ilex mites, Podocarpus falcatus, Disopodium penninervium* and *Pittosporum viridiflorum.* However, when the abundance of these species is reduced, they feed on low ranked food plant species like *Juniperus procera* and *Allophylus abyssinica* which can be considered as fallback foods (Marshall *et al.*, 2009).

6.3. Population estimate

The average encounter rate of Omo River guereza groups/km obtained deviate from the report of Fashing and Cords (2000) (1.2 ± SD 0.52) in the Kakamega Forest, Kenya. The mean number of Omo River guereza individuals counted per group was 6.8. This figure is higher than reported by Fentahun Shumet and Mesele Yihune (2017) in Finote Selam Forest, Ethiopia, where the maximum group size was 9 ±SD 1.2 and comparable with Hussein Ibrahim *et al.* (2017) number of 4 to 13 individuals/group in Borena-Sayint National Park, Ethiopia.

Based on sample group count, the average group density of the species was found to be 16.05 groups/km^2. This finding is comparable with Von Hippel *et al.* (2000) who reported a density of 14.6 groups/km^2 in the Kakamega Forest; though higher than that of Fashing and Cords (2000) finding (11.5 ± SD 1.9) at the same study site. The average individual density extrapolated from the calculated density was 106.05 individuals/km^2 which is in accordance with Hussein Ibrahim *et al.* (2017) who obtained 114.2 individuals/km^2. This figure of population estimate of Omo River guereza is 202.85 ± SE 54.06 individuals/km^2 when perpendicular distance was used from the transect to the first animal seen.

The finding of this study revealed that high mean encounter rate (1.96 groups/km^2), mean group density (19.72 group/ km^2) and lower group size (6.3 individuals/group) were found in the UDNF habitat. The highest encounter rate (3.1 groups/km) was recorded in the UDNF which is comparable with the finding of Nowak and Lee (2013) (3 groups/km) in the least human-disturbed area in Vundwe Island, Zanzibar. The lower group size of guerezas in the UDNF may be associated with visibility problem due to denser canopy cover. Moreover, there was no record of guerezas in the *Erica* bushland habitat as reported by Hussein Ibrahim *et al.* (2017). The lower abundance of guerezas in DNF habitat compared to UDNF is related to the overwhelming anthropogenic activity and canopy degradation in DNF (Rovero *et al.*, 2012). Undeniably, the effect of several disturbance variables (such as fuel wood collection, charcoaling, timbering, livestock grazing) on the species in DNF appears to devastate the vegetation structure and floristic composition of the forest. Though not supported by data, the high proportions of trees with lower canopy density and higher climbers in the DNF habitat is an indication of disturbance as high density canopy trees and rare climbers dominate the UDNF (Rovero *et al.*, 2006).

6.4. Sex and age group composition

The number of juvenile and infant individuals counted during the census period did not vary in guereza population in the study area. This indicates that reproduction takes place at all times of the year and no seasonality in their reproductive behaviour (Jensz and Finley, 2011). Although, guerezas give birth to white fur infant throughout the year, the elusive and secretive behaviour of adult females made the observation of infants very difficult though not impossible. When sex values are treated independently, females constituted of 52% and males 48%. This finding deviates from that of Fentahun Shumet and Mesele Yihune (2017) who stated that females constituted 73% and males accounted 10.8% while juveniles covered the remaining percentage. The plausible reason for the deviation may be the age and sex categories used in the study or the habitat variation in the two areas such as disturbance levels, food availability and quality. Indeed, results suggest a high potential for population expansion as the sex ratio is skewed more towards females.

Knowledge of sex ratio and age distribution of individual mammals is crucial for the evaluation of the viability of the species, because these variables reflect the structure and dynamics of the population (Wilson *et al.*, 1996). The protection and eventual survival of an animal species can be successful only when its population dynamics are well understood and its economic and other values are recognized. For instance, sex and age structure of a population at any given time manifests the status of the population whether it is stable, increasing or decreasing.

