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Effect of Anthropogenic Habitat Modification on Behavioural Ecology of Boutourlini's Blue Monkey (*Cercopithecus mitis boutourlinii* Giglioli, 1887) in Hamuma Coffee Forest, Southwestern Ethiopia

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Addis Ababa, Ethiopia

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By**: Meseret Chane Alemu**

A Thesis Submitted to the School of Graduate Studies of the Addis Ababa University, Department of Zoological Sciences, in Partial Fulfillment of the Requirements for the Degree of Doctor of Philosophy in Biology (Ecological and Systematic Zoology)

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I hereby declare that this thesis, entitled: "*Effect of Anthropogenic Habitat Modification on Behavioural Ecology of Boutourlini's Blue Monkey (Cercopithecus mitis boutourlinii Giglioli, 1887) in Hamuma Coffee Forest, Southwestern Ethiopia"* has been composed entirely by myself and has not been submitted for any other degree or qualification. The work complies with the regulations of the University and meets the accepted standards with respect to originality and quality and all sources of information have been specifically acknowledged.

Meseret Chane: Signature ___________________ Date _____________________

ABSTRACT

Effect of Anthropogenic Habitat Modification on Behavioural Ecology of Boutourlini's Blue Monkey (*Cercopithecus mitis boutourlinii* Giglioli, 1887) in Hamuma Coffee Forest, Southwestern Ethiopia

Meseret Chane Alemu. Addis Ababa University, 2020

Boutourlini's blue monkey (Cercopithecus mitis boutourlinii) is a subspecies of Cercopithecus mitis, endemic to southwestern tropical forest of Ethiopia. The subspecies is highly threatened by destruction of forest habitat for agricultural land and categorized as "Vulnerable" taxon. Understanding the effect of anthropogenic habitat destruction on behavioural ecology of this little known subspecies is crucial to design conservation and management plans. Therefore, the aim of this study was to examine the ecological and behavioural flexibility of Boutourlini's blue monkeys in response to anthropogenic habitat modification by comparing two habituated groups occupying two habitats at different levels of disturbance in Hamuma Coffee Forest. Vegetation surveys were carried out in the home ranges of each group to quantify the overall vegetation composition. A total of 40 10 × 50 m^2*quadrats along 8 randomly selected transect with 400–600 m long and 10 m wide were used and sampled for the diversity of big trees (DBH ≥ 10 cm) and small trees (≥2 m tall and <10 cm DBH). Phenological data were analyzed from 15 plant species: 11 trees, two shrubs and two climbers. The activity time budget, feeding ecology, ranging, habitat use and positional behaviour were studied in both groups for five minutes with 15 minutes interval scan sampling for 15 months study period. Species name and required characters of domicile trees selected by both groups were recorded for 12 months. Plant species with DBH ≥ 10 cm in the range of Natural coffee forest group (NCF-group) had higher stem density (443 stems/ha) than in Coffee plantation group (CP-group) (334 stems/ha). Plant species diversity was significantly greater in NCF (H'=2.82) than CP (H'= 2.47) (t = 4.57, df = 714.93,* $P < 0.001$*). Young leaves were the most abundant plant parts throughout the year and did not show significant difference in the home ranges of both groups (*$P > 0.05$*). Ripen fruit availability indices (RFAI) was significantly higher in NCF-group than CP-group across months (Wilcoxon S.R. W=107, P=0.045). The overall mean percentage time spent resting, feeding, moving, socializing, and other activities between two groups were not significantly different (ANOVA: df =1, F = 0.34,* $P > 0.05$*). Boutourlini's blue monkeys were observed feeding on 37 plant species belonging to 27 families. Mean proportion of feeding on young leaves and ripen fruits was significantly higher than, matured leaves, flowers and buds (*$P < 0.05$*) in both groups. The top 10 species comprised over 70% of the overall diet of Boutourlini's blue monkeys. Daily path length and movement rates did not show significant variation between the two groups. A 50% Kernel density estimate (KDE) was the core area utilized more frequently by the groups and a bit smaller in NCF-group (7.22 ha) than in CP-group (12.52 ha). Slight differences were seen in their positional behavioural repertoire, while domicile tree selection showed more profound differences between the two groups. Compared to other microhabitats, both groups spent more time in tree dominant forest more than expected. The results demonstrate that Boutourlini's blue monkey showed a tendency in ecological and behavioural flexibility in response to anthropogenic habitat modification. However, further and repeated studies are required to determine the threshold of habitat destruction that Boutourlini's blue monkey can cope with.*

Keywords*:* Anthropogenic disturbance, behavioural flexibility, Boutourlini's blue monkey, diet, Hamuma coffee forest, ranging, positioning

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ACRONYMS

ENMSA	Ethiopia National Metrological Service Agency
EWCA	Ethiopian Wildlife Conservation Authority
IUCN	International Union for Conservation of Nature
GME	Geospatial Modeling Environment
HRT	Home Range Tools
KDE	Kernel Density Estimate
MCP	Minimum Convex Polygon
ORFWE	Oromia Region Forest and Wildlife Enterprise

1. INTRODUCTION

1.1. Background of the study

Primates are an order of mammals that have distinctive features such as a clavicle, grasping hands, nails and stereoscopic vision. Extant primate species are found almost exclusively in one of the following four tropical regions: Neotropics (Central and South America), Africa, Madagascar, and southern and eastern Asia (IUCN, 2010). There are about 400 species of primates with a predominantly tropical distribution (Nystrom and Ashmore, 2008). Primates grouped consistently alongside the tree shrews (Scandentia) and colugos (Dermoptera) within the mammalian superorder Archonta (Janecka, 2007). The balance of evidence suggests primates are a monophyletic clade (Poux and Douzery, 2004) though, some studies suggest paraphyly (Arnason, 1998).

According to Butynski *et al.* (2013), primate conservation in Africa is a particular concern, because of a variety of reasons. The first reason is that it harbours at least 93 primate species of which, 21 prosimians, 68 monkeys, and four apes, that represent about 30% of the extant primate species. From the top 15 countries worldwide scoring highest for primate species richness, nine of them are in Africa. These countries are Democratic Republic of Congo (DRC), Cameroon, Nigeria, Peoples Republic of Congo, Equatorial Guinea, and Central African Republic (Cowlishaw and Dunbar, 2000). Second, the forests in Africa have shown high dynamism, experiencing several cycles of contraction and expansion and in many regions most of the forests have existed in fragmented forms (Hamilton and Taylor, 1991).

Most tropical forests are undergoing anthropogenic disturbance (Turner, 1996; Wright, 2005; Hartter *et al.*, 2011), resulting in forest loss, fragmentation, and changes in vegetation structure and composition, adversely affecting forest dwelling animals (Cowlishaw and Dunbar, 2000). Globally, most primate populations are facing an ongoing habitat disturbance (Mittermeier *et al.*, 2006) and the effects are likely to increase as human populations grow. Although disturbance may negatively influence primates through habitat degradation and reduced food availability (Fimbel *et al.*, 2001), it may also in some cases increase food availability by promoting highly productive pioneer plants (Johns, 1988; Johns, 1991) and hence influence their distribution and densities within a given area. Habitat fragmentation leads to disconnection of forest habitats leading to isolation and further destruction of the small fragments over time due to the edge effect (Chapman *et al.*, 2007).

Ethiopia is home for diverse biological resources with 311 species of mammals of which 55 of them are considered endemic (Lavrenchenko and Afework Bekele, 2017) and a variety of other fauna and flora. Among the mammals of Ethiopia, around 13 (4%) are species and subspecies of non-human primates (Kingdon, 1997; Grubb *et al.*, 2003; Groves, 2005; Afework Bekele and Yalden, 2013). These primates are Somali lesser galago (*Galago gallarum*) and Bush baby or Senegal lesser galago (*Galago senegalensis*) (Butynski and de Jong, 2004), two subspecies of blue monkeys (*Cercopithecus mitis stuhlmanni*) (Fairgrieve and Muhumuza, 2003) and *Cercopithecus mitis boutourlinii* (Kingdon, 1997), Bale monkey (*Cercopithecus aethiops djamdjamensis*), DeBrazza's monkey (*Cercopithecus neglectus*), Patas monkey (*Erythrocebus patas*), Sykes' monkey (*Cercopithecus albogularis*), Olive baboon (*Papio anubis*), Hamadryas baboon (*Papio hamadryas hamadryas)*, gelada baboon (*Theropithecus gelada*), black and white colobus monkey (*Colobus guereza*), grivet monkey (*Cercopithecus aethiops aethiops*) and Blackfaced vervet (*Cercopithecus aethiops pygerythrus*) (Grubb *et al.*, 2003; Groves, 2005). Of these, Boutourlini's blue monkey (*Cercopithecus mitis boutourlinii*), the Gelada baboon (*Theropithecus gelada*) and Bale monkey (*Cercopithecus aethiops djamdjamensis*) are endemic (Afework Bekele and Yalden, 2013). The high level of endemicity in the fauna of Ethiopia is related to the large extent of highlands. The variations in temperature and rainfall in different habitats have led to the diversity of species (Yalden, 1983). Although primates are quite well represented in Africa, particularly in forest zones, only 13 species are recorded in Ethiopia. Indeed, the absence of another 10 or more species that occur in nearby forests in Uganda or Sudan is one of the arguments for stating that Ethiopia has poor forest fauna (Afework Bekele and Yalden, 2013).

Leakey (1988) stated that genus *Cercopithecus* appeared in the fossil record about 2.9 mya. They had a semi-terrestrial frugivorous ancestor, inhabiting woodland habitats. However, once they became rainforest specialists, they started to diversify as a result of repeated isolation and divergence of populations as a consequence of the recurring division of continuous forests into fragments associated with glacial or interglacial cycles (Chapman, 1983; Hamilton, 1988). During isolation, populations of *Cercopithecus* species inhabited different fragments. The divergence of other sub-species from an ancestral *Cercopithecus mitis* occurred during one of these isolations (Twinomugisha *et al.*, 2003).

Blue monkeys (*Cercopithecus mitis*) are forest dwelling guenons belonging to the Old World monkeys (Kingdon, 1971; Estes, 1992). There are 17 subspecies of blue monkeys spreading in different habitat types and forests of south, east and central Africa (Wolfheim, 1982). They are among the most widely distributed of African arboreal primate species and inhabit a variety of forest types such as tropical moist forest (Butynski, 1990), tropical montane forest (Kaplin, 2001) and coastal dune forest including forest fragments across much of their range (Lawes, 1991). They are also known as the diademed monkey because they have a prominent row of forward pointing white fur just above the brow line (Rudran, 1978; Foster and Cords, 2005). The face is nearly naked, usually dark in colour (infrequently blue), and has a well-developed musculature. White whiskers are well developed in males (Lawlor, 1979). Males are larger than females. The canines of males are also slightly larger than those of females. They are catarrhine; the nostrils are close together facing downward. They have cheek pouches to store food while foraging (Rudran, 1978).

C. mitis is arboreal, but can occasionally be found foraging on the ground and moving across open areas (Stuart, 1997). It can be found in rain forests and montane bamboo forests in Angola, Burundi, the Democratic Republic of Congo, Ethiopia, Kenya, Malawi, Mozambique, Rwanda, Somalia, South Africa, Sudan, Swaziland, United Republic of Tanzania, Uganda, Zambia and Zimbabwe (IUCN, 2007).

C. mitis lives in matriarchal groups of 20–40 individuals, often with one adult male that can stay up to three years in the group. The female becomes sexually mature at 5–6 years old and the males when they are somewhat older (Rowell, 1984). The mating season is influenced by nutritional availability, which corresponds to the rain seasons (Swart and Lawes, 1996). In the southern range areas, the females give birth during the summer months, while reproduction is seasonal in the equatorial belt (Stuart, 1997).

Hybridizations producing fertile offspring have been observed between *C. mitis* males and females of its smaller relative, the red-tailed monkey (*C. ascanius*), in areas where the two species distributions overlap. The mothers of all known hybrid offspring were of the latter species (Rowell, 1984).

Tashiro (2006) has reported that the species *C. mitis* uses strata at around 20 m above ground for foraging. The species is considered to have a very flexible diet, as shown by various studies (Butynski, 1990; Lawes *et al.*, 1990; Chapman *et al.*, 2002; Twinomugisha *et al.*, 2006). *C. mitis* is mainly a frugivorous but can also eats larger amounts of leaves, flowers and insects depending on the food supply (Cords, 2002; Fairgrieve and Muhumuza, 2003). This flexibility is based on its large hindgut and substantial gut surface area as well as a specialized intestine micro-flora (Twinomugisha *et al.*, 2006).

Large variations in diet between different groups of *C. mitis* have been reported. In Kakamega, Kenya, the monkeys spent 54% of their foraging time on fruit, 16% on leaves and 17% on insects, while for an Ugandan population of the same species in Kibale, the numbers were 33 % for fruits, 24% for leaves and 30% for insects (Chapman *et al.*, 2002). Data from the Kalinzu Forest in Uganda showed that 50% of the species foraging time was spent on insectivory with fruit only second in place (Tashiro, 2006), while data from Kenya showed fruit to be the first choice and insects only to be consumed as a last resort (Cords, 1987a). The limiting feature for frugivorous primates in general is considered to be access of fruit during the lowest seasonal level. This is because fruit often serves as the primary energy source for these populations (Twinomugisha *et al.*, 2006). Record from Komto Protected Forest, Ethiopia showed that dietary composition of the species was dominated by young leaves which accounted for 27.4% of the total diet followed by mature leaves (20.3%), fruits (15.38 %), and flowers (11.24%) (Mosissa Geleta and Afework Bekele, 2016).

The Blue monkey is a generalist feeder and a forest dwelling guenon (IUCN, 2008). They are frugivorous and folivorous in nature, feeding mainly on fruits and leaves. They also consume seeds and arthropods (Cords, 1987a). As an omnivore, blue monkeys mostly feed on fruits, leaves, invertebrates, flowers, seeds, bark and shoots (Estes, 1992).

Blue monkeys as frugivorous primates, are sensitive to the removal of forest as it reduces the availability of food (Cordeiro *et al.*, 2004). Habitat loss due to commercial timber, agriculture and others means of human resource gathering threatens forest specialist primates (Chapman *et al.*, 2006). Remnant forest patches are surrounded by encroachments, overgrazing and agricultural lands. This has caused a number of changes such as reduction of mammal populations, altered diets and foraging behaviours (Mbora and Meikle, 2004). Plant species composition and diversity is low in fragmented and disturbed forests and this in turn affects the availability of food for the species (Wong and Sicotte, 2006). Food supply is an important determinant factor that limits population abundance (Rode *et al.*, 2006; Rovero and Struhsaker, 2007). Loss of food may increase competition between species and it is also a cause for aggressive interactions among animals thereby increasing stress and reduction of reproduction.

Consequently, such habitat loss and fragmented habitats leads to local extinction of species (Mbora and McPeek, 2009). Most primates are forest specialists and thus vulnerable to habitat fragmentation (Chapman *et al.*, 2007). As shown by IUCN (2010), approximately half of the species are threatened with extinction due to habitat destruction and hunting. Most primate species and subspecies are threatened due to habitat loss and degradation in tropical regions (Cowlishaw, 1999; Chapman and Peres, 2001; Kerr and Deguise, 2004).

Natural predators of blue monkeys are also present in the forest. Alarm responses to raptors are common, typically a near daily occurrence. The African crowned eagle (*Stephanoaetus coronatus*) is confirmed as primary predators of *C. mitis*, but they are also threatened by other primate species, leopards and snakes. Human activities impose negative effects on the species by decimating and fragmenting their habitat. In some areas it is also hunted as a vermin for destroying crops and debarking trees in plantations while foraging (Rowell, 1984).

Cercopithecus mitis boutourlinii is a subspecies of *Cercopithecus mitis*, endemic to Ethiopia, and received its name, Boutourlini's blue monkey, from a Russian Count, Augusto Boutourline. He travelled Asia and Africa in the year 1884–1887 and named this subspecies during his visit to Shewa, central Ethiopia, where this subspecies is widely distributed (Watkins and Grayson, 2009). Blue monkeys as a species are widely distributed and not threatened (Lawes, 1990a). However, there are highly localized subspecies, some of which are threatened or endangered (Oates, 1996). Boutourlini's blue monkey is one of them and is restricted to Ethiopia, occurring from Lake Tana southwards along the western side of the Ethiopian Rift Valley, but does not reach Lake Turkana (Yalden *et al.*, 1977; IUCN, 2008). Bailey (1977) recorded Boutourlini's blue monkey at the gorge of the Blue Nile River, near Bichena area. It is strictly associated with primary tropical deciduous and riverine forests (Yalden *et al.*, 1977) . *C. mitis* ssp. *boutourlinii* is categorized as "Vulnerable" (Dereje Tesfaye *et al.*, 2013). According IUCN (2014), its greatest threats are destruction and fragmentation of forest habitat for agricultural land.

To conserve such threatened species, information on the population size, diet selection and foraging behaviour of species are very important (Sutherland, 1998). But only few studies have been conducted on conservation, behaviour and ecology of Boutourlini's blue monkey in Jibat and Komto Protected Forest of Ethiopia (Dereje Tesfaye *et al.*, 2013; Mosissa Geleta and Afework Bekele, 2016). However, information is lacking along the Southwestern Coffee Forest of Ethiopia, on which the species lives sympatrically with other arboreal primates such as DeBrazza's monkey (*Cercopithecus neglectus*), grivet monkey (*Cercopithecus aethiops aethiops*) and colobus monkey (*Colobus guereza*). Therefore, the aim of this study was to examine the effect of habitat modification on behavioural ecology of Boutourlini's blue monkey in Hamuma Coffee Forest, southwestern Ethiopia.

1.2. Rationale of the study

The ability of *C. mitis* to consume a diverse diet may account for its geographic range extending to more southerly latitudes than that of other arboreal guenons. The species has an extensive distribution in evergreen forest of Africa from the southern Sudan to the Eastern Cape Province of South Africa (Wolfheim, 1982).

Blue monkeys as a species are considered to be at low risk of extinction, because of their wide distribution and ecological and behavioural flexibility in response to habitat change. However, there are several blue monkey subspecies with highly localized distributions whose basic biology and conservation requirements remain virtually unknown (Kingdon *et al.*, 2008). For example, Boutourlini's blue monkey (*Cercopithecus mitis boutourlinii*), a subspecies endemic to the western side of the Ethiopian Rift Valley between Lake Tana and Lake Turkana (Yalden *et al.*, 1977; Butynski and Gippoliti, 2008), has little information. Although this subspecies tolerates low quality and disturbed habitat better than most guenons (Lawes *et al.*, 1990; Dereje Tesfaye *et al.*, 2013), it nevertheless occurs in lower densities in these habitats (Chapman *et al.*, 2000). It shows poor local colonizing ability in response to forest fragmentation and seldom occupies small forest patches (Chapman *et al.*, 2000; Lawes *et al.*, 2000). In addition, the conservation status of Boutourlini's blue monkey, as their geographic distribution indicates, dwell outside of the natural reserve areas. Unless continuous survey on its population status, habitat quality, interference of human activities and conservation status are conducted, local extinction is likely to occur due to anthropogenic factors.

Hamuma Coffee Forest is one the forests found in Illu Aba Borra zone of Oromia region, southwestern Ethiopia, in which Boutourlini's blue monkey lives sympatrically with other arboreal primate species. On the other hand, the forest is exploited for coffee seed collection, illegal timber production and agricultural expansion by the local community. In addition, studies on the effect of habitat modification on behavioural ecology of Boutourlini's blue monkey is very limited in such type of coffee forest by which human interference is high. Thus, conducting a study of the effect of anthropogenic changes on behavioural ecology of Boutourlini's blue monkey will contribute to our understanding about the proximal factors involved in determining behaviour, habitat preferences and utilizations. It will also add new information by assessing how flexible it is for habitat modification and will help conservationists to predict future conservation plans in the area.

1.3. Objectives of the study

The general objective of this study was to examine the effect of anthropogenic habitat modification on behavioural ecology of Boutourlini's blue monkey (*Cercopithecus mitis boutourlinii*) in Hamuma Coffee Forest.

The specific objectives of this study were:

- to compare the activity time budget between two groups of Boutourlini's blue monkeys in natural coffee forest and coffee plantation
- to compare the feeding ecology between two groups of Boutourlini's blue monkeys
- to examine the ranging pattern between two groups of Boutourlini's blue monkeys
- to examine the habitat use between two groups Boutourlini's blue monkeys
- to compare the difference on the positional behaviour and strata and substratum use of Boutourlini’s blue monkeys
- to identify the domicile tree selection of Boutourlini's blue monkeys

1.4. Research questions

This study addressed the following research questions;

1. How does anthropogenic habitat modification affect the activity patterns, diet composition, feeding patterns, habitat use, and ranging patterns of Boutourlini's blue monkey in Hamuma Coffee Forest?
2. How does anthropogenic habitat modification affect the locomotor behaviour, postural mode, vertical habitat use, and substrate utilization of Boutourlini's blue monkey in Hamuma Coffee Forest?
3. How does domicile selection differ between the two groups of Boutourlini's blue monkeys?

1.5. Hypothesis of the research

This study tested the following predictions:

H01: The group living in a relatively heavily-modified habitat (Coffee plantation) is expected to consume more alternative food items, shows higher dietary diversity, spends more time feeding and moving, and less time resting and socializing, and possesses greater daily path length and home range size than the groups in minimally-modified habitat (Natural coffee forest).

H02: The group living in a relatively heavily-modified habitat would spend more time quadrupedal locomotion on the ground, spend less time in leaping and climbing and would differ in feeding posture and locomotor behaviour than conspecific in minimally-modified habitat.

H03: There is a domicile tree selection difference between two groups of Boutourlini's blue monkeys with regard to predation-avoidance, comfort and/or security strategies.

2. LITERATURE REVIEW

2.1. Taxonomy and distribution of blue monkeys

Guenons are a diverse and widely distributed primate groups that present taxonomic challenges due to unresolved phylogenies and methodological disagreements how best to classify closely related forms (Butynski, 2002). The most recent taxonomy lists four genera, 23 species, and 55 subspecies (Grubb *et al.*, 2003). Among the guenons, the blue monkey clade, or *Cercopithecus mitis*, is well known for its taxonomic complexity because of its phenotypic diversity found across the African continent (Lawes *et al.*, 2013).

For many years, the various populations of *C. mitis* were grouped under two main species: *C. albogularis* and *C. mitis* (Dandelot, 1971; Napier, 1981). This then increased to four species to include separate species of *C. doggetti* and *C. kandti* (Kingdon, 1997; Groves, 2001), although the number of subspecies corresponding to each taxon varied. Subsequently, after studying the literature and specimens at the Natural History Museum in London, Grubb (2001) concluded that all the populations were so morphologically similar to be grouped under 16 subspecies, in one species (*C. mitis*). Finally, the IUCN recognize these 16 subspecies plus *C. m. zammaronoi* (Kingdon *et al.*, 2008) after a study in Somalia gave sufficient evidence for the inclusion as a separate sub-species (Gippoliti, 2006).

The distribution of blue monkey is throughout much of Central and East Africa: ranging from Ethiopia in the north of their range, Angola to the west, and as far south as the Eastern Cape Province of South Africa. The distribution appears to be limited by the Itimbiri and Zaire-

Lualaba River systems (Colyn, 1988; Wilson and Reeder, 1993; Butynski *et al.*, 2013). As an arboreal species, their distribution is patchy and restricted to areas of forest (Wolfheim, 1982). Boutourlini's blue monkey is the Ethiopian representative of polytypic *C. mitis* group distributed from Lake Tana southwards along the western side of the Ethiopian Rift Valley, but does not reach Lake Turkana (Fig. 1.).

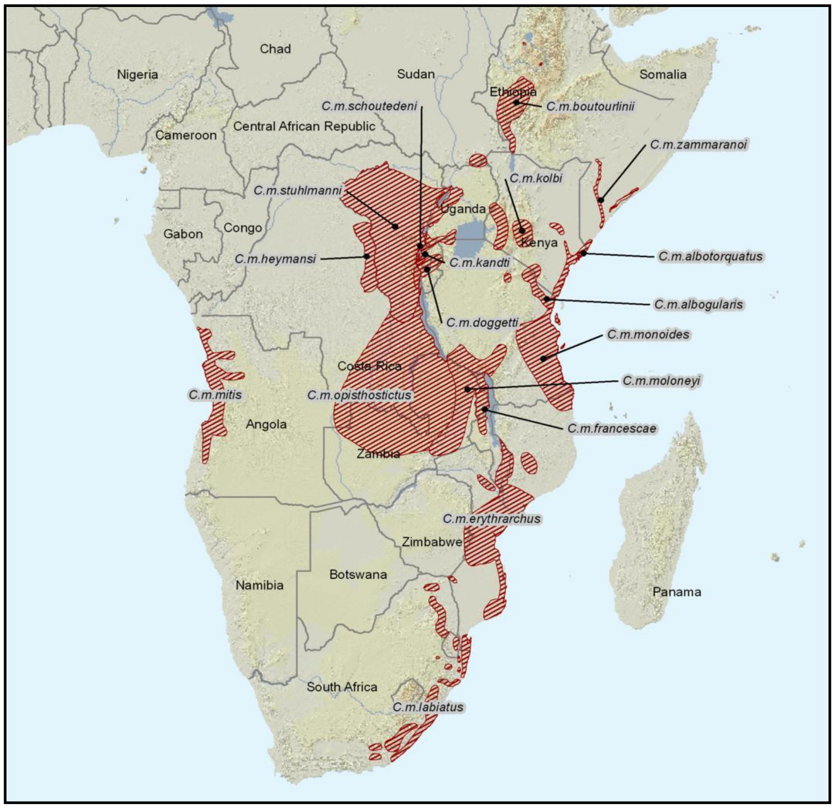


Figure 1. Distribution of *C. mitis* subspecies (Source: Colman, 2013).

2.2. Ecological and behavioural flexibility of blue monkey in response to habitat change

Ecological flexibility is loosely defined as the ability of an organism to adjust to changes, e.g., anthropogenic, gradual, stochastic, within its environment (Isaac and Cowlishaw, 2004; Nowak and Lee, 2013). More specifically, flexibility encapsulates behavioural modifications to the diet, exploitation of alternative food sources, as well as altering activity and vertical strata in response to new dietary opportunities. This ability to expand niche breadth is key to withstand the risks of anthropogenic and/or stochastic habitat modification (Lee, 2003).

A species' niche breadth can be described as the suite of environments or resources, in the broadest sense, that it can inhabit or use (Gaston *et al.*, 1997). Brown (1984) argued that, by utilizing a greater array of resources and maintaining viable populations within a wider variety of conditions, a species should become more widespread. Therefore, generalist species can more easily adjust their diets or shift their ranging patterns as long as there is still some suitable habitat available nearby (Channell and Lomolino, 2000; Devictor *et al.*, 2010). On the other hand, specialist species, i.e., those who specialize on particular foods and/or habitats are most vulnerable to disturbances that affect their narrow dietary breadth or habitat requirements. However, many species show large intra- and inter-specific variation (Shipley *et al.*, 2009), and so this definition is often regarded as when greater than 60% of a species’ diet consists of a single, distinct genus (Dearing *et al.*, 2000), or family of plants (Fox and Morrow, 1981).

Eppley (2015) argued that, flexibility in the use of habitat is equally important as dietary flexibility when understanding the ecological flexibility of a species. Essentially, if a species shows a high degree of ecological flexibility, it likely will be less affected by the degradation of habitat than one that relies on certain structural vegetation characteristics only present in specific habitat types. Specifically, habitat generalists should not exhibit large variations in their preference of micro-habitat and/or the structure of different forest types (Clavel *et al.*, 2011). In contrast, a habitat specialist will often be restricted to only its preferred microhabitat, unable to adjust to differing vegetation structures (Harcourt, 1998; Vazquez and Simberloff, 2002).

Behavioural flexibility is employed by many primate species as an adaptive response to changing environments and benefits individuals living in habitats experiencing anthropogenic or natural disturbance. For example, Orangutans (Pongo spp.) and Pitheciins take advantage of new forest strata by becoming more terrestrial (Barnett *et al.*, 2012a; Ancrenaz *et al.*, 2014). Howler monkeys (*Alouatta pigra*) reduce the number of energetically expensive behaviours such as agonistic behaviours in smaller forest fragments, thereby reducing the size of their behavioural repertoire (Rangel-Negrin *et al.*, 2016). Primates that are able to expand their trophic niche breath by changing their diet in response to anthropogenic or natural habitat disturbance may survive such disturbance events (Bicca-Marques, 2003; Galat-Luong and Galat, 2005; Cristóbal-Azarate and Arroyo-Rodríguez, 2007). For example, folivorous black-and-gold howler monkeys (*Alouatt caraya*) supplement their diet by predating on bird nests in impoverished environments (Bicca-Marques *et al.*, 2009). Likewise, diademed sifakas (*Propithecus diadema*) living in forest fragments consume mistletoe (*Bakarella clavata*) year-round instead of seasonally as they do in continuous forests due to the reduction of fruiting tree species in fragments (Irwin, 2008b). However, immediate responses to habitat disturbance may not guarantee long-term survival. In the case of the diademed sifakas, individuals living in fragments had lower body mass (Irwin, 2007) and decreased physiological health (Irwin *et al.*, 2010). Additionally, the level of frugivory (Johns and Skorupa, 1987) and diet specialization is an important factor in determining whether primates are able to persist in forest fragments (Abondano and Link, 2012). Species with highly specialized diets (i.e., less flexible or intolerant species) are at a disadvantage when their habitats and food sources change and may not be able to respond to this change as rapidly as more generalist species i.e, tolerant species (Meijaard *et al.*, 2008).

Habitat loss and fragmentation are the primary threats to biodiversity in the tropics (Haddad *et al.*, 2015). Among mammals, nonhuman primates are particularly threatened by tropical deforestation (Cowlishaw and Dunbar, 2000; Irwin, 2016). Some primates are adversely affected by the fragmentation of their habitat (Turner, 1996; Marsh, 2003; Isabirye-Basuta and Lwanga, 2008). Forest fragmentation results in population declines in some primates and complete extirpation in others (Estrada and Coates-Estrada, 1996; Chapman and Peres, 2001; Boyle, 2008). Many species are increasingly reliant on human modified landscapes (Arroyo-Rodríguez and Fahrig, 2014). The persistence of primates in small and isolated forest fragments depends on their behavioural and ecological flexibility (Onderdonk and Chapman, 2000). Therefore, understanding their behavioural and ecological flexibility is a key to link differences observed within a species to variations in the habitats that the different populations occupy.

Like other guenons, Boutourlini's blue monkeys show flexibility in dietary and ranging pattern living in fragments. This enables the species to feed on variety of foods and their conservation is promising (Dereje Tesfaye *et al.*, 2013; Mosissa Geleta and Afework Bekele, 2016). Despite the encouraging evidence of habitat, dietary and ranging flexibility presented in Jibat Forest of western Ethiopia, there are reasons that the long-term conservation of Boutourlini's blue monkeys is far from assured. Their limited distribution in the forests of southwestern and western Ethiopia, and the growing human population and related high rate of forest clearance in the region, highlight the need for protection of the remaining forests where Boutourlini's blue monkeys occur (Dereje Tesfaye *et al.*, 2013).

2.3. Feeding ecology

Feeding ecology is a central component of a species' biology, relating to its survival, reproduction, population dynamics, habitat requirement and pattern of sociality (Hohmann *et al.*, 2012). According to Kate (2000), understanding the diet of an animal helps to interpret its ranging behaviour in relation to food availability and it also indicates some of the ecological relationships between plants and animals.

Primates use variety of food sources such as leaf, fruit, seed and animal to obtain basic elements like carbohydrates, fats, proteins, vitamins, and minerals. Di Bitetti and Janson (2000) revealed that food availability is the most important ultimate cause of seasonality and its availability dictates the daily movement patterns of groups of primates (Lambert, 1998). Hohmann *et al.* (2012) observed that the environment and the primate itself plays an important role in determining the type of food sources. Thus, additional food components influence the density of primates that an area can support as well as modulate the population dynamics (Hohmann *et al.*, 2010).

Feeding ecology of primates is examined on the level of the organism, stating the level at which one can quantify the diet, the proportion of diet involved which consists of each type of plant parts (e.g. fruit, seed, pith, leaf and flower) of each species of plant consumed and the time spent.

Seasonal diet variation is common in many primates because the availability of certain food stuff depends on seasons. For example, fruit availability show strong seasonal fluctuations in many geographical locations (Conklin-Brittain *et al.*, 1998; Wrangham *et al.*, 1998). Although most primates are frugivorous, at times of low fruit availability they subsidize their diet with different food stuffs such as leaves (Stanford, 1991; Hill, 1997), seeds (Galetti and Pedroni, 1994; Peres, 2000b), flowers (Galetti and Pedroni, 1994) or invertebrates (Garber, 1993). For example, *C. mitis stuhlmanni* consumes a high proportion of fruit during the middle of the rainy and dry seasons. When fruit was less available, the proportion of leaves in the diet increase. Differences in food choice were also observed among lactating and non-lactating females. The former shows to eat more insects and less fruit, due to their greater need of food of high nutritional value, compared to non-lactating. Smaller juveniles consume more fruit, at the expense of leaves, than larger juveniles (Cords, 1986).

C. mitis tends to have a broader diet than most other arboreal *Cercopithecine* species (Lawes, 1991; Chapman *et al.*, 2002). *C. mitis* supplements its diet from a variety of different sources such as leaves (Fairgrieve, 1995; Beeson *et al.*, 1996), insects (Butynski, 1990; Kaplin, 2001) and flowers (Schlichte, 1978). These dietary diversity and increased leaf consumption are reflected in the gut morphology of *C. mitis*, which has a longer caecum, larger numbers of cellulases and more cellulose-digesting bacteria than other cercopithecines (Bruorton *et al.*, 1991). Similarly, Boutourlini’s blue monkey has special digestive adaptations that allow them to consume relatively large amounts of foliar materials (Dereje Tesfaye *et al.*, 2013; Coleman and Hill, 2014).

2.4. Activity patterns

Activity patterns and time budgets are the two important aspects of the temporal behaviour of animals. An activity budget, the amount of time allocated to different activities comprises resting, foraging, travelling, socialization, and etc. Comparisons of activity patterns and time budgets under different habitat set up and ecological conditions allow one to explore ecological influence on animal behaviour and consequently in behavioural strategies. It is imperative that measures of ranging, activities budget, group size and life history are crucial for both conservation management and hypothesis testing in behavioural ecology (Nekaris, 2001).

Activity time budget (i.e. how much time is spent performing certain activities) is an important aspect of behaviour. According to Halle and Stenseth (2000), they are directly linked to body's metabolism and energy requirements, which often change with seasons, through the individual's life span, including in relation to reproduction. Knowledge of an animal’s activity budget allows to certain conclusion related to behavioural strategies and even priorities in decision-making in conservation.

Comparative studies on the behavioural and ranging patterns of species in fragments and large forests can provide an indication of habitat quality such as food availability, density and distribution at least in short term (Zanette *et al.*, 2000). According to Onderdonk and Chapman (2000), the proportion of time spent travelling or feeding may increase if species must spend more time searching for food or are eating lower quality foods. Similarly Clark *et al.* (2002) pointed that, increasing in the amount of time spent on foraging may result in decline in social activity. Lower availability and density of food which may result in longer day journey, suggested that individuals have to travel more to meet their nutritional requirements and home range size may also increase in lower-quality habitats for the same reason.

Primates' activities can be determined by habitat types in which they are living (Cristóbal-Azarate and Arroyo-Rodríguez, 2007; Fashing *et al.*, 2007). This is influenced by the availability of food, water, cover, and other environmental factors (Fernandez-Duque, 2003; Riley, 2007). Because primates live in a variety of habitats, their activity depends on group size, site, time and individuals (Teichroeb *et al.*, 2003; Wijtten *et al.*, 2012). Some age groups tend to spend much time feeding while other groups spend more time grooming, playing and moving (Fashing, 2001a).

Blue monkeys' daily activities are heavily linked to their habitat requirements in that the presence of cover, water and food influence their feeding patterns and social behavioural activities such as grooming and breeding (Lawes, 1990b). When all organisms are well suited to their habitats, there is a tendency for population increase and non-stressful activities with low energy requirements such as playing and resting since most of their survival needs are easily accessed. The various habitat positions that blue monkeys spend their time are canopy, tree trunks, ground layer and the glade areas (Kaplin, 2001).

The different activities of Boutourlini's blue monkey were not equally likely to occur at different hours of the day. Feeding activity was most likely to occur in the morning and evening. Resting activity and associated behaviours such as grooming were more common in the middle of the day. The proportions of time used by Boutourlini's blue monkey for different activities depend on the availability of specific resources and dietary diversity. They spend more time in feeding than moving and resting, and show high movement patterns to encounter fruit when there is fruit scarcity (Dereje Tesfaye *et al.*, 2013).

