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Distribution of the Bale monkey (*Chlorocebus djamdjamensis*) in the Bale Mountains and its Ecology in the Odobullu Forest, Ethiopia – A Study of Habitat Preference, Population Size, Feeding Behaviour, Activity and Ranging Patterns

(Photo: Anagaw Atickem, February 2007)

A Thesis Submitted to the School of Graduate Studies of Addis Ababa University, in Partial Fulfillment of the Requirements for the Degree of Master of Science in Biology

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ABSTRACT

The Bale monkey (*Chlorocebus djamdjamensis*) is endemic to Ethiopia. Bale monkeys are recorded as Data Deficient in the IUCN Red List of Threatened species categories. This study was conducted from August 2007 to May 2008 to determine the habitat preference, population size, feeding ecology, activity and ranging patterns of the Bale monkey in the Odobullu Forest and distribution pattern across the Bale Mountains, Ethiopia. A total of 136 censuses of 1.8 to 3.2 km transects were conducted with a cumulative distance of 302.4 km in three different habitat types. A total of 62 Bale monkey groups were sighted and all of the encounters were observed in the bamboo forest habitat. In addition, the two study groups spent all group scan time exclusively in the bamboo forest habitat irrespective of seasons. Thus, Bale monkeys could be considered as bamboo forest specialists. The average group encounter rate of the monkeys in the bamboo forest was 0.44 per km and the average density was 124.69 per km^2. The total population of Bale monkeys in the Odobullu bamboo forest is estimated to be 1746 individuals. The distribution of Bale monkeys in the Odobullu Forest was interlinked with bamboo forest habitat. The presence or absence of Bale monkeys in the bamboo forest habitat with altitude between 2400-3250 m asl was surveyed in the Bale Massif and three new Bale monkey populations were discovered. The activity pattern, feeding ecology and ranging behaviour were studied in two neighbouring groups with 15 minutes interval scan sampling for eight month study period. Feeding comprises the majority of their activity time with 65.7% followed by moving and resting that comprises 14.4% and 10.7%, respectively. Bale monkeys spent 7.1% of their time for social and the remaining 2.4% for other activities. The overall diet composition of Bale monkeys was dominated by young leaves, contributing 80.2%. In addition, they feed on fruits (9.6%), flowers (3.1%), animal preys (2.3%), shoots (1.5%), stems (1.4%), mature leaves (1.1%) and roots (0.9%). Bale monkeys consumed a total of 11 plant species, of these, the top five accounted 94.3% of their overall diet. Of these, bamboo (*Arundinaria alpina*) contributed 76.7% of their overall diet, of which 73% was from young leaves. The mean daily range length for the study groups was 928 m and the average yearly home range size of the study groups was 15.2 ha. The narrow ecological niche of the species may be a threat for its survival due to the bamboo harvest by local people for commercial purposes. The population status and distribution pattern of the Bale monkeys has to be studied in the neighbouring Bale Mountains Massif as well. Results from such future studies combined with these obtained in the present study could contribute in preparing proper management and conservation plans for the Bale monkeys. Thus, appropriate management action should be taken to conserve the species and their most important food resources, bamboo.

Key words: **Bale monkey, diet, distribution, Ethiopia, habitat preference, home range, Odobullu Forest, population size**

DEDICATION

This thesis is dedicated to my mother Alem Desta for her love and support and to Anagaw Atickem for his help, sharing ideas and generosity in inviting me to join this wildlife research

1. INTRODUCTION

The mammalian order, Primates, occupy a wide range of habitats even though they are a relatively small order. In addition, they occupied a wide diversity of ecological niches (Robbins and Hohmann, 2006).

Different species and subspecies of primates occur in Ethiopia. These are Bushbaby or Senegal lesser galago *(Galago senegalensis)* and Somali lesser galago (*Galago gallarum)* (Butynski and de Jong, 2004), Hamadryas baboon *(Papio hamadryas hamadryas)*, olive baboon *(Papio h. anubis)*, black and white colobus monkey *(Colobus guereza),* gelada baboon *(Theropithecus gelada)*, grivet monkey *(Cercopithecus aethiops aethiops),* Black-faced vervet *(C. a. pygerythrus)*, Bale monkey *(C. a. djamdjamensis)*, De Brazza's monkey *(Cercopithecus neglectus)*, Patas monkey *(Erythrocebus patas),* Sykes' Monkey *(Cercopithecus albogularis)* (Kingdon, 1997; Grubb *et al*., 2003; Groves, 2005), two subspecies of blue monkey (*Cercopithecus mitis stuhlmanni*) (Fairgrieve and Muhumuza, 2003) and (*Cercopithecus mitis boutourlinii*) (Kingdon, 1997).

Guenons are the group of Old World monkeys of the genus *Cercopithecus* that are distributed in Africa. Savannah monkeys are guenons whose taxonomy is a subject of much debate. According to Grubb *et al*. (2003), the taxonomic relationships of savannah-dwelling guenons (specifically, *Cercopithecus aethiops)* are conflicting. Many authors divide into six sub-species*: C. a. aethiops* (grivet monkey)*, C. a. djamdjamensis* (Bale monkey or Bale Mountains grivet), *C. a. pygerythrus* (vervet monkey or black-faced vervet), *C. a. tantalus* (tantalus monkey), *C. a. sabaeus (*green monkey) and *C. a. cynosuros (*malbrouck monkey) (Kingdon, 1997; Shimada *et al*., 2002; Grubb *et al*., 2003; Grubb, 2006). Based on these classification scheme, the estimated divergence time of subspecies of *C. aethiops* occurred during the Pleistocene (2.3 million years ago) (Shimada *et al*., 2002). On the other hand, some authors classify savannah monkeys as distinctive species under the Genus *Chlorocebus* rather than a subspecies of *Cercopithecus aethiops* groups (Groves, 2005).

As for savannah monkeys, in general, the taxonomic position of Bale monkeys is still debated. Neumann first described Bale monkeys in 1902 as a species and named *Cercopithecus djamdjamensis*. This species was named after the Djam-Djam Mountains, a region found approximately 30 km west of Harenna Forest and east of Lake Abaya (Carpaneto and Gippoliti, 1994). Based on new records, Dandelot and Prévost (1972) redescribed Bale monkeys and named *Cercopithecus aethiops djamdjamensis* as a distinct form of vervet/grivet complex. This taxonomy was also accepted by Carpaneto and Gippoliti (1994), Kingdon (1997) and Grubb *et al*. (2003) as they interbreed where the taxa have over-lapping ranges. Even though *Cercopithecus aethiops djamdjamensis* is classified as a subspecies under *Cercopithecus aethiops,* it is distinctive compared to its members (Kingdon, 1997; Grubb *et al*., 2003). However, Groves (2005) categorized the subspecies of savannah monkeys in a single Genus *Chlorocebus* that contains the six distinct species. Thus, based on this classification, the Bale monkey is now no longer part of the Genus *Cercopithecus* and classified as a distinct species as *Chlorocebus djamdjamensis* (Groves, 2005) and this taxonomic status is adopted in this study. The hierarchical classification of the Bale monkey is as follows:

- Kingdom: Animalia
  - Phylum: Chordata
    - Class: Mammalia
      - Order: Primates
        - Family: Cercopithecidae
          - Sub-family: Cercopithecinea
            - Genus: *Chlorocebus*
              - Species: *Chlorocebus djamdjamensis*

Savannah monkeys or *Chlorocebus* species are the most widely distributed non-human primates in Africa occurring from Senegal to Ethiopia and southwards to South Africa (Kingdon, 1997; Groves, 2005). Vervet monkeys (*Chlorocebus pygerythrus)* are distributed in southern Ethiopia, Somalia to Zambia and southern part of Africa, tantalus monkey (*C. tantalus*) are found in the north central to western African countries and in Sudan and Kenya, green monkeys (*C. sabaeus*) are distributed in the west African countries. Grivet monkeys *(C. aethiops)* are distributed along the southeastern Sudan, north central Ethiopia and Eritrea. Malbrouck monkeys *(C. cynosuros)* are distributed from Democratic Republic of Congo to Namibia and Zambia (Kingdon, 1997; Groves, 2005). They inhabit a wide range of habitat types including savannah, woodland, forest, grassland, riverine and gallery forests (Kingdon, 1997; Nakagawa 1999; Barrett, 2005). Savannah monkeys are generalists inhabiting different habitat types and feeding on different food sources. They are opportunistic omnivores but fruits are the preferred items and most important. They also consumed flowers, leaves, young shoots, bulbs, roots and grass seeds. In addition, they also feed on insects and other invertebrates and bird nestlings (Kingdon, 1997; Barrett, 2005). As a genus, they are second to baboons in their ability to survive across a diverse range of ecological conditions and they appear to cope in most habitats (Kingdon, 1997; Barrett, 2005). They are also regarded as pests wherever they live in close proximity to humans and feed on agricultural crops resulting in human-wildlife conflict (Barrett, 2005). The population status of other savannah monkeys is Lower Risk while the Bale monkey status is not determined (Kingdon, 1997; IUCN, 2007). However, Kingdon (1997) argued that Bale monkeys are an endangered species which inhabit areas where other unique species are similarly endangered.

The distribution of Bale monkeys was little-known with few known populations which are found in the Harenna Forest of the Bale Mountains National Park, Kacha (Butynski *et al*., in press) and Rira area at altitude 2800 m asl (Carpaneto and Gippoliti, 1994; Kingdon, 1997), and also Odobullu Forest (Anagaw Atickem, pers. comm.). In addition, Bale monkeys were recorded in the bamboo forest 23 km northwest of Dodolla, and Djam-Djam Mountains near “Abera” area, a region east of Lake Abaya at about 3000 m asl (Carpaneto and Gippoliti, 1994; Butynski *et al*., in press). However, the current status of the Bale monkeys around Djam-Djam Mountains and Dodolla localities is unknown which is typically deforested (Carpaneto and Gippoliti, 1994).

The Bale monkey (*Chlorocebus djamdjamensis*) is endemic to Ethiopia (Carpaneto and Gippoliti, 1994; Kingdon, 1997; Butynski *et al*., in press) and currently restricted only to the Bale Mountains and Hagere Selam regions (Southern Nations Nationalities Region, Sidamo). The Bale Mountains region is one of the global biodiversity hotspots, part of the eastern Afromontane hotspot (Myers *et al*., 2000) which harbours a diverse range of endemic animal and plant taxa.

The Bale monkey may be threatened as a result of habitat destruction it inhabits (Hillman, 1986; IUCN, 2007). The Harenna forest that harbour Bale monkeys is increasingly utilized for the supply of construction material, fuel and charcoal for the increasing human population in Ethiopia (WWF, 2001). Kingdon (1997) suggested that hybridization with the widespread and adaptable grivet monkey *(Chlorocebus aethiops*) and vervet monkey (*Chlorocebus pygerythrus)* due to forest clearance in lowland areas is a real threat facing the Bale monkey (*Chlorocebus djamdjamensis)*.

The ecology and behaviour of other savannah monkeys have been relatively well studied. However, information on the ecology, conservation and behaviour of Bale monkeys is lacking – in fact, they remain one of Africa’s least known primates. The combination of their thickly forested habitat on mountainous terrain, tendency to flee rapidly upon encountering humans, and quiet behaviour patterns may explain why no detailed field studies had yet been undertaken prior to this study. In particular, there is inadequate data on the Bale monkey's distribution, feeding ecology, activity pattern, habitat use, ranging behaviour and population biology. In fact, due to this absence of data on its geographic distribution and population status, the Bale monkey is not listed in the IUCN Red List of Threatened Species categories. Rather its status is not determined and is recorded as “Data Deficient” (DD) as *Cercopithecus aethiops djamdjamensis* (IUCN, 2007).

According to Grubb *et al*. (2003) and Ehardt and Butynski (2006), irrespective of the debate on the taxonomy of the species concerning information on taxonomic diversity and distinctiveness, it is essential to examine the distribution pattern, ecology and degree of threat to establish priorities for long term conservation and management of the species. Thus, the objectives of the present study were to determine the habitat preference, distribution, population size, feeding ecology, activity pattern and ranging behaviour of the Bale monkey in Odobullu Forest.

2. OBJECTIVES

General and specific objectives

The goal of the present study was to provide information on the habitat preference, population size, feeding ecology, activity pattern and ranging behaviour of the Bale monkey (*Chlorocebus djamdjamensis*) in Odobullu Forest and to determine the monkey's distribution pattern across the Bale Mountains.

The specific objectives of the present study are:

1. To examine the habitat use of the Bale monkey.
2. To monitor the distribution pattern of Bale monkeys in Odobullu Forest and across Bale Mountains.
3. To provide a population size for the Bale monkey in Odobullu Forest
4. To examine the feeding ecology of Bale monkeys in Odobullu Forest
5. To determine the activity time budget of Bale monkeys in Odobullu Forest
6. To determine the ranging pattern of Bale monkeys in Odobullu Forest

3. STUDY AREA AND ANIMALS

3.1. Location and topography

The Odobullu Forest covers an area of 71 km^2 and located at 06^{o}50'-6^{o}56'N and 40^{o}07'-40^{o}12'E (Fig. 1). Odobullu Forest is located east of the Bale Mountains National Park (BMNP) and currently owned by private organization, Rift Valley Hunting Safaris, in which they offer tourists the opportunity for sport hunting (with a hunting concession) and the forest is partially protected. However, Bale monkeys are not allowed to be hunted. The topography of the study area is mountainous with cliffs and valleys accompanied by streams. The altitudinal variation ranges from 2250 m to 3022 m asl.