6.5. Habitat use

Though the difference was not significant, the mean rate at which guerezas encountered per km walked was higher in the UDNF habitat than other habitat types. Moreover, both group density and population density of guerezas was higher in the UDNF than in DNF habitats. This finding is contrary to the notion that guerezas flourish better in the disturbed (logged) habitats than undisturbed (unlogged) ones (Fashing and Cords, 2000; Lwanga, 2006; Fashing, 2007; Mammides *et al.*, 2009). However, this finding supports Von Hippel *et al.* (2000) statement that guereza population in the Kakamega Forest, strikingly declined in density over a six-year period during which the forest was degraded by human activity. Moreover, this study is in line with Anderson *et al.* (2007) who reported that disturbances such as the density of tree removal, paths, roads, snares, charcoal producing activities and proximity of human settlement jointly or in particular cause reduced patch size and increased resource competition leading to changes in colobus abundance.

The high densities of guerezas in disturbed habitats may possibly be attributed to habitat compression rather than intrinsic growth as stated by Nowak and Lee (2013). Struhsaker (2005) also reviewed that habitat loss, degradation and fragmentation are obvious threats to red colobus monkeys combined with hunting for meat by humans throughout their range with some intrinsic biotic factors. The number of individuals seen in an area correlates to the availability of resources in the area (Delany and Happold, 1976). This depends on what the habitat provides in terms of food, breeding site and protection (cover) from predation and overheating. Any fluctuation observed in the number of individuals between the habitat types is, therefore, an indicative of habitat association change in level of use. Such patterns are greatly influenced by the quality and quantity of various resources in any habitat.

Altitudinally, guerezas were more abundant in the Dry Evergreen Afromontane Forest ecosystem (the Montane forest belt) along the range 2510-3100 m asl where major food components like *Olea europaea subsp. cuspidata, Juniperus procera*, *Vernonia leopoldi, Podocarpus falcatus, Allophylus abyssinicus, Haleria lucida, Maesa lanceolate, Ilex mites, Disopodium penninervium* and *Olinia rochetiana* are abundant. Accordingly, they avoid the higher Afroalpine habitat possibly due to lack of suitable food resources and restricted plant growth like *Kniphofia foliosa*, Clumps of *Helichrysum* spp. and *Festuca* where extreme cold climatic conditions occur demanding more energy expenditure for the animals.

6.6. Activity pattern

Both P and N groups of Omo River guerezas spent most of their time resting followed by feeding. The activity budgets resulting from group scans generally are comparable with those of guerezas and other species of the black and white colobus monkeys studied at other sites of Ethiopia and other African countries (Bocian, 1997; Teichroeb *et al.*, 2003; Wong and Sicotte, 2007; Wijtten *et al.*, 2012; Fentahun Shumet and Mesele Yihune, 2017). However, there are extreme values of time spent on resting that range from 32% (Fashing *et al.*, 2007b) to 76.4 % (Fentahun Shumet and Mesele Yihune, 2017) and feeding range 12%-42%. Omo River guereza group in the natural forest habitat spent significantly more time moving and less time playing and aggression than the group in plantation forest. However, there were no statistically significant differences in resting, feeding, grooming and other activities between groups in the plantation and natural forest habitat types.

More time spent resting may possibly reflect the overall moderate density of food resource and sleeping trees in the habitat, as the encounter rate with potential resource trees may be higher than in highly degraded habitat. Additionally, more time for resting than feeding and less time for moving may be associated with the energy conservation strategy of colobus monkeys (Oates, 1977; Milton, 1998; Fashing, 2001; Wijtten *et al.*, 2012). The daily resting pattern of Omo River guereza which decreased from its highest peak in the morning to the very low peak in the late afternoon at which feeding pattern oscillates inversely may also be a mechanism of energy conservation (Appendix II). These energy management strategies vary based on the habitat type inhabited, time of the day, month or season and even sex. Oates (1977) stated that energy conservation strategies like sunbathing or hunching in cool weather while resting is possibly a way to cope with energetic demands.