2.5. Home range and habitat use

Most of the group living animals including primates have well defined ‘home range’ for their use, which caters to their needs. Traditionally, this area has been considered as the animal’s feeding, resting and sleeping site (Burt, 1943; Jolly, 1985). The size of this home region corresponds somewhat with the size of the animal. It also may vary with sex, possibly age, and season. For example, flesh-eaters as a class have a larger home region than herb-eaters and young adolescent animals often do a bit of wandering in search of a home region (Burt, 1943). The distance within the home range, that an animal covers in a single day is the “day range” (Stanford, 1989).

The way in which resources are distributed in time and space influence patterns of movement by primate groups (Milton, 1980; Sigg and Stolba, 1981). Relationships between the biology of different primate taxa and range use have been utilized to generate predictive statements about ranging behaviour (Stanford, 1989). Studies of ranging behaviour in forest primates (Struhsaker, 1975; Wrangham, 1977) showed complex interactions and decision making about where to go and what to eat in forest monkeys.

In non-human primates, home range size is a function of body size (Milton and May, 1976), and also depends on social interactions and behaviour (Gittleman and Harvey, 1982; Lindsted *et al.*, 1986). Ecological factors also affect the size of the home range in different species. Even, small differences in feeding ecology might affect markedly the ranging pattern of primates (Clutton-Brock and Harvey, 1977). Ranging pattern can also be influenced by weather conditions (Isbell, 1983), the need to patrol territory (Whitten, 1982), interaction between con-specific groups (Sekulic, 1982), location of domicile tree (Davies, 1984), group movement on the previous days (Fossey and Harcourt, 1977), and group size (Olupot *et al.*, 1994). Milton and May (1976) pointed out that folivore primates occupy smaller home ranges which are proportionate to their body weight than do frugivores and omnivores. They also pointed out that the terrestrial folivores do have longer home range value than arboreal folivores.

A comparative study on Boutourlini's blue monkeys in Jibat Forest, Ethiopia showed that the group inhabited a continuous forest leading to large home ranges than the second group, which inhabited a fragmented range and consistently used the home range throughout the year. This consistent ranging patterns of Boutourlini's blue monkey is due to their territorial nature and a combination of diet shift and resource monitoring. The mean day length of Boutourlini's blue monkey in Jibat Forest, Ethiopia (Dereje Tesfaye, 2010), was less than other subspecies of blue monkeys such as *C. mitis doggetti* in Nyungwe Forest Reserve, Rwanda (Kaplin, 2001), *C. m. stuhlmannii* in Kakamega Forest, Kenya (Cords, 1987b), and *C. mitis kandti* in Mgahinga Gorilla National Park, Uganda (Twinomugisha and Chapman, 2008). Contrary to some *Cercopithecus* species, Boutourlini's blue monkey show more wide ranging when excess fruit was available than fruit scarcity period (Dereje Tesfaye *et al.*, 2013)

2.6. Positional behaviour

Positional behaviour was first defined by Prost (1965) as the study of posture and locomotion. Locomotion is “the displacement of the centre of gravity” and posture is described as an alternative to locomotion, where the body mass remains stable (Prost, 1965).

Positional behaviour has evolved in primates in different ways. This enables them to move from one location to another (locomotion) and to position their limbs and trunk while stationary (posture). Most primates are capable of walking, running, leaping, clinging, climbing, standing, hanging, and brachiating on different strata. Some can do all of these and several primates are even accomplished swimmers (Stern and Oxnard, 1973). Most species are capable of performing multiple versions of these adaptations; therefore, agility, flexibility, and locomotor diversity are primate hallmarks (Garber, 2011). Schmidt (2010) stated that primates may do these often or rarely, quickly or slowly, with agility or clumsiness, on the ground or on the trees or swimming in the water on thick branches or thin ones, on vertical, oblique or horizontal supports, with all appendages or only some. Among mammals, order primate is practically unique with respect to its broad spectrum of locomotor and non-locomotor behaviours. Therefore, non-locomotor behaviours comprise all the activities and movements related to food acquisition, social behaviour, communication and object manipulation. Whereas, the locomotor apparatus has multiple functions and is therefore better termed as motion apparatus (Schmidt, 2010).

Positional behaviours of primates are influenced by both extrinsic and intrinsic factors (Addisu Mekonnen *et al.*, 2018b). Ecological factors are among extrinsic (Gebo and Chapman, 1995b;

Bitty and McGraw, 2007) and postcranial morphology and anatomy are intrinsic factors (Garber, 2007; Fleagle, 2013).

The most important ecological factors influencing positional behaviour and strata use of many primates are habitat structure, food availability, diet, and the presence of predators (Gebo and Chapman, 1995b; Bitty and McGraw, 2007; Huang *et al.*, 2015). The locomotor behaviour of some species varies in different context and among forest types: for example, red colobus monkeys (*Colobus badius*) (Gebo and Chapman, 1995a), lemurs (Dagosto and Yamashita, 1998), and black-and-gold howlers (*Alouatta caraya*) (Prates and Bicca-Marques, 2008). These locomotor behavioural differences across the same species are due to variation in forest structure associated with changes in diet and the availability and distribution of food resources (McGraw, 1998; Youlatos, 2002; Prates and Bicca-Marques, 2008). On the contrary, locomotor behaviour is often invariable within species even across forest types (Addisu Mekonnen *et al.*, 2018b). For instance, despite differences in habitat quality, locomotor modes were similar in studies of mustached tamarin monkeys (*Saguinus mystax*) in Peru (Garber and Pruetz, 1995) and five species of cercopithecid monkeys (*Cercopithecus* spp. and *Colobus* spp.) in Ivory Coast (McGraw, 1996). On the other hand, habitat fragmentation and degradation had variable effects on the feeding and resting postural behaviours of these species due to architectural differences across habitats (Garber and Pruetz, 1995; Gebo and Chapman, 1995b; McGraw, 1998). In particular, feeding posture appears to be most affected by dietary and architectural differences across habitats (Gebo and Chapman, 1995b; Garber, 1998), whereas resting posture seems less likely to be affected by habitat structure.

Many studies show that primates exhibit flexibility in their positional behaviour in response to habitat alteration due to habitat fragmentation and degradation. For instance, Bale monkeys (*Chlorocebus djamdjamensis*) shift from an arboreal lifestyle to a semi-terrestrial lifestyle in response to habitat change. In addition, locomotor mode, feeding posture, and strata use are strongly influenced by forest fragmentation and associated habitat degradation (Addisu Mekonnen *et al.*, 2018b).

Study on positional behaviour and habitat use of five sympatric species of Old World monkeys in Kibale Forest Reserve, Uganda pointed out that *C. mitis* commonly utilize three varieties of locomotion (quadrupedalism, leaping, and climbing) and two postures (sitting and standing), and are likely be categorized as arboreal quadrupeds (Rose, 1973; Daniel and Colin, 1995).

2.7. Sleeping site selection

According to Rasch and Born (2013), sleep can be defined as a natural and reversible state of reduced responsiveness to external stimuli and relative inactivity, accompanied by a loss of consciousness. Reduced responsiveness is risky, however, as animals must respond to life threatening cues such as predators. In addition, this inactivity implies missing out on feeding, caring for young, or socializing; in short, a reduced investment in activities necessary for an individual's fitness (Fruth *et al.*, 2018).

Sleep provides a number of physiological functions for individuals such as energy saving (Siegel, 2005), tissue repairing (Oswald, 1980), thermoregulation (Parmeggiani, 1986), metabolic regulation (Sharma and Kavuru, 2010), immunological enhancement (Besedovsky *et* *al.*, 2012) and memory formation (Rasch and Born, 2013). Therefore, behavioural ecology researches have looked within and across species to better understand how natural selection has shaped sleep and sleep-related behaviour, particularly in the context of predation where vigilance should supplant states of unconsciousness (Lima *et al.*, 2005).

Primates exhibit a vast array of different sleeping behaviours. Timing of sleeping pattern varies quite markedly; some species are considered nocturnal, such as the African and Asian Strepsirrhine prosimians (Reinhardt and Nekaris, 2016) and the South American genus, *Aotus* (Wright, 1989). Most primates, however, are diurnal, although a few species, such as the owl monkey, *Aotus azarai*, and several Malagasy Strepsirrhines (e.g., *Eulemur* spp*.*, *Hapalemur* sp., *Lemur catta*), exhibit cathemerality (Curtis and Rasmussen, 2006).

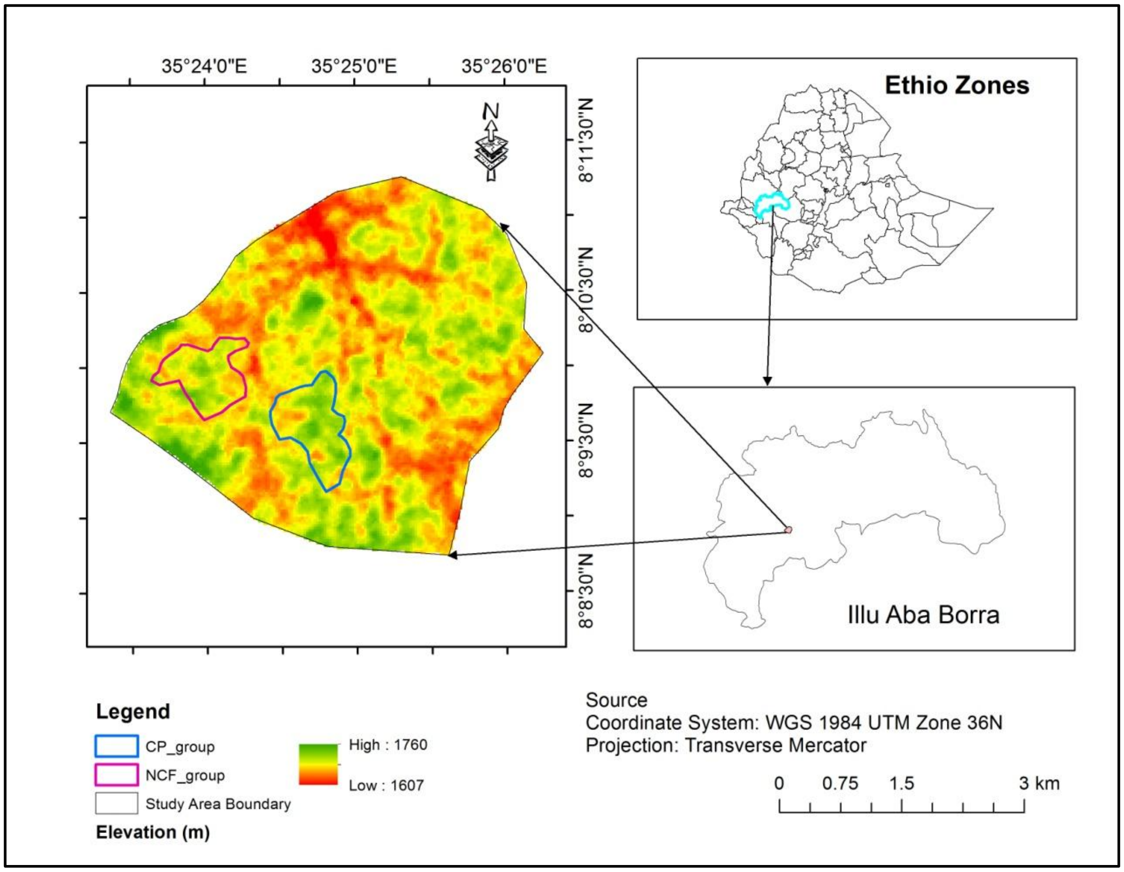
Primates spend a substantial portion of their lives asleep; while sleeping, they are subjected to many of the same selective pressures they face when active such as predation, disease, thermoregulation and food availability (Feilen and Marshall, 2014). The choice of sleeping site may also be influenced by several other factors, including body size, rainfall, temperature, season, social organization and reproductive state (Anderson, 1998). Although these factors are not mutually exclusive in influencing sleeping site selection, however, certain requirements potentially play a priority role over the other in preferring specific sleeping sites (Brotcorne *et al.*, 2014). Therefore, sleeping site selection may have important fitness consequences. Identification of the factors influencing the selection of sleeping sites and how these factors vary within and among species can provide important insights into primate ecology and evolution (Barnett *et al.*, 2012b).

Studying sleeping site selection and sleep-related behaviour is essential for understanding ecological adaptations, evolution of primate behaviour and survival of the species. Consequently, several hypotheses for sleeping site selection have been proposed in response to the wide range of slumber patterns exhibited by primate species (Fei *et al.*, 2012). However, studies on sleeping site and trees selection of Boutourlini's blue monkey and its implication for conservation are null and seek attention in this study.

3. STUDY AREA DESCRIPTION

3.1. Geographical location

The study was carried out in Hamuma Coffee Forest which is located in Illu Aba Borra Zonal Administration of Oromia Region, Ethiopia. It is located at a distance of 636 km southwest of Addis Ababa and 36 km west of the zonal capital (Mettu) along Addis Ababa–Mettu–Gambella main road. It lies between 8°08′45″–8°11′15″ N latitude and 35°23′20″–35° 26′15″ E longitude and covers a total area of 1606.2 hectares (Fig. 2).



Source
Coordinate System: WGS 1984 UTM Zone 36N
Projection: Transverse Mercator

Figure 2. Map of the study area.

3. 2. Climate

The area is characterized by hot and humid temperatures and tropical rainfall patterns. In order to construct the climate diagram of Hamuma Coffee Forest, 17 (2000–2017) years climate data of Ukka station was obtained from the Ethiopian Metrological Service Agency, 5 km away from the forest (ENMSA, 2018). The mean monthly minimum temperature of the coldest month is 12 °C and mean monthly maximum temperature of the warmest month is 29.8 °C. Moreover, the mean annual temperature and mean annual rainfall of this area is 20 °C and 1713 mm, respectively. The area possesses unimodal rainfall pattern by which it receives rainfall from April to October and reaches peak in September (Fig. 3).

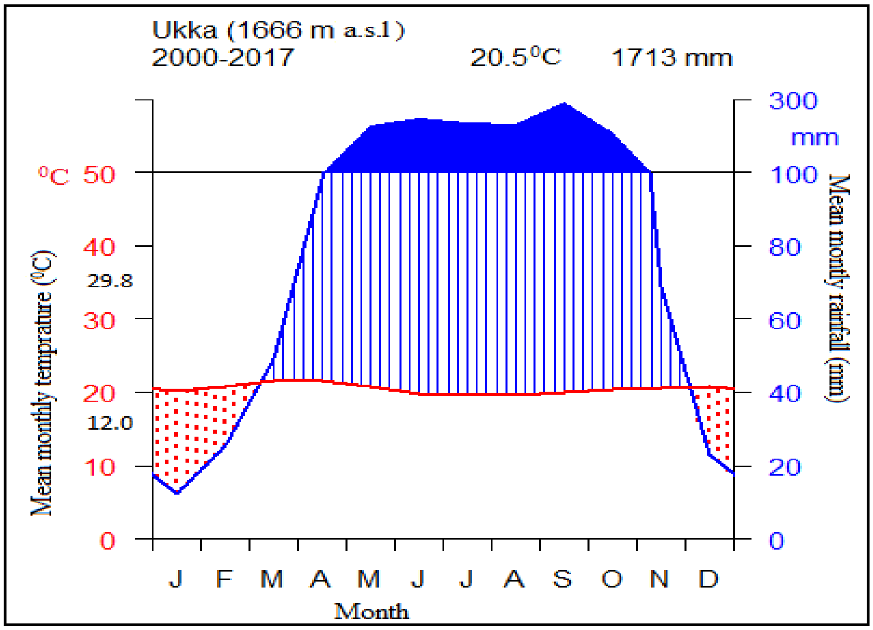


Figure 3. Walter and Lieth climate diagram showing a summary of climate conditions for the nearest metrological station, Ukka town (ENMSA, 2018).

To compare with the 17 year data obtained from ENMSA, rainfall and temperature data were recorded in the camp site near to the study area using Oregon wireless rain gauge and Taylor digital water proof maximum/minimum thermometer for a year from December 2016 to January 2017. Accordingly, the annual rainfall of the study area was 1823 mm for the year 2017 and the mean annual temperature of the study area was 19.9 °C ranging from the mean annual minimum temperature of the coldest month, 13.2 °C to the mean annual maximum temperature of the hottest month, 29.5 °C (Fig. 4).

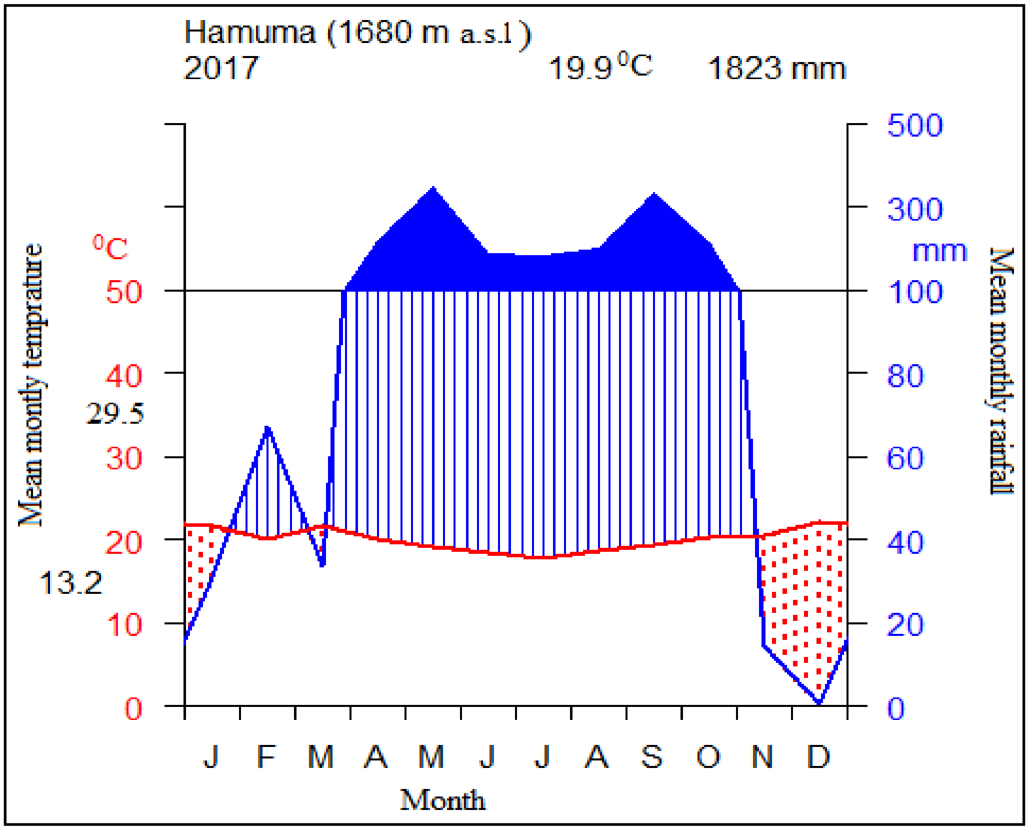


Figure 4. Walter and Lieth climate diagram showing a summary of one-year climate conditions for Hamuma coffee forest (2017).

3.3. Floristic composition and habitat classification

In Illu Aba Borra Zone, approximately 40% of the area is covered with forest whilst agriculture, which is dominated by maize cultivation, accounts for 20% of the area (Plate 1). Coffee is the major cash crop. This grows wild in the forest but is increasingly cultivated in domesticated stands. The zone is known for its extensive coffee forest and broad leaved natural forest with high biodiversity. The study area possesses modified coffee plantation with large fruiting trees such as *Ficus* and *Podocarpus*. The climax vegetation is tropical montane rain forest (Plate 2). According to the climatic zonation, Illu Aba Borra zone is categorized by three agro-ecozones. These are three major climatic zones in this area as highland (13%), intermediate land (57.25%), and lowland (29.75%) (Wood and Dixon, 2000).

Plate 1. Maize cultivation in the agricultural field (Photo: Meseret Chane, 2017).

Plate 2.Forest view of the study area (Photo: Meseret Chane, 2017).

3.5. Primate fauna

The area harbours the endemic and vulnerable Boutourlinii's blue monkey (Plat 3a) and the rare DeBrazza’s monkey (Plate 3b). Other primates found in the study area are the more common grivet monkey (Plate 3c), Omo River guereza (Plate 3d) and anubis baboon.

Plate 3. Primate spices of the study area (Photo: Meseret Chane, 2017).

4. MATERIALS AND METHODS

4.1. Materials used in the study

Binoculars, a digital photographic camera, video camera a Garmin Global Positioning System (GPS), a tape measure, rain gauge, thermometer, clinometer, flagging and a plant press were used for this study.

4.2. Methodology

4.2.1. Study groups

Two groups of Boutourlini's blue monkey whose habitats differed in levels of anthropogenic alteration were studied (Table 1). The first group (hereafter, “NCF-group”) occupied natural coffee forest, characterized by minimal conversion to coffee plantation and rarely used by villagers. The second group (hereafter, “CP-group”) occupied coffee plantation, characterized by relatively heavily modified habitats, intercepted from the continuous forest by road, and frequently visited by villagers. Although levels of disturbance varied between habitats, both groups occupied habitats similar in topography and climate. Because this research was the first to study the ecology and behaviour of Boutourlini's blue monkey at the chosen field site, a number of months (NCF-group: 3 months, CP-group: 4 months) were required prior to the start of systematic data collection to habituate the two groups to the point of tolerating the presence of researcher. We habituated the species through continuous follow up without disturbing them by wearing the same uniform to distinguish us (the researcher and field assistants) from villagers and kept tolerable distance of 5–10 m.

Table 1. Group composition and habitat characteristics of NCF and CP groups.

Feature	**NCF-group**	**CP-group**
Group size	55–58+	32–35+
Group composition[x]	6AM, 11AF, 11SAF, 8SAM, 15J, 4I+U	4AM, 6AF, 5SAM, 7J, 2I+U
	Birth: 5+U	Birth:3+U
	Death:1J	Death: 2(1AF,1I)
Habitat modification	Natural coffee forest dominated by large shed trees	Coffee plantation with sparsely distributed shed trees

[x] At start of study, with information on births and deaths during the course of the study. AM = adult male, AF = adult female, SAM = sub-adult male, SAF = sub-adult female, J = juvenile and I = infant and U = unknown.

4.2.2. Habitat description

To assess habitat variation, we sampled the vegetation in the habitats of the study groups using two complementary techniques. First, a total of four (400–600 m) long transects (5 m wide on both sides of the transects) were randomly established in the habitats of each group. To sample trees ≥10 cm diameter at breast height (DBH), 10 x 50 m^2 vegetation quadrats (20 in natural coffee forest, and 20 in coffee plantation) were established on transects (Fig. 5). In each vegetation quadrat, the species name, growth form, DBH (cm) (using tape measure), height (m) (clinometer) and canopy size/diameter (m) (tape measure) for all trees with DBH ≥ 10 cm were measured and recorded. Second, all of the vegetation quadrats for each group were sampled and all plants ≥ 2 m tall were counted and identified to species level (Addisu Mekonnen *et al.*, 2017).

This is because it is assumed that the monkeys depend not only on large trees but also on liana and shrubs. Plant growth forms were classified into categories: large trees (≥10cm DBH), small trees (≥2 m tall and <10 cm DBH), shrubs, lianas (including climbers and epiphytes) (Addisu Mekonnen *et al.*, 2017). In each group's habitats, species richness, stem density, and species diversity for all plants ≥2 m tall and trees ≥10 cm DBH were quantified. Then plant species diversity using the Shannon-Wiener index of diversity, Ή, dominance index, D and evenness index, J were calculated using PAST software (Krebs, 1999). Plant species richness and similarity were also assessed. Plant species similarity was calculated by Sorensen's (S) index of similarity coefficient using EstimateS (Colwell, 2013). To estimate the biomass of each large tree species, the basal area (BA) of each tree from the DBH recorded was calculated by using the following formula (BA = $[0.5 \times \text{DBH}]^2 \pi$ (Fashing, 2001b).

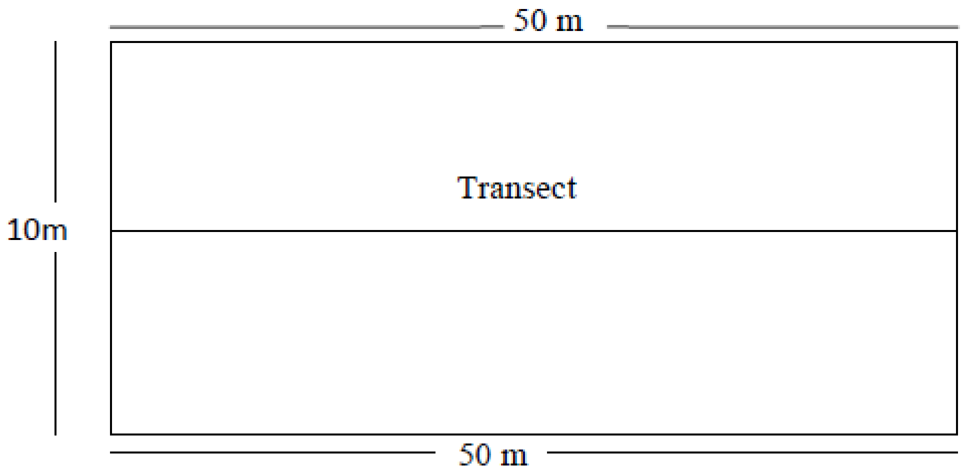


Figure 5. Plot layout for collecting vegetation data.

4.2.3. Phenology as indictor of food availability

To evaluate temporal changes in the availability of potential food resources, monthly phenological assessments over an annual cycle for selected food plant species found at each of the study sites were carried out. A total of 10–15 trees per species were selected in the vegetation transects from a total of 15 frequently consumed plant species in the home range of each study group. Each selected tree was monitored on a monthly basis and estimated the abundance of young and matured leaves, flowers, fruits (ripe and unripe) and buds with abundance score ranging from 0 to 8 with 0 complete absence and 8 full abundance of the item. The phenological scores of individual trees of each species were averaged to provide mean monthly phenology for each species i. Since DBH is the main predictor of food availability, monthly Food Availability Index (FAI) unit per hectare (ha) for each species i were obtained by multiplying mean monthly phenology scores of species i by the basal area (cm^2/ha) estimated in the vegetation survey of specie i.

4.2.4. Behavioural observation

Following the initial period of habituation, each group was followed on four consecutive days each month for 15 months between November 2016 and January 2017. The only exceptions were March 2017 – July 2017, when the CP-group was followed for 3 days, and April 2017, when NCF-group was followed 3 days too. Data on activity patterns were collected using instantaneous scan sampling method (Altmann, 1974), from “NCF” and “CP” groups. Activities were recorded from 07:00–18:00 hour at 15 minute intervals for up to 5 minutes (Fashing, 2001b). The first activity by each monkey at instant of time was recorded. One of the following activities were recorded such as feeding, moving, resting, grooming, playing and aggression for the first 1–5 visible individual/s of adult males, adult females, sub-adult males, sub-adult females or juveniles, ignoring infants.

4.2.5. Feeding ecology

Data on feeding ecology were collected during activity scan sampling. If a monkey was observed feeding, the type of food item (young leaves, mature leaves, ripe fruit, unripe fruit, seed, flower, animal prey, and others), species consumed and growth form (tree, shrub, liana/climbers, herb) were recorded with the help of binoculars if it was not seen by a naked eye. However, when identification of food species was difficult in recording food items, the species were recorded with specific codes and sample specimens were collected for further identification. The collected plant specimens were identified at Addis Ababa University Herbarium. Identifications of species were confirmed by curator working in the Herbarium.

The dietary preference or selection ratio of Boutourlini's blue monkey on specific tree species was determined by dividing the percentage of a specific species in the diet with 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 indicate avoidance (Fashing *et al.*, 2014; Addisu Mekonnen *et al.*, 2018a).

4.2.6. Ranging ecology

During scan sampling, the geographic centre of the study groups were recorded using hand held Garmin GPS Map 62s every 15 minute intervals from dawn to dusk (Fashing, 2001a). Day range length was estimated by using Geospatial Modeling Environment (GME) (Beyer, 2015) and R(R

Development Core Team, 2015). Home range was estimated by using Home Range Tools (HRT) version 2.0 (Rodgers *et al.*, 2015) in ArcGIS 10.2 using two methods: Minimum Convex Polygon (MCP) and fixed kernel density estimations (KDE). Home range was calculated at 95% of KDE and core area at 50% KDE. The 95% and 100% MCP was also calculated for comparison.

4.2.7. Habitat use data collection

During activity scan sampling, the dominant habitat type (range point) where the majority (about two-third) of the study group observed was recorded every 15 minutes. The micro-habitats were categorized as natural coffee forest, coffee plantation, and tree dominant forest. Within each group's 95% KDE home range, habitat selection ratios were calculated by dividing the frequency of observed use (% of scans in each habitat type) by the frequency of expected use (% of home range area accounted for by each habitat type) (Manly *et al.*, 2004). To obtain the frequency of expected use, the habitat types within each home range were classified using high resolution Google Earth images of the study area in ArcGIS 10.2 (Pebsworth *et al.*, 2012; Kelley, 2013) and ground truthed with the GPS and habitat type data collected during group follows. A habitat selection ratio close to 1 indicates no selectivity for that habitat, <1 indicates a habitat is avoided and >1 indicates a habitat is selected.

4.2.8. Positional behaviour and strata and substratum use

Data on positional behaviour and strata and substrate use were collected during the activity scan sampling (Altmann, 1974). This sampling method is standard in studies of positional behaviour because it helps ensure independence of data points (Fei *et al.*, 2015; Zhu *et al.*, 2015). Locomotor and postural modes, strata use, and substrate utilization were recorded via visual estimation as well as by using a measuring tape and rangefinder where appropriate for every individual on inspection (Iurck *et al.*, 2013; Huang *et al.*, 2015; Addisu Mekonnen *et al.*, 2018b).

During each individual scan, when a monkey was observed travelling, its locomotor mode was recorded. Postural behaviours for feeding and resting bouts were recorded based on body shape and limb position (Addisu Mekonnen *et al.*, 2018b). The definitions of both locomotor modes and postural behaviours for this study followed Hunt *et al*. (1996), as cited in Addisu Mekonnen *et al.* (2018b) (Table 2).

To investigate the relative use of different strata in the environment (i.e., vertical habitat utilization), the strata use category for each scan record was recorded (Table 2). To examine substrate use patterns, the type, size, and inclination (Fig. 6), and number of substrate(s) that supported the main weight of the animal during each scan record were visually estimated (Table 2).

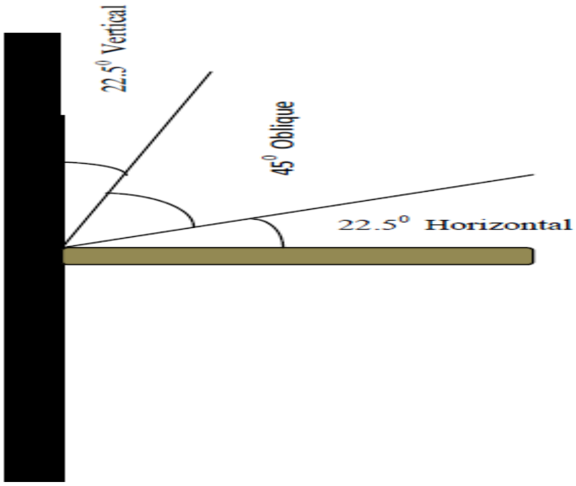


Figure 6. Diagram showing the categories of substrate and horizontal substrate at 90° from the trunk. Horizontal angles were between 90°–67.5°, oblique angles were between 67.5°–22.5°, and vertical angles were between 22.5°–0° (Nekaris, 2001).

Table 2.Variables and definitions recorded for the study of Boutourlini's blue monkey positional behaviour, strata use, and substrate utilization.

No	Terms	Definitions
1	**Locomotary mode**	
	Climbing	Upward or downward movement on a vertical or steeply angled substrates
	Leaping	Movement between substrates involving free flight in which the hind limbs provide the propulsive force
	Walking	Progression along a substrate in which all four limbs follow a regular pattern of movement
	Running	Rapid progression along a substrate
	Galloping	Movement in which each homologous pair of limbs acts as a unit
	Bridging	A short gap crossing involving active or passive compliance of initial and landing supports
2	**Postural mode**	
	Sitting	Stationary position where the monkey rests on its hind limbs in a pronograde or semi-pronograde posture
	Quadrupedal stand	Standing posture on four limbs
	Tripedal stand	Standing posture on three limbs
	Bipedal stand	Standing posture on two hind limbs
	Lying	When a ventral, dorsal, or side of the torso support the body
3	**Strata use**	
	Ground	When a monkey uses the ground as support
	Lower	Shrub and understory layer up to 5 m above the ground
	Middle	Small tree and bamboo layer between 5 and 15 m high
	Upper	Forest stratum over 15 m high

Table 2. Continued

No	Terms	Definitions
4	**Substrate type**	Type of substrate that supports the main weight of the animal
	Trunk	The main woody structure of a tree
	Bough	The major branch that occurs between the trunk and a branch of a tree
	Branch	Branch of a tree between a bough and a twig (>2 cm in diameter)
	Twig	Small terminal branches less than 2 cm in diameter on trees
	Liana	Vines and climbers
5	**Substrate size**	
	Small	Small and flexible supports <2 cm in diameter
	Medium	Supports between 2 and 10 cm in diameter
	Large	Supports between 10 and 20 cm in diameter
	Very large	Supports >20 cm in diameter
6	**Substrate inclination**	
	Horizontal	Angle between 0 ± 22.5°
	Oblique	Angle between 22.5° and 67.5°
	Vertical	Angle ≥67.5° to 90°
7	**Substrate number**	
	Single	Only a single support
	Multiple	Two or more main weight-bearing supports

*Definitions for locomotor and postural modes, strata use, and substrate type, inclination, and size, and number were adapted and modified fromAddisu Mekonnen *et al.* (2018b)

4. 2. 9. Domicile tree selection behaviour

The following characteristics of each domicile or selected tree was recorded and modified from Phoonjampa *et al.* (2010); Fei *et al.* (2012); Hernandez-Aguilar *et al.* (2013): 1) species, 2) DBH, 3) height, 4) height of the lowest branch, 5) size of the lowest branch, 6) height of the sleeping place, 7) diameter of the crown, 8) visibility of tree canopy and 9) phenology. To identify the species of sleeping selected trees, local name was recorded and unidentified species were collected and submitted to AAU Herbarium for identification. Clinometer and standard measuring tape were used to calculate tree, sub-canopy, and bottom-most branch heights at each location (Williams *et al.*, 1994). The percentage of crown projection of each sleeping selected tree was measured using an internal crosshair sighting tube and 20 sample points per tree (Jennings *et al.*, 1999). Crown projection refers to the proportion of total observations where sky is obscured by vegetation (Johansson, 1985). Basic phenology data for the selected trees were collected on the day after use according to the following scale for maturity and density of leaves, fruit and flowers: 0 (none), 1 (1-25 percent), 2 (26-50 percent), 3 (51-75 percent), and 4 (76-100 percent). DBH at 1.3 m from the ground (Husch *et al.*, 2017) was measured. To avoid problems with inter-observer reliability in data collection, one observer recorded all measurements.

4.3. Data analyses

Statistical tests and comparison between groups**:** All data were tested first for normality and if normally distributed, parametric tests were used otherwise non-parametric tests unless the data was log transformed to fit normality. Data were tasted for normality and homogeneity of variances using the Shapiro–Wilk and Levene tests, respectively. R 3.5.0 programming language was used to compare the differences in vegetation description, food availability index, activity patterns, habitat and dietary overlap, ranging patterns, positional behaviour and domicile tree selection between the two study groups (Boutourlini's blue monkeys).

Plant sampling effort varied between the two sites. Because the observed number of species depends on sample size, our estimations of plant species richness were standardized for comparisons. Individual-based rarefaction curves, which are plots of randomized richness vs. individual collection effort, i.e. the total number of plant specimens counted were produced (Gotelli and Colwell, 2001). Rarefaction generated the expected number of plant species versus total number of individuals counted. Mao Tau randomizations computed with EstimateS was used (Colwell *et al.*, 2004). Then average species richness per sampling unit over the two sites were compared using randomization tests. Computations required Monte Carlo re-sampling (Manly, 1997), so the PAST software was used. The "true species richness" was also approximated by computing Chao1 estimators with EstimateS (Colwell, 2011).