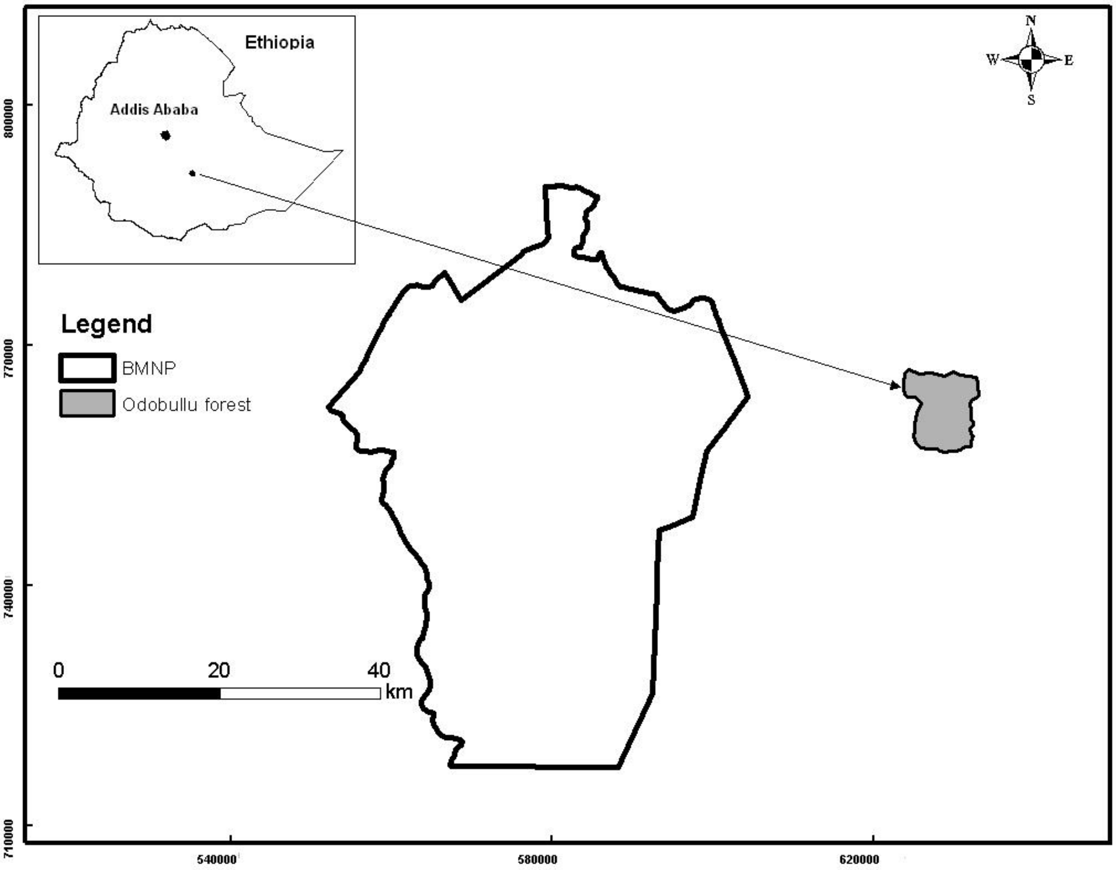

Figure 1. The main study area, Odobullu Forest and Bale Mountain National Park.

The spatial distribution of Bale monkeys was assessed in the main study area and across the Bale Massif in 5551 km^2 area between 2400 m to 3250 m above sea level (asl) (Fig. 2). A short survey was conducted in West Shewa, Jibat Forest, for presence of the Bale monkey.

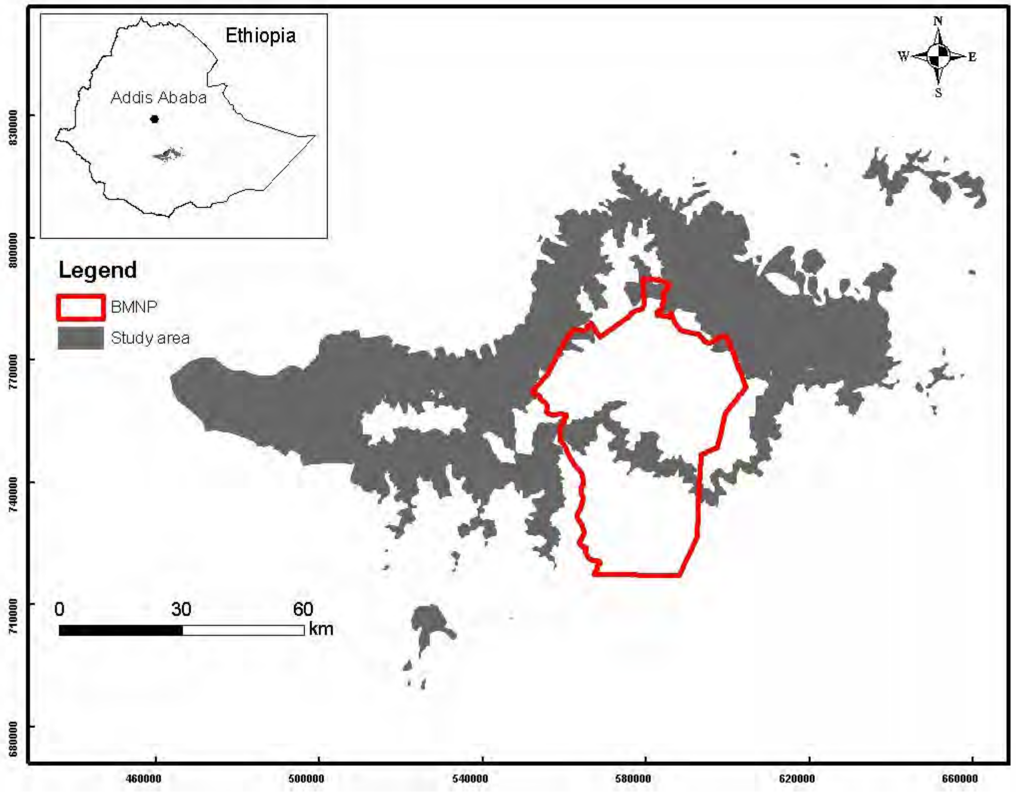

Figure 2. The survey study areas across the Bale Massif.

3.2. Climate

The Bale Mountains region experiences distinct dry and wet seasons with a long wet season from March to October and relatively short dry season from November to February. During the wet season, most of the time, the area is blanketed by thick white fog and clouds usually accompanied with rain. The average monthly rainfall and temperature for the study area over six years was obtained from the Ethiopian Meteorology Agency, Robe Field Station, which is approximately 30 km northwest of Odobullu Forest. The region experiences a seasonal bimodal distribution of rainfall. The average annual rainfall for the study area for the period 1999 to 2004 was 796.1 mm. However, the rainfall distribution may be underestimated as the forest (like Odobullu) receives more rain than non forested areas (like Robe). The average monthly variation in rainfall and temperature is presented in Figure 3. The rainfall distribution for the region varies between average monthly minimum with 9.8 mm in February (driest) to maximum rainfall with 143.4 mm in August (wettest). The temperature data ranges from a lowest mean monthly minimum temperature 6.4°C in January to the highest 24.0°C in February (Fig. 3).