Although males devoted more time for feeding and aggression than females, females and males devoted nearly similar amounts of time to moving, other activities and playing. Wijtten *et al.* (2012) also reported the same finding that females devoted significantly more of their daily time than males for resting and grooming in the coastal forest patch of southeastern Kenya on black and white colobus monkeys (C*olobus angolensis palliates).*

6.7. Feeding Ecology

The total number of dietary plant species identified as food for guerezas in WWNSF were 31, belonging to 31 genera and 26 families. Omo River guerezas exhibit remarkable dietary diversity. A comparable figure was reported by Bocian (1997) (Ituri

Forest, DRC), Fashing (2001b) (Kakamega Forest), Hussein Ibrahim *et al.* (2017) Jansson (2011) (Diani Forest, Kenyea) and Oates (Kibale Forest). However, Fashing (2001b) stated low diversity value relative to most other colobine species even in species-rich rain forest habitat (Appendix III). Conversely, Harris *et al.* (2010) revealed that *Colobus guereza* increases not only its dietary diversity but also the percentage of time spent on feeding when its major food trees are scarce. Fashing *et al.* (2007a) reported that other food items than the preferred ones might be selected in times of food scarcity. This high level of dietary diversity is an asset for colobines coping with forest fragmentation and food scarcity which otherwise would make guerezas and other colobines highly vulnerable.

Primates may select certain foods based on accessibility, economic exploitation, availability throughout the year, nutritional content, or simply preference. It is likely that guerezas WWNSF selected certain species based on a combination of these factors. The present study revealed that the highest percentage of food sources for guerezas were trees, shrubs and lianas in respective order. Although leaves comprised the major diet composition in both plantation and natural forest groups, young leaves of different species of plants accounted the highest proportions in this study. This is in line with the finding of Mohammed Hussen and Dessalegn Ejigu (2017) for the sister subspecies (*C. g. gallarum*). Oates and Davies (1994) also stated that guerezas fed mainly on young leaves of different plant species to maximize their physiological demand and minimize toxicity from mature leaves whereby they rarely include more than 30% mature leaves in their diet unless they are of good quality.

The Shannon Wiener diversity index (H’) calculation revealed that the dietary diversity was low in the study area for both guereza groups. The P and N groups combined mean monthly H’ (1.92) was in accordance with other studies conducted on the different species of the black and white colobus monkeys in various localities such as 1.90 for *Colobus guereza* at Ituri (Bocian, 1997), 1.83 for *Colobus angolensis* at Ituri (Bocian, 1997) and 1.61 for T-group and 1.73 for O group at Kakamega forest (Fashing, 2001b). Moreover, The mean of the 12 month food species evenness index (J) is lower than what has been reported from Kakamega forest (J=0.71 for T-group) guereza and (J= 0.72 for O-group) for *Colobus guereza* (Fashing, 2001b). This might possible be due to the impact of deforestation in the current study area leading to decline some food tree species and domination by others.

6.8. Ranging Ecology

In the present study, the natural forest group made significantly longer daily travel distance (DTD) compared to plantation forest group. This might be due to the small core area size available in the plantation group which is a bottleneck between the natural forest group and human settlement that forced them to have shorter DTD. However, the highly folivorous Omo River guerezas did not increase their daily travel distance (DTD), percentage of time to moving, or their travel rate during periods of lower food availability though these variables are expected to force guerezas to visit additional food sources each day. Accordingly, there is no indication that guerezas devoted additional effort to finding additional food sources by ranging further or travelling more (Mean=729.5, n=2) when the food sources are less abundant, as reported by Di Fiore (2003) for woolly monkeys, Fashing (2001) for guerezas, and Clutton-Brock and Harvey (1977) for other primates (Appendix IV). Instead, they switched their feeding preferences to a more available food item and reduced the time spent moving. This may be due to the daily amount of protein ingested by primates which is maintained remarkably stable despite significant variation in food composition and comparatively lower daily protein gain (Felton *et al.*, 2008a). Moreover, the stability in DTD may be associated with balance between the energetic benefits of obtaining food and the energetic costs of moving longer to obtain the food (Isbell, 1991).