The t-value ($t = H_1' - H_2' /' v s_1^2 + s_2^2$) was computed and compared to the critical value of Student's t to determine whether the diversity indices computed for each group were significantly different (Brower and Zar, 1984; Zar, 2014). A one-tailed t-test was used to test the prediction that mean DBH was greater in NCF-group's habitat (minimally-modified) than in CP-group's habitat (heavily-modified). A one-tailed Fischer's Exact probability test was used to test the prediction that the NCF-group habitat had a greater proportion of mid-canopy (16–29 cm DBH) and canopy (>30 cm DBH) trees. Differences in total basal area, DBH, height and canopy-size of large trees between the two habitats were tested with two-tailed t-tests.

Kolmogorov-Smirnov tests were used to determine whether rainfall and forest food production exhibited uniform distributions across the study period. To determine whether rainfall was correlated with forest food availability, Spearman rank-order coefficients (r_s) were calculated. The difference in food availability between the two habitats was using one-tailed Wilcoxon rank sum test. To test the relationship between unripe fruit availability with flower availability in both habitats a linear regression analysis was employed.

When the data satisfy the assumptions of normality and homogeneity of variance, monthly activity budgets were compared and analyzed using one-way Analysis of Variance (ANOVA) model followed by Tukey's HSD post hoc test, otherwise non-parametric Kurskal-Walis flowed by Dunn Test for multiple mean comparison with Bonferroni correction was employed. To test effects of seasonal changes on activity time budget of different behavioural responses in both groups, one way Multivariate Analysis of Variance (MANOVA) was used for mean comparison since these behavioural responses are potentially correlated and also help to reduce the likelihood of committing type I error (rejecting true null hypothesis), which cannot be achieved in using multiple separate ANOVA/t-tests (Scheiner, 2001; Warne, 2014).

One-way analysis of variance (ANOVA) using the log transformed monthly values as replicas was used to examine differences in monthly Shannon–Wiener dietary diversity indices between groups. To examine differences in monthly dietary dominance and evenness indices between natural coffee forest and coffee plantation groups, a generalized linear model (GLM) with a quasi binomial error distribution and logit link-function was used as recommended for proportional data (Crawley, 2012; Addisu Mekonnen *et al.*, 2018a). Spearman coefficient of correlation (r_s) was calculated to determine whether monthly food availability index was related with the type of food item consumed and association between each food items and food species by study groups in each month.

The mean monthly day path length (DPL), and movement rate (MVR) between the two study groups were compared across months using one-way ANOVA. Spearman correlation was used to test the association between the day range length and weather condition (rainfall and temperature). Habitat use frequencies of the both groups were analyzed using Chi-square goodness of fit test.

Percentage of positional mode behaviours, and substrate utilization between two study groups in natural coffee forest and coffee plantation were compared using one-way ANOVA or Kruskal–Wallis test depending on the distribution of recorded data. Chi-square goodness of fit test was employed to compare the frequency of domicile tree selection with expected frequency in the home ranges of both groups. The mean height and DBH of domicile trees between two groups were compared using one-way ANOVA and the mean DBH of these trees used by both groups with all large trees DBH $\geq$ 10 cm trees recorded on quadrats using one-sided single sample t-test.

5. RESULTS

5.1. Vegetation description and resource availability

Twenty quadrants covering a total area of one hectare were sampled in each group's habitat. The count plant species was 45 in natural coffee forest (NCF) and 32 in coffee plantation forest (CP) (Appendices 1 and 2, respectively). However, none of the rarefaction curves reached true plant species richness (Fig. 7). This indicted that some of the species were not represented in the enumeration. Therefore, the estimated species richness (using Chao1 estimator) was 60 species in NCF and 47 in CP. Comparing species richness based on a standardized number of quadrats (N = 20), there was no significant difference between the two habitats (Monte Carlo randomization test: P = 0.76). Both habitats shared plant species with similarity index Sorensen's S = 0.78 (30 shared species). But, estimating using Chao1 estimator, the shared species were approximately 37.

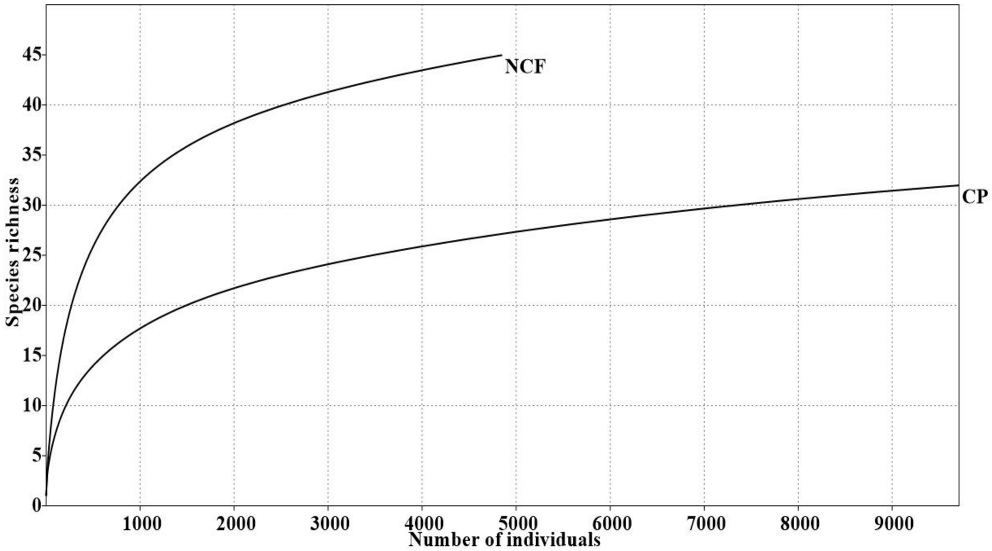


Figure 7. Plant species richness in the two sites. Rarefaction curves represent the cumulative number of recorded species, i.e. randomized species richness as a function of the number individuals counted in the two sites.

Species diversity was significantly greater in NCF (H' = 1.26) than CP (H' = 0.99) for all plants ($t = 9.74$, df = 8022.6, $P < 0.001$). Dominance was less in NCF (D = 0.52) than in CP (D = 0.55), while evenness was larger in NCF (J = 0.084) than CP (J = 0.078). Similarly, the diversity of large trees (DBH $\geq$10 cm) was significantly greater in NCF (H' = 2.82) than CP (H' = 2.47) ($t = 4.57$, df = 714.93, $P < 0.001$) (Table 3).

Coffee arabica dominated about 70% of all stems ≥ 2m tall in both natural coffee forest (NCF) and coffee plantation (CP). However, the density of *Coffee arabica* was more than two-times greater in CP (n = 7032 stems/ha) than in NCF (n = 3388 stems/ha) (Table 3). Trees (≥10 cm DBH) were more abundant in NCF (n = 443 stems/ha) than in CP (n = 334 stems/ ha). However, shrubs were more abundant in CP (n = 2150 stems/ha) than in NCF (n = 834 stems/ha) (Table 3).

The distribution of trees across different size classes for the two habitats was not statistically different ($\chi^2 = 1.15$, df = 2, $P = 0.56$; Fig. 8). In contrast to what was expected, the NCF habitat did not have a significantly higher proportion of mid-canopy sized (one-tailed, Fisher's Exact test, $P = 0.28$) or large canopy-sized (one-tailed, Fisher's Exact test, $P = 0.381$) trees than CP habitat.

Basal area, DBH and height of large trees (≥10 cm DBH) did not show significant difference between NCF and CP. But canopy size was significantly higher in NCF (mean = 4.48 m) than in CP (mean = 3.52 m) ($t = 3.45$, df = 38, $P = 0.001$) (Table 3).

Table 3. Feature of Boutourlini's blue monkey study habitats, group, and home ranges in Hamuma Coffee Forest.

Features of habitats	**NCF**	**CP**	**t, df, P-value**
Size (ha)	1 ha	1ha	
Mean elevation (m asl)	1690	1720	
Distance to the nearest village (m)	1500	2000	
Habitat quality			
Total species richness ≥ 2m tall	45	32	
All plant species diversity index, Shannon-Weaver, H'	1.26	0.99	9.74, 8023, < 0.001**
All plant species evenness index, J	0.084	0.078	
All plant species dominance index, D	0.52	0.55	
Large tree species richness ≥ 10 cm DBH	35	25	
Large tree species diversity index, Shannon-Weaver H'	2.82	2.47	4.57, 715, < 0.001**
Large tree species evenness index, J	0.48	0.44	
Large tree species dominance index, D	0.09	0.08	
Coffee stem density per ha	3388	7032	
Large tree stem density per ha	443	334	
Shrub density per ha	834	2150	
Liana density per ha	196	261	
Total stem density per ha	4861	9777	
Characteristics of home ranges (large trees ≥10 cm DBH)			
Number of large trees measured (N)	443	334	
DBH of large trees (cm)	32.92 ± 7.88	30.84 ± 8.40	0.90, 38, 0.38
Height of large trees (m)	22.55 ± 6.12	22.47 ± 8.26	0.035, 38, 0.97
Canopy size of large trees (m)	4.48 ± 0.97	3.52 ± 1.00	3.45, 38, 0.001**
Basal area of large trees (cm^2/ha)	1518.63 ± 818.62	1218.96 ± 689.40	1.14, 38, 0.26

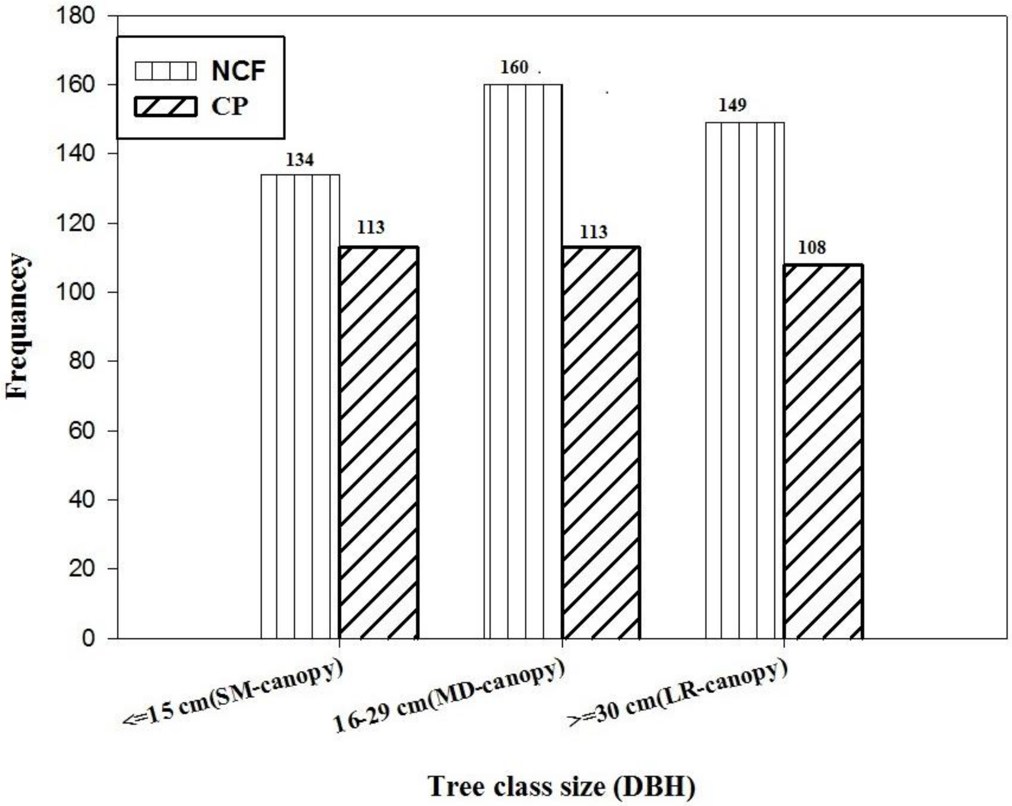


Figure 8. Distribution of trees across three DBH size classes in the two habitats.

5.2. Rainfall and forest phenology

In Hamuma Coffee Forest, there is all year round rainfall and therefore there was no significant variation in rainfall distribution across months of the year from December, 2016 to November, 2017. But it peaked in April–June and August–October, 2017 (one-sample Kolmogorov-Smirnov test, D = 0.19, P = 0.71; Fig. 9).

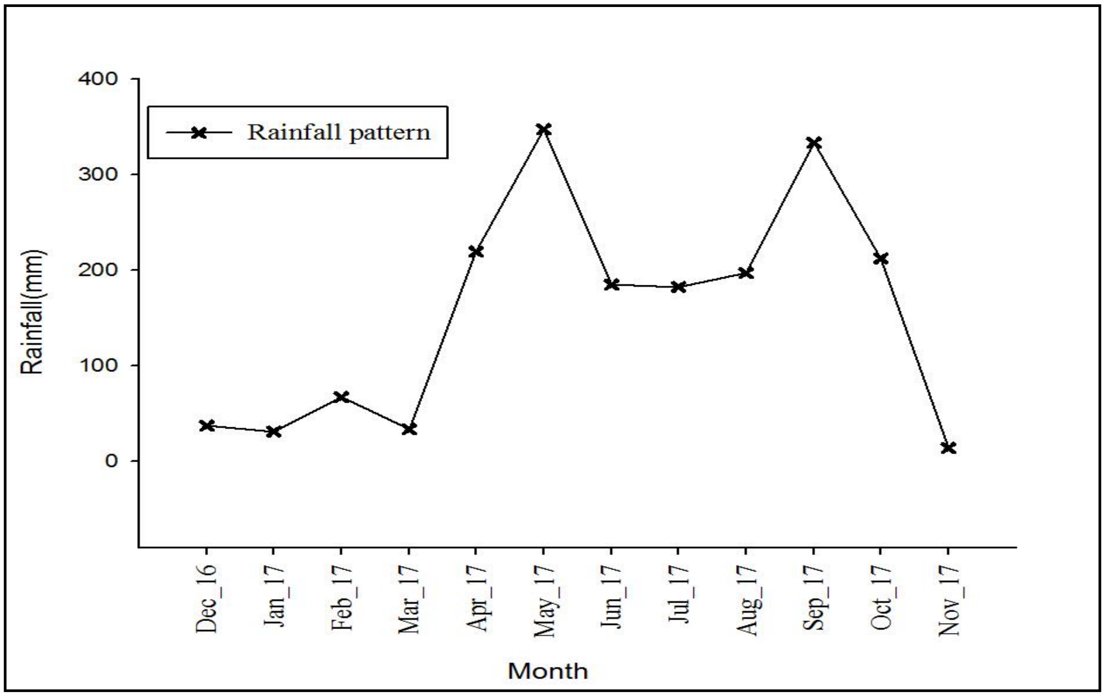


Figure 9. Rainfall patterns of the study area during 12 months of the study period.

The most abundant item (in terms of food availability index units/ha) in the home ranges of both study groups was mature leaves. These are available in large quantities throughout the year. However, three food items important in the diets of study groups were young leaves, fruits and flowers and they varied in FAI units/ha from month to month (Table 4).

Table 4. Monthly food availability indices (FAI units/ha) for NCF and CP groups.

	Young leaves		Ripen fruit		Unripe fruit		Flower	
Month	NCF	CP	NCF	CP	NCF	CP	NCF	CP
Dec_16	858183	748006	116307	88462	126181	25431	5934	9787
Jan_17	783660	694996	91405	38369	40660	14012	35777	34489
Feb_17	754469	554686	59145	58084	48135	41719	70136	1910
Mar_17	926027	782805	62572	25755	27553	10581	7309	6070
Apr_17	1661233	1308549	29039	7618	51392	5799	63689	78454
May_17	1146892	1200463	110576	64693	133749	79982	65676	61087
Jun_17	1121386	886171	79479	19140	57616	27560	83798	701
Jul_17	1537897	1152235	26184	709	1079	192	1555	568
Aug_17	1476000	1019051	12829	201	711	192	3578	1101
Sep_17	1326499	1015841	9240	4584	1192	1013	2743	3658
Oct_17	1316549	906651	27289	4467	31153	13520	3362	960
Nov_17	936650	905472	54073	31159	147183	61835	30213	25058
Mean	1153787	931243.8	56511.39	28603.41	55550.44	23486.23	31147.44	18653.5

Significant positive correlation was observed between young leaf availability indices and rainfall in the home ranges of both study groups (NCF: Spearman correlation coefficient (r_s) = 0.66, P = 0.02; CP: r_s= 0.71, P = 0.01; Fig. 10).

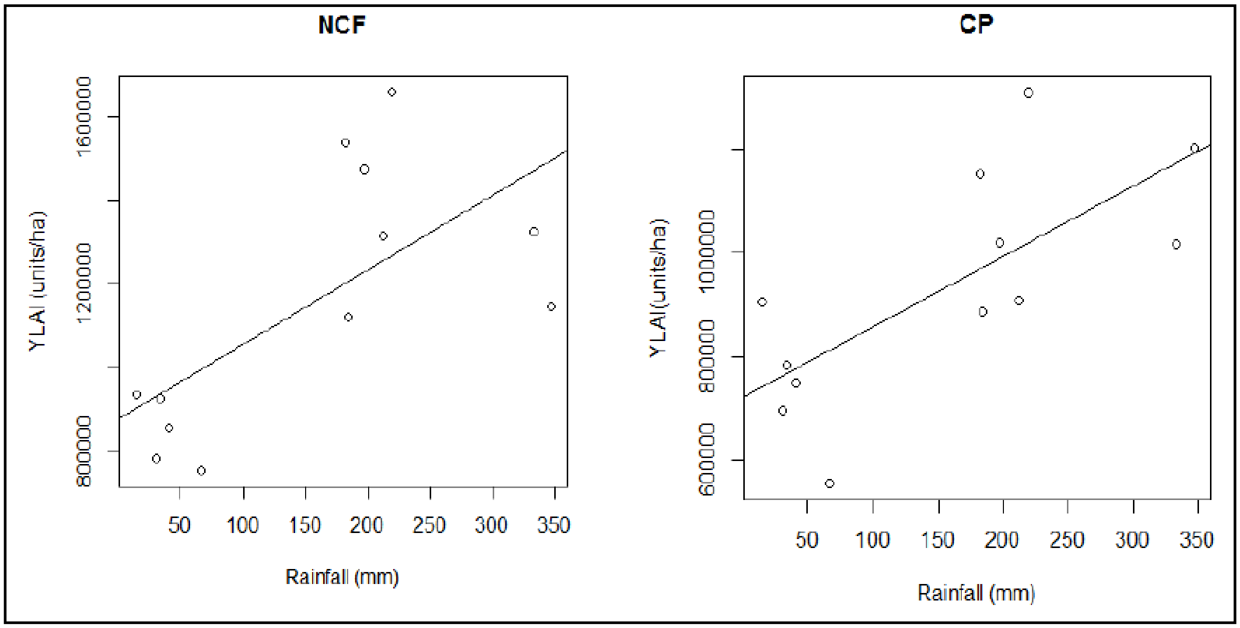


Figure 10. Correlation graph of rainfall with young leaf availability indices (YLAI) in home ranges of both groups.

Moreover, in home ranges of both groups, young leaves availability across moths did not differ significantly from a uniform distribution (one-sample Kolmogorov-Smirnov test, NCF: D = 0.18, P = 0.79; CP: D = 0.13, P = 0.98; Fig. 11). During the 12-month study period, the availability of young leaves was not significantly higher in NCF than in CP (Wilcoxon rank sum test, W = 103, P = 0.078; Fig. 11).

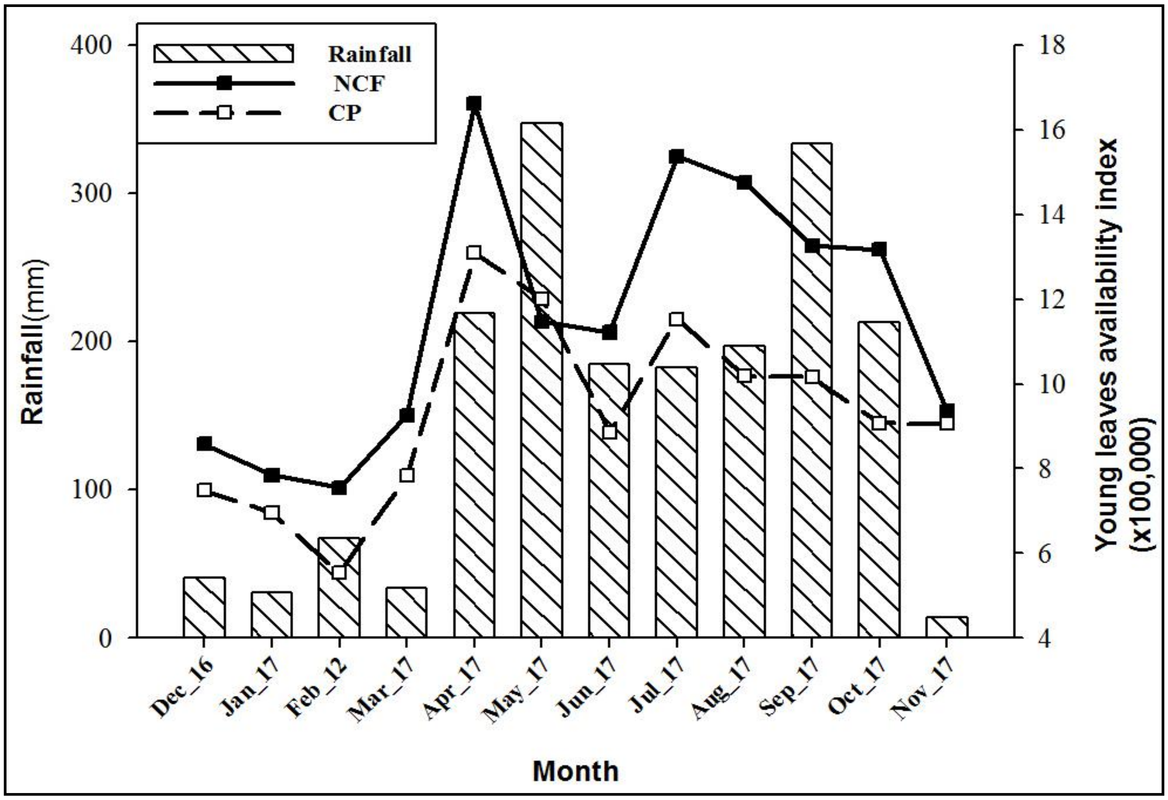


Figure 11. Temporal distribution of rainfall and forest young leaf availability in the home range of two groups.

Ripen fruit availability in the home ranges of two groups was not significantly correlated with rainfall (NCF: $r_{s} =$ -0.34, P = 0.29; CP: r_s = -0.33, P = 0.3). Moreover, the availability of ripen fruit did not show significant variation from uniform distribution across months in home ranges of both groups (one sample Kolmogorov-Smirnov test, NCF: D = 0.19, P = 0.72; CP: D = 0.1, P = 0.75; Fig. 12).

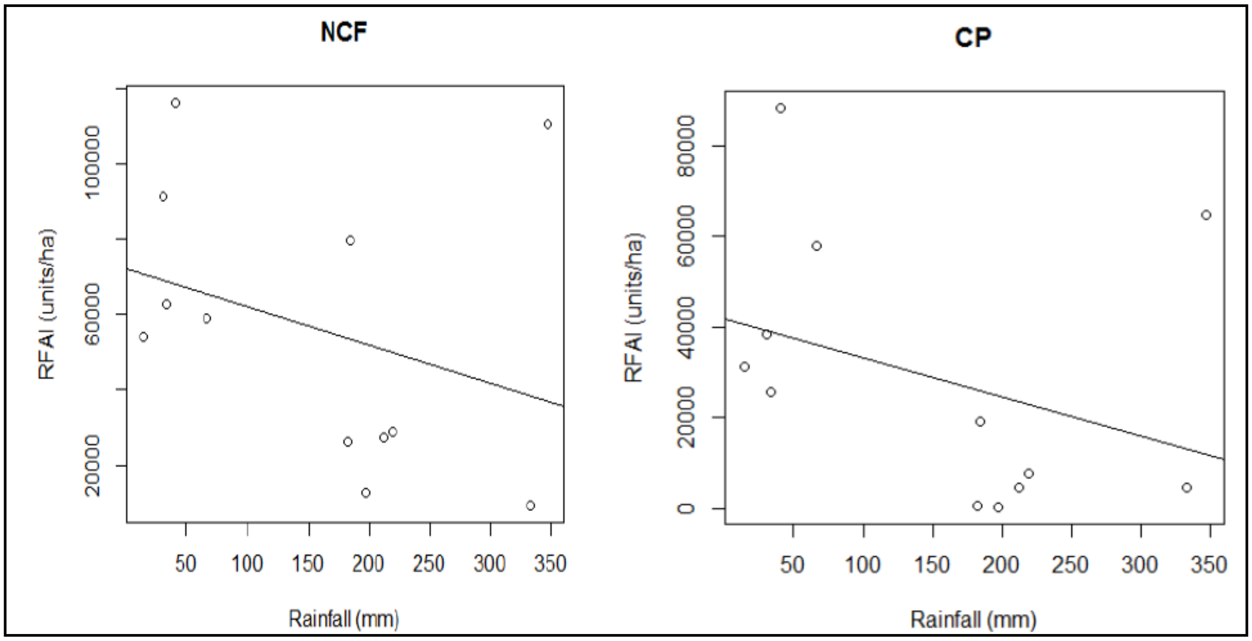


Figure 12. Correlation graph of rainfall with ripen fruit availability indices (RFAI) in the home ranges of both groups.

Figure 13 shows the monthly patterns of ripen fruits availability within home ranges of the two study groups in association with the rainfall. During of 12 months of the study period, the availability of ripen fruits significantly varied between the home ranges of the two groups (Wilcoxon S.R. W = 107, P = 0.045); NCF-group having significantly higher ripen fruit availability per hectare than CP-group.

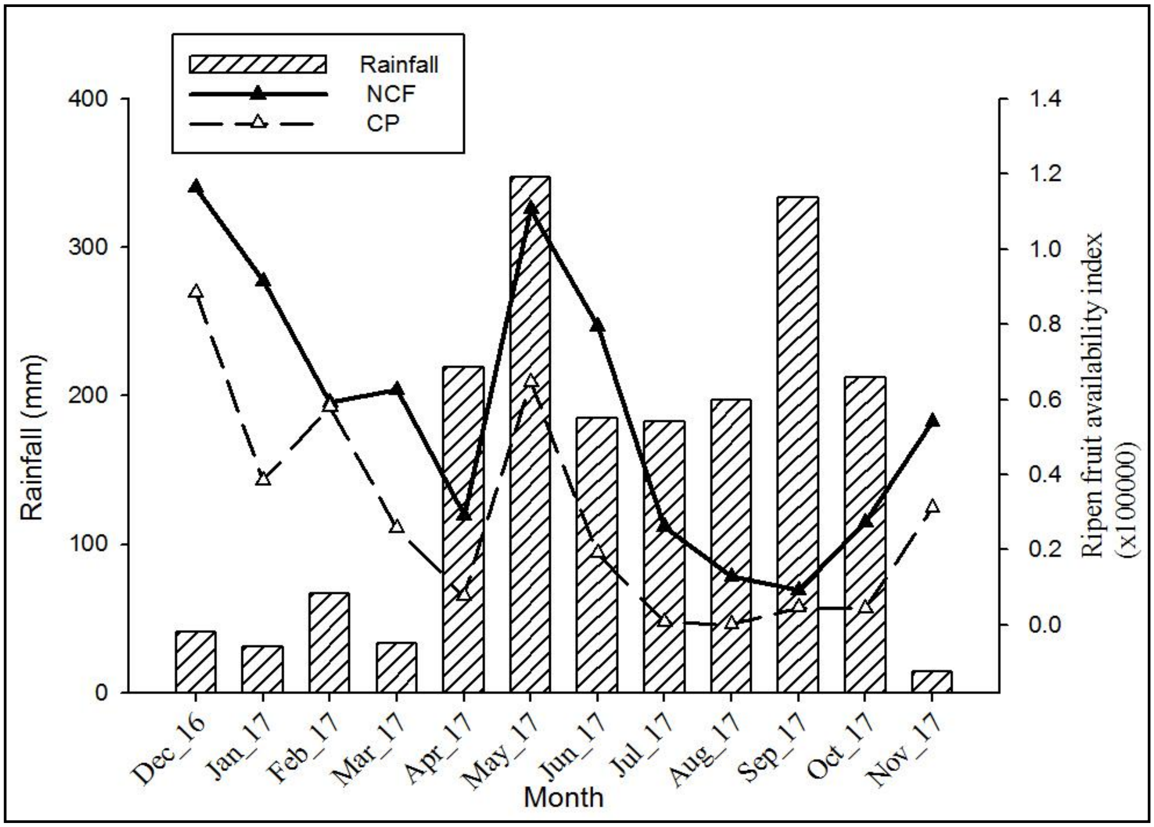


Figure 13. Temporal distribution of rainfall and forest ripen fruit availability in home ranges of both groups.

Unripe fruits and flower availability did not show significant correlation with rainfall in home ranges of both study groups (NCF: r_s = -0.16, P = 0.62; CP: r_s = -0.21, P = 0.51 and NCF: r_s = 0.07, P = 0.83.; CP: r_s = 0.02, P = 0.96, respectively; Fig. 14). Moreover, the availability of unripe fruit did not show significant variation from uniform distribution across months in NCF and CP habitat group (one-sample Kolmogorov-Smirnov test, D = 0.23, P = 0.46 and D = 0.23, P = 0.57, respectively; Fig. 15). On the contrary, flower availability across months showed a significant variations from uniform distribution in the home ranges of both groups (one-sample Kolmogorov-Smirnov test, NCF: D = 0.28, P = 0.27; CP: D = 0.28 P = 0.24; Fig. 15).

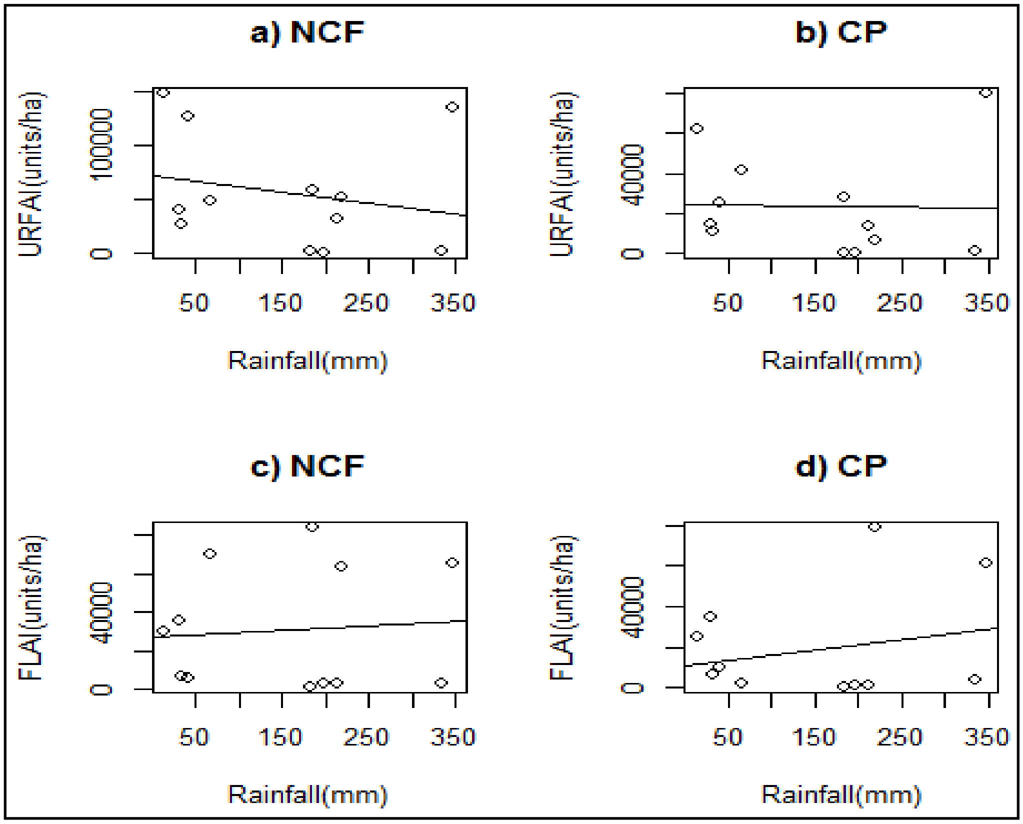


Figure 14. Correlation graph of rainfall with unripen fruit availability indices (URFAI) and flower availability indices (FLAI) in the home ranges of both groups.

Figure 15 shows the association of rainfall with the monthly patterns of unripe fruit (a) and flower (b) in home ranges of the study groups. During 12 months of the study period, there was no significant variation in unripe fruit and flower availability between the home ranges of the two groups (unripe fruit: Wilcoxon S.R. W = 100, P = 0.11; flower: Wilcoxon S.R.W = 96, P = 0.18).

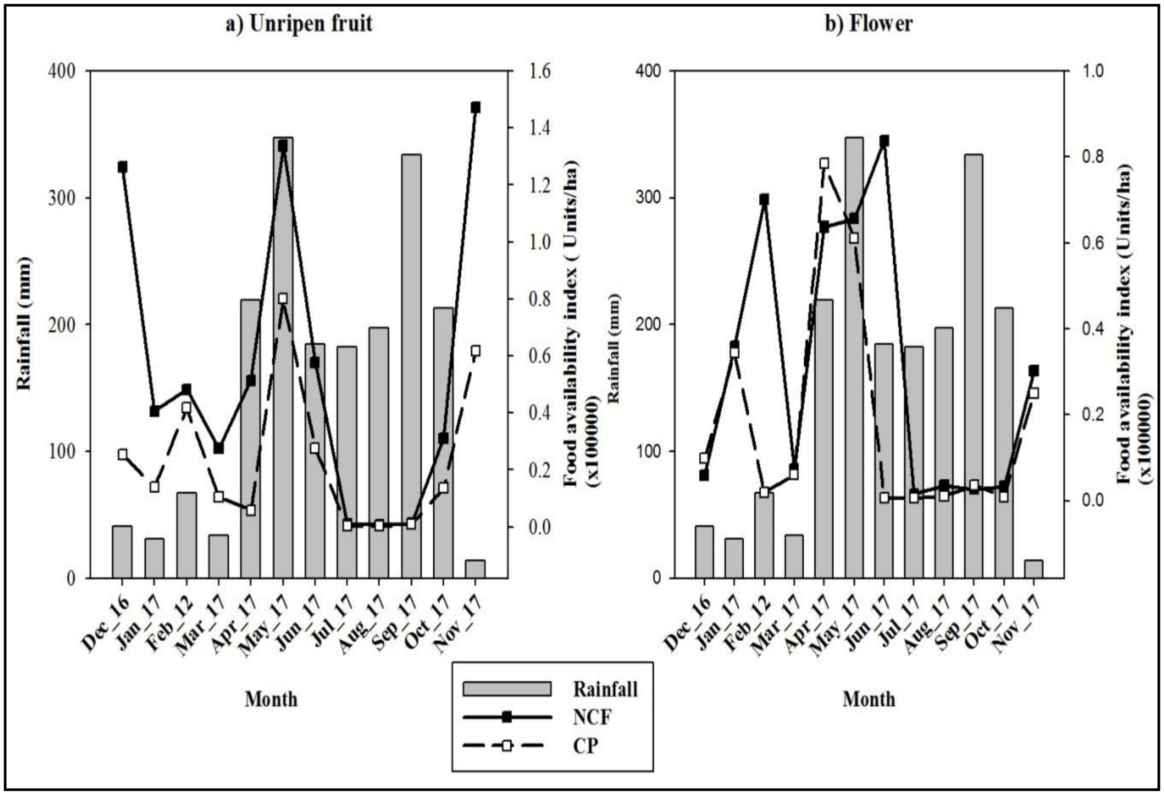


Figure 15. Temporal distribution of rainfall and forest (a) unripen fruit and (b) flower availability in the home ranges of two groups.

Linear regression analysis of unripe fruit availability with flower availability in NCF and CP indicated that, during the study period, there was no significant relationship between unripe fruit and flower availability in the home ranges of both groups (NCF: $R^2 = 0.13$, $P = 0.26$; CP: $R^2 = 0.12$, $P = 0.28$; Fig. 16).