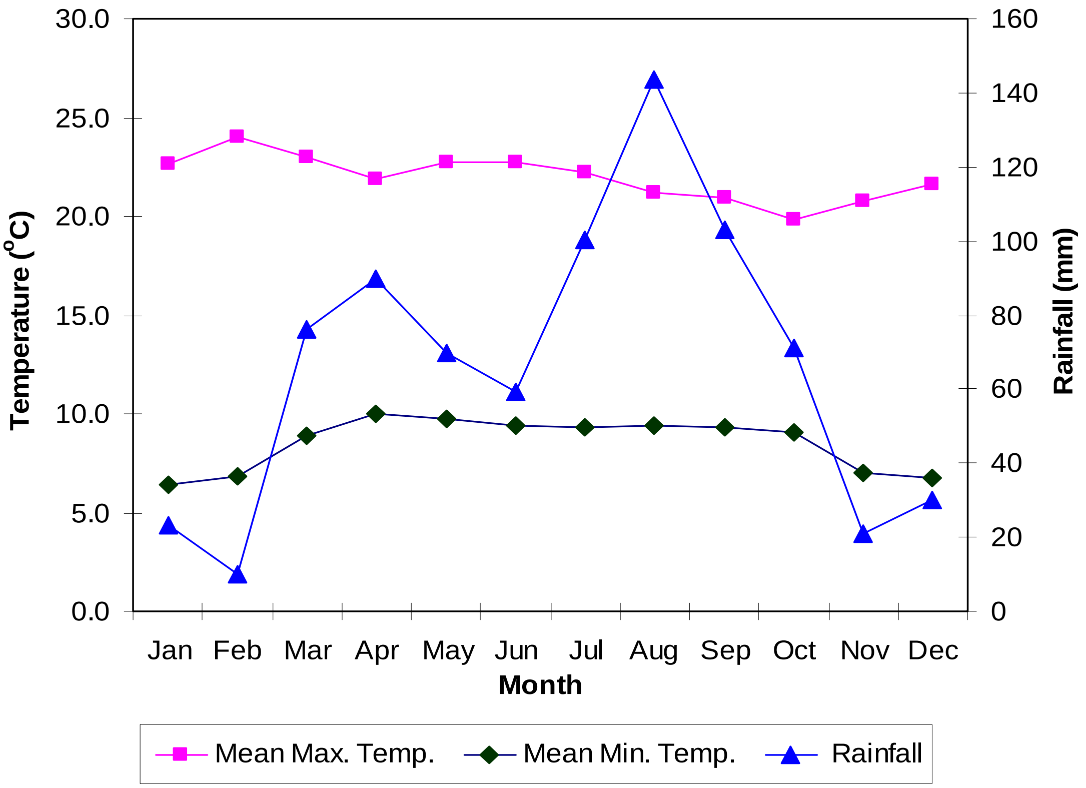

Figure 3. Changes in mean monthly minimum and maximum temperature, and rainfall for the study area from data accumulated between 1999 and 2004.

3.3. Study animals

Bale monkeys are medium-sized, short tailed, predominantly arboreal primates which rarely go to the ground (pers. observ.). The monkeys usually give birth to a single individual and no twins were observed carried under the belly of the mother. At least four infants were born from group A and three from group B during the study period. They have similar vocalization to other members of the genus *Chlorocebus* such as *C. pygerythrus* and *C. aethiops* and appear well-adapted for vocal communication in the thick bamboo forest (pers. observ.).

3.4. Fauna

According to personal observation and personal communication the following mammalian species are known to occur in the study area. These included: Mountain nyala (*Tragelaphus buxtoni*), Menelik's bushbuck (*Tragelaphus scriptus meneliki*), spotted hyaena (*Crocuta crocuta*), golden jackal (*Canis aureus*), Bohor reedbuck (*Redunca redunca bohor*), black and white colobus monkey (*Colobus guereza*), anubis baboon (*Papio hamadryas anubis*), giant forest hog (*Hylochoerus meinertzhageni*), bush pig (*Potamochoerus larvatus*), warthog (*Phacochoerus aethiopicus*), rock hyrax (*Procavia capensis*), leopard (*Panthera pardus*), porcupine (*Hystrix spp.*), common duiker (*Sylvicapra grimmia*), and lion (*Panthera leo*). In addition, the area contains several species of birds and amphibians including endemic ones.

4. METHODS

4.1. Preliminary study and materials

The present research was conducted from August 2007 to May 2008. Preliminary surveys were conducted for two weeks in August 2007 to identify study sites. Based on these reconnaissance surveys, promising sites were identified and habitat types were classified based on the dominant vegetation type. Transect sites were selected based on the habitat types depending on the altitudinal range and the proportion of the dominant vegetation they cover. Two neighbouring Bale monkey troops were selected for scan sampling to record the activity, diet and ranging pattern of the groups in the study area. Organization and arrangement of the base camp and logistic support, hiring assistants, purchasing field equipment, and layout of transects was also carried out during this period. The study troops were partially habituated to human observer for one month by following the group throughout the day after which my assistants and I were able to approach the monkeys to within 15 metres.

Materials used for this study were two pairs of 10x42 Bushnell binoculars, a digital photographic camera, two Garmin Global Positioning System (GPS) 12, a tape measure, flagging, a compass, 10 m resolution satellite image, 200 m digital elevation model and plant press.

4.2. Sampling design and data collection

4.2.1. Habitat stratification and vegetation mapping

The habitat types in the Odobullu Forest were classified based on the dominant vegetation they contained. The habitat types were classified by using 10 m resolution satellite image. To make the satellite image interpretation and analyses easier, GPS locations from each representative habitat type were collected randomly (bamboo forest, tree dominated forest, bushland and grassland).

No prior vegetation studies have been conducted in the Odobullu Forest. Details of the vegetation composition of the study groups home range was carried out by using two 50X10 m quadrats (Siex, 2003) in each of the home ranges of the two study groups (A and B) to sample plant species greater than 2 m tall including lianas. Quadrats were separated in space within each of the study group's home ranges to sample all plant species. The quadrats used 0.1 ha correlate with big 1 ha quadrat to be sufficient for botanical analyses (Grassi, 2006). In each quadrat, the type and number of plant species were recorded. These quadrats were used to quantify the vegetation composition of the home ranges of the study groups.

4.2.2. Habitat preference

Habitat preference of Bale monkeys was assessed via a combination of transect sampling in the three different habitat types and scan sampling on the selected study groups. However, survey was not conducted in the grassland as it relatively covered small area and found dispersed. During transect walking when Bale monkeys encountered, the habitat types were recorded on the basis of the dominant habitat they were observed (Wallace *et al*., 1998). In addition, the habitat types were recorded during scan sampling or activity time budget study every 15 minutes as the group moved from point to point in their home ranges (Vié *et al*., 2001).

4.2.3. Population estimate

Population estimate was carried out by line transect survey (Peres, 1999). Survey sites were selected to cover suitable altitudinal ranges and vegetation types of the area (Baumgarten, 2006). Transects were placed by stratified random sampling approach in which transect placement was proportional to the area of different habitats (Chapman *et al*., 1988; Plumptre, 2000; Lacher, 2003). Random transects were placed in the study area within the different habitat types aided by Arc GIS (Timmuck and Vaughan, 2002). A total of 9 transects ranged from 1.8 to 3.2 km in length were censused from each of the three habitat types with the existing trails and new trail cut. Each transect was censused 6-8 times in one season and conducted at an equal rate in the morning and afternoon (Lacher, 2003). Censuses were conducted during both the rainy season (September and October), and dry season (December and January).