Despite the variations in home range size according to differences in food abundance and quality across sites, daily ranging may be physiologically constrained in primates due to their high consumption of low energy food, such as mature leaves as reported by Milton (1980) for Howler monkeys. In this study, home range size ranged from 2.98 ha (P group) to 5.4 ha (N group). These findings were remarkably smaller than what has been reported by Oates (1977) (32 ha, Kibale), Bocian (1997) (100 ha, Ituri) and Fashing (2001a) (18 ha, Kakamega) (Appendix IV). The difference might be attributed to the fact that home range size has inverse relationship with guereza population density as stated by Fashing (2001a). Contrary to guerezas at Kakamega (77%) and in accordance with these in Ituri (22%), guerezas at WWNSF had remarkably lower home range overlap (19.1% of P group and 10.6% of N group) (Bocian, 1997; Fashing, 2001a). Extensive home range overlap is the norm for guerezas at large forest blocks, though it was not supported by data (von Hippel, 1996). The possible reason for lower home range overlap in this study may be contest competition.

7. CONCLUSION and RECOMMENDATIONS

7.1. Conclusion

The present study offers valuable information on different aspects of the ecology of Omo River guereza viz. population estimate, habitat use, feeding ecology and activity and ranging patterns in WWNSF which serve as spark plug to ignite conservation demands to concerned bodies for correlating the management of the forest directly with the wildlife dwelling within. Both group density and individual density of guerezas are higher in the undisturbed natural forest habitat than other habitat types though the difference was not significant. The population is dominated by more adult individuals compared to sub-adults and young ones for both sexes in the study area. This observation of low percentage of young and sub-adult is manifested either by high level of young mortality or low female reproductive performance. According to personal communication with local elders, there is a population decline trend in the area due to high level of habitat degradation, human disturbance, livestock grazing, human settlement and agricultural expansion. Therefore, as primate species, to which guerezas belong, continue to decline across the globe, it becomes increasingly essential that primatologists try to look at mechanisms to save these primates. Guerezas spent much of their activity time budget resting followed by feeding and moving with lower time budget for socializing and other activities. Adults spent more time in resting and less time feeding than sub-adults and juveniles subsequently. High time budget for feeding in juveniles may be interlinked with the high physiological demand for growth. Guerezas did not increase their daily travel distance (DTD), percentage of time to moving, or their travel rate during periods of lower food availability. This may be associated with their digestive anatomy and folivorous diet that enable them to switch their feeding preferences to a more available food item and reduce the time spent moving which otherwise energy demanding.

7.2. Recommendations

- ☞ As census during few years cannot track the course of a population trend, whether the numbers are increasing, decreasing, or stable, continuous long-term studies using the same method should be carried out in subsequent years to determine the population trajectory of guereza in the area.
- ☞ Further study needs to be conducted to examine the impact of anthropogenic forest disturbances on the reproduction performance and behaviour of guerezas.
- ☞ Study on the gastrointestinal parasite infections should also be investigated to identify and quantify load of these parasites as they can influence host survival, fecundity, behaviour and the overall sustainability of wildlife populations.
- ☞ The nutritional content of food plant species should also be investigated to give special conservation emphasis to highly nutritious preferred dietary plants species.
- ☞ To ensure the efficient management of the indigenous forests and sustainable utilization of resource through generations, legislation should be enforced.
- ☞ Increased law enforcement measures, particularly forest patrols that will help decrease in utilization of timber, and all other illegal activities should be applied by enhancing the scout competency and increasing their effectiveness significantly through training and personal patrol equipment (modern arms, binoculars) and other incentives.
- ☞ Raise awareness of local communities about forest conservation values and the importance of preserving the wildlife within, and engage them in monitoring and patrolling initiatives to feel ownership.

- ☞ Serious involvement of stakeholders like the Amhara Forest Enterprise through community-based conservation activities should be practiced in the WWNSF for the long-term survival of the forest and the wildlife within.
- ☞ Upgrade the forest to a level of income generating institution so that the wildlife revenues from tourism industry can be distributed for basic infrastructure development such as electricity, road, water, health centre and school construction for the local development. These can change the attitude of the local community positively.
- ☞ Unless these management recommendations are implemented, the survival of the forest and the Omo River guereza along with other wildlife could be at risk.