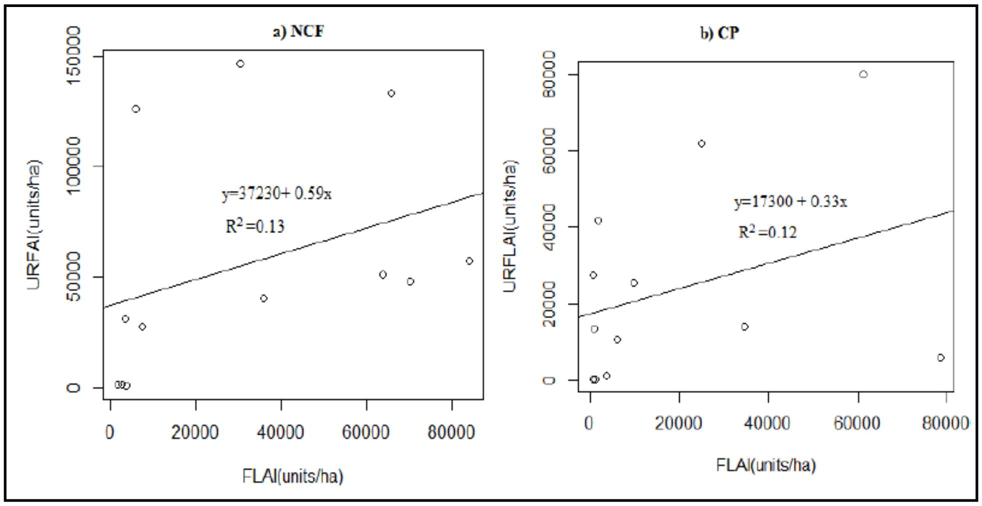


Figure 16. The linear regression analysis of unripen fruit availability with flower availability in NCF (a) and CP (b).

The overall annual ripen and unripe fruits availability per hectare was two times higher in home range of NCF-group than in CP-group. However, young leaves and flowers availability did not show variations in the home ranges of both groups. The annual plant parts food availability in the home ranges of both groups was depicted in figure 17.

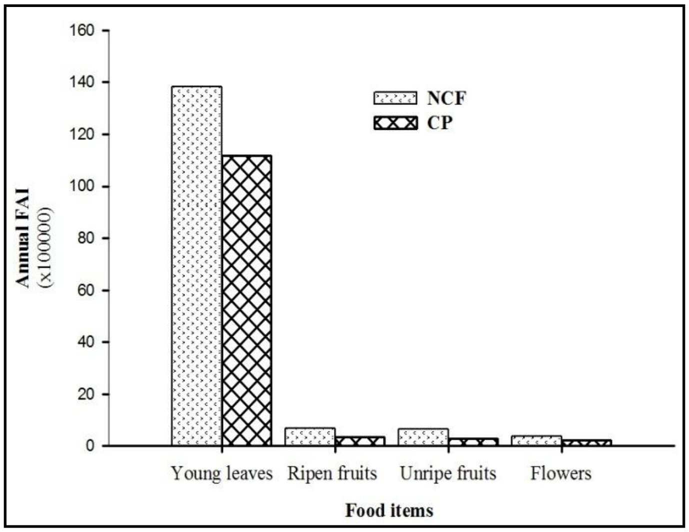


Figure 17. Comparison of annual food availability index (FAI) values of plant food items in the home ranges of natural coffee forest and coffee plantation groups.

5.3. Diurnal activity patterns

A total of 17634 individual behavioural observations were recorded from 4816 group scans during 15 consecutive months of the study period in 114 total observation days. From the total behavioural activity records, 9305 were collected from NCF-group, whereas 8329 were obtained from CP-group. Boutourlini's blue monkeys spent the largest proportion of their time resting, followed by feeding in both study groups. Consequently, on average, NCF-group spent 35.2% (21.5–52.78%) of their time resting followed by 33.42% (22.47–33.47%) (Fig. 18). Similarly, CP-group spent 37.34% (21.51–53.45%) of their time resting followed by 30.24% (20.33–41.44%) feeding (Fig. 18).

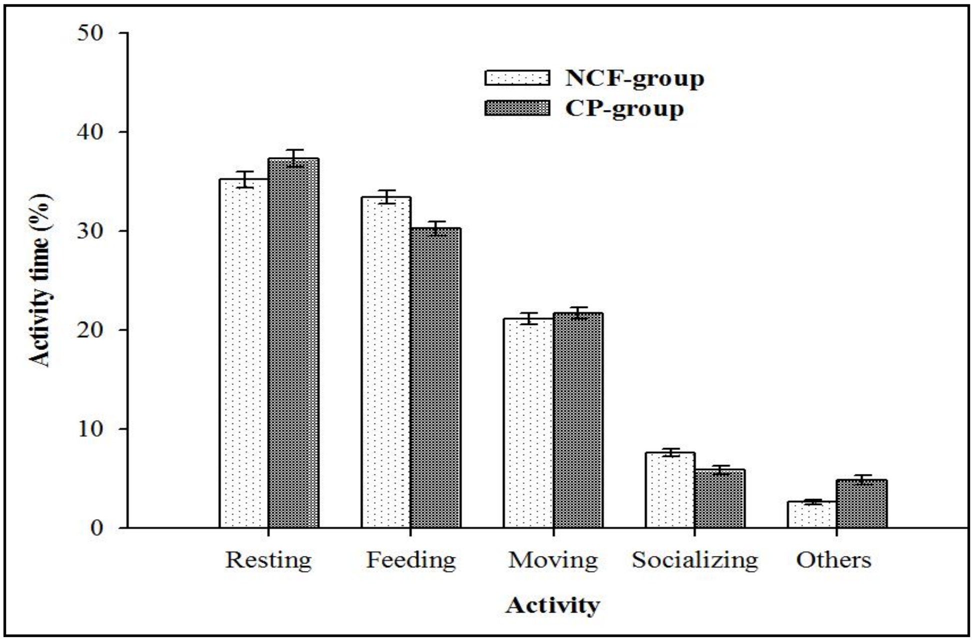


Figure 18. Activity time budget (mean ± SE) of Boutourlini's blue monkey in home ranges of both groups.

During the study period, in the NCF-group, significant difference was observed among mean percentage time spent for different behavioural activities (Kruskal-Wallis χ^2 = 64.97, df = 4, P = 0.00) and mean separation Dunn Test for multiple mean comparison with Bonferroni correction showed that there was no significant variation between mean percentage time spent for resting and feeding, (P = 0.89) and between socializing and other activities (P = 0.058) (Fig. 19). Similarly in CP-group, significant difference was observed among mean percentage time spent for different activities (Kruskal-Wallis χ^2 = 59.52, df = 4, P = 0.00). But the variations were not significant between mean percentage time spent for resting and feeding (P = 0.35), feeding and moving (P = 0.13) and socializing and other behavioural activities (P = 0.59) (Dunn Test) (Fig. 19).

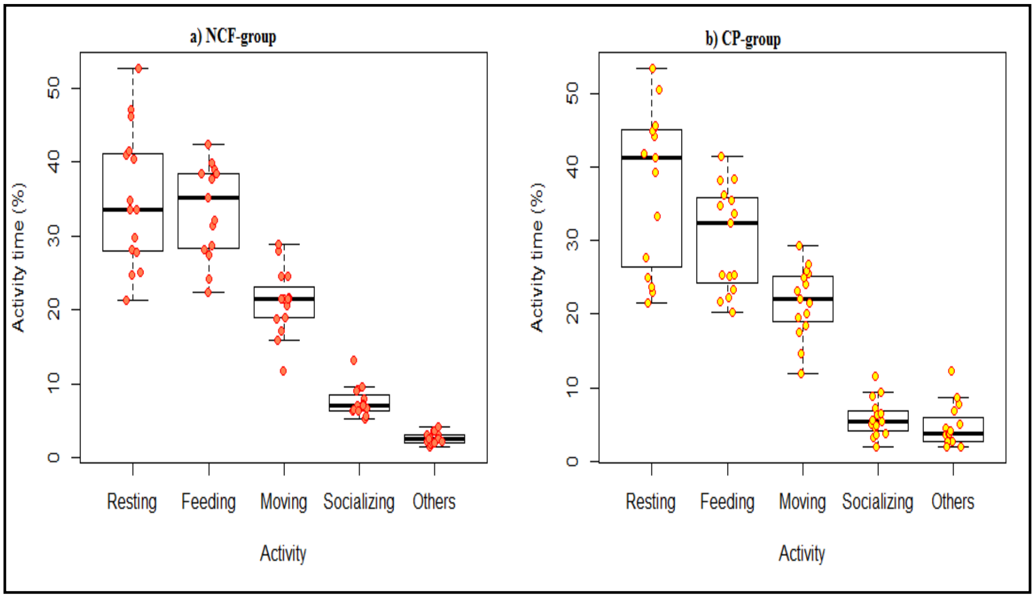


Figure 19. Box plot of the mean activity time budget of NCF-group (a) and CP-group (b).

There were no significant differences in mean percent time spent in the different activities between the two groups (ANOVA: df = 1, P > 0.05, Fig. 20). In contrast to what was predicted, the CP-group did not spend a significantly greater proportion of time feeding (30.24 v 33.4%;

ANOVA: F =1.71, df = 1, P = 0.20), and moving (21.71 v 21.15%; ANOVA: F = 0.11, df = 1, P = 0.74), less time resting (37.34 v 35.2%; ANOVA: F = 0.34, P = 0.56) than NCF-group (Fig. 20). Conversely in NCF-group, mean percent time socializing was significantly greater (7.61 v 5.86%; Kurskal-Walis χ^2 = 5.49; df = 1, P = 0.02) and other activities were significantly less (2.63 v 4.84%; Kurskal-Walis χ^2 = 7.84, df = 1, P = 0.00) than in CP-group (Fig. 20).

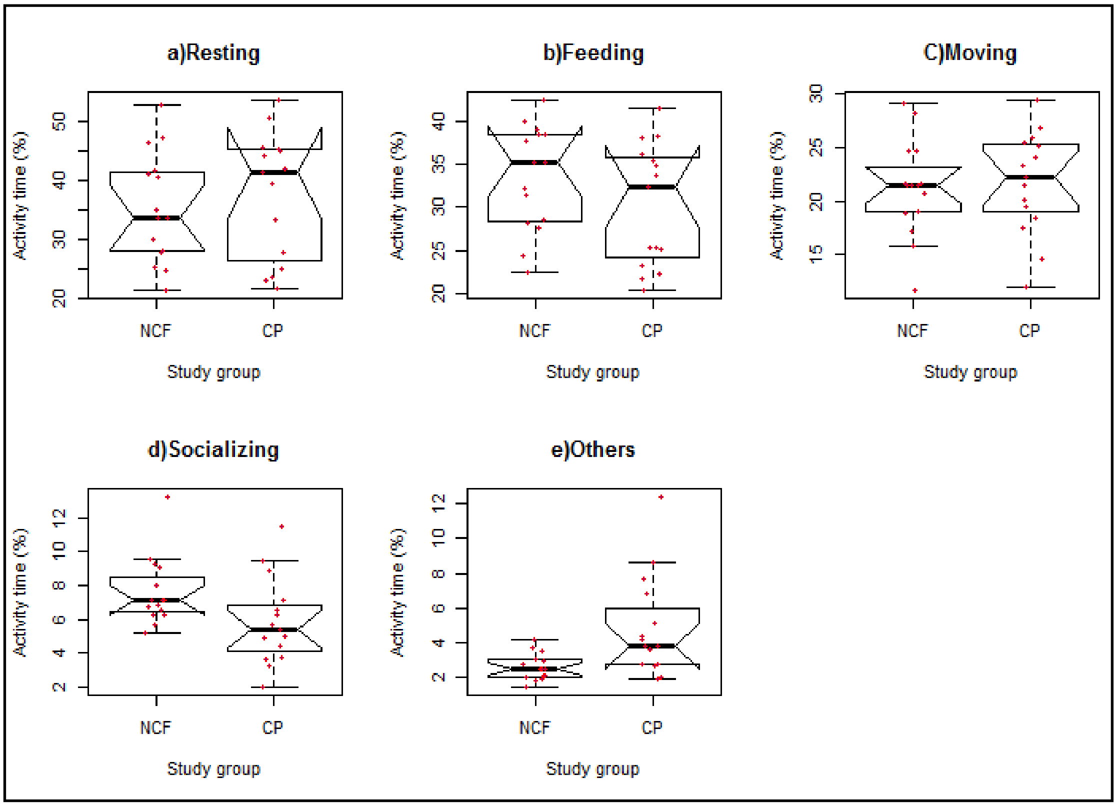


Figure 20. Box-and-whisker plots with notches comparing the mean activity time budget of NCF and CP groups.

In both NCF and CP groups, the proportion of monthly activity time budget varied for each activity. In NCF-group, the proportion of time budget for resting was the highest of all activities, ranging from 21.25% in September to 52.78% in March. Time proportion spent in feeding was the second and ranged from 22.47% in April to 42.45% in November 2017, followed by moving which ranged from 11.69% in November, 2016 to 28.98% in September, 2017. Monthly proportion of time spent in socializing ranged from 6.27% in November to 13.22% in December. Other activities such as drinking, vocalization and defecation took the lowest proportion of time in all months during the study period which ranged from 1.45% to 4.19% (Fig. 21).

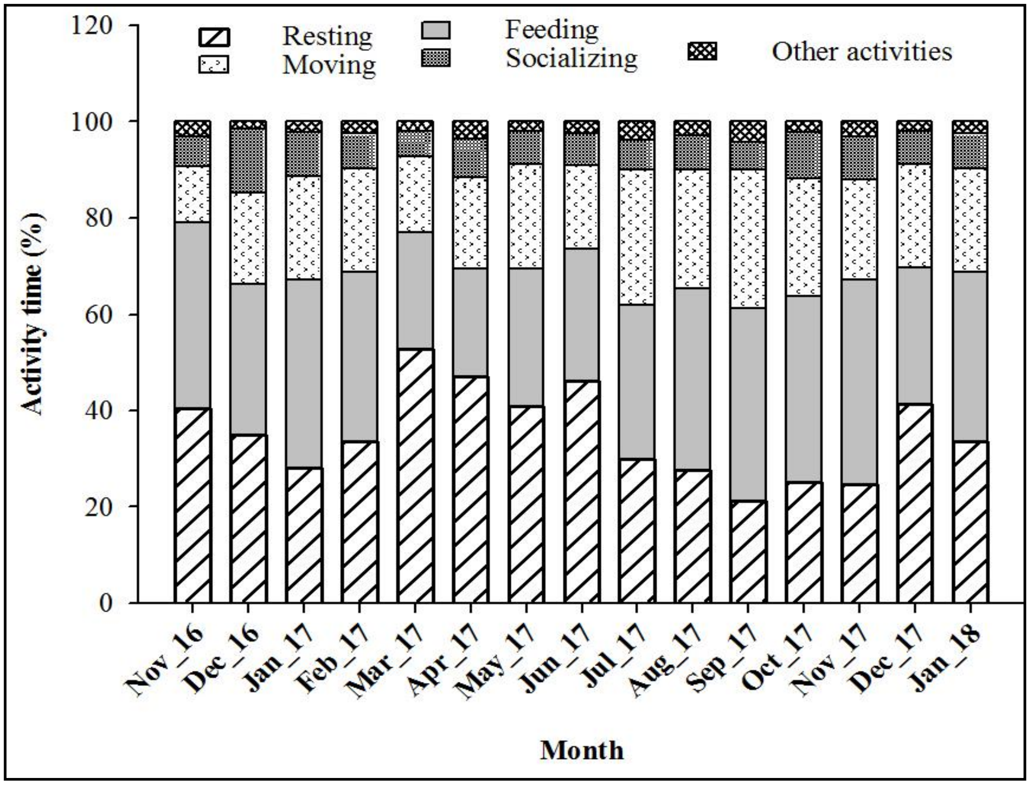


Figure 21. Monthly percentage proportion of time budget of NCF-group during the study period.

Similarly, in CP-group, monthly proportion of time budget spent in resting was the highest ranging from 21.51% in November to 53.45% in March, followed by feeding ranging from 21.63% in December to 41.44% in January. Other behavioural activities took the lowest proportion of time ranging from 1.95% in December to 12.38% in June (Fig. 22)

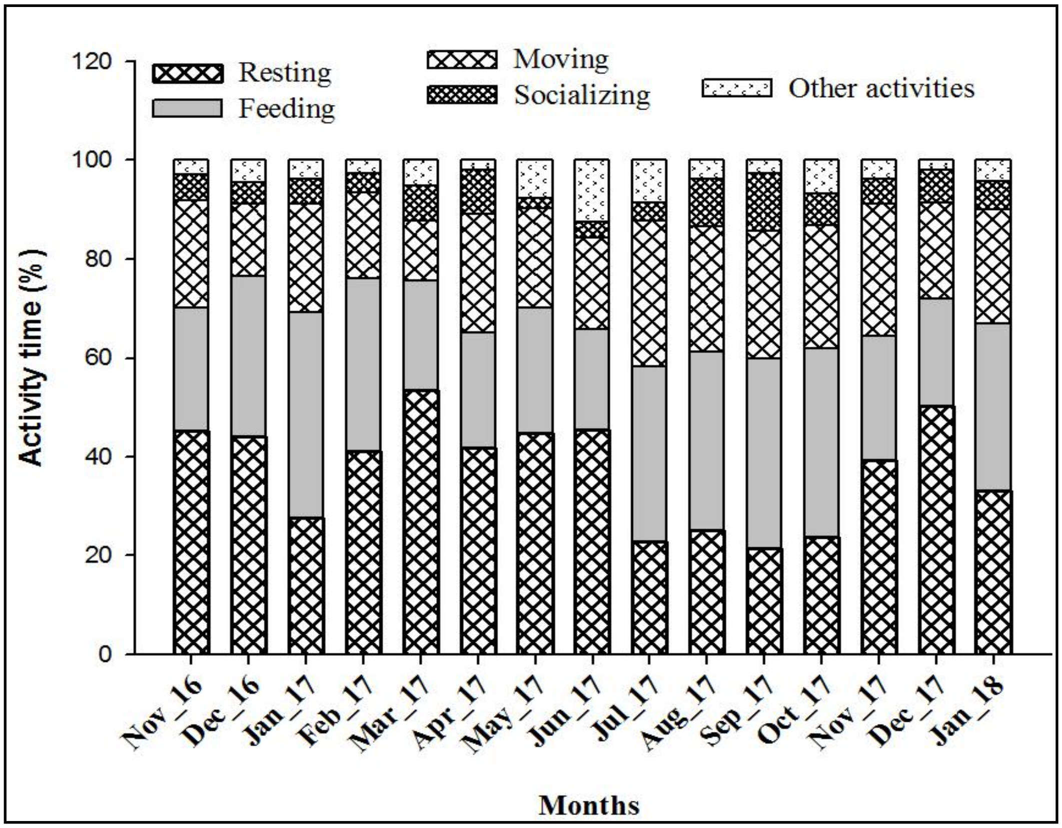


Figure 22. Monthly percentage proportion of time budget of CP-group during the study period.

Activity patterns of both study groups showed more or less similar properties in fluctuation. In NCF-group, the proportion of time budge spent in resting reached its highest peak during February 2017 and continuously declined and reached its lowest point in September. Monthly time proportion of feeding oscillated in the reverse direction of resting and reached its highest peak in November and lowest point on April. Proportion of time spent in moving oscillated in the same direction of feeding and had the highest peak and lowest point in September and November, respectively. Continuous and constant patterns of socializing and other activities were observed with slight variation across months (Fig. 23a). In CP-group, resting had highest peak in March and gradually declined the lowest point in September and rose up to the second peak in December. Feeding fluctuated in the opposite direction to resting and the same direction to moving. Socializing and other activities continuously fluctuated with slight variation across months (Fig. 23b).

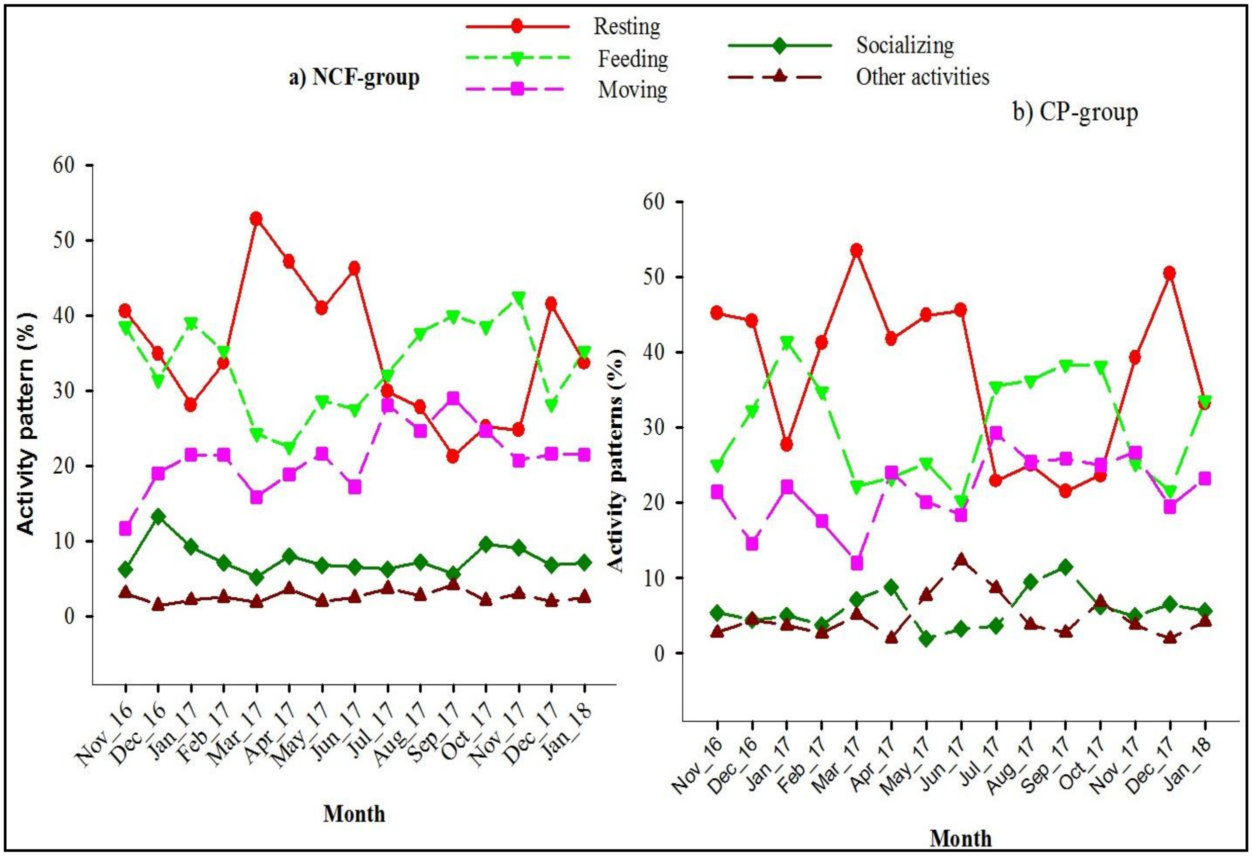


Figure 23. Monthly activity patterns of NCF-group (a) and CP-group (b).

Resting was the most important diurnal activity, followed by feeding in the home ranges of both study groups (Fig. 23). In NCF-group, there was significant relationship between time allocated to resting and feeding and time block of the day. However, time allocated for moving, socializing and other behavioural activities did not show significant relationship with time block of the day (Table 5). Resting activity varied among daylight hours and was higher at noon (B_3 = 11:30–13:30 h; 48.03 ±1%) and in the afternoon (B_4 = 13:45–15:45 h; 40 ± 0.99%) hours than during evening (B_5 =16:00–18:00; 25.1 ± 0.88%) and morning (B_1 = 07:00–09:00 h; 33.3 ± 0.67%).

Thus, using Dunn Test, significant difference was observed in B_5 compared to B_3 (P = 0.00) and B_4 (P = 0.02). However, B_1 did not show significant difference compared to B_3 (P = 0.13) and B_4 (P=0.26). The peaks in feeding were recorded in the morning (B_1 = 07:00–09:00 h; 36.3 ± 0.55%) and late afternoon (B_5 = 16:00–18:00 h; 43.6 ± 0.62%) than during the mid-day (B_3 = 11:30–13:30 h; 22.3 ± 0.8%, Table 5). Therefore, B_5 showed a significant difference compared to B_2 (P = 0.015), B_3 (P = 0.00) and B_4 (P = 0.0038). Similarly, time allocated for feeding in B_1 was statistically different from B_3 (P = 0.007).

Table 5. Percentage of time spent (mean ± SE) on different activities by NCF-group in relation to time of the day (χ^2 = Kruskal-Wallis chi-squared value; P = p-value).

Activities	**Time bocks of the day, h**						
	B_1	**B_2**	**B_3**	**B_4**	**B_5**	**χ^2**	**P**
Resting	33.3 ± 0.67	38 ± 0.91	48.03 ± 1	40 ± 0.99	25.1 ± 0.88	21.23	0.00*
Feeding	36.3 ± 0.55	31.9 ± 0.75	22.3 ± 0.8	30.7 ± 0.88	43.6 ± 0.62	32.52	0.00*
Moving	19.9 ± 0.58	20.2 ± 0.67	19.3 ± 0.65	19.6 ± 0.71	23.4 ± 0.65	3.1	0.55
Socializing	5.5 ± 0.54	6.6 ± 0.43	7.3 ± 0.45	5.9 ± 0.43	5.4 ± 0.44	5.1	0.28
Others	5.1 ± 0.46	3.4 ± 0.34	3.1 ± 0.34	3.7 ± 0.41	2.6 ± 0.36	12.45	0.17

*Differ significantly (Kruskal–Wallis test χ^2, P<0.05) among time blocks (B_1=07:00–09:00 h, B_2= 09:15–11:15 h, B_3= 11:30–13:30 h, B_4= 13:45–15:45 h, B_5=16:00–18:00 h).

Similarly in CP-group, significant difference was observed between time allocated for resting and feeding across time blocks of the day (Table 6). Mean percentage of time allocated to rest was higher during the mid-day (B_3 = 11:30–13:30, 47.17 ± 1.10%) than during late afternoon (B_5 = 16:00–18:00, 26.76 ± 0.78%). Thus, there was a significant difference between B_5 and B_3 (P =

0.004). However, significant difference was not observed between the times allocated for resting with the remaining time blocks of the day. Feeding was the second most important activity which varied across time block of the day. It was higher in the morning (B_1 = 07:00–09:00 h, 37.45 ± 0.75%) and late afternoon (B_5 = 16:00–18:00 h, 40.99 ± 0.70%) than during mid-day (B_3 = 11:30–13:30 h, 20.37 ± 0.86%). Consequently, significant difference was observed in B_5 compared to B_3 ($P = 0.00$) and B_4 ($P = 0.014$). In addition, there was significant difference between B_1 and B_3 ($P = 0.03$). Conversely, time allocated for moving, socializing and other behavioural activities during the study period did not show significant variation across time blocks of the day (Table 6).

Table 6. Percentage time spent (mean ± SE) on different activities by CP-group in relation to time blocks of the day (χ^2 = Kruskal-Wallis chi-squared value; P = p-value).

Activities	**Time blocks of the day, h**						
	B_1	**B_2**	**B_3**	**B_4**	**B_5**	**χ^2**	**P**
Resting	36.03±0.71	37.16±0.91	47.17±1.10	39.54±0.98	26.76± 0.78	13.3	0.01*
Feeding	37.45±0.75	29.99±0.82	20.37±0.86	27.41±0.93	40.99±0.70	24.4	0.00*
Moving	18.34±0.51	22.76±0.66	21.42±0.67	21.81±0.64	24.50± 0.71	7.27	0.12
Socializing	5.95±0.60	5.16±0.46	6.38 ± 0.48	6.65±0.50	4.09± 0.45	5.64	0.23
Others	4.92±0.47	4.94±0.47	4.68±0.44	4.60±0.55	3.67±0.56	4.61	0.33

*Differ significantly (Kruskal–Wallis test χ^2, $P < 0.05$) among time blocks (B_1= 07:00–09:00 h, B_2 = 09:15–11:15 h, B_3= 11:30–13:30 h, B_4 = 13:45–15:45 h, B_5 = 16:00–18:00 h).

Patterns of activity time budget between NCF and CP groups did not show significant variation in major behavioural categories along time block of the day. The trend of resting pattern between NCF-group and CP-group is presented in figure 24. In both study groups, time spent for resting was low in the morning and showed an increasing trend reaching its peak at noon when the temperature is maximum and then gradually decreased until late afternoon .

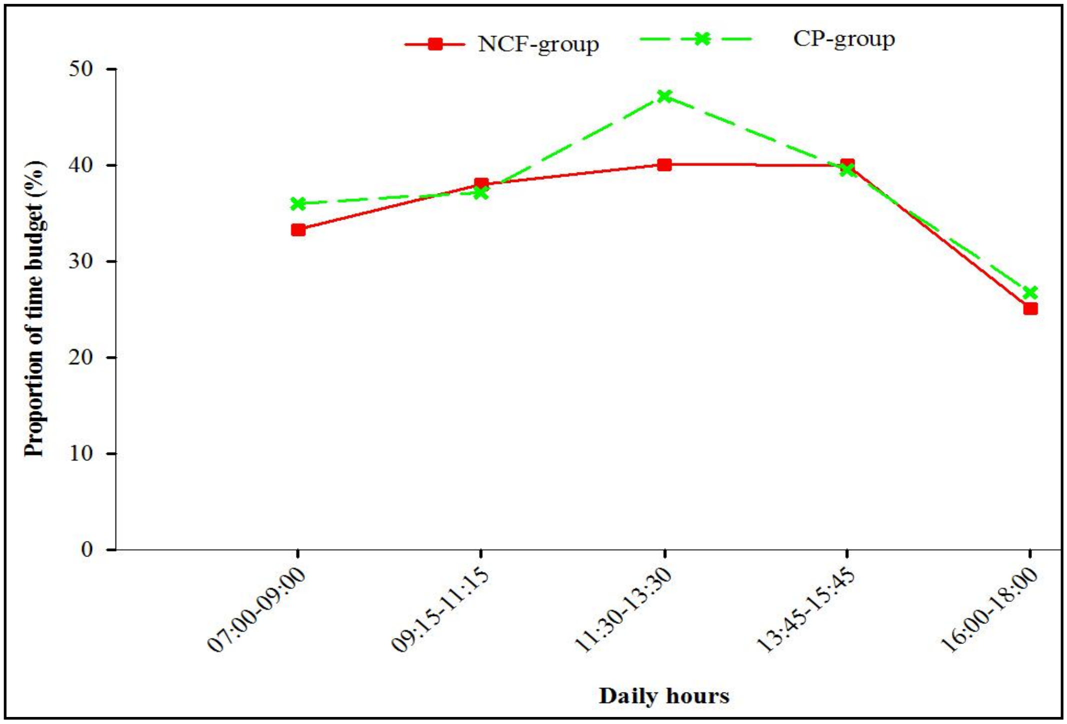


Figure 24. The distribution of resting activity pattern over the daylight hours between NCF and CP groups.

Comparison of feeding and moving activity patterns between NCF and CP groups are depicted in figures 25 and 26. Both groups tended to start feeding activity earlier in the morning and declined progressively until mid-day, of which the lowest peak was recorded. However, following mid-day, feeding activity increased progressively and reached its highest peak during late afternoon. Whereas, the activity pattern of moving for both groups seemed linear throughout the day except for some slight variation during early in the morning recording the lowest peak.

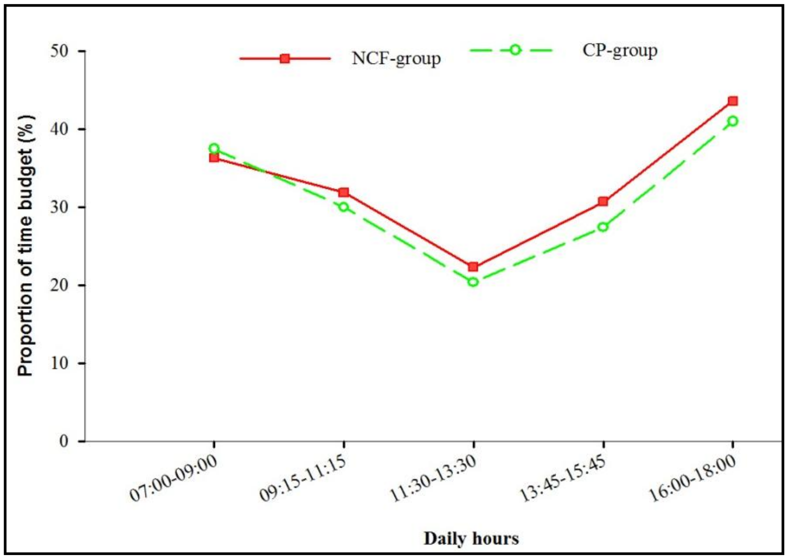


Figure 25. Distribution of feeding activity pattern over the daylight hours between NCF-group and CP-group.

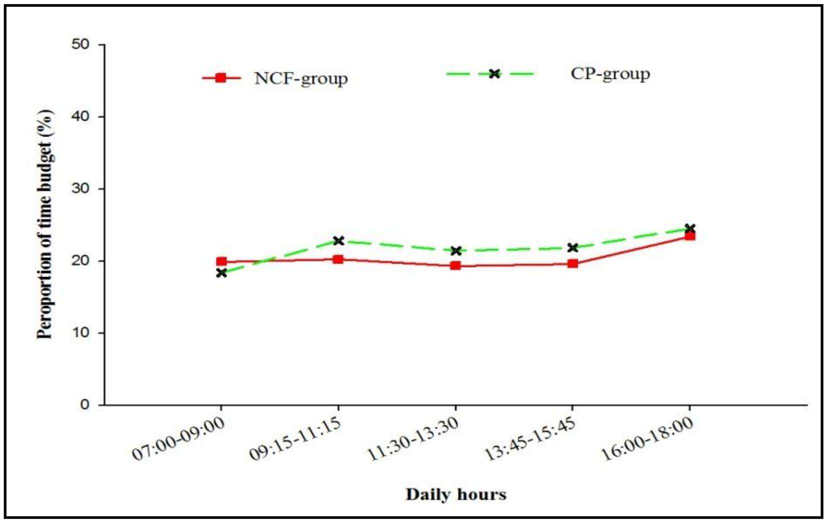


Figure 26. Distribution of moving activity pattern over the daylight hours between NCF and CP groups.

Time budgets in age-sex categories**:** This study compared the activity time budgets between members of different age-sex categories of both study groups. Adult females spent slightly more time resting (37.72%) than adult males (33.61%) in NCF-group, while adult females spent more or less equal time resting (36.95%) with adult males (37.2%) in CP-group. Juveniles spent the highest proportion of time resting in both NCF-group (47.59 %) and CP-group (42.49 %). Sub-adult females spent slightly more time resting (36.32 %) than sub-adult males (32.34%) did in NCF-group, whereas sub-adult males spent slightly more time resting (35.59%) than sub-adult females (33.42%) did in CP-group. In both groups, during the study period, feeding was the second common activity scanned in all age-sex categories. Adult females spent almost equal proportion of time feeding (35.88%) with adult males (36.53%) in NCF-group, while adult females spent slightly less time (31.93%) than adult male (33.21%) in CP-group. Juveniles spent the least proportion of time in feeding than other age-sex categories in both NCF (17.66%) and CP (15.67%) groups. In NCF-group, moving was recorded the highest (23.15%) in adult males and the lowest (20.39%) in adult females whereas in CP-group, the highest was recorded in juveniles and sub-adult females (23.8%) and the lowest was in adult female (21.2%). In NCF-group, socializing was recorded the highest (8.55%) time budget in sub-adult males, followed by sub-adult females (7.5%). Conversely, in CP-group, the highest proportion of time budget (8.26%) was recorded in juveniles, followed sub-adult males (6.57%) (Fig. 27). However, in NCF-group the difference was not significant for all activities (except feeding) in each age-sex category; resting (ANOVA: F = 1.97, df = 4, P = 0.1), moving (Kruskal-Wallis χ^2 = 1.67, df = 4, P = 0.8), socializing (Kruskal-Wallis χ^2 = 8.6, df = 4, P = 0.07) and other activity (Kruskal-Wallis χ^2 = 8.6, df = 4, P = 0.07). Conversely, significant difference was observed in feeding across all age-sex categories (Kruskal-Wallis χ^2 = 17.94, df = 4, P = 0.001). Consequently, juveniles showed a significant difference with adult females (P = 0.01), adult males (P = 0.00) and sub-adult females (P = 0.02). Similarly, CP-group did not show significant difference for all activities (except feeding) in each age-sex category in resting (ANOVA: F =1.16, df = 4, P = 0.34), moving (Kruskal-Wallis χ^2 = 2.71, df = 4, P = 0.61), socializing (Kruskal-Wallis χ^2 = 7.91, df = 4, P = 0.095) and other activity (Kruskal-Wallis χ^2 = 5.51, df = 4, P= 0.24). Whereas, juveniles spent significantly less proportion of time in feeding with adult females, adult males, sub-adult females (P = 0.00) and sub-adult males (P = 0.01)

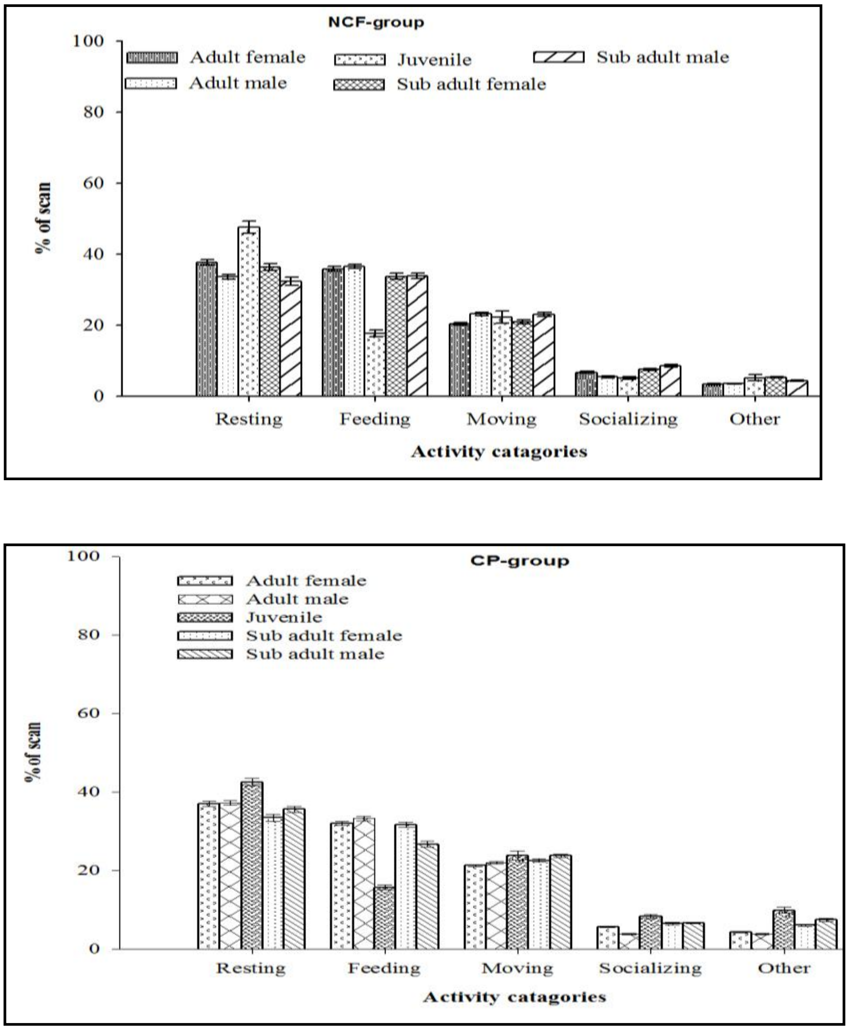


Figure 27. Differences between age-sex classes in time spent on different activities within NCF and CP groups.