During transect walking, the observers recorded the start and end time, start and end GPS location, personnel, weather condition, and GPS ID. When Bale monkeys were encountered, the observer recorded the time, GPS location, group size, group spread, animal observer distance, sighting angle, transect-animal distance or perpendicular distance (PD) and habitat type where the group was spotted (Chiarello, 2000; Fashing, 1999; Fashing and Cords, 2000; Bennet *et al*., 2001; Anderson *et al*., 2007). Sighting distance and angle were estimated visually.

Censuses were conducted on foot by the researcher and a well trained field assistant together with villagers who are familiar with the area. At the beginning of the study, the field assistant was trained to estimate animal-observer distance, sighting angle and perpendicular distances. Surveys were conducted on transects starting from 06:30-06:45 to 10:30-10:45 in the morning and from 14:00 to 18:00 in the afternoon (Peres, 1999; Timmuck and Vaughan, 2002) at an average speed of 1 km/hr in the forest or 2 km/hr in the bushland (Wallace *et al*., 1998; Peres, 1999; Chapman *et al.*, 2000). Transects were walked with a brief stops for listening to increase the probability of detecting the monkeys (Wallace *et al*., 1998).

4.2.4. Distribution pattern

Surveys were conducted to determine the presence or absence of Bale monkeys in different forest types in the study area by line transect survey (Iwanaga and Ferrari, 2002; Teelen, 2007). Based on the bamboo forest habitat preference and altitudinal preference of Bale monkeys in Odobullu Forest (2600-3000 m asl), the existence of bamboo forest habitat (2200-3200 m asl) (Kingdon, 1997), intensive ground survey and literature review (Carpaneto and Gippoliti, 1994; Groves, 2005; Butynski *et al*., in press), the altitudinal range from 2400 to 3250 m asl was chosen as a potential suitable habitat for survey. The survey study area across Bale Massif was classified into three different altitudinal ranges using 200 m digital elevation model ArcMap and GIS (Fig. 4). Vegetations were classified by using satellite imagery (Rappole *et al*., 2000).

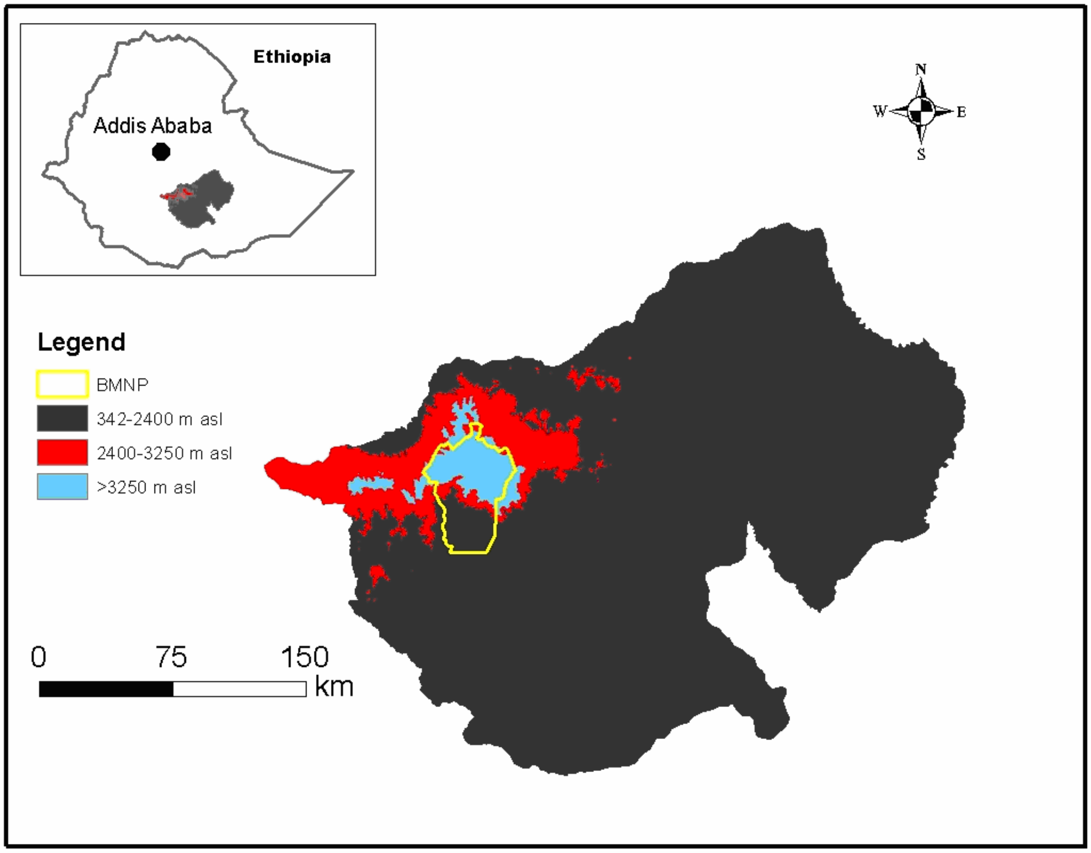

Figure 4. Map of the altitudinal classification of the Bale Massif.

Based on the bamboo forest habitat preference of Bale monkeys, the Bale Massif with altitude ranging from 2400-3250 m asl was further classified into different habitat types by using 10 m resolution satellite image with Erdas Imagine 8.6 software. GPS location for the bamboo forest, tree dominated forest, and cultivated land and human settlement areas collected from field work were used to make the satellite image interpretation and analyses easier thereby identifying the survey area of the bamboo forest across the Bale Massif. Thus, the whole area between 2400-3250 m asl was classified into three habitat types (Fig. 5). However, some areas of the satellite images were covered by cloud and make the vegetation classification a bit difficult.