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Appendices

Appendix I. List of mammal species recorded from WWNF during the study period

NO.	Common Name	Family Name	Scientific Name	Local Name
1	Menelik's bushbuck	Bovidae	*Tragelaphus scriptus Meniliki*	YeMenilik Duculla
2	Common Jackal	Canidae	*Canis aureus*	Tekula
3	Guereza	Colobidae	*Colobus guereza*	Guereza
4	Crested Porcupine	Hystricidae	*Hystrix cristata*	Jart
5	Klipspringer	Bovidae	*Oreotragus Oreotragus*	Ses
6	Gelada Baboon	Cercopithecidae	*Theropithecus gelada*	Tikurie Zinjero
7	Rock Hyrax	Hyracoidae	*Procavia Capensis*	Shikoko
8	BushbHrax	Hyracoidae	*Hetrohyrax brucei*	Shikoko
9	Starck's Hare	Leporidae	*Lepus starckii*	Tinchel
10	Common Duiker	Bovidae	*Sylvicapra grimmia*	Midakua
11	Abyssinian Genet	Herpestidae	*Genetta abyssinica*	Shelemetemat
12	White tailed mongoose	Herpestidae	*Ichnumia albicauda*	Faro
13	Haney Badger	Mustelidae	*Mellivora capensis*	Kefo Defi
14	Zorilla/	Mustelidae	*Ictonix striatus*	Fadet
15	Girvet Monkey	Cercopithecidae	*Cercopithecus aethiops*	Tota
16	Spotted Hyaena	Hyaenidae	*Crocuta crocuta*	Zigurgur Jib
17	Caracal	Felidae	*Felis caracal*	Delg ambesa
18	Serval	Felidae	*Felis serval*	Aner
19	Leopard	Felidae	*Panthera pardus*	Nebr
20	Common Jackal	Canidae	*Canis aureus*	Tera Kebero
	Small mammals			
21	Ethiopian White-footed Mouse	Muridae	*Myomys albipes*	Ayit
22	white-tailed Rat	white-tailed Rat	*Stenocephalemys albicuadata*	Ayit
23	Dega rat /Harrington's scrub rat	Muridae	*Pelomys harringtoni*	Ayit
24	harsh-(brush)-furred mouse	Muridae	*Lophuromys flavopunctatus*	Ayit
25	groove-toothed (swamp) rat	Otomyinae	*Otomys typus*	Ayit
26	natal multimammate mouse	Muridae	*Mastomys natalensis*	Ayit
27	gray-tailed rat	Muridae	*Stenocephalemys griseicauda*	Ayit

Appendix II. Comparison of activity time budget (%) of black and white colobus monkey groups with other studies in Africa. GS =group size; R = resting; F =feeding; MV =moving; SO =social; O = others.

Study species and Sites	Sources	GS	R	F	MV	SO	O
C. guereza Kibale Forest, Uganda	Oates (1977)	9	57	20	5	11	7
C. guereza Ituri Forest, DRC	Bocian (1997)	8-10	44	26	24	5	1
C. angolensis Ituri Forest, DRC	Bocian (1997)	19–20	52	19	22	5	
Colobus polykomos Tiwai, Sierra Leone	(Dasilva, 1992)	9–11	55	31	12	2	-
C. guereza Kakamega Forest, Kenya	Fashing (2001a)	10-13	63	28	2	7	-
		5-8	64	23	3	10	-
Colobus guereza Rau Forest, Tanzania	Eustace *et al.* (2015)	8-12	58	28	10	4	-
C. vellerosus Boabeng-Fiema, Ghana	Teichroeb *et al.* (2003)	7-33	59.1	23.7	14.6	2.6	
C. angolensis Nyungwe Forest, Rwanda	Fashing *et al.* (2007b)	>300	32	42	20	5	1
C. vellerosus Boabeng-Fiema, Ghana	Wong and Sicotte (2007)	8-30	68.6	22	6.8	2.6	
C. angolensis Shimoni, Kenya	Wijtten *et al.* (2012)	5.6	64	22	3	4	7
C. g. guereza Finote Selam Forest,West Gojjam, Ethiopia	Fentahun Shumet and Mesele Yihune (2017)	focal	76.4	12	9.1	2.6	
C. g. gallarum Gidabo forest, Ethiopia	Mohammed Hussen and Dessalegn Ejigu (2017)	-	55.77	22.64	-	-	
C. guereza **(P)** WWNSF, Ethiopia	This study	7	41.3	33.1	11.5	8.6	5.3
C. guereza **(N)** WWNSF, Ethiopia	This study	6	44.9	30.4	14.3	6.1	4.3