Seasonal variation on activity time budgets: One-way MANOVA was conducted to determine the effect of season on the overall five behavioural activity time budgets. The analysis indicated that season had no significant effect on the overall activity time budgets in Hamuma Coffee Forest.

Seasonal changes in the environment had no major influence on the activity time budgets of Boutourlini's blue monkeys. Consequently in NCF-group, the result of multivariate analysis showed that season had no significant effect on activity time budget, [Wilks' $\lambda = 0.052$, $F_{[4, 10]} = 3.43$, $p > 0.05$, partial $\eta 2 = .58$]. Similarly in CP-group, there was no significant difference on the overall activity time budgets during dry and wet seasons, [Wilks' $\lambda = 0.5$, $F_{[4, 10]} = 2.46$, $p > 0.05$, partial $\eta 2 = .50$]. This low effect size (partial $\eta 2$] implies, season had no strong effect on changes in the activity time budget of different behaviours between wet and dry seasons. Thus, activity time budgets of blue monkeys in Hamuma Coffee Forest are not influenced by season.

Comparing the mean percentage time spent in the different activities between two groups, significant difference was not observed during the dry season (Kruskal-Wallis $\chi^2 = 0.003$, df = 1, P = 0.96). Similarly, mean percentage time spent in the different activities between two groups was insignificant during the wet season (Kruskal-Wallis $\chi^2 = 0.0002$, df = 1, P = 0.99). Thus, there was no seasonal difference in mean percentage time spent in different activities of Boutourlini’s blue monkeys in Hamuma Coffee Forest.

5.4. Feeding ecology of Boutourlini's blue monkeys

***Dietary species richness, diversity and similarity*:** A total of 5,676 individuals feeding scans were collected during the study period. Of these, 3089 scans (monthly mean ± SD scans = 205.9 ± 51.1) were recorded from NCF-group and 2587 (monthly mean ± SD scans = 172.5 ± 72.2) from CP-group. About 37 plant species (trees, shrubs, linas/climbers) belonging to 34 genera and 27 families were identified as food for Boutourlini's blue monkeys (Table 7). They also consumed lichen and many unidentified species of insects. Dietary species richness was a bit less than in NCF-group (28 species) than CP-group (32 species).

The mean monthly Shannon–Wiener diversity index (H′) of food species did not show significant difference between NCF (mean ± SD = 2.00 ± 0.26) and CP groups (mean ± SD = 2.20 ± 0.37) (ANOVA: F = 2.12, df = 1, P > 0.05; Fig. 28a). Similarly, mean monthly dietary species evenness (*J*) was not significantly different between groups inhabiting NCF (mean ± SD = 0.51 ± 0.12) and those in CP (mean ± SD = 0.56 ± 0.10) (GLM: F = 2.1, df = 1, P = 0.16; Fig. 28b). Moreover, mean monthly food plant species dominance (*D*) did not show significant difference for groups inhabiting NCF (mean ± SD = 0.20 ± 0.07) and CP (mean ± SD = 0.17 ± 0.08) (GLM: F = 0.98, df = 1, P = 0.33; Fig. 28c). The annual dietary species overlap between the groups inhabiting NCF and CP was S = 0.77 (23 of 37 species were shared).

Table 7. Overall percentage of feeding records on different food items from each plant species between the two groups of Boutourlini's blue monkeys during the study periods.

Family	Species consumed	Growth form	Percentage of feeding records for each food item						
			ML	YL	RF	UF	FL+ BU	AP	Total
NCF-group									
Fabaceae	*Albizia schimperiana*	Tree	0.74	12.05	–	–	–	–	12.79
Combretaceae	*Combretum paniculatum*	Climber		0.03	0.26	0.03	0.13	–	0.45
Fabaceae	*Millettia ferruginea*	Tree	0.74	2.88	0.10	0.29		–	4.01
Euphorbiaceae	*Croton macrostachyus*	Tree	2.55	7.40	0.87	5.33	0.19	–	16.35
Euphorbiaceae	*Sapium ellipticum*	Tree	0.55	2.33	0.03	–	–	–	2.91
Rubiaceae	*Coffee arabica*	Shrub	–	–	0.26	–	–	–	0.26
Moraceae	*Ficus thonningii*	Tree	0.19	1.58	0.65	3.52	–	–	5.95
Myrtaceae	*Syzygium guineense*	Tree	0.19	1.55	0.23	–	–	–	1.97
Apocynaceae	*Landolphia buchananii*	Climber	–	0.03	–	0.16	–	–	0.19
Araliaceae	*Schefflera volkensii*	Tree	0.23	0.71	–	–	–	–	0.94
Myrtaceae	*Psidium guajava*	Shrub	–	0.06	0.74	–	–	–	0.81
Podocarpaceae	*Podocarpus falcatus*	Tree	0.10	0.65	0.45	0.68	–	–	1.87
Sapotaceae	*Pouteria altissima*	Tree	0.06	0.45	0.03	0.10	–	–	0.65
Araliaceae	*Polyscias fulva*	Tree	0.06	0.19	–	0.03	–	–	0.29
Rhizophoraceae	*Cassipourea malosana*	Tree	–	0.16	–	–	–	–	0.23
Ebenaceae	*Diospyros abyssinica*	Tree	–	0.32	–	–	–	–	0.32
Euphorbiaceae	*Suregada procera*	Tree	–	0.19	–	–	–	–	0.19
Meliaceae	*Trichilia dregeana*	Tree	0.29	0.87	0.29	0.10	–	–	1.55
Asparagaceae	*Dracaena fragrans*	Shrub	0.10	0.23	–	–	–	–	0.32
Meliaceae	*Ekebergia capensis*	Tree	–	0.16	0.03	–	–	–	0.19
Moraceae	*Ficus sur*	Tree	–	0.19	7.59	0.68	–	–	8.47
Sapindaceae	*Allophylus abyssinicus*	Tree	–	0.06	0.10	–	–	–	0.16
Apocynaceae	*Carissa edulis*	Shrub	–	–	0.10	–	–	–	0.10
Boraginaceae	*Ehretia cymosa*	Tree	0.10	0.16	–	–	–	–	0.26

Table 7. (Continued)

Family	Percentage of feeding records for each food item								
	Species consumed	Growth form	ML	YL	RF	UF	FL + BU	AP	Total
Rosaceae	*Rosa abyssinica*	Shrub		–	0.16	–	–	–	0.16
Boraginaceae	*Cordia africana*	Tree	0.10	0.42	3.17	0.74	–	–	4.43
Moraceae	*Ficus vasta*	Tree	0.39	1.00	8.76	2.91	–	–	13.05
Oleaceae	*Olea africana*	Tree	–	0.19	–	–	–	–	0.19
	Lichen		_	0.29	_	_	_	–	0.29
	Insect		_	_	_	_	_	14.57	0.16
	Total		**6.40**	**34.18**	**23.81**	**20.65**	**0.39**	**14.57**	**100.00**
CP-group								–	
Fabaceae	*Albizia schimperiana*	Tree	0.70	11.58	1.05	–	–	–	13.32
Combretaceae	*Combretum paniculatum*	Tree	–	0.04	–	0.08	0.50	–	0.62
Fabaceae	*Millettia ferruginea*	Tree	0.54	3.99	0.08	–	–	–	4.61
Euphorbiaceae	*Croton macrostachyus*	Tree	2.83	5.77	1.78	3.95	0.08	–	14.40
Euphorbiaceae	*Sapium ellipticum*	Tree	0.62	3.41	0.23	–	–	–	4.26
Rubiaceae	*Coffea arabica*	Tree	–	–	0.50	–	–	–	0.50
Moraceae	*Ficus thonningii*	Tree	–	0.58	–	0.89	–	–	1.47
Myrtaceae	*Syzygium guineense*	Tree	0.08	1.20	1.08		–	–	2.36
Apocynaceae	*Landolphia buchananii*	Shrub	–	–	0.43	0.35	–	–	0.77
Araliaceae	*Schefflera volkensii*	Tree	0.27	–	1.01	–	0.31	–	1.59
Mimosaceae	*Acacia abyssinica*	Tree	0.04	0.15	–	–	–	–	0.19
Asteraceae	*Vernonia amygdalina*	Tree	0.12	–	–	–	–	–	0.12
Myrtaceae	*Psidium guajava*	Shrub	–	–	2.98	0.31	–	–	3.29
Flacourtiaceae	*Dovyalis abyssinica*	Shrub	–	–	0.16	–	–	–	0.15
Capparidaceae	*Capparis tomentosa*	Shrub	0.08	0.43	–	–	–	–	0.50
Anacardiaceae	*Rhus ruspolii*	Shrub	–	0.15	–	–	–	–	0.15
Podocarpaceae	*Podocarpus falcatus*	Tree	0.19	0.77	0.04	0.15	–	–	1.16

Table 7. Continued

Family	Percentage of feeding records for each food item								
	Species consumed	Growth form	ML	YL	RF	UF	FL + BU	AP	Total
Araliaceae	*Polyscias fulva*	Tree	0.46	0.58	–	–		–	1.05
Ranunculacea	*Clematis longicauda*	Shrub	–	–	0.12	–		–	0.12
Musaceae	*Ensete ventricosum*	Herb	–	0.19	0.23	–		–	0.43
Sapotaceae	*Pouteria altissima*	Tree	0.04	0.97	2.83	–	0.04	–	3.95
Asetraceae	*Echinops giganteus*	Shrub	–	–	–	–	0.12	–	0.12
Ebenaceae	*Diospyros abyssinica*	Tree	0.12	1.20	–	–	–	–	1.32
Meliaceae	*Trichilia dregeana*	Tree	0.19	1.36	1.66	–	–	–	3.37
Primulaceae	*Maesa lanceolata*	Shrub	–	0.04	0.27	–	–	–	0.31
Asparagaceae	*Dracaena fragrans*	Tree	0.08	0.04	–	–	–	–	0.12
Moraceae	*Ficus sycomorus*	Tree	–	–	0.85	–	–	–	0.85
Moraceae	*Ficus sur*	Tree	–	–	5.54	–	–	–	5.92
Boraginaceae	*Ehretia cymosa*	Tree	0.08	0.77		0.04	–	–	0.89
Flacourtiaceae	*Dovyalis abyssinica*	Shrub	–	–	0.08	0.04	–	–	0.12
Euphorbiaceae	*Cordia africana*	Tree	0.58	0.50	5.73	3.76	–	–	10.57
Moraceae	*Ficus vasta*	Tree	0.15	0.93	2.56	1.63	–	–	5.27
	Lichen		–	0.62	–	–	–	–	0.62
	Insect							15.52	15.52
Total			**7.05**	**35.27**	**29.31**	**11.81**	**1.05**	**15.52**	**100**

ML = Matured leaves, YL = Young leaves, RF= Ripen fruits, UR = Unripe fruits, Fl + BU = Flowers + Buds, AP = Animal products.

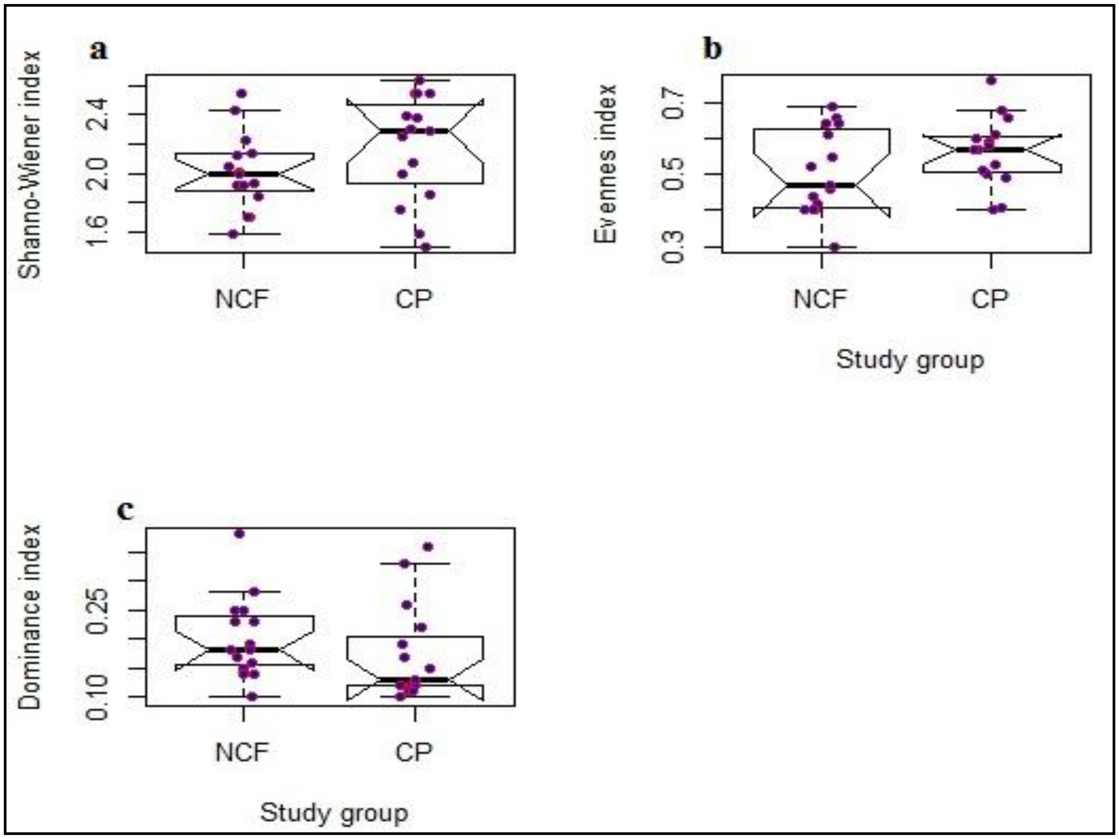


Figure 28. Box-and-whisker plots with notches showing dietary diversity (a), evenness (b) and dominance indices (c) between groups in natural coffee forest and coffee plantation.

The above box-and-whisker plots showed variations between groups in coffee plantation and natural coffee forest and **a** Shannon–Wiener dietary diversity index, **H′**, **b** dietary plant species evenness index, ***J*** and **c** dietary plant species dominance index. Dots represent the corresponding data set in each study group, the line in the box indicates the median of the corresponding index value, and the box shows the 25 and 75% inter-quartile. Vertical dotted lines represent the acceptable range with IQD (inter-quartile distance) multiplied by 1.5. Both groups did not show significant differences ($P > 0.05$).

Food items consumed**:** For both groups, young leaves made up the largest proportion and ripen fruits comprised the second largest proportion of the diet (Table 8). However, there was no significant difference between NCF and CP groups in mean proportion of feeding on young leaves (33.76% vs. 35.02%; ANOVA: F = 0.09; P = 0.76), ripen fruits (25.86% vs. 32.99%; ANOVA: F = 0.91; P = 0.35), animal products/insects (19.20% vs. 14.34%; ANOVA: F= 1.48; P =0.23), unripe fruits (14.69% vs. 10.34%; Kruskal-Wallis χ^2 = 0.69, df = 1, P = 0.41), matured leaves (5.62% vs. 6.62%; Kruskal-Wallis χ^2 = 0.03, df = 1, P = 0.86), flowers (0.55% vs. 0.35%; Kruskal-Wallis χ^2 =1.45, df = 1, P = 0.23) and buds (0.33% vs. 0.34%; Kruskal-Wallis χ^2 = 0.10, df = 1, P = 0.76; Table 8).

Table 8. Mean percentage contribution of each food item to total diet by groups during the study period.

Food Item	**NCF-group**		**CP-group**	
	%	**SE**	**%**	**SE**
Young leaves	33.76	0.93	35.02	0.79
Ripen fruits	25.86	1.19	32.99	1.44
Animal products	19.20	0.90	14.34	0.80
Unripe fruits	14.69	1.10	10.34	0.96
Matured leaves	5.62	0.70	6.62	0.81
Flowers	0.55	0.23	0.35	0.25
Buds	0.33	0.22	0.34	0.23

Total number of feeding records: NCF-group = 3095, CP-group = 2587.

As shown in figure 29 below, both groups showed variation on consuming different food items. In NCF-group, there was significant differences in mean proportion of all food items consumption (Kruskal-Wallis $\chi^2 = 69.20$, df = 6, $P = 0.00$). Mean proportion of feeding on young leaves and ripen fruits was significantly higher than, matured leaves, flowers and buds ($P < 0.05$). Feeding on animal products/insects and unripe fruits was also significantly higher than flowers and buds ($P < 0.05$). Similarly in CP-group, there was significant differences in mean proportion of all food items consumption (Kruskal-Wallis $\chi^2 = 71.07$, df = 6, $P = 0.00$). Therefore, mean proportion of feeding on young leaves and ripen fruits was significantly higher than matured leaves, flowers and buds ($P < 0.05$). Feeding on animal products/insects and unripe fruits was also significantly higher than flowers and buds ($P < 0.05$).

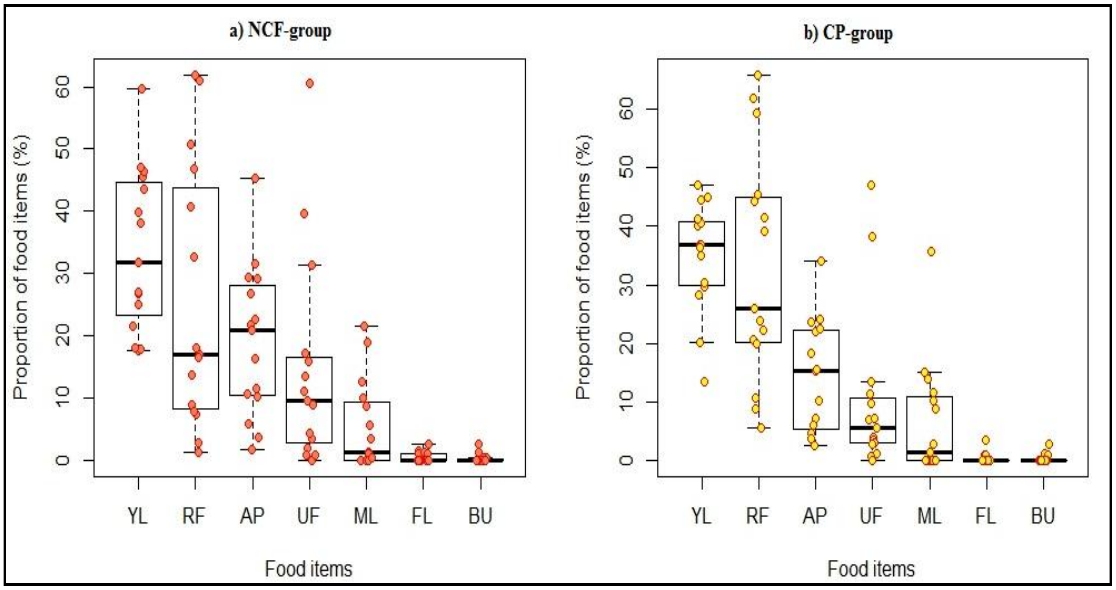


Figure 29. Box plot showing the proportion of food items consumed by NCF-group (a) and CP-group (b). YL = Young leaves, RF = Ripen fruits, AP = animal products, UF = Unripen fruits, ML = Matured leaves, FL= Flower, BU = Buds.

Correlation between plant diet consumption and plant phenology: For both groups the proportion of feeding on fruits (ripen and unripen fruits) was associated with availability during 12 months of study period (Fig. 30a). Consequently, the Spearman coefficient of correlation between proportions of fruits consumption and availability indices revealed that the correlation was significant in the home ranges of both study groups (NCF-group: $r_s = 0.59$; $P < 0.05$; CP-group: $r_s = 0.67$; $P = 0.02$, Fig. 30b).

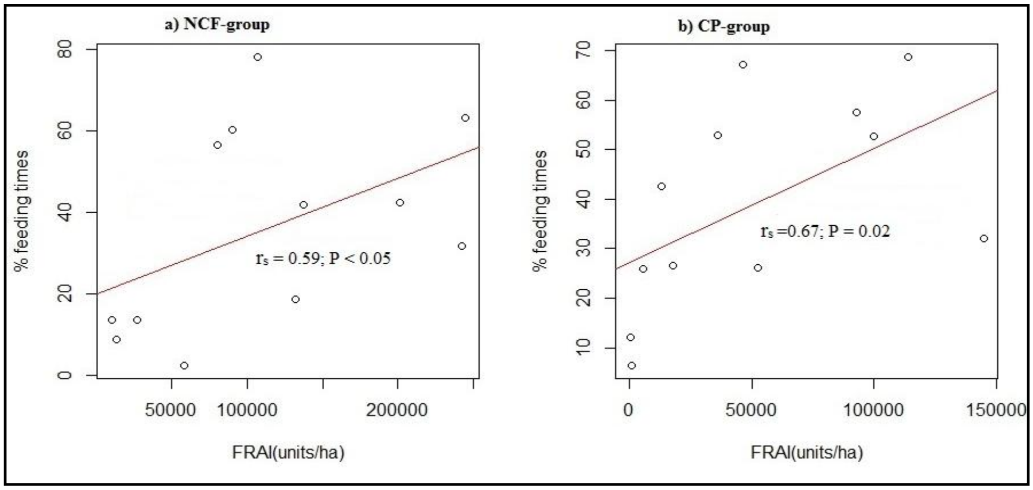


Figure 30. Correlation between percentages of feeding times with fruit availability index (FRAI) in NCF-group (a) and CP-group (b).

The availability of young leaves was high compared to other food items in the home ranges of both study groups. Conversely, there was no significant correlation between feeding proportions on young leaves and availability indices in the home ranges of both NCF (r_s= 0.27; $P = 0.40$; Fig 31a) and CP ($r_s = -0.06$; $P = 0.87$; Fig. 31b) groups .

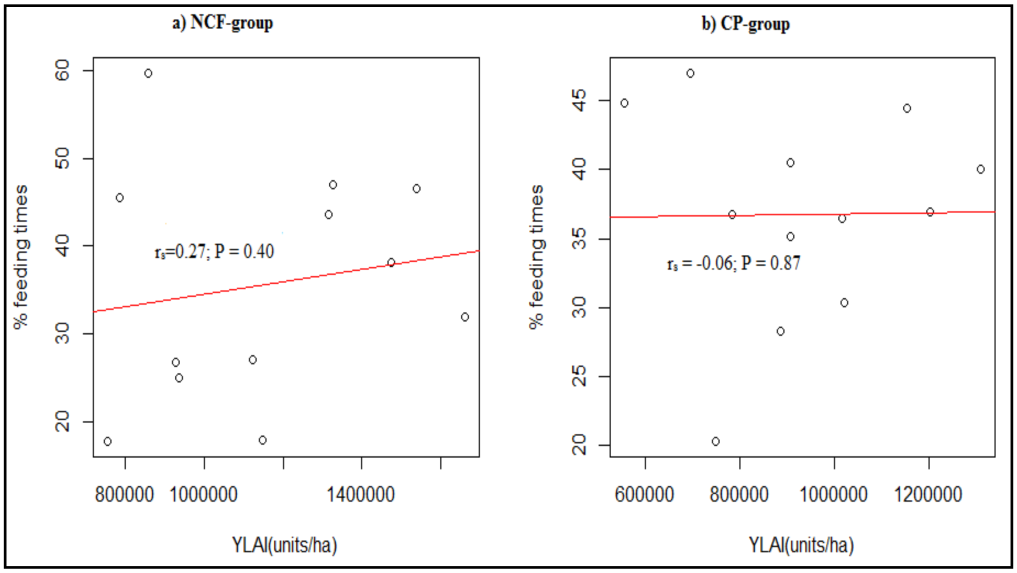


Figure 31. Correlation between percentages of feeding times with young leaves availability index (YLAI) in NCF-group (a) and CP-group (b).

Temporal variability in food items consumption: A pooled data from two groups revealed that young leaves comprised the largest proportion of diets of Boutourlini's blue monkeys. However, there was extensive variation in the contribution of different food types to diets on monthly bases (Fig. 32). Consumption on young leaves peaked 46.4% of the diet in January 2017 (dry season) and lowest at 16.1% during December 2017 (dry season). Ripen fruits consumption varied from a high of 60.97% during November 2016 (dry season) to a low of 5.6% during November 2017 (wet to dry transition). The proportion of animal products/insects in the diet reached a high of 34.04% of the diet in October 2017 (wet season), and it was at a low of 3.8% during December, 2017 (dry season). The proportion of unripe fruits consumption reached at peak (42.2%) in November 2017 (dry season) and there was not record in September 2017 (wet season). Finally, flowers and buds constituted negligible proportion of the diet of Boutourlini's blue monkeys in Hamuma Coffee Forest.

However, there were no significant differences in the average consumption of each food type between the wet and dry seasons, except for animal products/insects consumption where it was significantly high during wet (P = 0.01) and unripe fruits during dry seasons (P = 0.01).

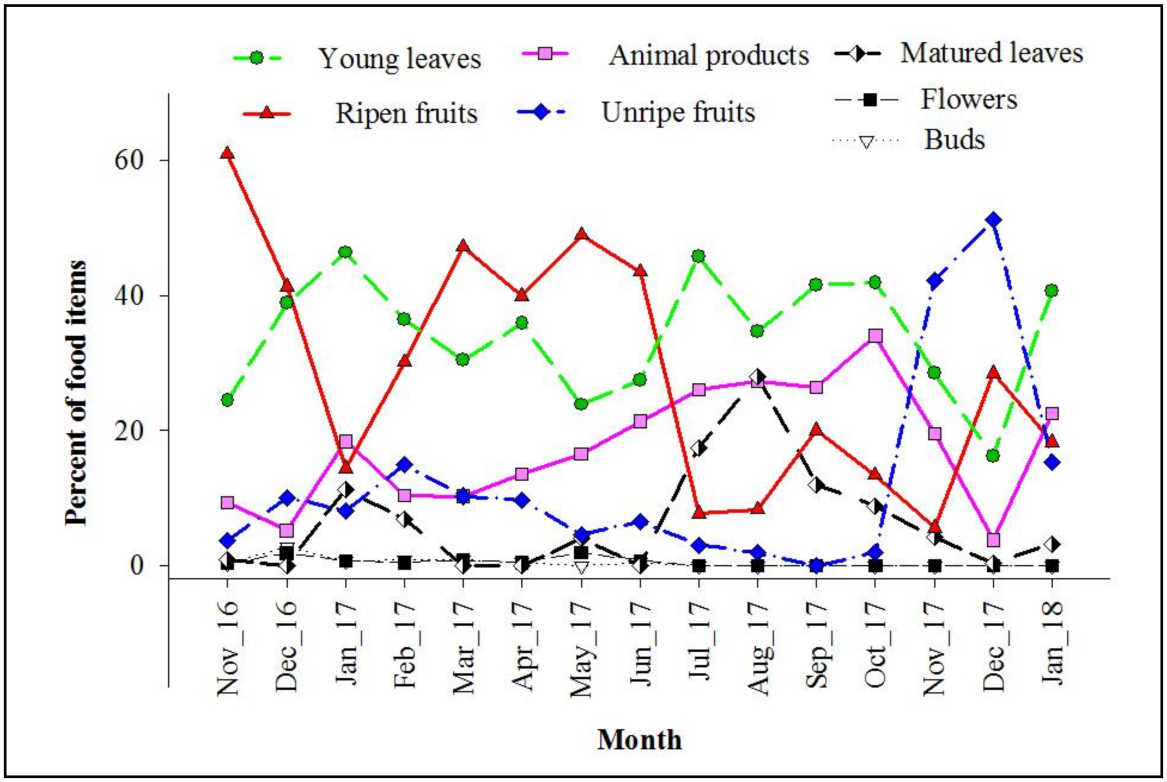


Figure 32. Combined monthly diets of both study groups in Hamuma Coffee Forest.

Spearman rank correlations (based on combined data from two groups) revealed that across months, the consumption of young leaves decreased as the consumption of ripen fruits increased and the relationship was significant (r_s= -0.54, P = 0.04, N = 15). Young leaves consumption also showed a negative correlation with unripe fruits, although this association was not significant (r_s = -0.32, P = 0.24, N = 15). There was a non-significant positive correlation between the consumption of matured and young leaves, and a significantly positive correlation between the consumption of ripen fruits and flowers ($r_s = 0.74$, $P = 0.001$, $N = 15$). However, significant and negative relationship was observed between the consumption of mature leaves and ripen fruits ($r_s = 0.7$, $P = 0.004$, $N = 15$). These patterns were consistent, in which seasonal resources were favoured as food sources, with mature leaves serving as a perennially available fallback resource. Boutourlini's blue monkeys apparently alternate between fruits and young leaves as major seasonal food sources.

The two study groups did not differ in the overall proportions of different foods in their diets, although there are times when consumption of certain food types increased for both groups (Fig. 33). NCF-group consumed the highest proportion of young leaves in December 2016 (dry season) and sharply declined to law proportion during the immediate next month and oscillated until May 2017. The second peak was observed during September 2017 (wet season) and sharply declined until January 2018. Whereas in CP-group, the consumption of young leaves sharply inclined through December 2016 to February 2017 (dry season) and oscillated up and down until December, 2017 (dry season), where the lowest proportion was recorded. There was an overlap between two groups in the consumption of matured leaves except in May 2017 (wet season) and August 2017 (wet season) where, NCF-group consumed smaller proportion than CP-group. The patterns of consumption on ripen fruits and unripen fruits were highly synchronous between groups and both groups showed increase in unripen fruits consumption between May 2017 (end of dry season) and June 2017 (early wet season), although, peak consumption of unripen fruits for both groups were seen in November 2017 (early dry season).

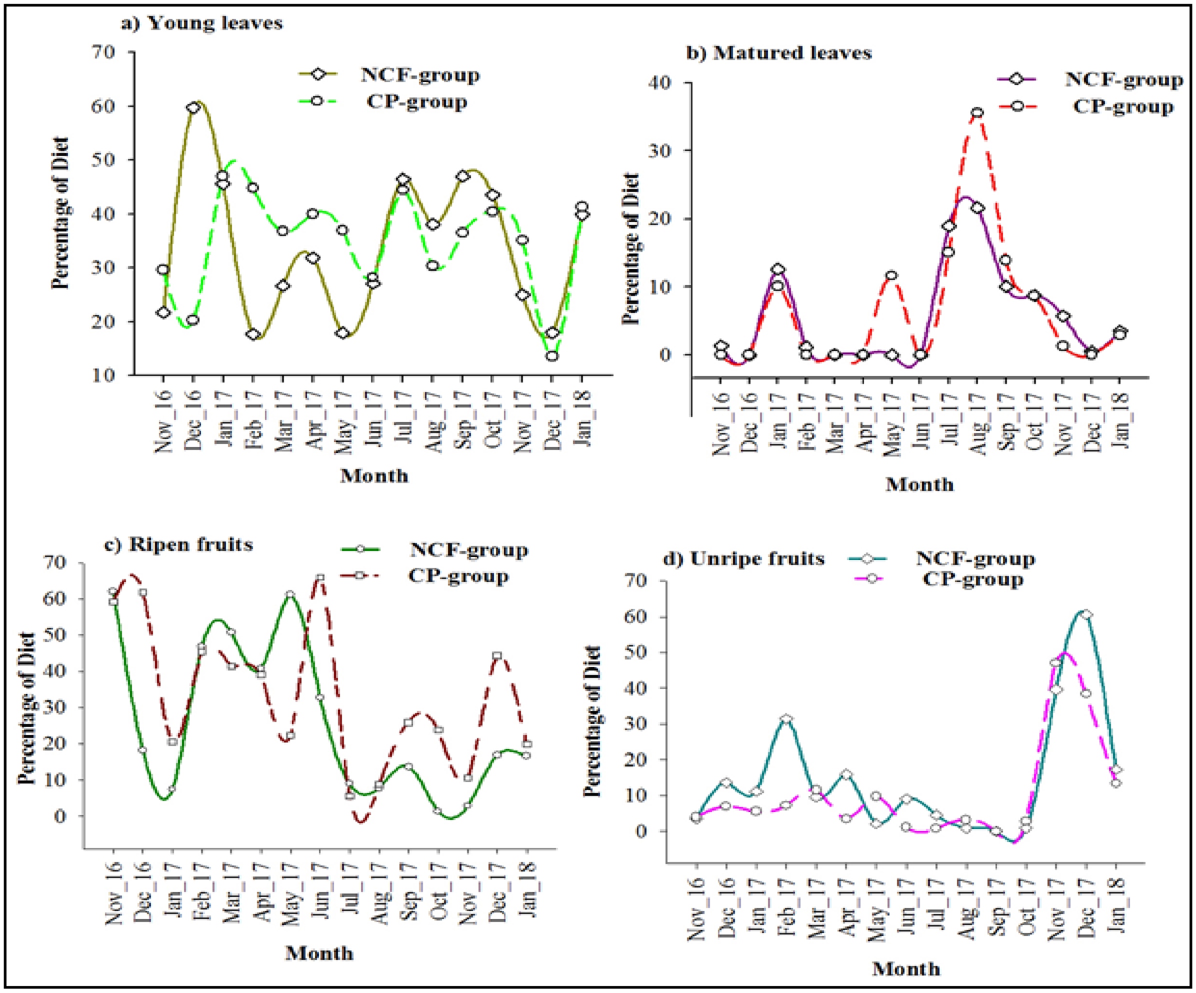


Figure 33. Proportions of (a) young leaves, (b) matured leaves, (c) ripen fruits, and (d) unripen fruits in the monthly diets of the two study groups.

The proportions of each food type in monthly diets showed positive correlations between two groups, although the association did not reach significance for young leaves from the major food items (Table 9). Nevertheless, taken together these results suggest that seasonal changes in the diets of the study groups were related and may reflect home range-wide changes in the abundance and availability of foods.

Table 9. Spearman rank correlation coefficients and associated P-values between the two groups in the percentage composition of monthly diets by food items.