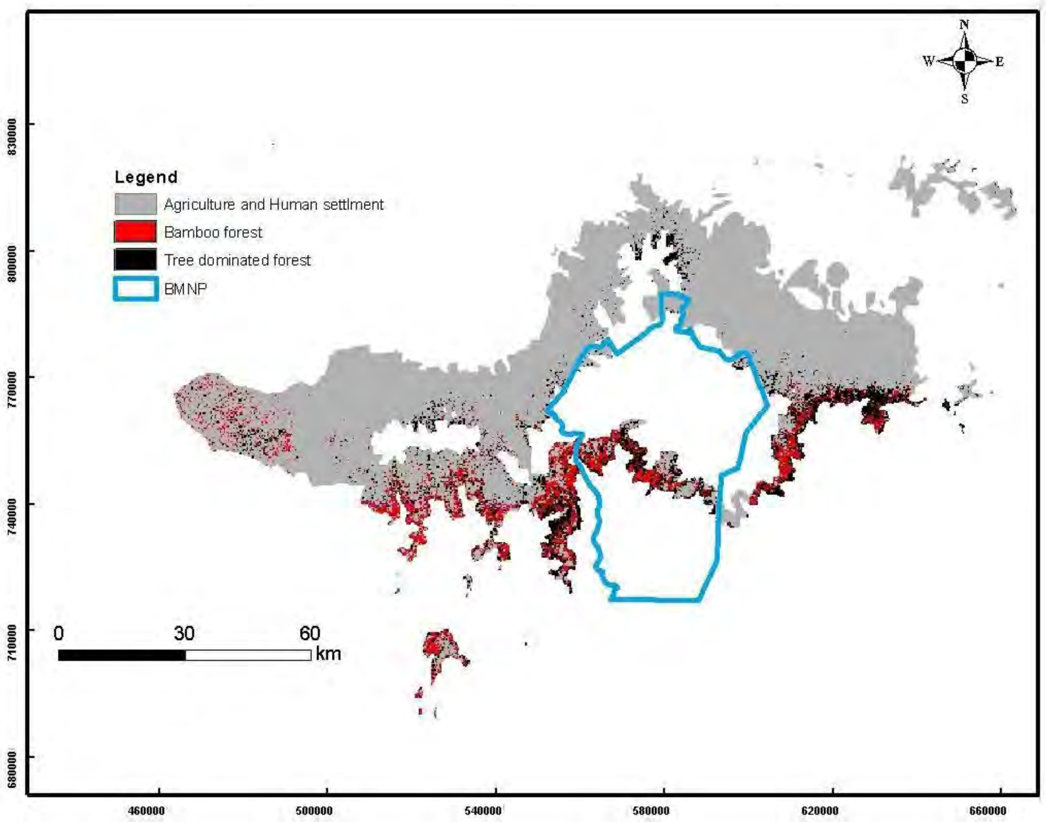

Figure 5. Map of bamboo forest distribution across Bale Massif with altitude 2400-3250 m asl.

Based on the bamboo forest map in between 2400 to 3250 m asl, survey on the Bale monkeys across the Bale Mountains and West Shewa were conducted in some areas from January to April 2008 where the bamboo forest occurred. Field survey was conducted by direct field observation by crossing existing tracks, rivers and new trial cuts in the bamboo forest. This survey was assessed by questionnaire survey via informal interview (Iwanaga and Ferrari, 2002) focusing on the local people who are familiar with and reside in the vicinity of the forest by showing the photograph of the monkey. Bale monkeys' presence or absence was surveyed in a total of eight areas by direct field observations out of the main study site, Odobullu. At each survey area, when the Bale monkeys were sighted; GPS location, group size, altitude and habitat types were recorded to map the localities in the topographic map (Lehman, 2004a; Isbell, 2007).

4.2.5. Activity time budget

Behavioural data were collected using instantaneous scan sampling method described in Altmann (1974). Scan sampling involves the observation of multiple group members. Activity types and dietary data were collected from two selected and partially habituated neighbouring study troops of monkeys, Group A and Group B, on an average of five–six days per month from September 2007 until May 2008. The focal groups were identified by the natural markings, sizes, coat colour and facial features of some distinctive members of each group. Wet season data were collected during September 2007 to October 2007 and April 2008 to May 2008 whereas dry season data were collected from November 2007 to February 2008. However, data was not collected during March.

Data on individual behaviour were collected by approaching monkeys to about 7–30 m and observing them with or without binoculars to identify their activities and food items that they consume. During activity scan sampling, the activities of monkeys were recorded every 15 minutes interval up to 5 minutes duration from 0700-1730 hrs (Fashing, 2001a; Wong and Sicotte, 2007). The activity recorded for each individual was the first activity that lasted for 5 seconds once the monkeys came into view. Data were collected for the first 2-5 adults, sub-adults or juveniles (ignoring neonates) at the time of each scan. We ignored collecting data for a single individual observed and set the cut-off at 5 when more than 5 individuals were clearly observed. However, we did not always reach cut-off during scanning the group due to the poor invisibility of monkeys in the thick bamboo forest. The group was scanned each time from left to right to avoid possible biases on eye-catching activities like grooming, fighting and mating (Fashing, 1999; Fashing, 2001a). Care was taken to avoid sampling the same individual more than once in a given scan. However, the same individual could be scanned in successive scans (Di Fiore, 2003).

The identity of the scanned individual was recorded and the unidentified individual was assigned to one of the age/sex classes as adult male, adult female, sub-adult male, sub-adult female, juvenile male and juvenile female. Group scans were recorded as performing one of the following behavioural records on the standardized data sheet: feeding, moving, resting, playing, aggression, grooming, sexual activity, and other activities such as vocalization, defaecation, drinking, and looking towards the observer (Di Fiore and Rodman, 2001; Fashing, 2001a). Feeding was recorded when the monkeys manipulated, masticated and ingested a particular item of food. Moving was recorded when the monkeys change their spatial position within or between the tree or showed any locomotor behaviour, including walking, jumping or running. Resting was recorded when the monkeys observed were inactive alone or together either sitting or lying. Playing includes chasing, hitting and other vigorous activities involving exaggerated movements and gestures by more than one monkey that were clearly interacting with each other in a non-aggressive manner (Fashing, 2001a). Aggression was recorded when a monkey chased, bit, grabbed, displaced, threatened another monkey or during crying as a result of aggression. Grooming was recorded when a monkey used its hands to explore or to clean its body or the body of another monkey. Sexual activity was recorded when a monkey groomed the sexual organs, mounted another monkey or engaged in mating activity. Other activities were recorded when the animal observed performing activities such as vocalization, defaecation, looking towards the observer, drinking or other activities that do not fit in this category.

4.2.6. Feeding ecology

During instantaneous scan sampling, dietary data were collected every 15 minutes interval on identified two study groups, Groups A and B. During the activity scan sampling, when the monkey was observed feeding, the type of food item: young leaves, mature leaves, root, stem, flower, fruit, shoot or animal prey and the type of species consumed were recorded (Fashing, 2001b; Di Fiore, 2004). The type of species consumed was noted and unidentified species were collected for further taxonomic identification in the National Herbarium, Addis Ababa University. Animal prey was recorded when a monkey was searching for animal prey by scratching tree bark, exposing curled leaves and when it perform the activity of masticating and ingesting or directly seen eating on insect (Dietz *et al*., 1997).

4.2.7. Ranging pattern

During scan sampling, the location of the geographic centre of the group was recorded at 15 minutes intervals. In addition, the GPS location of the group was recorded even if activity data were not recorded when there was poor visibility of the whole group but their location could be confirmed due to other cues such as leaf crush, tree movement and vocalization.

4.3. Data Analysis

4.3.1. Statistical tests

All statistics were carried out on SPSS 15.0 software for Windows Evaluation Version. Statistical tests were two-tailed with 95% confidence intervals. Nonparametric Mann-Whitney U tests were used to compare seasonal differences and Kruskal-Wallis H tests were used to compare monthly variation as the data were not normally distributed.

4.3.2. Vegetation

The Odobullu Forest is classified into four habitat types as bamboo forest, tree-dominated forest, bushland and grassland by using 10 m resolution satellite image with Erdas Imagine 8.6 software and GIS analysis using the GPS locations collected from different habitats (Fig. 6). The areas of each habitat types were calculated by GIS Arc View 9.1.