Note: Social includes aggression, grooming and play in this study

Appendix III. Summary of guereza diet from long-term colobine field studies. YL = young leaves; ML = mature leaves; UL = unclassified leaves; TotL= total leaves; FR = fruit; FL = flowers; # spp. = number of species in diet.

		Food items								
Study species and Site	Sources	YL	ML	UL	**TotL**	FR	FL	SH	ST	#spp
C. guereza Kibale Forest, Uganda	Oates (1977)	57.7	12.4	2.5	72.6	13.6	2.1	-		43
C. guereza Ituri Forest, DRC	Bocian (1997)	26.2	3.8	24.2	54.2	24.6	2.9	-	-	31
C. angolensis Ituri Forest, DRC	Bocian (1997)	23.5	2.4	22	47.9	5.4	7.2	-	-	37
Colobus polykomos Tiwai, Sierra Leone	Dasilva (1994)	29.7	26.4	-	56.1	34.6	1.7	-	-	56
C. guereza Kakamega Forest, Kenya	Fashing (2001a)	20.4	6.6	22.5	49.5	38.6	0.5	-	-	28+
C. angolensis Diani Forest, Kenyea	Jansson (2011)	21.1	35.4	4.1	60.6	9.5	27.6	-	-	42
C. g. guereza Finote Selam Forest,West Gojjam, Ethiopia	Fentahun Shumet and Mesele Yihune (2017)	78.3	-	-	78.3	12.8	-	-	-	11
C. guereza BSNP, Ethiopia	Hussein Ibrahim *et al.* (2017)	44.1	27.5	-		18.4	2.9	1.8	-	31
C. g. gallarum Gidabo forest, Ethiopia	Mohammed Hussen and Dessalegn Ejigu (2017)	52.4	26.9	-	79.3	8-9	6-8	-	-	15
***C. guereza* (P)** WWNSF, Ethiopia	This study	57.7	22	-	79.7	16.1		1.2	2.9	18
***C. guereza* (N)** WWNSF, Ethiopia	This study	55.1	31.2	-	86.3	5.5		6.1	2.1	30

Appendix IV. Comparison of ranging data of black and white colobus monkey groups with other studies in Africa. DTD =Daily travel distance; MVR= Movement rate

Study species	Mean DTD (m)	Range of DTD	MVR (m/hr)	Home range area (ha)	Study site, country	Sources
C. guereza	535	288-1004	45	32	Kibale Forest, Uganda	Oates (1977)
C. guereza	609	268-112	51	100	Ituri Forest, D. R. Congo	Bocian (1997)
C. angolensis	983	312-1914	82	371	Ituri Forest, DRC	Bocian (1997)
Colobus polykomos	832	350-1410	69	24	Tiwai, Sierra Leone	(Dasilva, 1992)
C. guereza	588	166-1360	49	18	Kakamega Forest, Kenya	Fashing (2001a)
C. angolensis	-	-	141	2440	Nyungwe Forest, Rwanda	Fashing *et al.* (2007b)
C. vellerosus	321.4	256.9-408.4	-	9.96	Boabeng-Fiema, Ghana	Wong and Sicotte (2007)
Colobus angolensis	-	-	-	4.6	Diani Beach, Kenya	André (2011)
C. guereza (P)	658.5	110.7-1743.9	62	3.92	WWNSF, Ethiopia	This study
C. guereza (N)	800.5	331.3-1733.2	76.3	6.29	WWNSF, Ethiopia	This study

Note: Social includes aggression, grooming and play in this study