	Pair wise comparison
Food Items	**NCF-group** vs. **CP-group**
Young leaves	0.12, 0.68
Matured leaves	0.76, 0.00*
Ripen fruits	0.62, 0.01*
Unripen fruits	0.73, 0.00*
Animal products/ insects	0.63, 0.02*
Flowers	0.21, 0.46
Buds	0.04, 0.88

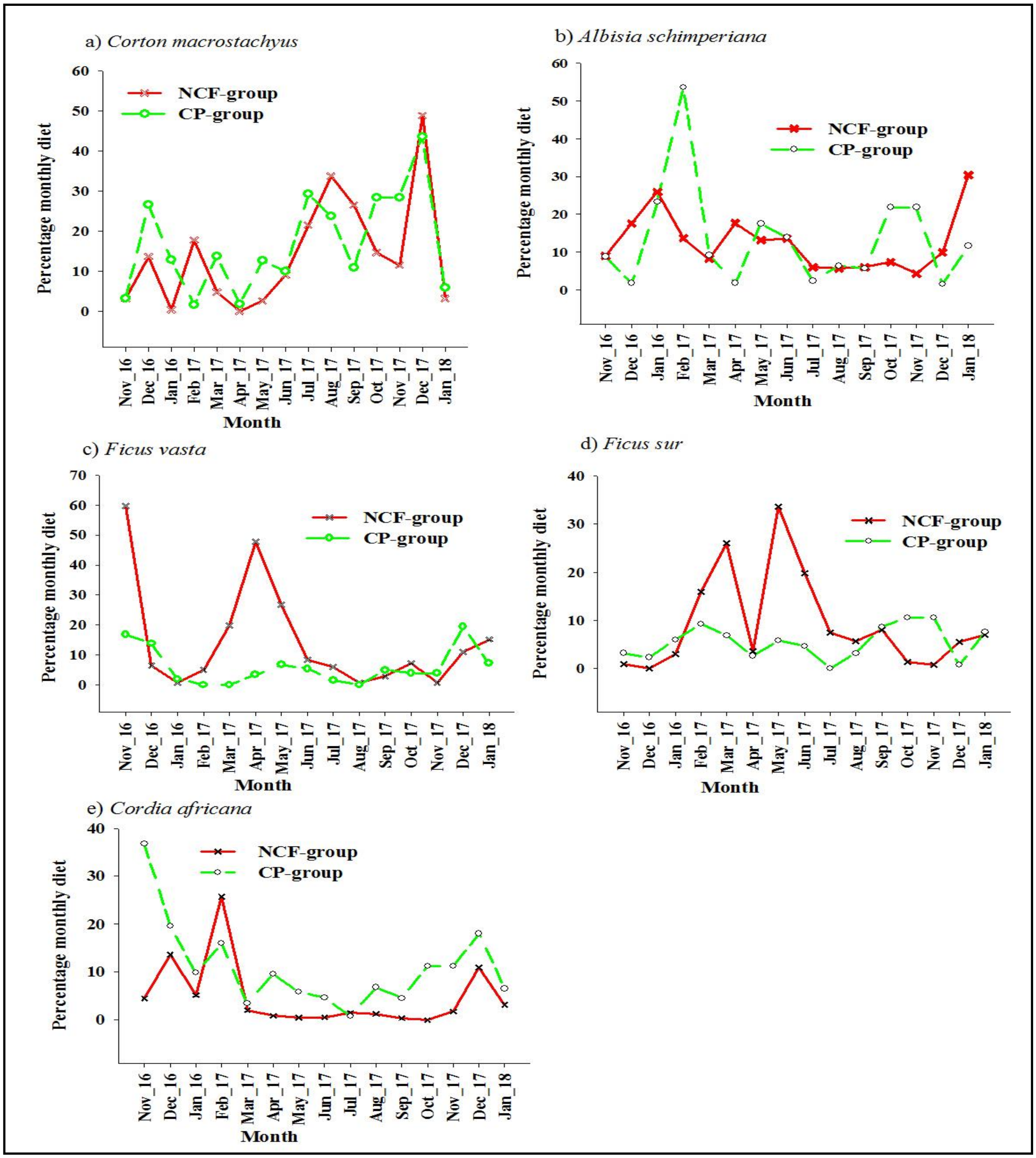
n = 15 for all cells; all tests are 2-tailed and * statistically significant at $P < 0.05$.

Monthly variation in species consumtion: The recorded data obtained from the combined groups revealed that, the top 10 species comprised over 70% of the overall diet during the study period. This does not mean that Boutourlini's blue monkeys can depend on these species alone, instead, they also consumed many unidentified animal/insect species that comprised over 18% of their diet and other species when these species failed to provide the required quality and quantity consistently. Consequently, their presence in the diet on a monthly basis was highly variable (Table 10). Eight of the top ten plant species were consumed during every month of the study period while variation existed in the occurrence of feeding bouts on different plant speciesto the extent that some species were consumed during only few months sample. *Croton macrostachyus* contributed the highest percentage (15.75%), ranging from 0.9% (April) to 46.7% (December). *Albizia schimperiana*was the second most consumed plant species followed by *Ficus vast* and *Ficus sur*.

Table 10. Monthly percent variation in the contribution of plant species to the diet of Boutourlini's blue monkeys.

Species consumed	**Nov.**	**Dec.**	**Jan**	**Feb.**	**Mar.**	**Apr.**	**May**	**Jun.**	**Jul.**	**Aug.**	**Sep.**	**Oct.**	**Nov.17**	**Dec.17**	**Jan.18**
Croton macrostachyus	3.2	20.5	7.0	20.5	8.2	0.9	9.3	7.3	24.5	29.2	18.4	11.3	17.4	46.7	4.5
Albizia schimperiana	8.9	9.2	24.5	9.2	8.6	9.6	22.3	11.1	4.6	5.9	5.8	8.7	10.5	6.3	21.1
Ficus vast	44.3	10.4	1.4	10.4	12.4	25.4	9.3	5.7	4.3	0.5	3.9	5.3	1.9	14.6	11.3
Ficus sur	1.7	1.2	4.5	1.2	18.9	3.1	36.3	32.1	4.6	4.5	8.3	4.0	4.2	3.5	7.3
Cordia africana	16.1	16.8	7.7	16.8	2.6	5.3	3.6	0.4	1.2	3.8	2.5	3.6	5.1	14.0	4.8
Millettia ferruginea	3.7	4.6	1.0	4.6	3.0	11.0	5.2	5.7	10.7	6.9	5.0	7.4	2.6	3.2	0.5
Ficus thonningii	1.1	4.0	1.9	4.0	2.6	1.3	_	1.1	0.0	0.5	1.0	1.3	26.0	3.2	4.5
Sapium ellipticum	3.4	3.4	2.8	3.4	0.0	6.1	2.6	1.1	9.5	4.8	5.0	4.0	1.2	0.3	5.6
Trichilia dregeana	0.3	2.8	4.3	2.8	1.3	1.3	7.3	5.3	1.8	0.7	1.6	0.4	2.1	1.6	2.3
Syzygium guineense	–	0.3	2.6	0.3	12.4	5.3	2.6	1.1	0.6	0.2	2.5	1.7	0.9	1.0	4.1
Pouteria altissima	–	6.7	0.9	6.7	9.4	1.3	1.6	–	0.0	–	–	0.9	3.3	–	1.6
Psidium guajava	0.3	–	0.5	–	–	0.4	1.0	–	0.3	5.9	10.7	3.8	–	–	0.7
Podocarpus falcatus	–	–	2.1	–	–	0.9	–	–	0.3	–	0.8	2.6	–	–	4.5
Schefflera volkensii	0.3	–	1.0	–	0.9	2.2	1.0	–	4.3	1.9	0.8	1.1	0.5	0.6	–
Diospyros abyssinica	–	4.0	0.7	4.0	3.4	0.9	1.6	–	–	1.2	0.2	0.2	1.2	0.3	0.9

The top five plant species constituted over 50% of the diet in each groups. These are among the few tree species which not only produce several different palatable phenophases (e.g., young leaves, matured fruits, and flowers), but also have asynchronous phenological schedules (individuals usually bear only one seasonal phenophase at a time, but the timing of production differs between individuals: *Ficus*) or which bear different seasonal phenophases throughout the year (most individuals have a few young leaves, fruits, and/or flowers throughout the year: *Cordia*). When considering variation in the contribution of each of the top five species to each group's diet, the two groups generally focus on the same species at the same time (Fig. 34). Nearly all pair-wise comparisons between groups in the proportions of these food species in monthly diets were positive; in some cases they were significant (Table 11). The positive relationships between the consumption of key food species suggest that the intensity with which the two groups feed on these species relates to home range-wide changes in the production of edible phenophases. Although there were differences in the number of species consumed per month, one-way ANOVA demonstrated no significant differences in the number of species used between groups: $F_{[1,\ 28]} = 0.94$, $P = 0.34$, seasons: $F_{[1,\ 28]} = 0.62$, $P = 0.44$ or months: $F_{[14,\ 15]} = 2.48$, $P = 0.05$.



a) *Corton macrostachyus*

b) *Albisia schimperiana*

c) *Ficus vasta*

d) *Ficus sur*

e) *Cordia africana*

Figure 34. Proportions of (a) *Croton macrostachyus*, (b) *Albizia schimperiana*, (c) *Ficus vast*, (d) *Ficus sur*, and (e) *Cordia africana* in the monthly diets of the two study groups.

Table 11. Spearman rank correlation coefficients between groups in the percentage composition of monthly diets by species.

Food species	**Pairwise comparison**
	NCF-group vs. CP-group
Croton macrostachyus	0.52*
Albizia schimperiana	0.08
Ficus vast	0.42
Ficus sur	0.07
Cordia africana	0.56 *

n= 15 for all cells; all tests are 2-tailed. * significant at $P < 0.05$.

***Dietary selection*:** The selection ratios of plant food species accounting for more than one percent in the diet of Boutourlini's blue monkeys during the study period is presented in Table 12. Based on the dietary preference ratio, *Ficus thonningii* was the most selected plant species by NCF-group with a selection ratio (SR) of 26.43 followed by *Ficus sur* (6.28) and *Ficus vast* (5.28). Whereas, *Psidium guajava, Ficus vast* and *Trichilia dregeana* were ranked first, second and third in CP-group with selected ratio (SR) of 31, 17.57 and 5.62, respectively. Despite its highest percentage contribution in the overall diet of Boutourlini's blue monkeys, *Croton macrostachyus* had a low selection preference in the home ranges of both study groups.

Table 12. Selection ratios of food species contributing ≥ 1% to the diet of the two groups of Boutourlini's blue monkeys.

NCF-group				**CP-group**			
Species consumed	% of diet	% of stem density	Selection ratio (Rank)	Species consumed	% of diet	% of stem density	Selection ratio (Rank)
Croton macrostachyus	16.34	10.84	1.51(5)	*Croton macrostachyus*	14.42	10.27	1.4(8)
Ficus vast	13.10	2.48	5.28(3)	*Albizia schimperiana*	13.33	18.43	0.72(14)
Albizia schimperiana	12.78	12.87	0.99(6)	*Cordia africana*	10.58	4.83	2.20(6)
Ficus sur	8.48	1.35	6.28(2)	*Ficus sur*	6.78	2.72	2.49(5)
Ficus thonningii	6.08	0.23	26.43(1)	*Ficus vast*	5.27	0.3	17.57(2)
Cordia africana	4.43	1.58	2.8(4)	*Millettia ferruginea*	4.61	25.08	0.18(16)
Millettia ferruginea	4.01	20.09	0.20(10)	*Sapium ellipticum*	4.19	3.93	1.07(10)
Sapium ellipticum	2.91	3.84	0.76(7)	*Pouteria altissima*	3.95	3.93	1.01(11)
Syzygium guineense	1.97	6.77	0.29(8)	*Trichilia dregeana*	3.37	0.6	5.62(3)
Podocarpus falcatus	1.88	7.45	0.25(9)	*Psidium guajava*	3.10	0.1	31(1)
Trichilia dregeana	1.55	2.03	0.76(7)	*Syzygium guineense*	2.36	3.02	0.78(13)
				Schefflera volkensii	1.59	0.91	1.75(7)
				Ficus thonningii	1.47	1.81	0.81(12)
				Diospyros abyssinica	1.32	9.06	0.15(17)
				Podocarpus falcatus	1.16	0.91	1.28(9)
				Ehretia cymosa	1.09	2	0.55(15)
				Polyscias fulva	1.05	0.3	3.5(4)

5.5. Ranging patterns of Boutourlini's blue monkeys

Daily path length and movement rates: A total of 4810 GPS points (2527 for NCF-group and 2283 for CP-group) were recorded in 59 and 55 days follow up period, respectively. Boutourlini's blue monkey exhibited wide variation in daily path length. Thus, on average, the NCF-group travelled 1041.9± 2.18 m, and the CP-group moved 1040.8 ± 2.5 m each day. The longest daily path length distance (DPL) made by NCF-group was 2074.8 m (July 2017) and the shortest was 113.1 m (December 2016). On the other hand, the longest DPL made by the CP-group was 2085 (May 2017) and the shortest was 224.7 m (August2017). Monthly mean DPL did not significantly differ between the two groups (One-way ANOVA: $F_{[1,\ 28]} = 0.001$, $P = 0.97$). NCF-group travelled nearly significant distances during the dry season than in the wet season ($F_{[1,\ 13]} = 3.88$, $P = 0.07$), while CP-group did not change their daily journey following seasons ($F_{[1,\ 13]} = 0.14$, $P = 0.7$). Similarly, mean MVR of NCF and CP groups were 94.54 ± 13.91 m/h and 94.73 ± 17.49 m/h, respectively (Table 13), and they did not significantly differ between the two Boutourlini's blue monkey groups ($F_{[1,\ 28]} = 0.001$, $P = 0.97$). Furthermore, Boutourlini's blue monkey groups did not show any difference in MVR between seasons (NCF-group: $F_{[1,\ 13]} = 1.21$, $P = 0.29$; CP-group: $F_{[1,\ 13]} = 0.021$, $P = 0.89$). Monthly mean daily path length was not correlated with rainfall or temperature for either of the groups (NCF: rainfall, $r_s = 0.41$, $P = 0.19$, temperature, $r_s = -0.53$, $P = 0.08$; CP: rainfall, $r_s = 0.13$, $P = 0.68$, temperature, $r_s = 0.07$, $P = 0.48$). Whereas, mean monthly DPL had significant negative correlation with mean monthly availability of fruit for the NCF group ($r_s = -0.55$, $P < 0.05$), while the association was not significant for CP group ($r_s = 0.48$, $P = 0.1$).

Table 13. Overall and seasonal monthly mean (± SE) and range values of daily path length (DPL) and monthly mean (± SD) movement rates (MVR) for the two Boutourlini's blue monkey groups (NCF-group and CP-group).

Group	No. of months (no. of days)	Monthly mean ± SE DPL (m)	Range DPL (m)	Monthly mean ±SD MVR (m/h)
Overall				
NCF	15 (59)	1041.9 ± 2.18	113–2074.8	94.54 ± 13.91
CP	15 (55)	1040.8 ± 2.5	224.7–2085	94.73 ± 17.49
Dry season				
NCF	8 (35)	997.5 ± 4.31	780.5–1181	90.68 ± 13.48
CP	8 (31)	1025.1 ± 4.63	807–1357	93.19 ± 15.62
Wet season				
NCF	7 (24)	1093.0 ± 4.67	877.9–1384	99.36 ± 13.87
CP	7 (24)	1057 ±5.69	780–1327	96.10 ± 20.58

Home range size and use: A total of 4810 GPS points were recorded to determine the home range size of two groups of Boutourlini's blue monkey in Hamuma Coffee Forest. The overall 95% KDE utilization distribution of the NCF-group was smaller (38.21 ha) than CP-group (60.17 ha). A 50% KDE core area utilized by the focal group more frequently and concentrated at central locations in the home ranges. It was also smaller in NCF-group than CP-group (Fig. 35). A 100% MCP analysis overestimates the home range (Table 14). It comprised large area not actually utilized by the group. A 95% MCP estimate is more appropriate for home range analysis than 100% MCP and smaller in NCF-group (38.21 ha) than CP-group (60.17 ha). The 95% MCP estimate was also more inclusive compared to 95% KDE in both groups of Boutourlini's blue monkey (Fig. 35). The 95% KDE home ranges of both groups formed an irregular landscape with small fragment located apart from the main which were often utilized as sleeping places near to the settlements (Fig. 35).

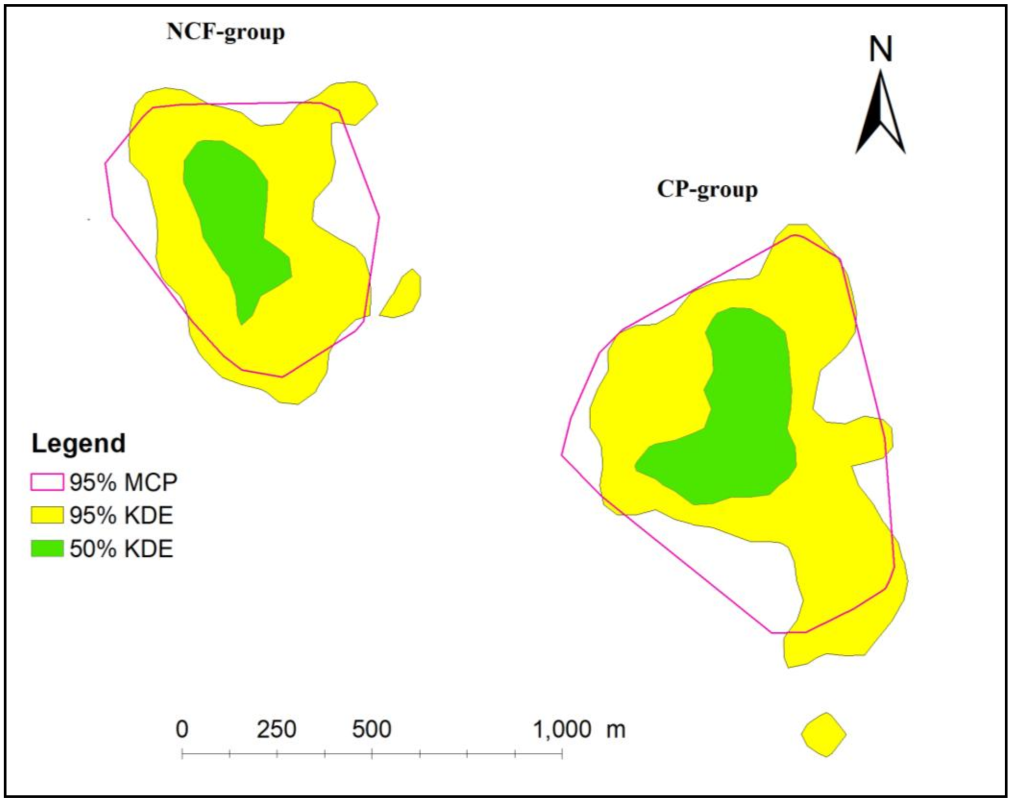


Figure 35. Overall home-range (95% KDE), core area (50% KDE) and (95% MCP) sizes of Boutourlini's blue monkey in natural coffee forest and coffee plantation continuous red line (95% MCP), yellow highlight (95% KDE), and green highlight (50% KDE).

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

Group	No.days	No.GPS pts	Overall home range size (ha)				
			100% MCP	95% MCP	90%MCP	95% KDE	50% KDE
NCF	59	2527	76.73	38.21	25.79	36.33	7.22
CP	55	2283	85.31	60.17	47.99	52.34	12.52

Seasonal home range size: Seasonal home range size of Boutourlini's blue monkey in Hamuma Coffee Forest is presented in Table 15. There was seasonal variation in home range size utilization in both groups. In NCF-group, the 95% MCP estimate was greater during wet (41.82 ha) than dry season (31.33 ha). On the other hand, both 95% KDE and 50% KDE core area had greater area coverage during wet season than the dry season. Similarly, CP-group had greater home range during wet season compared to the dry season. The 95% MCP home range size was greater during wet (52.5 ha) than dry seasons (48.85 ha). Whereas, the 50% KDE core area covered 10.90 ha during wet season and 14.16 ha during the dry season. On the other hand, the 50% KDE core area was utilized more frequently by both groups (Table 15).

Table 15. Seasonal home range size (ha) estimated by MCP (100%, 95% and 90%) and 95% fixed kernel density estimate, and core area size estimated as 50% fixed kernel density analysis for the two groups.

			Seasonal home range size (ha)				
Group	Season	GPS pts	100% MCP	95% MCP	90% MCP	95% KDE	50% KDE
NCF	Wet	995	76.12	41.82	27.76	45.40	10.20
	Dry	691	39.04	31.33	23.90	31.43	7.64
CP	Wet	740	60.28	52.51	47.60	44.38	10.90
	Dry	1543	65.26	48.85	43.74	53.58	14.16

5.6. Habitat use of Boutourlini's blue monkeys

***Forest strata use*:** Overall, and during moving and feeding, as predicted, CP-group spent significantly more time on the ground than NCF-group (Table 16; Fig. 36a–c). The middle canopy was the most frequently used by both study groups during moving and resting (Fig. 36b, d), while the upper emergent was used during feeding (Fig. 36c). Moreover, the NCF and CP groups spent 95% and 89% of their time, respectively in the middle and upper forest strata levels, with very little time spent at lower level.

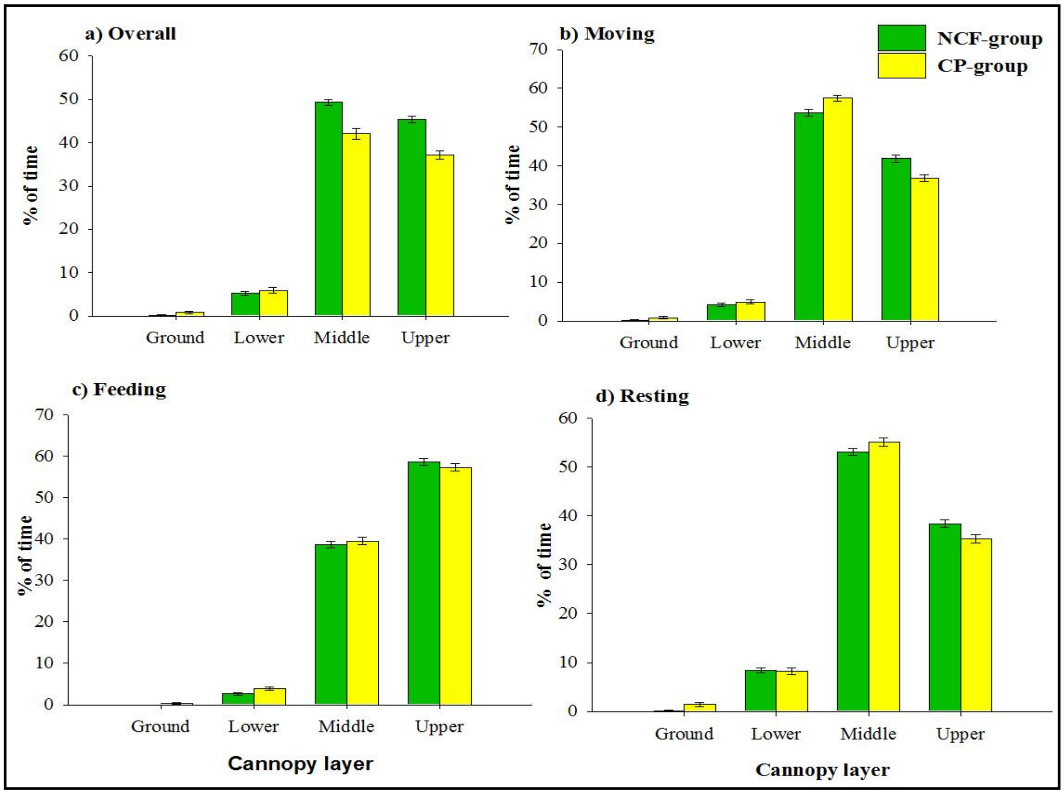


Figure 36. The proportion of time spent using different forest strata between Boutourlini's blue monkey groups in natural coffee forest and coffee plantation during (a) overall behavioural activity, (b) moving, (c) feeding, and (d) resting.

Table 16. Comparison of percentage strata use between blue monkey groups in natural coffee forest (NCF-group) and coffee plantation (CP-group) using Kruskal–Wallis test.

No	Features	Variables	NCF (%)	CP (%)	Df =1,χ^2-value	p-value
1	Strata use					
1.1	Overall	Ground	0.10	0.81	5.88	0.02*
		Lower	5.21	5.94	0.04	0.85
		Middle	49.29	42.07	0.08	0.77
		Upper	45.40	37.20	3.41	0.07
1.2	Moving	Ground	0.19	0.82	4.17	0.04*
		Lower	4.19	4.89	0.16	0.69
		Middle	53.72	57.40	1.03	0.31
		Upper	41.91	36.76	1.12	0.29
1.3	Feeding	Ground	0	0.35	4.43	0.04*
		Lower	2.63	3.86	2.17	0.14
		Middle	38.74	39.57	0.07	0.79
		Upper	58.63	57.36	0.23	0.63
1.4	Resting	Ground	0.13	1.42	2.45	0.12
		Lower	8.382	8.25	0.72	0.4
		Middle	53.09	55.07	0.47	0.49
		Upper	38.40	35.26	1.12	0.29

Microhabitat use: The home ranges of natural coffee forest and coffee plantation groups consisted solely of natural coffee forest, coffee plantation and tree dominant forest in different proportion. Both groups of Boutourlini’s blue monkeys used these three habitat types in accordance with their respective availabilities in their home ranges. Chi-square tests comparing the observed frequency of microhabitat use with the expected frequency showed significant differences for both groups (Fig. 37). NCF-group spent more time in tree dominant forest than expected (based on the percent of each microhabitat type in the home range), less time in natural coffee forest and coffee plantation than expected (Fig. 35; $\chi^2 = 3379.7$, df = 2, $P < 0.001$). Whereas, CP-group spent less time in coffee plantation than expected, and more time in a tree dominant forest and natural coffee forest than expected (Fig.35; $\chi^2 = 1253.9$, df = 2, $P < 0.001$).

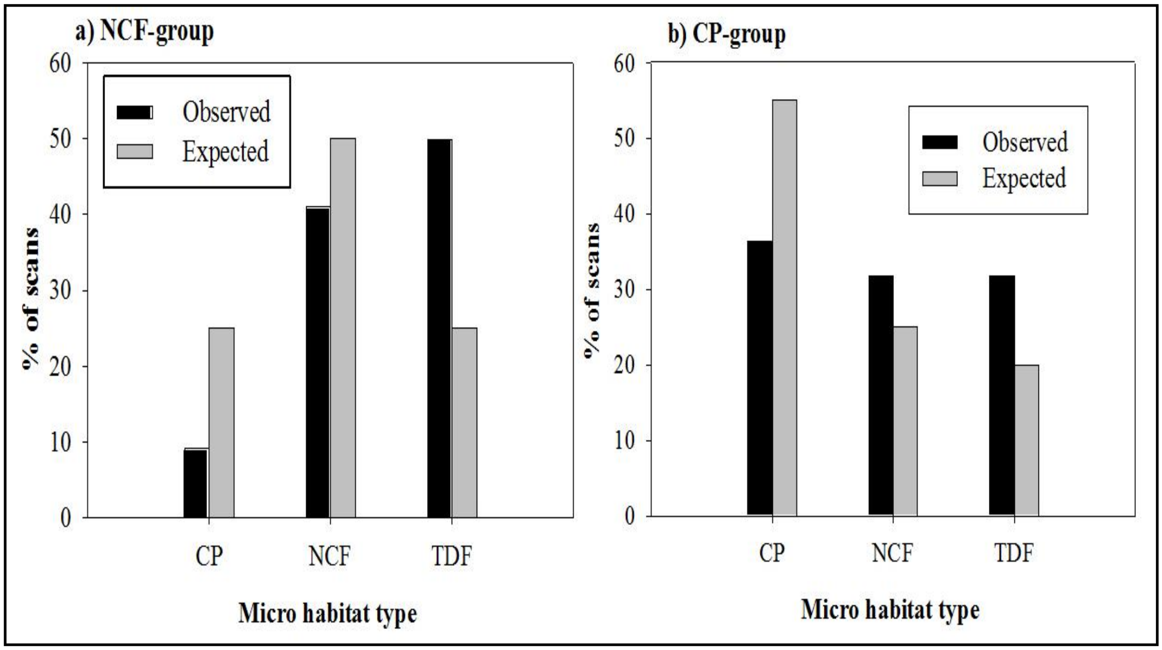


Figure 37. Percentage of scans in each microhabitat (CP = coffee plantation, NCF = natural coffee forest, TDF= Tree dominant forest) and expected observations based on the proportion of each microhabitat within each group's home range.

5.7. Positional behaviour and substratum utilization

***Locomotor and postural* behaviour:** The group in natural coffee forest did not spend significant proportion of time in any of the locomotor modes than in coffee plantation (Fig. 38; Table 17). However, the overall proportions of time spent for locomotor modes significantly differ in both groups (NCF-group: Kruskal-Wallis $\chi^2 = 53.1$, df = 4, P = 0.00; CP-group: Kruskal-Wallis $\chi^2 =$

45.1, df = 4, P = 0.00). Therefore, Boutourlini's blue monkey spent large proportion of time bridging and walking during their travel in Hamuma Coffee Forest.

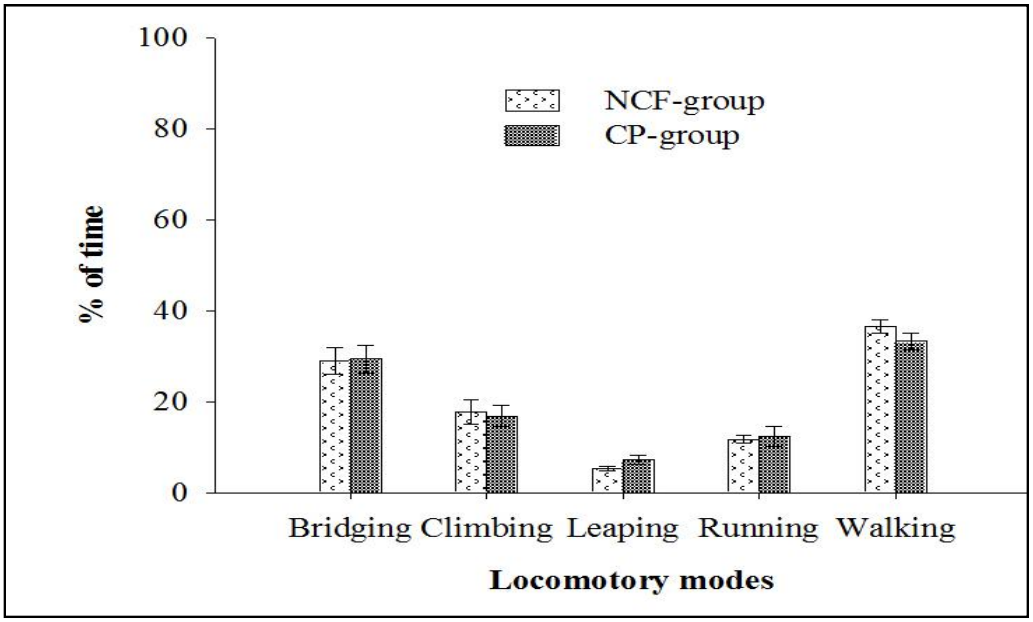


Figure 38. Proportion of scan adopting different locomotor modes during travel between two study groups in natural coffee forest and coffee plantation.

Overall, Boutourlini's blue monkys in both study groups spent most of their time in a sitting posture and nearly all of their remaining time standing (Fig. 39). However, group in natural coffee forest did not use a sitting and standing posture more frequently than in the coffee plantation during feeding, resting, and feeding and resting combined (Table 17; Fig. 39). Moreover, there was no significant difference in all posture uses between natural coffee forest and coffee plantation groups (Table 17).

Table 17. Comparison of percentage positional mode behaviours, and substrate utilization between two study groups in natural coffee forest and coffee plantation using One-Way ANOVA or Kruskal–Wallis test.

No	Features	Variables	NCF (%)	CP (%)	df = 1, F-value	P-value
1	**Locomation**					
1.1	Locomation mode	Briging	28.9	29.3	0.01	0.93
		Climbing	17.8	16.8	0.08	0.78
		Leaping	5.2	7.1	2.98	0.1
		Running	11.6	12.2	^{K}0.12	0.72
		Walking	36.5	33.3	1.82	0.19
2	**Postural mode**					
2.1	Overall (F+R)	Lying	0.7	1.2	2.49	0.13
		Standing	37.7	37.6	^{K}0.07	0.79
		Siting	61.6	61.2	0.01	0.92
2.2	Feeding (F)	Lying	0.1	0.1	^{K}0.46	0.5
		Standing	53.8	51.5	0.09	0.77
		Siting	46.1	44.5	0.05	0.83
2.3	Resting (R)	Lying	1.0	1.7	2.55	0.12
		Standing	21.4	23.5	0.05	0.83
		Siting	77.6	71.6	0.39	0.53
3	**Substrate type**					
3.1	Overall (F+M+R)	Branch	95.4	93.6	2.91	0.1
		Trunk	4.6	6.4	2.91	0.1
3.2	Feeding (F)	Branch	92.6	96.6	0.04	0.85
		Trunk	3.8	9.4	0.66	0.42
3.3	Moving (M)	Branch	93.6	90.6	5.9	0.02*
		Trunk	6.4	9.4	5.9	0.02*
3.4	Resting (R)	Branch	95.3	92.8	^{K}2.96	0.09
		Trunk	4.7	7.2	2.96	0.09
4	**Substrate size**					
4.1	Overall (F+M+R)	Large	36.7	27.3	12.28	0.001***
		Medium	45.5	43.3	0.46	0.50
		Smalll	22.5	29.4	^{K}4.56	0.03*
4.2	Feeding (F)	Large	33.8	24.1	4.73	0.04*
		Medium	42.5	41.8	0.03	0.87
		Smalll	23.7	34.1	2.79	0.11
4.3	Moving (M)	Large	41.4	31.9	8.1	0.01**
		Medium	45.6	46.1	0.024	0.88
		Smalll	13.0	22.0	10.67	0.003**
4.5	Resting (R)	Large	35.3	26.3	8.49	0.01**
		Medium	45.9	42.5	0.7	0.41
		Smalll	23.6	31.1	2.53	0.12

Table 17. (Continued)

No	**Features**	**Variables**	**NCF (%)**	**CP (%)**	**df = 1,F-value**	**P-value**
5	**Substrate inclination**					
5.1	Over (F+M+R)	Horizontal	56.8	55.5	0.13	0.72
		Oblique	8.2	10.4	0.78	0.38
		Vertical	35.1	34.1	0.14	0.71
5.2	Feeding (F)	Horizontal	56.5	55.5	0.04	0.85
		Oblique	6.6	10.7	1.3	0.25
		Vertical	37.0	30.0	3.63	0.07
5.3	Moving (M)	Horizontal	55.0	54.5	^{K}0.1	0.76
		Oblique	5.5	7.3	1.3	0.25
		Vertical	39.5	38.1	^{K}0.25	0.62
5.4	Resting (R)	Horizontal	56.9	52.5	1.12	0.30
		Oblique	9.8	11.7	0.4	0.53
		Vertical	33.3	35.9	0.72	0.40
6	**Substrate number**					
6.1	Overall (F+M+R)	Multiple	96.0	93.5	^{K}2.55	0.11
		Single	3.1	6.5	^{K}2.17	0.14
6.2	Feeding (F)	Multiple	96.5	94.5	^{K}1.45	0.23
		Single	3.4	5.5	^{K}1.45	0.23
6.3	Moving (M)	Multiple	94.7	92.4	^{K}0.8	0.37
		Single	5.3	7.6	^{K}0.8	0.37
6.4	Resting (R)	Multiple	95.6	93.3	2.93	0.09
		Single	4.4	6.8	2.93	0.09

The last column shows p-value with significant difference, $P < 0.001$ (***); $P < 0.01$ (**); $P < 0.05$ (*) . ^{K}Kruskal–Wallis test (χ^2) .