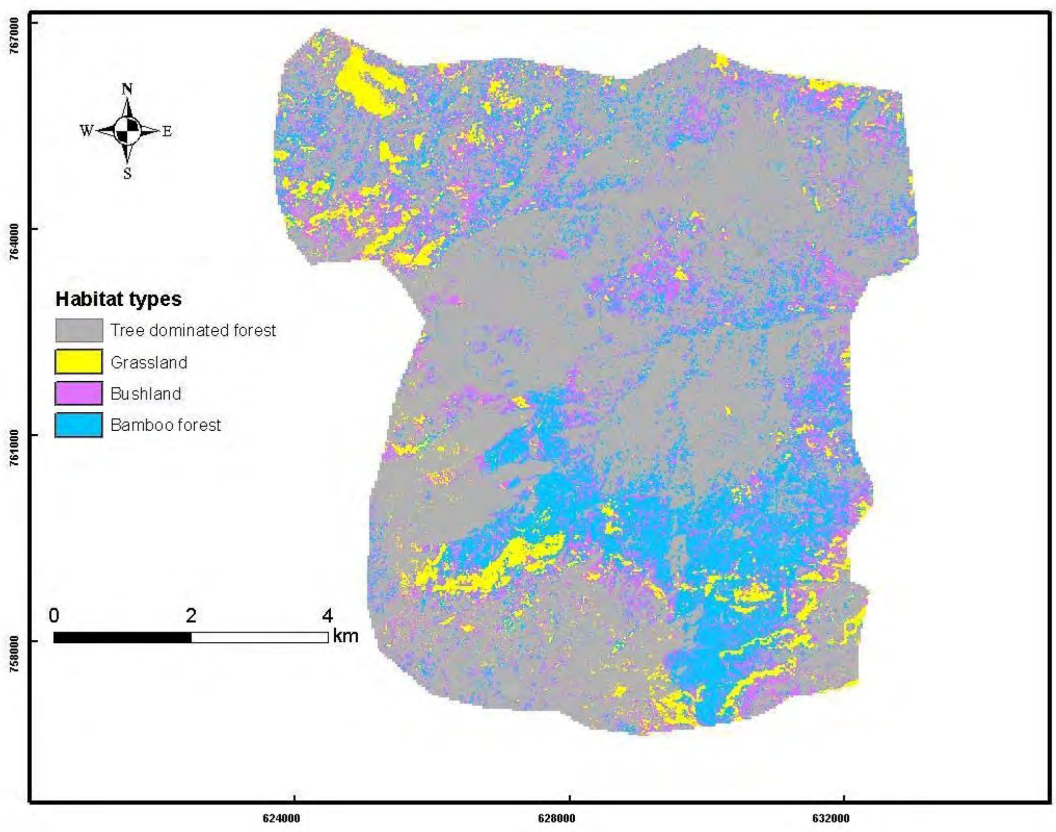

Figure 6. Habitat types in the main study area, Odobullu Forest.

The tree dominated forest habitat contains dominant *Hagenia* trees *(Hagenia abyssinica)* (Rosaceae) with mixed other tree species such as *Dombeya torrida* *(*Sterculiaceae*),* *Schefflera volcansii* *(*Araliaceae*),* *Manilkara butugi (Sapotaceae), Schifflera abyssinica (*Araliaceae*)* and other tree species (Plate 1)*.*

Bamboo forest habitat contains homogeneous bamboo with very few or no big trees and bamboo usually with dispersed big trees such as *Hagenia abyssinica* (Rosaceae)*,* *Dombeya torrida* (Sterculiaceae) and *Psychotria orophila* (Rubiaceae) (Plate 2). Bushland habitat is dominated by *Erythrococca sp.* (Ephorbiaceae) (Plate 3). Bushland and grassland habitats occur as dispersed.

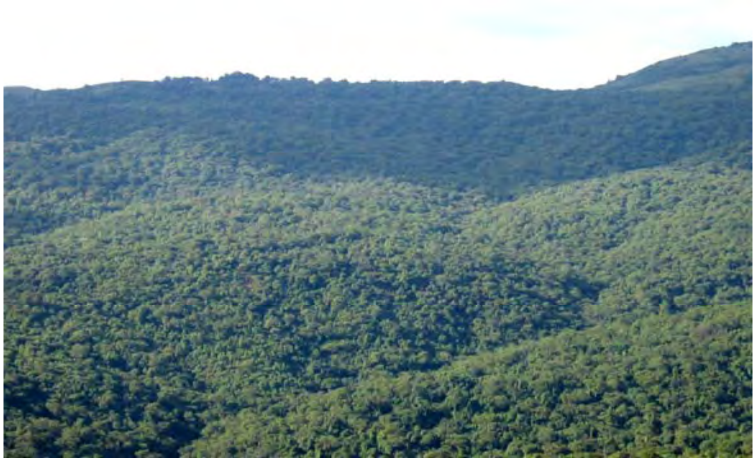

Plate 1. View of tree dominated forest habitat. (Photo: Addisu Mekonnen, September 2007).

Plate 2. View of bamboo forest habitat. (Photo: Addisu Mekonnen, September 2007).

Plate 3. Bushland habitat dominated by *Erythrococca sp.* (Photo: Addisu Mekonnen, September 2007).

From the vegetation data collected, the density of each plant species was calculated as the total number of each plant species divided by the total number of all plant species sampled per hectare in the home range. The density of plant species was calculated including the lianas > 2 m tall found in the home range of Bale monkeys. In addition, plant species diversity was calculated using the Shannon-Wiener index, H’ and plant species evenness was calculated using the evenness index, J.

$$H' = -\sum_{i=1}^{S} Pi \ln Pi$$

Where,

H’ is Shannon-Wiener index of diversity

Pi is the proportion of plant species i from the s species.

S is the total species in the area sampled

Evenness of the species was calculated as

J = H’/H maximum

Where,

H’ is Shannon-Wiener index of diversity
H maximum is maximum diversity index

4.3.3. Habitat preference

The habitat preference of Bale monkeys were assessed by using encounter rates of monkeys along transect walking in different habitat types (Wallace *et al*., 1998; Bobadilla and Ferrari, 2000). Bale monkey sightings were summarized for each habitat type as the total number of groups and individuals observed, and the encounter rates (groups/km) (Anderson *et al*., 2007). The analysis of habitat preferences was determined from the expected number of sightings in each habitat type. However, these were not compared with observed frequencies using the chi-square test (Bobadilla and Ferrari, 2000; Haugaasen and Peres, 2005) as there were no observations of any Bale monkey troop in other habitat types. Thus, it was not applicable for statistical tests to compare the encounter rates of the monkeys in different habitats.

In addition, habitat preference was analyzed by the use of areas within the home range by the study groups with respect to the availability of habitats in their home range (Zabala *et al*., 2005). Therefore, the habitat preference of the study groups was analyzed by the proportion of the number of scans where the groups spend in different habitats in the home range during the study period (Vié *et al.,* 2001; Wallace, 2006).

4.3.4. Population estimate

The density of Bale monkeys from the line transect surveys was analyzed by using maximum reliable animal-observer distance method which has been used to produce density estimates for primates at several forested sites (Chapman *et al*., 1988; Chapman *et al*., 2000; Fashing and Cords, 2000; Shah, 2003; Twinomugisha *et al*., 2003; Irwin *et al.,* 2005; Marshall *et al*., 2008).