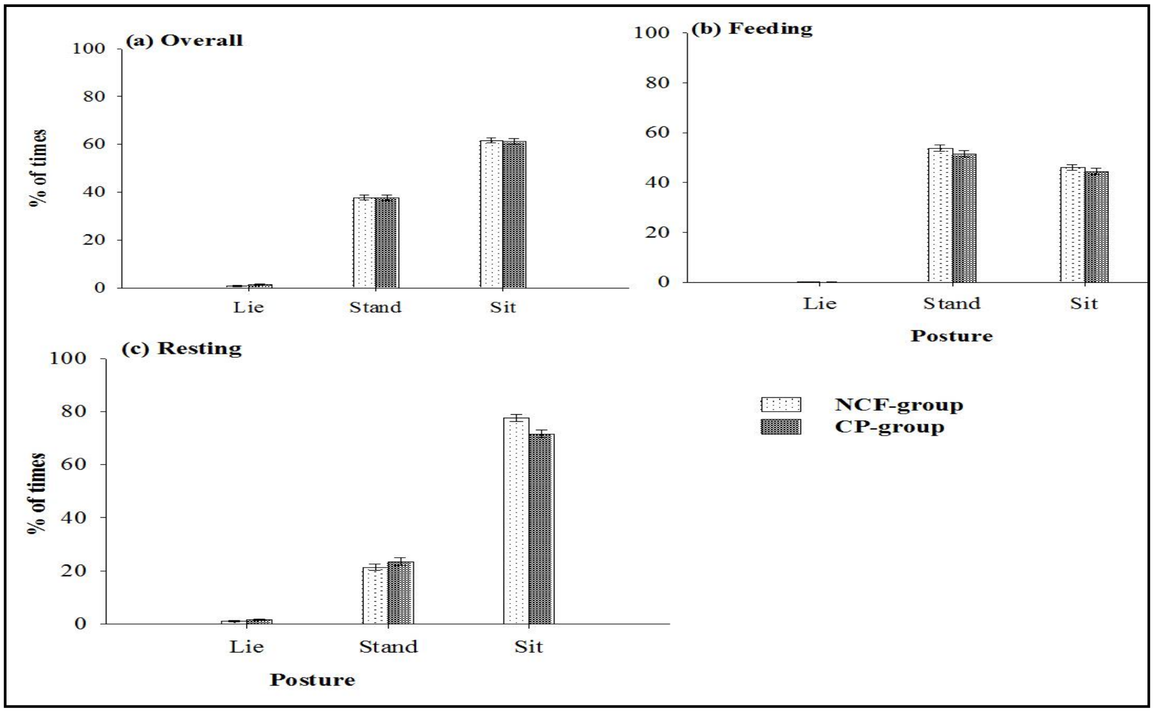


Figure 39. Posture use between two groups in natural coffee forest and coffee plantation during (a) feeding and resting combined, (b) feeding, and (c) resting.

Substrate type: Overall, groups in both natural coffee forest and coffee plantation mostly used branches as support, though they some times used trunks, twigs, or lianas instead (Table 17; Fig. 40a). Group in natural coffee forest did not show significant difference in frequancey of using branches and trunks during feeding and resting than group in coffee plantation (Table 17; Fig. 40b and d). Whereas, during moving group in natural coffee forest used branches more frequantly, and trunks less frequantly than group in coffee plantation (Table 17; Fig. 40c).

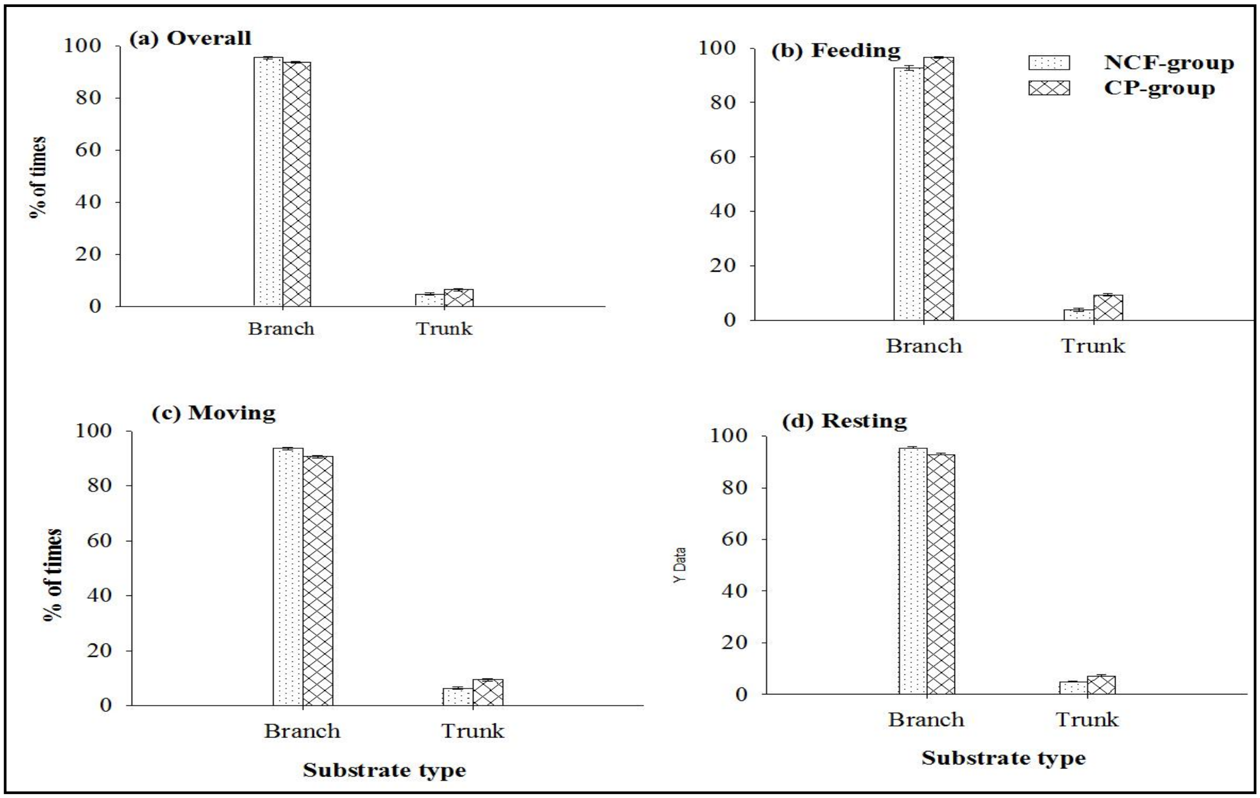


Figure 40. Substrate type used between two groups in natural coffee forest and coffee plantation during (a) feeding, moving, and resting combined, (b) feeding, (c) moving, and (d) resting.

***Substrate size*:** Figure 41 shows the proportion of time spent adopting different locomotor modes during travel between Boutourlini's blue monkey study groups. Overall, Boutourlini's blue monkeys in both study groups most often used medium sized supports, followed by large and small supports (Fig. 41a). Furthermore, the group in natural coffee forest used large substrates more frequently and small sized substrates less frequently, than group in coffee plantation (Table 17). However, there was no significant difference in the use of medium substrates between natural coffee forest and coffee plantation groups (Table 17). During feeding, the group in natural coffee forest used medium and large substrates frequently whereas, the group in coffee plantation rarely used large substrate (Fig. 41b). The group in natural coffee forest used large size substrates significantly more than the group in coffee plantation, whereas significant difference were not observed in medium and small sized substrate used by both groups during feeding (Table 17). During moving, the most frequently used substrate size class was medium followed by large and small substrates (Fig. 41c). The group in natural coffee forest used large substrates significantly more and small substrates significantly less, than group in coffee plantation, but there were no significant differences in the use of medium substrates between natural coffee forest and coffee plantation groups (Table 17). During resting, the natural coffee forest group used large substrate significantly more frequently than coffee plantation group (Fig, 41d), but there were no differences in the use of medium and small substrates between natural coffee forest and coffee plantation groups (Table 17).

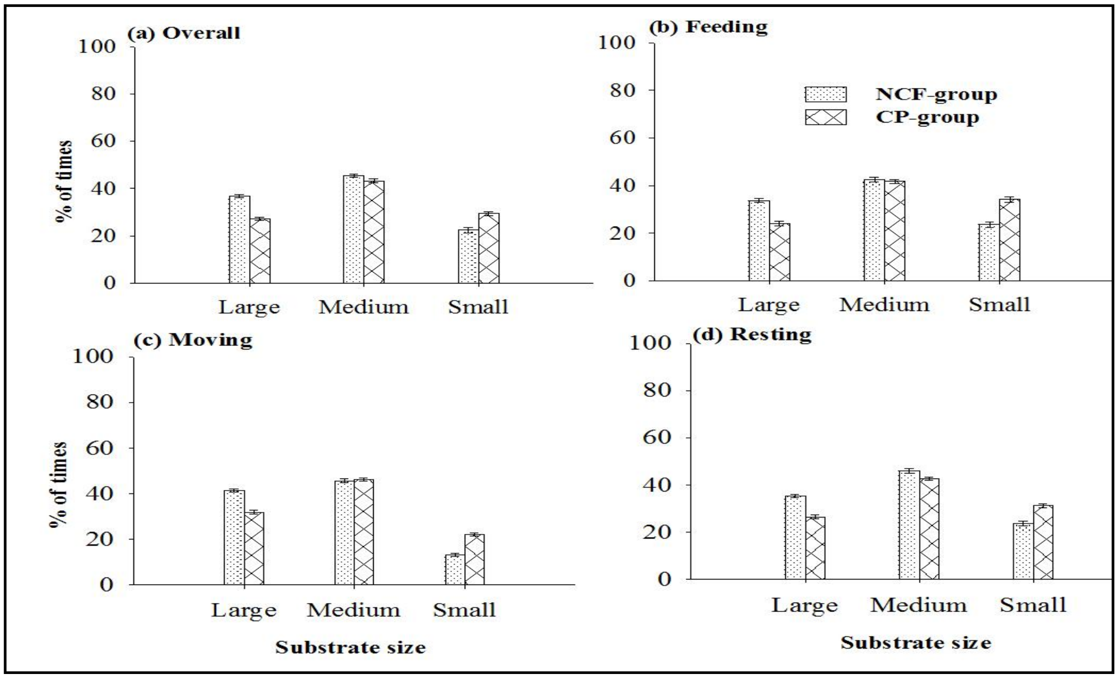


Figure 41. Substrate size used between two groups in natural coffee forest and coffee plantation during (a) feeding, moving, and resting combined, (b) feeding, (c) moving, and (d) resting.

Substrate inclination: Overall, both groups used horizontal and vertical substrates more frequently and oblique substrates less often (Table 17; Fig. 42a). During feeding, moving, and resting, the most frequently used substrate inclination class was horizontal followed by vertical and oblique substrates (Figs. 42b–d). But, no significant differences in patterns of substrate inclination use were found between groups in natural coffee forest and coffee plantation during any of the activities mentiond (Table 17).

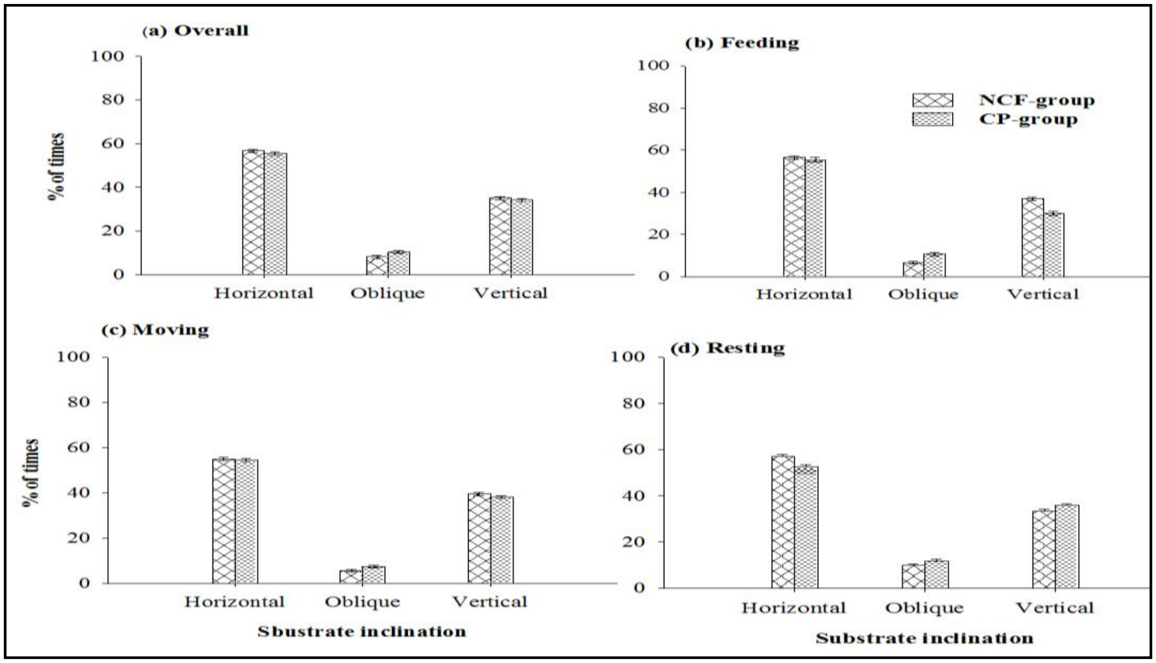


Figure 42. Substrate inclination used between two groups in natural coffee forest and coffee plantation during (a) feeding, moving, and resting combined, (b) feeding, (c) moving, and (d) resting.

***Substrate number*:** Overall, both groups used multiple supports more frequantly than single suppprts (Fig.43a). During feeding (Fig. 43b), moving (Fig. 43c), and resting (Fig. 41d), use of a multiple support was more common. However, there was no difference in the use of multiple and single substrates between natural coffee forest and coffee plantation groups (Table 17).

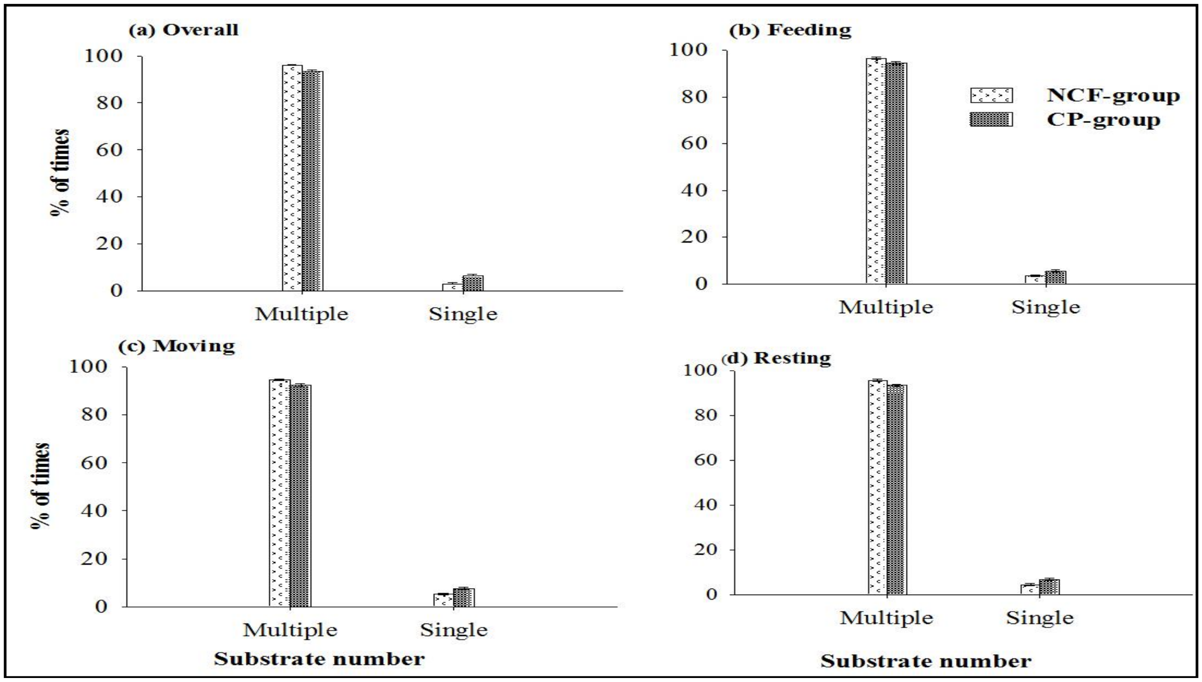


Figure 43. Substrate number used between two groups in natural coffee forest and coffee plantation during (a) feeding, moving, and resting combined, (b) feeding, (c) moving, and (d) resting.

5. 8. Domicile tree use

Tree species: Boutourlini's blue monkeys slept on 228 trees during 132 nights of data collection over 12 months and used 1–6 domicile trees per night. A total of 19 different species of trees were used for sleeping by two groups during the study period (Table 18). The study groups preferentially selected *Albizia schimperiana* (n = 49), *Pouteria altissima* (n = 42), and *Ficus vasta* (n = 28) as trees used for sleeping purpose which constituted more than 50 percent of the total number. *Albizia schimperiana* exhibited a low percentage of canopy cover (33.9 percent) and a low density of mature leaves during the study period, whereas *Ficus vasta* exhibited high canopy cover (71.8 percent) and a greater density of mature leaves. Based on 40 (10 x 50 m^2

quadrats) in the home ranges of our study groups, *Albizia schimperiana*, *Pouteria altissima,* and *Ficus vasta* account for 15.6 percent, 5 percent, and 2.6 percent, respectively of trees with a DBH > 21 cm (minimum recorded domicile tree DBH). Thus, these three tree species were selected significantly more often than expected based on their availability in the study groups' home ranges (chi-square goodness of fit test, $\chi^2 = 162.28$, df = 2, P = 0)

Table 18. A comparison of the percentage of nights spent on different tree species by two groups of Boutourlini's blue monkeys in Hamuma Coffee Forest.

Tree species	**NCF(n=132)**	**CP (n=96)**	**Total (n=228)**
Acacia lahai	1.3	–	1.3
Albizia schimperiana	14.9	6.6	21.5
Allophylus abyssinicus	0.9	–	0.9
Cordia africana	1.8	1.3	2.1
Croton macrostachyus	2.2	1.8	3.9
Diospyros abyssinica	0.4	0.9	1.3
Ficus sycomorus	2.2	0.4	2.6
Ficus sur	4.4	3.1	7.5
Ficus thonningii	2.2	1.8	3.9
Ficus vast	6.6	5.7	12.3
Olea africana	1.8	0.4	2.2
Pouteria altissima	7.5	11	18.4
Prunus africana	1.8	–	1.8
Trichilia dregeana	3.5	4.4	7.9
Trilepisium madagascariense	_	0.9	0.9
Sapium ellipticum	3.5	1.8	3.3
Schefllera volkenissi	1.8	1.8	3.6
Podocarpus falcatus	0.45	0.45	0.9
Celtic africana	1.3	_	1.3

Boutourlini's blue monkeys slept most often on trees containing fruits. The three mostly used fruiting species were *Pouteria altissima* (n = 42*), Ficus vast* (n = 28) and *Trichilia dregeana* (n = 18). The fruiting species used as sleeping sites were normal constituents of Boutourlini's blue monkey diet. The groups also selected non-fruiting trees that were directly adjacent to fruiting trees on which they had been foraging.

The mean DBH of trees used for sleeping was also compared to the mean DBH of all trees ≥10 cm measured along quadrats placed in the home ranges of the study groups. Based on data from 20 (10 x 50 m^2 quadrats), the mean DBH of these trees in NCF-group were significantly larger than the largest category of the trees recorded on quadrats (one-sided single sample t-test, $t = 5.97$, $df = 11$, $P < 0.001$). Similarly, the mean DBH of the trees used by CP-group were significantly higher than all large trees DBH ≥ 10 cm trees recorded on quadrats (one-sided single sample t-test, $t = 6.11$, $df = 11$, $P < 0.001$). This indicates that Boutourlini's blue monkeys selected trees of very large girth for sleeping.

The mean canopy cover and height of the lower most branches for all trees used by NCF-group was significantly higher than CP-group during the study period (Table 19). Similarly, the mean height of the sub-canopies and diameter of crown projection of trees in the natural coffee forest group were significantly higher than coffee plantation group (Table 19).

Table 19. Comparison of mean characteristics trees used for sleeping between Boutourlini's blue monkey groups in natural coffee forest and coffee plantation using One-Way ANOVA.

Character of domicile trees	NCF-group (Mean ±SD)	CP-group Mean ±SD	df = 1, F-value	LS
Height of the trees (m)	34.0±3.0	27.1±3.1	30.6	***
DBH (cm)	59.5±15.5	55.9±14.2	0.36	ns
Canopy cover (%)	57.97±10	44.7±12.1	8.59	***
Height of the lowest most branch (m)	10.1± 1.1	8.1±0.9	23.47	***
Height of the sub-canopies of trees (m	26.8±3.0	21.7±2.5	20.4	***
Dimeter of the crown projection (m)	10.2±2.3	6.8±1.9	15.08	**

The last column showed the level of significance (LS) with significant difference, P = 0.00 (***); P > 0.001(**); ns (no significance).

6. DISCUSSION

6.1. Resource availability and phenology

In this study, anthropogenic habitat modification was expected to result in lower quality habitat for Boutourlini's blue monkey. As we predicted, one of the key features often used to measure habitat quality, tree species diversity, was significantly greater in the minimally modified habitat (NCF) than the relatively heavily modified habitat (CP). This is consistent with patterns found in other tropical forests (Putz *et al.*, 2011; Souza *et al.*, 2012). It also goes in line with the study of Dereje Tesfaye *et al.* (2013) that indicated continuous intact forest contained higher species diversity than fragmented one as observed in Jibat Forest. Whereas, the second key feature, mean DBH and height of large trees (DBH ≥ 10cm) did not show significant difference between NCF and CP habitats. The observed similarities in mean DBH and height may be due to most of the large trees (DBH ≥ 10 cm) were left as coffee shade trees when the villagers modified the natural coffee forest (NCF) in to coffee plantation (CP). However, shrubs and weeds were more abundant in relatively heavily modified habitat (CP) than in minimally modified habitat (NCF). This high abundance in the coffee plantation habitat may reflect the fact that secondary growth areas are often characterized by higher levels of shrubs and weeds due to the presence of pioneer species (Corlett, 1995; Tabarelli *et al.*, 2010).

The progressive changes in resource abundance and availability have fundamental effects on the behaviour and ecology of primates (Dunbar, 2013). The abundance and productivity of important food resources may be better indicators of habitat quality; a more food species rich and dense habitat may ultimately provide more foraging options than a habitat where only species diversity is high (Poulsen *et al.*, 2001). In the present study, food abundance was greater in the natural coffee forest than coffee plantation habitats. This might possibly be due to different spatial and temporal distribution of food resources in the two habitats. Therefore, there were a number of important food species that were rare or non-existent, and exhibited a more patchy distribution in the CP habitat than in the NCF habitat. Fruit production was fairly uniform across the research period in both habitats, indicating that there are no extreme bad periods of resource scarcity for Boutourlini's blue monkeys. However, total fruit production was significantly less in the CP habitat than in the NCF habitat, indicating that the CP-group may be subject to shift to other food source from overall resource availability to subsidize the scarcity. In sum, the results suggest that the habitat within the CP group's range should be characterized relatively as lower in quality than NCF's habitat.

6.2. Activity patterns and time budget

Dunbar (1992) suggested that time is a limiting factor in behaviours and individuals should alter the amount of time allocated to specific behaviour based on the surrounding ecological variables. Behaviour is the response of both physical as well as habitat condition of the animal. In primates, food, mates, drinking and roosting trees are the most important resources that control the activity patterns. Among these resources, food seems to be the most crucial factor that regulates the day to day activity profiles. So, allocation of time to various activities is important to identify, the interaction of species with environment.

In this study, both NCF and CP groups of Boutourlini's blue monkeys spent most of their time resting followed by feeding. The activity budgets resulting from group scans generally are comparable with those of other species of the *C. mitis* studied at other sites of Ethiopia and African countries (Appendix 3). However, the proportion of time spent on each activity varied in different species and geographical locations. Boutourlini's blue monkeys group in the natural coffee forest habitat spent significantly more time socializing and less time for other activities than the group in coffee plantation forest. Group in coffee plantation spent relatively more time resting, less time feeding and moving than the conspecific in natural coffee forest, although, the differences were not significant. This might be associated with an energy minimization strategy. A number of primates adopt a similar strategy to cope with the limited density and quality of food resources in modified habitats, including several other folivores, *Colobus velleros*us (Wong and Sicotte, 2007), *Alouatta palliata* (Dunn *et al.*, 2009), *Alouatta seniculus* (Palma *et al.*, 2011), and *Chlorocebus djamdjamensis* (Addisu Mekonnen *et al.*, 2017). In addition, Boutourlini's blue monkeys in Hamuma Coffee Forest spent more time resting, and less time feeding than its conspecific in Jibat Forest, Ethiopia (Appendix 3). This may reflect the overall moderate density of food resource and trees used for sleeping in Hamuma Coffee Forest than Jibat Forest, as the encounter rate with high potential resource trees. However, these findings do not agree with the results reported on the activity time budget of *Alouatta palliata* in a Nicaraguan shade coffee plantation, where time spent resting is relatively low and time spent travelling is high which may reflect the overall low density of trees in shade coffee plantation (Williams, 2003).

In contrast to many social primates, socializing is not a common prevailing behaviour and rarely occurred in *Cercopithecus* species (Appendix 3). Consequently in this study, Boutourlini's blue monkeys spent smaller proportion of time socializing than overall activities.

This study indicated that Boutourlini's blue monkey devoted significant portion of monthly time budgets on feeding and showed as the predominant activity next to resting in Hamuma Coffee Forest. This was supported by similar study conducted in Jibat Forest, where Boutourlini's blue monkeys spent 50% of their time on feeding activity (Dereje Tesfaye *et al.*, 2013). Dunbar (1992) suggests that the availability of food and its energy content are critical determinants of daily activity budgets. The type of food that animals fed may determine the time allocated in feeding and other activities.

Daylight hours have significant impact on the diurnal activity patterns, and daily rhythms in behavioural activity are a common feature of arboreal primates (Robinson, 1986; Lawes and Piper, 1992), and they usually involve peaks in feeding in the morning and afternoon (Lee, 1997). Similarly, the daily resting pattern of Boutourlini's blue monkey increases from its low peak in the morning to the very high peak at noon, when the temperature is highest, while the feeding pattern inversely may also be a mechanism of energy conservation. Similar trends on activity patterns were seen for a number of primates such as black and white colobus monkey (Fashing, 2001a; Dereje Yazezew, 2018), gelada baboon (Zewdu Kifle, 2018; Amera Moges, 2019), and Bale monkey (Addisu Mekonnen *et al.*, 2017). It was also indicted that energy conservation strategies like sunbathing or hunching in cool weather while resting is possibly a way to cope with energetic demands (Oates, 1977; Fashing *et al.*, 2014). Moving activity was lower in mean time during the noon and afternoon session due to increased atmospheric temperatures hence Boutourlini's blue monkeys had to restrict movements and seek shelter from the direct sunlight underneath the trunk and the leaf covered canopy. Some studies have also shown that primates increase their resting time and deprive moving in response to high temperature by staying in the forest (Campos and Fedigan, 2009; Zewdu Kifle, 2018).

Most tropical forests have distinct dry and rainy seasons that influence food production by tropical plants (Tutin *et al.*, 1997; Janson and Chapman, 1999). Therefore, a number of previous primate studies have observed effect of seasonality on food availability and activity budget (Garber, 1993; Doran, 1997; Hill, 1997; Gursky, 2000; Guo *et al.*, 2007; Chaves *et al.*, 2011). But the results of this study showed seasons have no significant effect on the activity patterns of Boutourlini's blue monkeys in Hamuma Coffee Forest. This might be associated with feeding flexibility of the species in the absence of fruits as observed in an increase in time spent feeding on leaves during winter months. In many instances, this relationship is explained by a shift from a mostly frugivorous to a mostly folivorous diet (Fairgrieve, 1995; Beeson *et al.*, 1996). Arguing with this study, Coleman (2013) also stated that there was no evidence that season had effects on the activity patterns of Samongo monkeys in Lajuma, South Africa.

These energy management strategies vary based on the habitat type inhabited, time of the day, month or season and even sex. The study conducted on black and white colobus monkeys (C*olobus angolensis palliates)* in the coastal forest patch of southeastern Kenya showed that females devoted significantly more of their daily time than males for resting and grooming (Wijtten *et al.*, 2012). In contrary, the present study found out that both groups of all sex-age categories devoted similar proportion of time in each activity except juveniles spent significantly less time feeding and more time resting. This may be due to inaccessibility of potential food sources and avoiding diurnal predators. The juveniles and the sub-adults were also involved in this activity with the adults occasionally involved such as climbing, jumping with or without one another and mock fighting characterized this activity.

6. 3. Dietary diversity and composition in relation to habitat quality and time

Dietary diversity and composition, when viewed in relation to the differences between the two habitats, is primarily linked to habitat quality for Boutourlini's blue monkey. Group in natural coffee forest had a little bit less dietary diversity, species richness and evenness than in coffee plantation, although these differences were not significant. This implies, CP-group which occupies relatively highly modified habitat, showed a tendency to feed on a variety of foods to cope up anthropogenic pressure. Addisu Mekonnen *et al.* (2018a), in their research on *Chlorocebus djamdjamensis,* showed that a similar pattern with groups occupying habitats with different levels of disturbance. Harris *et al.* (2010) reported 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.

Although fruit is the most preferred food items, it was not abundant in all months and seasons. Therefore, Boutourlini's blue monkeys tend to depend on feeding on young leaves in Hamuma Coffee Forest. This is also supported by Mosissa Geleta and Afework Bekele (2016), in their study on the same species in Komto Protected Forest, Ethiopia, where young leaves ranked first and constituted 27.40% of the total diet. On the other hand, Dereje Tesfaye *et al.* (2013)

revealed that fruit was the first ranked food item, which accounted 53% of the overall diet of Boutourlini's blue monkey in Jibat Forest of Ethiopia. Even though young leaves and fruits constituted the largest proportion, both groups of Boutourlini's blue monkeys in natural coffee forest and coffee plantation consumed significantly greater proportion of animal products/ insects to supplementing their diet. The same feeding pattern on insects was observed in different primates species such as *Macaca nigra* (Lee, 1997), and *Macaca tonkeana* (Riley, 2007).

Comparison of dietary composition of Boutourlini’s blue monkey recorded in this study with other *C. mitis* populations is given in Appendix 4. In the present study, Boutourlini's blue monkey showed some differences in relative intakes of diet, but broad similarity in terms of composition with other *C.mitis* populations in previous studies (Appendix 4). In most sites, the major component of the diet by proportion of feeding records is fruit, which may also be the most nutritionally rewarding component of the diet (Lawes, 1991; Fairgrieve and Muhumuza, 2003; Coleman and Hill, 2014). The remainder of the diet is made up of other items such as young leaves, seeds and invertebrates (Butynski, 1990; Fairgrieve and Muhumuza, 2003; Coleman, 2013).

Although the coffee plantation habitat has reduced tree diversity and density, it apparently does not result in extremely reduced availability of high-quality, seasonal food items. Therefore, the Boutourlini′s blue monkey in coffee plantation is able to maintain a diet of presumably similar quality with natural coffee forest. This might be due to the presence of key fruiting tree species as coffee shade. According to Riley (2007), the presence of key plant species are determinant both in disturbed and undisturbed habitats and vary the diet of *Macaca tonkeana* regardless of the totality of diversity.

Contrary to conspecifics at other seasonal sites, Boutourlini's blue monkeys at Hamuma Coffee Forest demonstrate a less degree of seasonal variation in feeding behaviour. Only feeding on animal products/ insects was significantly greater during the wet than during the dry season. The scarcity of fruit during wet season, forces them to feed on animal products or insects to compensate the protein deficit in their diet. Similar with this finding, Coleman (2013) also confirmed that temperature seasonality becomes more pronounced and has an effect on the proportion of fruit and animal matter in Samango monkeys diet. He also indicated that they tend to feed on large proportion of animal products/insects when fruit availability is scarce. Moreover, many studies showed that Cercopithecines often consume relatively high proportions of invertebrates in their diets. This reflects the value of insects in offering a readily digestible source of protein (Redford and Dorea, 1984; Chapman *et al.*, 2002; Coleman and Hill, 2014).

The monthly changes in the use of phenophases and their proportional contribution to the diet observed at Hamuma Coffee Forest resemble those observed in many of other studies on *C. mitis* populations (Lawes, 1991; Beeson *et al.*, 1996; Coleman, 2013). Boutourlini's blue monkeys, at Hamuma Coffee Forest had pronounced relationships between the consumption and availability of seasonal resources. Coleman (2013), in his research on Samango monkey, South Africa, also observed positive correlations between the consumption of fruits and flowers with their availability in the habitat; such relationships are also observed at Hamuma Coffee Forest. Indeed, the relationship between the availability and consumption of vegetative parts is stronger.

Contrary to this, the consumption of young leaves is negatively correlated with the availability in this study since they used as “fallback” food at the time of fruit scarcity. However, the close relationship between the consumption of phenophases by species indicates that certain key resources are heavily exploited when they become available (e.g. *Ficus*). Similarly, Chapman *et al.* (2002) revealed that the degree to which *Cercopithecus ascanius* relied on particular plant species appeared to be related to the plant density. Therefore, *Cercopithecus ascanius* consumed fruit of *Mimusops bagshawei* at Kanyawara (1.8% of annual diet and 32.0% of the diet in the month when it fruited) and at Dura River (4.5% of total annual diet and 57.2% of the diet in the months it was available) in Kibale National Park, Uganda.

Fairgrieve and Muhumuza (2003) point out that the diet of blue monkeys comprises a few key plant species. However, Boutourlini's blue monkeys at Hamuma Coffee Forest differs in species consumption with other conspecifics in different sites. The top ten species comprised over 70% the overall diet during the study period. This over all diet proportion is less than the result reported by Mosissa Geleta and Afework Bekele (2016), in Komto Protected Forest, Ethiopia, in which the top ten consumed plant species accounted for 79.85% of their overall diet. On the other hand, the contribution of top ten species in the diet of Boutourlini's blue monkeys at Hamuma Coffee Forest is greater compared to other similar studies conducted on two groups of *Cercopithecus ascanius* at Kakamega Forest, Kenya, which the top ten species-specific food items accounting for 60.3 and 60.7% of the two groups' total plant diets (Gathua, 2000). This variation is due to the differences in biogeography, climate and ecological conditions (Coleman and Hill, 2014). Whereas, the figure obtained from this study is comparable with similar finding by Dereje Tesfaye *et al.* (2013) on Boutourlini's blue monkey group inhabiting relatively undisturbed continuous forest at Jibat, where the a top ten species accounted for 71% of the total diet.

Boutourlini's blue monkeys at Hamuma Coffee Forest differs from conspecifics at other sites in their lower levels of selectivity of food resources: the species that comprise the majority of their diet are fairly common, and the Boutourlini’s blue monkeys frequently feed on species, preferred less elsewhere. For example, the selection ratio for the top ten foods consumed at Hamuma Coffee Forest (Table 12) averages approximately 4.5 in natural coffee forest and 6.3 in coffee plantation, indicating that feeding trees were used somewhat more frequently than encountered. However, at comparable sites, the selection ratio for the top 10 species averages 496 in continuous and 175.6 in fragmented at Jibat Forest of Ethiopia (Dereje Tesfaye *et al.*, 2013), indicating more frequent use of rarer trees as food sources. This difference probably results both from the more diverse nature of the forest in less-disturbed sites and the selection of primary food sources at Hamuma Coffee Forest that are largely ignored at other sites. Many of the staple foods consumed by Boutourlini's blue monkeys at Hamuma Coffee Forest are eaten in much lower quantities at Komto Protected Forest and Jibat Forest, Ethiopia. For example, at Jibat Forest, *Croton macrostachyus* comprised only 0.34% of the annual diet, while Boutourlini's blue monkeys at Hamuma Coffee Forest spent little time feeding on Syzygium *guineense*, *Prunus africana.* These species are much more abundant in the coffee plantation.

6.4. Ranging behaviour and habitat use

***Movement patterns and home range* use:** Many studies indicated that the movement patterns in primate groups have been shown to be influenced by climate (Swedell, 2002; Stevenson, 2006;

Zhou *et al.*, 2007; Irwin, 2008a), an effect that might be accentuated for groups occupying disturbed habitats (Lee, 1997; Riley, 2008). However, in this study, daily path length was not correlated with either rainfall or temperature, but there was strong and negative correlation between daily path length and fruit availability, which suggested that a variable may be more important determinant of movement patterns in Hamuma Coffee Forest. Otherwise, it is not characterized by strong seasonal variation in rainfall and temperature. These results are consistent with those studies elsewhere on some primates such as Tonkean macaques (*Macaca tonkeana*) in Lore Lindu National Park, Sulawesi, Indonesia (Riley, 2008), Boutourlini's blue monkeys, at Jibat Forest, Ethiopia (Dereje Tesfaye *et al.*, 2013), and Samango monkey (*Cercopithecus mitis erythrarchus*), at Lajuma Environmental Research Centre, South Africa (Coleman, 2013).

Anthropogenic habitat modification and the concomitant reduction in food supply may, however, be creating foods scarcity to which Boutourlini's blue monkeys must respond in Hamuma Coffee Forest. Among those responses, one could be to increase daily path length and home range size in order to cover more area to obtain sufficient nutrients in a lower quality habitat (Dunbar, 1987; Chapman, 1988). This expected response makes assumptions about group size in relation to resource availability (Riley, 2008). It is therefore, group size is expected to be an important factor influencing ranging and movement in primates, if habitat quality and structure are similar, with larger groups exhibiting longer daily path lengths and larger home ranges (van Schaik *et al.*, 1983; Isbell, 1991; Barton *et al.*, 1992; Ostro *et al.*, 1999). However, there exists a growing body of evidence in several primate species, that group size is not a strong predictor of daily path length and home range size (Gillespie and Chapman, 2001; Arrowood *et al.*, 2003; Chhangani and Mohnot, 2006; Sussman and Garber, 2011; Chapman and Valenta, 2015) and other factors such as dietary selectivity, intergroup interactions in response to mate and resource defense, predation and infanticide risk, and extra-group mating opportunities play a more prominent role in determining ranging patterns and daily path length (Peres, 2000c; Willems and Hill, 2009; Rano *et al.*, 2016).

In heavily-altered environments, however, the home range size and daily path length will reflect habitat quality, with groups that have large home range and daily path length able to more efficiently utilize what resources are available. It is, therefore, possible to say that the large home range size of the CP-group is the direct result of diminishing habitat quality and producing fission in a once larger group.

The smaller overall home range of the NCF-group may reflect better quality of habitat and higher availability of food resource for NCF-group, or perhaps more appropriately, the grater overall home range of CP-group reflects the lower resource availability in their habitat. Whereas, the equivalence between the two groups in daily path length, on the other hand, indicates that despite the better resource availability, the NCF-group must still travel as far as a CP-group in order to acquire necessary resources on a daily basis, given the sparsely distributed fruiting trees in their habitat. This is also consistent with the larger areas utilized on an individual basis by CP-group members relative to NCF individuals. Overall, these results suggest that in heavily-modified habitat, small group size may permit a larger overall home range, but the abundance and distribution of the limited resources may still require significant movement on a daily basis.

According to Ostro *et al.* (1999), the most unrecognized difference between groups living in relatively heavily-versus minimally-modified habitats may have less to do with amount of daily and annual area they explore, than how they actually use the areas within their range. Therefore, the NCF-group, occupying minimally-modified habitat, utilized limited core area within the home range, given the better quality of habitat. In contrast, the CP-group showed an even use of its large core area in their range with greater intensity to acquire the required resources. This result may reflect that key resources are more limited and spatially concentrated in the CP-group's habitat, while the NCF-group's range contains a greater number of resource options distributed throughout its smaller range. For the CP-group, the individuals expand their home range demanding more resource utilization and access to limited sleeping and food trees were located. Access to cultivated foods such as *Psidium guajava*, which are spatially concentrated at the edge of habitat and abundant at predictable times, may also have contributed to periodic expansion of their home range for the CP-group. This also has been shown in other studies (Saj *et al.*, 1999; Riley, 2008).

In the present study, taking all the realities on the ground into consideration, human-induced habitat modification to some extent results in a reduction in tree abundance, key food species density, and levels of fruit production. These appear to be important influences on ranging patterns and habitat use in Boutorlini's blue monkeys at Hamuma Coffee Forest. Consequently, Boutorlini's blue monkes may show a responding tendency to anthropogenic disturbance by adjusting their use of forest strata in order to facilitate travel and increase foraging opportunities, by intensively using particular areas within their home range where known resources are present and predictably available (e.g., *Ficus* sp.), but also by increasing their home range size per individual to cover more area and extending their overall search effort on a daily basis as it has been explained in many studies on different primates (Dereje Tesfaye *et al.*, 2013; Eppley, 2015; Addisu Mekonnen *et al.*, 2017; McKinney, 2019).

Daily path length and home range size of Boutorlini's blue monkeys at Hamuma Coffee Forest fall withn the range of varation with other species, given that the habitat in Hamuma Coffee Forest is relatively disturbed, with low tree species diversity and stem density than other protected natural forests, one might expect Boutorlini's blue monkeys to have large home range sizes and day path lengths in comparison to conspecifics at other sites (Appindex 5). Range sizes at sites where studies encompassing 6 to 63 months cycle have been conducted to vary from 10 ha (Fairgrieve and Muhumuza, 2003) to 252.75 ha (Butynski, 1990). Relatively small home ranges do not reflect unusually small group sizes at Hamuma Coffee Forest: the home range area per individual depends on the habitat quality. Given the large group sizes, the relatively small home ranges of the Boutorlini's blue monkeys at Hamuma Coffee Forest probably do not reflect crowding or habitat contraction, as has been observed at other sites (Cords, 1987b; Lawes, 1990a; Coleman, 2013). Although the density of individual trees is lower at Hamuma Coffee Forest than less-disturbed habitats, several of the tree species used have high densities and often have large basal areas, suggesting that resource availability may not be as low as stem density or tree species diversity would suggest.

Day path lengths of Boutorlini's blue monkeys at Hamuma Coffee Forest are shrorter following similar patterns with the typical sizes of their home ranges than reported at most of other sites (Appendixe 5). It is not surrprizing why day ranges should be shorter at Hamuma Coffee Forest than at other sites, given that most food sources are abundant and nutritious in the shade coffee plantation (Williams, 2003). Day range length is more sensitive to patterns of food distribution than is home range size (Chhangani and Mohnot, 2006), and the short distances travelled may relate specifically to the distribution and density of foods containing the required availabile nutrients, which are ripe fruits and other sources of simple carbohydrates (Williams, 2003). In addition, feeding flexibilty on other alternative foods at a time of preferred foods scarcity might be one reason for their shorter day path length. Similar results were reported on two blue monkey groups at Jibat, which travelled considerably shorter distances per day than other blue monkeys and guenons (*Cercopithecus* spp.) in most other African forests. This pattern suggests that blue monkeys at Jibat do not need to travel far to find sufficient food or will settle for non preferred food items to avoid increasing daily travel distances (Dereje Tesfaye *et al.*, 2013).

Forest strata and micro-habitat use: The results of this study showed that Boutorlini's blue monkeys that live in coffee plantation spend a significantly greater proportion of time on the ground than those living in natural coffee forest habitat. Riley (2008) found a similar pattern in Tonkean Macaques (*Macaca tonkeana*); the group living in a heavily-altered forest. Addisu Mekonnen *et al.* (2018b), in their research on *Chlorocebus djamdjamensis*, also revealed that groups in forest fragments spent more than one-third of their time on the ground whereas those in continuous forest were observed on the ground only 2% of the time. A significantly greater proportion of time spent on the ground may reflect the CP group's need to adjust forest strata use in habitat where there are fewer large trees and significant forms of modification (e.g., expansion of coffee plantation areas). This tendency towards terrestriality in disturbed habitats could also be related to rates of insect foraging and consumption (Lee, 1997; Riley, 2007).

However, this is not the case in the present study, because the CP-group consumed less proportion of insects than NCF-group. Instead, the possible reason of this difference might be associated with CP-group travelling more on the ground to have access on spatially distributed fruiting trees in their habitat. Other similar study on *Chlorocebus djamdjamensis* found out that degraded habitats with disconnected canopies may probably led them to increase terrestrial activity (Addisu Mekonnen *et al.*, 2010; Addisu Mekonnen *et al.*, 2018b).

Although the natural predators of Boutorlini's blue monkeys at Hamuma Coffee Forest are fewer compared to other sites where conspcifics are found, examination of forest strata use in heavily-modfied areas is important with respect to allied concerns which can negatively impact populations. Humans, although not typically viewed as “natural predators,” can also negatively impact primate population sizes and densities through hunting (Peres, 2000a; Riley and Priston, 2010). During this study, hunting of Boutorlini's blue monkeys is a common practice in a number of areas in Hamuma Coffee Forest, despite the unknown status of Boutorlini's blue monkeys. Therefore, villagers typically hunt Boutorlini's blue monkeys by setting up traps on the ground or by throwing rocks at solitary individuals which are then chased by dogs assuming them as a coffee seed pest (personal observation).

A tendency of Boutorlini's blue monkeys to wards a terrestrial mode of life in human-modified habitats may therefore pose a threat to their survival. This may be the case even if hunting devices, such as traps, are not intended to capture Boutorlini's blue monkeys, as was evident in the present study when monkeys were caught in a trap set for forest Menilik's bush buck. On the other hand, when Boutorlini's blue monkeys were forced to spend most of their time on the upper and middle forest strata in disturbed habitats, where canopy has been lost and gaps are large, this can result in an increased rate of falling, as it has been stated by Singh *et al.* (2001); Riley (2008); Addisu Mekonnen *et al.* (2018b). When faced with a significant loss of trees in their habitat, Boutorlini's blue monkeys may be forced to travel more on the ground, as well as exploiting the resources available there, but these activities are not without risk.

Assessment of varying micro-habitats is key element to understand what resources are available to groups and how those resources are distributed spatially in Hamuma Coffee Forest. It was also indicated in many studies that most species of primates prefer primary (undisturbed) forest than secondary (disturbed) forest areas (Lee, 1997; Riley, 2005; Dereje Yazezew, 2018). In this study, both NCF and CP groups spent more time in the tree dominant forest areas than was expected, which may reflect these groups' reliance on food resources (e.g. *Ficus* spp., and others) that tend to be high in density in tree dominant forests than other microhabitats. More time than expected in tree dominate forest areas may also be the result of the groups being secured and hide from human and other natural predators interference (a compromise between the need for a good energy intake and a defense strategy against “predators”). They also feel more comfortable during sleeping on tree dominant forest than other microhabitats. This microhabitat may therefore represent space where they can efficiently use their energy; that is, to obtain nutrients without having to expend additional energy in the access of the resources available. A similar pattern was also reported by Dereje Tesfaye *et al.* (2013), who found that the Boutourlini's blue monkey group inhabiting relatively undisturbed continuous forest at Jibat was able to meet its needs almost exclusively in the tree-dominated forest, coming out into nearby bushland occasionally, and mostly to feed on *Rubus apetalus* fruits. Studies carried out on Stuhlmann's blue monkeys (*Cercopithecus mitis stuhlmanni*) in Kakamega Forest, also showed that forest-dwelling group occasionally come out of the forest to access trees of *Bischofia javanica* cultivated in the surrounding human-dominated landscape to feed on fruit (Cords, 1987b; Pazol and Cords, 2005). In other study of Samango monkeys (*Cercopithecus mitis labiatus*) inhabiting forest fragments of *Podocarpus* in South Africa, never entered plantations of *Acacia* or other matrix habitats near by (Lawes *et al.*, 2000). The extent to which differences in habituation to humans or hunting threats that might play a role in these differences in matrix use between blue monkey subspecies and populations is unclear (Dereje Tesfaye *et al.*, 2013).

6.5. Plasticity in positional behaviour and substratum utilization

In contrast to our prediction, the results of the present study showed that no marked significant differences in locomotor behaviour and support use between Boutourlini's blue monkeys in natural coffee forest and coffee plantation forest. Although, this difference is not significant, group in coffee plantation forest tended to show slight modification of locomotor modes, which could be strategic response to anthropogenic habitat alteration. However, the closer in locomotor behaviour and support use between two groups might be associated with similarity in habitat quality and canopy structure between natural coffee forest and coffee plantation forest.

Boutourlini's blue monkeys in Hamuma Coffee Forest often use quadrapedal locomotion (walking) and bridging to cross gaps between canopies, while travelling and searching for food resources. In particular, group in coffee plantation forest travelled quadrupedally more on the ground than in natural coffee forest. The possible reason for travelling quadrupedally on the ground could be to minimize locomotor routes and thus energy expenditure (Huang *et al.*, 2015).

Boutourlini's blue monkeys spent less time climbing than walking and bridging, perhaps because it is energetically expensive to climb vertically, and frequent ascent and descent. This goes in line with the fact that in primates the metabolic cost of climbing is higher than the cost of walking or running because of the additional work required to lift of the centre of mass (Hanna *et al.*, 2008; Addisu Mekonnen *et al.*, 2018b). They also spent less time leaping because of sparsely distributed trees and discontinuous canopies, where gaps are too large to cross via leaping, as has been revealed in different studies (Lawler *et al.*, 2006; Workman and Schmitt, 2012; Zhou *et al.*, 2013; Addisu Mekonnen *et al.*, 2018b).

The result of Boutourlini's blue monkeys postural use in Hamuma Coffee Forest contradicts our prediction. It is, therefore, group in coffee plantation forest did not show remarkable difference in all posture uses than in natural coffee forest. However, both groups of Boutourlini's blue monkeys used standing posture more frequently while they were feeding than resting. This might be associated with their feeding preference on fruits. Similar results were reported by Addisu Mekonnen *et al.* (2018a) on Bale monkeys', which showed greater use of standing postures in fragments, where frugivory is common than in a continuous forest. On the other hand, to reduce the risk of falling, monkeys may frequently use sitting postures while resting. Moreover, Youlatos (1998) and Addisu Mekonnen *et al.* (2018b) stated that frugivorous species feed more often in a standing posture related to the more mobile, softer, or harder to obtain feeding sources they exploit than folivorous species, which tend to sit while feeding because their food sources are easy to collect and must be chewed for long periods of time.

Both groups of Boutourlini's blue monkeys used branches more frequently than trunks irrespective of any activities that are involved in their habitats. This is because, in many cases branches are rich in food source and can be used as confortable and safe substrate during feeding and resting. However during moving, group in natural coffee forest used branches more and trunks less frequantly than group in coffee plantaion forest. This might be due to the size of branches in the home range of NCF-group, which are strong enough to allow easier and more confortable movements than in home range of CP-group. This pattern is similar with other studies in different sites, where branches are used most frequently by primates irrespective of the habitat types (McGraw, 1998; Huang *et al.*, 2015; Addisu Mekonnen *et al.*, 2018b).

It is not striking that Boutourlini's blue monkeys used medium to large, horizontal and multiple weight-bearing supports more frequently than small-sized, oblique and single support during feeding, resting and travelling. It is because these are easily accessible to food sources and safe place to hide animals from diurnal predators. This is consistent with the report by Grueter *et al.* (2013), which stated that some primates occupy places that make them maximally hidden during a period of vulnerability, from both terrestrial and aereal predators. It is also similar with the argument that, despite the architectural differences between habitats, monkeys most frequently used medium to large horizontal branches to rest in well hidden parts of the tree crown as well as to ensure stability (McGraw, 1998; Grueter *et al.*, 2013; Addisu Mekonnen *et al.*, 2018b).

6. 6. Selection of trees to sleep

Choice of tree species for sleeping by Boutourlini's blue monkeys in Hamuma Coffee Forest was not random. Instead, they select tree species based on the role that they play as means for predation-avoidance, maximizing comfort and security. Consequently, both groups in natural coffee forest and coffee plantation forest preferred to sleep on tree species which are tall and have large canopy covers with many branches that can support many individuals compared to the overall trees available in their home range irrespective of the habitat types. Selected trees were visibly emergent relative to other trees in the surrounding forest. *Albizia schimperiana*, *Pouteria altissima*, and *Ficus vasta* typically attain large, emergent size with branches of substantial girth, which could account for the preferential selection of these species for sleep. This may help them both to deter predators, and also for greater comfort and security. These results go in line with other studies on certain arboreal primates such as *Cebus capucinus* (Holmes *et al.*, 2011), *Nomascus nasutus* (Fei *et al.*, 2012), and *Nasalis larvatus* (Feilen and Marshall, 2014). Moreover, they also choose food species particularly fruiting trees for sleep, given that all the factors influencing the preference of the trees for sleeping are maintained. This might be associated with the energy minimizing mechanism during searching for food species. Therefore, the result of this study coincides with the common consensus that the choice of primate sleeping site proximal to food sources is crucial in order to reduce the time and energetic costs of travel, and give them immediate access to food either in the morning or right before they retire (Chapman, 1989; Chapman *et al.*, 1989; Heymann, 1995; Smith *et al.*, 2007; Li *et al.*, 2011; Teichroeb *et al.*, 2012). On the other hand, Asensio and Gómez-Marín (2002) clearly indicated that maturity and density of fruits on sleeping sites could affect a primates' proximity to predators that have frugivorous or carnivorous diets. Therefore, predators might forage on the same or nearby trees. Despite these facts, Boutourlini's blue monkeys in Hamuma Coffee Forest slept on fruiting trees often times indicated that they were not under considerable predation pressure except few snake and raptor species. Holmes *et al.* (2011) revealed that white-faced capuchins did not appear to avoid sleeping on fruiting trees, despite the predation-avoidance strategy.

In agreement with our prediction, group in coffee plantation forest slept on trees which had significantly lower mean height, canopy cover, height of the lower most branches, height of the sub-canopies and diameter of crown projection than groups in natural coffee forest. This may be due to the relative scarcity of large trees in coffee plantation forest that are characterized by young age and ongoing regeneration compared to the natural coffee forest. Therefore, this coincides with the fact that secondary forest is characterized by trees of small girth and height, even relatively tall, emergent trees in that forest are shorter than those found in primary forests (Meyfroidt and Lambin, 2008).

A higher average tree girth and height compared to all trees DBH ≥10 cm in the surrounding across Hamuma Coffee Forest, where Boutourlini's blue monkeys use have been documented to explain with predation-avoidance strategy. This goes in line with other studies which stated that tall, emergent trees with high sub-canopy and bottom most branch heights and large girth (i.e., higher DBH) decrease tree accessibility to terrestrial predators, and a lower percentage of canopy cover facilitates increased ability to detect predators (Holmes *et al.*, 2011; Fei *et al.*, 2012; Feilen and Marshall, 2014).

6.7. Conservation implications of behavioural flexibility

This study revealed that, like most other forest primates, Boutourlini's blue monkeys have the flexibility to cope with changes in the type and abundance of foods through diet shift, being flexible in activity and ranging pattern resulting from habitat modification because of coffee plantation in the area, at least over the short-term. More intensive long-term studies of Boutourlini's blue monkeys in disturbed habitats are, however, needed to examine and address some of the potential drawbacks on their life and the extent to which they are flexible in such disturbed habitats. The greatest conservation concern that the species face is the loss of natural habitats through different anthropogenic activities such as high population growth related to a high rate of forest clearance for coffee plantation and timber production. In addition, as in many other sites where primates raid crops (Hill and Webber, 2010), local community sometimes responded to Boutourlini's blue monkey through hunting by spears and dogs. Their narrow geographic range, low population density along with other threats may cause local extinction in the future. Since the species has been classified under 'Vulnerable' category of IUCN Red List of Threatened Species (Dereje Tesfaye *et al.*, 2013) and mostly live out of protected areas, special conservation and management strategies should be designed to sustain the continuity of the species in its natural habitats. Effective conservation management plan should focus on their dietary and habitat requirements, and awareness creation through community participation. Therefore, Hamuma Coffee Forest with other southwestern forests should be considered as priority areas for the survival of this little known and endemic subspecies of Ethiopia. In sum, given all the anthropogenic threats in southwestern Ethiopia, the ability to withstand habitat modification and other disturbance to their habitat will likely be the key factor in determining the long-term conservation prospects of Boutourlini's blue monkeys.

7. CONCLUSION AND RECOMMENDATIONS

7.1. Conclusion

This study compared data from heavily-modified and relatively minimally-modified habitats to contribute to our understanding of the ecological and behavioural flexibility of non-human primates in human-modified environments as well as conservation implication of such flexibility. The results indicate that Boutourlini's blue monkeys showed tendency to respond to anthropogenic habitat modification by being flexible in their diet, by incorporating more alternative food items, such as insects, leaves and shoots, by exploiting resources that dominate human-modified areas (e.g. *Psidium guajava, Coffee arabica*), and by adjusting their activity budgets to devote more time to foraging. They also showed plasticity in positional behaviour and tree selection for sleeping in order to maximize energy conservation and promote predation-avoidance strategies.

Boutourlini's blue monkeys also appear to be flexible in how they move on space. They use the forest strata in order to facilitate travel on the ground and increase access to food sources so as to promote foraging opportunities. Because there are relatively fewer resources available in the CP-group's home range than the conspecific in natural coffee forest, this group may have shifted its use of space to cover wider areas where their preferred resources are available, and where they can monitor changes in food availability more easily.

Ecological variables such as habitat quality, and the availability and distribution of food affect the group size of Boutourlini's blue monkeys in Hamuma Coffee Forest. The results from this research presented a small group size of the CP-group may be the direct result of diminishing habitat quality impacting mortality or producing fission in a once larger group to multi-small groups. Therefore, they can reduce habitat depletion and intra-group competition. The group size observed for the CP-group may be the optimal size in which foraging efficiency is maximized, and therefore may be the response, in combination with dietary and behavioural flexibility, to disturbance of their habitat.

Relatively similar in forest structure and ecological variables between the home ranges of the two groups accounted for the insignificant variation in overall strata and support use. Locomotor and postural behaviours are relatively consistent between habitat types. However, we assume that the link between morphology and behaviour yield significantly different positional behaviour repertories. Despite of all these, Boutourlini's blue monkeys in disturbed habitat still showed slight plasticity in mode of life style and in positioning on forest strata.

In sum, based on our results, we can conclude that Boutourlini's blue monkeys in Hamuma Coffee Forest showed a tendency to be ecological and behavioural flexible like other arboreal primates living in forest, in spite of how flexible is in question. They developed a certain degree of dietary flexibility, habitat adaptability, and positional plasticity for living on the relatively heavily-modified environment. They also developed a better way of survival strategies to live in unprotected southwestern coffee forest of Ethiopia sharing the available resource with other primates harbouring in the areas. This ecological and behavioural flexibility may help them to occupy in areas where human interference is high. The findings suggest that Boutourlini's blue monkeys mostly found outside of protected areas and conservation and management strategies require special attention which enables them how they co-exist with the local community. In addition, how much they are flexible is unknown and still needs further studies.

7.2. Recommendations

Based on findings of the study, the following recommendations are forwarded to ensure the sustainable and long-term conservation of Boutourlini's blue monkeys in southern and western Ethiopia where they sympatrically live with other primates.

- Total population survey and census in all over the ranges where this little known Ethiopian endemic, Boutourlini's blue monkey occurs, is required to track the population trend, and evaluate the current IUCN status.
- Repeated and further studies need to be conducted to examine the impact of anthropogenic forest disturbances on the reproduction performance and behaviour of Boutourlini's blue monkeys and enable us to come into general conclusion how much they are flexible.
- Population distribution of Boutourlini's blue monkey is mostly outside of the protected areas where the species face high anthropogenic pressure. Therefore, special conservation and management strategy is crucial to sustain their abundance without compromising the livelihood of the local community.
- Research such as habitat suitability and vulnerability of the species should be carried out in the area.
- The area is underappreciated as a potential primate conservation priority and further effort on promotion and advertisement is required to attract many primatologists and tourists.

- The area harbours many primates, therefore, primatologist should be encouraged to come and design a long-term plan on the conservation and management strategies to sustain the wildlife in general and primates in particular in their natural habitats.
- *Ficus* species conservation should be promoted since their fruits are reliable and main food sources for Boutourlini's blue monkeys in the area.
- Indigenous knowledge of the local community maintaining large trees as coffee shade trees should be encouraged and promoted
- A community-based conservation education and outreach programme especially outside of the protected areas is essential to improve the awareness of local community and to develop positive attitude towards the conservation of Boutourlini's blue monkeys.

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APPENDICES

Appendix 1. Relative abundance of plant species within the home range of NCF-group.

Vernacular name	Scientific name	Family	Growth form	No. of stem in study quadrates	Relative abundance (%)
Buna	*Coffea arabica*	Rubiaceae	S/T	3388	69.8
Dhumuga	*Justicia schimperiana*	Acanthaceae	S	796	16.34
Dedatu	*Millettia ferruginea*	Fabaceae	T	89	1.83
Bagee	*Combretum paniculatum*	Combretaceae	C	70	1.44
Geboo	*Landolphia buchananii*	Apocynaceae	C	60	1.23
Ambabessa	*Albizia schimperiana*	Fabaceae	T	57	1.17
Bakanissa	*Croton macrostachyus*	Euphorbiaceae	T	48	0.99
Birbissa	*Podocarpus falcatus*	Podocarpaceae	T	33	0.68
Badessa	*Syzygium guineense*	Myrtaceae	T	30	0.62
Kosoro	*Acanthus sennii*	Acanthaceae	S	28	0.58
Tiloo	*Cassipourea malosana*	Rhizophoraceae	T	23	0.47
Sarxee	*Dracaena fragrans*	Asparagaceae	S	22	0.45
Bururi	*Grewia ferruginea*	Tiliaceae	T	22	0.43
Hachacha	*Maytenus arbutifolia*	Celastraceae	T	19	0.39
Bosoka	*Sapium ellipticum*	Euphorbiaceae	T	17	0.35
Qewwisa	*Buddleia polystachya*	Milantaceae	S	15	0.31
Reejji	*Vernonia myriantha*	Asteraceae	S	15	0.31
Lokko	*Diospyros abyssinica*	Ebenaceae	T	14	0.9
Kilto	*Ficus vasta*	Moraceae	T	11	0.23
Atat (Am)	*Maytenus gracilipes*	Celastraceae	S	10	0.21
Wendebiy	*Apodytes dimidiata*	Icacinaceae	T	9	0.19
Luyaa	*Trichilia dregeana*	Meliaceae	T	9	0.19
Kuraro	*Pouteria altissima*	Sapotaceae	T	8	0.16

(Continues)

Appendix 1. (Continued)

Karasho	*Polyscias fulva*	Araliaceae	T	7	0.14
Wadessa	*Cordia africana*	Boraginaceae	T	7	0.14
Harbu	*Ficus sur*	Moraceae	T	6	0.12
Harragaamaa	*Capparis tomentosa*	Capparidaceae	C	5	0.1
Getema	*Schefflera volkensii*	Araliaceae	T	5	0.1
Loko adii	*Suregada procera*	Euphorbiaceae	T/S	4	0.08
Seho	*Allophylus abyssinicus*	Sapindaceae	T	4	0.08
Sondi	Acacia lahai	Fabaceae	T	4	0.08
Ulagaa	*Ehretia cymosa*	Boraginaceae	T	3	0.06
Agamsa	*Carissa edulis*	Apocynaceae	S	3	0.06
Abayi	*Maesa lanceolata*	Primulaceae	S	2	0.04
Chayi	*Celtis africana*	Cannabaceae	T	2	0.04
Chato	*Albizia gummifera*	Fabaceae	T	2	0.04
Akukku	*Oncoba spinosa*	Flacourtiaceae	T	1	0.02
Dambi	*Ficus thonningii*	Moraceae	T	1	0.02
Deqoo	*Ritchiea albersii*	Canellaceae	S	1	0.02
Lolchissa	*Bersama abyssinica*	Melianthaceae	T	1	0.02
Kurawa	*Dovyalis abyssinica*	Flacourtiaceae	S	1	0.02
Ejerssa	*Olea africana*	Oleaceae	T	1	0.02
Harbu	*Ficus sycomorus*	Moraceae	T	1	0.02
Hoomi	*Prunus africana*	Rhizophoraceae	T	1	0.02
Somboo	*Ekebergia capensis*	Meliaceae	T	1	0.02

T = Tree, S = Shrub, C = Climber, H=Herb, Am = Amharic

Appendix 2. Relative abundance of plant species within the home range of CP-group.

Vernacular names	Scientific name	Family	Growth form	No. of stem in study quadrates	Relative abundance (%)
Buna	*Coffea arabica*	Rubiaceae	S/T	7032	72.23
Dhumuga	*Justicia schimperiana*	Acanthaceae	S	1650	16.95
Atat	*Maytenus gracilipes*	Celastraceae	S	500	0.21
Bakanissa	*Croton macrostachyus*	Euphorbiaceae	T	110	1.13
Dedatu	*Millettia ferruginea*	Fabaceae	T	88	0.90
Bagee	*Combretum paniculatum*	Combretaceae	C	80	0.82
Ambabessa	*Albizia schimperiana*	Fabaceae	T	64	0.66
Geboo	*Landolphia buchananii*	Apocynaceae	C	40	1.24
Loko adii	*Suregada procera*	Euphorbiaceae	T/S	31	0.32
Sarxee	*Dracaena fragrans*	Asparagaceae	S	16	0.16
Wadessa	*Cordia africana*	Boraginaceae	T	16	0.16
Tiloo	*Cassipourea malosana*	Rhizophoraceae	T	14	0.14
Bosoka	*Sapium ellipticum*	Euphorbiaceae	T	13	0.13
Kuraro	*Pouteria altissima*	Sapotaceae	T	13	0.13
Badessa	*Syzygium guineense*	Myrtaceae	T	12	0.12
Harbu	Ficus sur	Moraceae	T	9	0.09
Ulagaa	*Ehretia cymosa*	Boraginaceae	T	8	0.08
Goffa	*Psidium guajava*	Myrtaceae	T/S	8	0.08
Dambi	*Ficus thonningii*	Moraceae	T	6	0.06
Sondi	Acacia lahai	Fabaceae	T	4	0.04

Appendix 2. (Continued)

Getema	*Schefflera volkensii*	Araliaceae	T	3	0.03
Birbissa	*Podocarpus falcatus*	Podocarpaceae	T	3	0.03
Lokko	*Diospyros abyssinica*	Ebenaceae	T	2	0.02
Luyya	*Trichilia dregeana*	Meliaceae	T	2	0.02
Seho	*Allophylus abyssinicus*	Sapindaceae	T	2	0.02
Tatesa	*Rhus gultinosa*	Anacardiaceae	T	2	0.02
Adami	*Euphorbia candelabrum*	Ephorbiaceae	T	2	0.02
Warka	*Ficus vasta*	Moraceae	T	1	0.01
Ejerssa	*Olea africana*	Oleaceae	T	1	0.01
Karasho	*Polyscias fulva*	Araliaceae	T	1	0.01
Chayi	*Celtis africana*	Cannabaceae	T	1	0.01
Agamsa	Carissa edulis	Apocynaceae	S	1	0.01

T = Tree, S = Shrub, C = Climber, H=Herb

Appendix 3. Annual activity budgets at Hamuma coffee forest and other sites where *C.mitis* have been studied.

Subspecies	**Location**	**% F**	**% R**	**% M**	**% S**	**% O**	**Reference**
C.m. boutourlinii	NCF, Hamuma forest, Ethiopia	33.4	35.2	21.1	7.6	2.6	Current study
C.m. boutourlinii	CP, Hamuma forest, Ethiopia	30.2	37.3	21.7	5.9	4.7	Current study
C.m. boutourlinii	Jibat forest, Ethiopia	50	24	16	10	-	Dereje Tesfaye (2010)
C.m.stuhlmannis	Kanyawara, Kibale Forest, Uganda	36.2	32.7	19.7	8.3	-	Butynski (1990)
C.m.stuhlmannis	Ngogo, Kibale Forest, Uganda	31.7	36.2	24.7	7	-	Butynski (1990)
C.m.stuhlmanni	Kakamega Forest, Kenya	49.4	31.7	15.8	1.2	1.9	Cords (1986)
C.m.erythrarchus	Lajuma, South Africa	28.1	41.5	23.2	7.1	0.1	Coleman (2013)
C.m.erythrarchus	Cape Vidal Forest,South Africa	35.8	22.6	29.4	12	-	Lawes *et al.* (1990)

F= Feeding; R = Resting; Moving; S = Socializing; O = Other activities; NCF = natural coffee forest, CP = Coffee plantation

Appendix 4. Diet composition data from all available *C. mitis* studies with a minimum study period of six months.

Location	**Method**	**F %**	**L %**	**Fl %**	**O %**	**An %**	**Fu %**	**Un %**	**Reference**
Robe, Hamuma forest, Ethiopia	Obs.	40.6	39.38	0.55	0.33	19.2	_	_	Current study
Littu, Hamuma forest, Ethiopia	Obs.	42.2	41.64	0.35	0.35	14.4	–	–	Current study
Komto Forest, Ethiopia	Obs.	15.5	47.7	11.24	20.1	3.4	0	1.5	Mosissa Geleta and Afework Bekele (2016)
Jibat Forest, Ethiopia	Obs.	53.1	14.2	7.3	10.4	14.7	0	0.4	Dereje Tesfaye *et al.* (2013)
Budongo Forest, Uganda	Obs.	44.9	29.0	6.2	10.3	9.7	0	0	Fairgrieve and Muhumuza (2003)
Kanyawara, Kibale Forest, Uganda	Obs.	42.7	21.3	11.8	4.4	19.8	0	0	Rudran (1978)
Kanyawara, Kibale Forest, Uganda	Obs.	27.7	33.0	6.9	0	37.7	0	0.6	Butynski (1990)
Ngogo, Kibale Forest Uganda	Obs.	30.1	22.8	9.8	0	35.9	0	1.3	Butynski (1990)
Kakamega Forest, Kenya	Obs.	54.6	18.9	3.7	5.5	16.8	0	0.5	Cords (1987b)
Mgahinga Gorilla National Park, Uganda	Fae.	26.3	51.6	0	4.6	16.3	0	1.2	Twinomugisha *et al.* (2006)
Nyungwe Forest, Rwanda	Obs.	47.4	6.2	6.2	0	24.9	0	6.2	Kaplin (2001)
Diani Beach Forest, Kenya	Obs/Fae.	57.1	7.1	14.3	21.4	0	0	0	Moreno-Black and Maples (1977)
Zomba Plateau, Malawi	Obs.	53.5	32.6	10.2	2.9	0.8	0	0	Beeson *et al.* (1996)
Entabeni Forest, South Africa	Sto.	73.1	13	4.5	7.8	1.5	0	0	Breytenbach (1988)
Lajuma, South Africa	Obs.	51.7	43.9	0.4	1.1	1.3	1.6	0	Coleman (2013)
Cape Vidal Forest, South Africa	Obs.	51.7	25.8	13.4	0.9	5.8	0	2.3	Lawes (1990a)
Ngoye Forest, South Africa	Obs.	91.1	3.0	2.1	0	0	0	3.8	Lawes *et al.* (1990)
Ngoye Forest, South Africa	Fae.	84.4	1.6	0.6	8.9	0.4	0.5	0	Lawes *et al.* (1990)

Obs= Observation; Fae analysis; Sto= Stomach analysis; F= Fruit; L= Leaves; Fl= Flowers; O= Others, An= Animals; Fu= Fungi; Un= Unknown

Appendix 5. Home range area (ha) and daily path length (m) data from all available *C. mitis* studies with a minimum study period of six months.

Location	Latitude	Longitude	Dur. months	Group size	HR. ha	DPL m	**Reference**
Robe, Hamuma forest, Ethiopia	8°08′–8°11′N	35°23′–35°26′E	15 mo	58	76.73	1042	Current study
Littu, Hamuma forest, Ethiopia	8°08′–8°11′N	35°23′–35°26′E	15 mo	32	85.31	1041	Current study
Jibat Forest, Ethiopia	8°43′ N	37°33′ E	10 mo	9	72	799	Dereje Tesfaye *et al.* (2013)
Budongo Forest, Uganda	1°35′–1˚55′ N	31°18′–31°42′ E	13 mo	–	10	–	Fairgrieve and Muhumuza (2003)
Kanyawara, Kibale Forest, Uganda	0°34′ N	30°21′ E	24 mo	20.8	72.5	–	Rudran (1978)
Kanyawara, Kibale Forest, Uganda	0°34′ N	30°21′ E	63 mo	18.4	32.4	1,216	Butynski (1990)
Ngogo, Kibale Forest Uganda	0°13′–0°41′ N	30°19′–30°32′ E	63 mo	15	252.75	1,406	Butynski (1990)
Kakamega Forest, Kenya	0°14′ N	34°52′ E	11 mo	43	38	1,136	Cords (1987b)
Mgahinga Gorilla National Park, Uganda	1°23′17″ S	29°38′31″ E	6 mo	–	–	–	Twinomugisha *et al.* (2006)
Nyungwe Forest, Rwanda	2°17′–2°50′S	29°07′–29°26′ E	8 mo	29	112.2	1,306.7	Kaplin (2001)
Diani Beach Forest, Kenya	4°17′ S	39°35′ E	6 mo	–	–	–	Moreno-Black and Maples (1977)
Zomba Plateau, Malawi	15°20′ S	35°19′ E	12 mo	15	16.5	–	Beeson *et al.* (1996)
Entabeni Forest, South Africa	23°02′ S	30°17′ E	9 mo	–	–	–	Breytenbach (1988)
Lajuma, South Africa	23°02′23″ S	29°26′05″ E	12 mo	40	54.7	1,906	Coleman (2013)
Cape Vidal Forest, South Africa	28°05′35″ S	32°33′40″ E	13 mo	32.5	15	–	Lawes (1990a)
Ngoye Forest, South Africa	28°50′ S	31°42′ E	12 mo	16	–	–	(Lawes *et al.* (1990))

Dur = study duration; HR = home range size; DPL= day path length