The maximum reliable animal-observer transect width was calculated by plotting a graph frequency distribution or histogram of all total sightings of animal to observer distances at 10 m class interval (Müller *et al*., 2000). Then, the fall-off distance or the maximum reliable observer-animal distance was determined by applying the 50% cut-off rule where sighting frequencies decrease at least by half from the previous sighting class interval (Chapman and Chapman, 1999; Chapman and Chapman, 2002; Fashing and Cords, 2000; Teelen, 2007; Weghorst, 2007). This value can be calculated as if $\boldsymbol{X_i}$ is the number of sightings in distance class $\boldsymbol{i}$ and the last distance considered was at the end of the first class in which $\boldsymbol{X_{i+1}/X_i}$ and $\boldsymbol{X_{i+2}/X_i}$ were both equal to 0.50 or less**.** Thus, the maximum reliable animal-observer distance was determined as the boundary of the previous class interval where both values dropped to less than or equal to 0.5 (Chapman and Lambert, 2000; Irwin *et al*., 2005; Teelen, 2007; Weghorst, 2007). Animal-observer distances were relatively consistent on the bamboo forest transects and the maximum reliable animal-observer distance was determined from the combined transects. Thus, the observer selected a cut-off distance beyond which there is a large and sustained fall in observations (Chapman *et al*., 2000; Chapman, and Chapman, 2002; Marshall *et al*., 2008). This distance was considered as the distance within which one could reliably observe the groups (Butynski, 1990). Group sightings beyond fall-off distance were excluded from density estimations (Twinomugisha *et al.,* 2006).

Density estimates were calculated only once animals had been frequently encountered during transect sampling (n ≥ 40 encounters) (Chapman *et al*., 1988; Marshall *et al*., 2008). These values were chosen to ensure that small sample sizes did bias the density analyses (Lehman *et al*., 2006). Group density was calculated as the total number of groups sighted within the fall-off sighting distance divided by the total transect length sampled times both sides of the transect width.

$$\text{Group density (D)} = \frac{Sum\, of\ groups\ sighted}{2\,(L\, x\, width\, of\ one\, side\, of\ transect\ \ in\, km)}$$

Where,

D= the density of individuals or groups per km^2

L= Total transect length (the sum of the lengths of all trials walked in each habitat per km).

> *Sum of group sightings refers to the total number of groups sighted at distances equal to or smaller than the fall-off distance.*

Bale monkey population density estimates were obtained by multiplying the product of group density estimates with the observed mean group size (Rosenbaum *et al*., 1998; Müller *et al*., 2000). The mean group size used to calculate density was recorded from groups counted during transect walks only (Plumptre, 2000). Sightings of solitary individuals were excluded from the analysis to calculate group density estimates and encounter rates (Whitesides *et al*., 1988; Fashing and Cords, 2000; Worman and Chapman, 2006). The total population was estimated by multiplying the average group density estimates with the total area of suitable habitat in the study site (Chiarello, 2000).

4.3.5. Distribution pattern

The result of Bale monkey existence in the survey area was mapped in the topographic map from the GPS locations recorded. In addition, the historical Bale monkey localities recorded from literature were mapped. The GPS locations recorded during the survey and historical sites recorded from literature (Butynski *et al*., in press) were incorporated in GIS (ArcMap version 9.1) to superimpose the distribution data (Baumgarten, 2006). However, vegetation analyses of the bamboo forest existence were not carried out for the historical records of Bale monkey sites as the study was aimed across the Bale Mountains Massif.

4.3.6. Activity time budget

To calculate time budgets, all activity records were first assigned to one of the activity categories to determine the proportion of time budget allocation of Bale monkeys for different activities. First, the proportion of the number of behavioural records for each activity category represented was divided by the total number of activity records (Vasey, 2005). Time budgets were calculated for the combined study groups A and B. The behavioural records of the combined groups were used to calculate the time budgets for each day and then summed within each month to construct monthly proportions of time budgets. The grand mean the proportions of the monthly budgets provided the overall wet and dry season, and also yearly time budgets (Di Fiore and Rodman, 2001; Di Fiore, 2003). Social activities such as playing, aggression, grooming and sexual activities were merged together for analyses. The percentage of time the combined study groups engaged in major activities was compared between seasons using Mann-Whitney U test and across months using Kruskal-Wallis H test.

4.3.7. Feeding ecology

Diet composition was evaluated by using the proportion of different food items and type of species consumed by the monkeys (Grassi, 2006). The daily food items and type of the species consumed by the combined study groups were summed within each month to construct monthly proportion of food items and food types consumed (Isbell, 1998; Di Fiore, 2003; Xiang *et al*., 2007). The monthly proportion of each food item scans was calculated as the total number of monthly individual scans for each food item divided by the total number of individual scans for all food item scans spent for the groups. The relative proportion of plant species used as food for Bale monkeys was calculated from the monthly percentage contribution of different species (Fashing, 2001b; Di Fiore, 2003; Di Fiore, 2004). The grand mean of the set of monthly proportion of food items and food species consumed was used to calculate the overall wet and dry seasons and also yearly food items and food species consumed by the monkeys. These to reduce biases from unequal sample size collected per each month. The diet selection of the combined study groups was determined from the relative proportions of the number of scans spent feeding on different food items and plant species in their diet. However, the percentage contributions for the specific food items consumed from each plant species were calculated from the total number feeding contribution of each plant species during the study period rather than averaging the monthly percentage contributions. The percentage contribution of food items and the species consumed by the combined study groups were compared between seasons using Mann-Whitney U test and across months using Kruskal-Wallis H test.

To assess dietary diversity over the study period, the Shannon-Wiener index of diversity was used. This dietary diversity index was used to examine potential differences in diet (over time) by the species. The Shannon-Wiener index of diversity has been used by many researchers on a variety of species (Fashing, 2001b on black and white colobus monkeys; Grassi, 2006 on Bamboo lemur and Xiang *et al*., 2007 on snub-nosed monkeys). Dietary diversity was measured via the Shannon-Wiener index, H' and calculated each month for each individual species as in Krebs (1989).

$$H' = - \sum_{i=1}^{S} Pi \ln Pi$$

Pi is the proportion of feeding records of each species in the overall monthly diet
S is the number of species consumed each month

Dietary evenness was assessed by evenness index. Dietary evenness, J was calculated by

$$J = H'/H' \text{ maximum}$$

Where,

H' is Shannon-Wiener index of diversity
H maximum is maximum diversity index

J indicates the evenness of the different food plant species represented in the diet of the study groups each month. J ranges from 0 most evenly represented to 1 least evenly represented.

Dietary preference of food species in the study groups was calculated the proportion of time spent feeding in certain species *i* divided by the density of that species *i* in the study group home ranges (Fashing, 1999; Fashing, 2001b, Chapman and Chapman, 2002). A food species that is selected by the monkeys is consumed more frequently than expected based on its proportional representation in the home range (Fashing, 2001b; Shah, 2003).

Dietary preference (Selection ratio) = $$\frac{\%\ of\ annual\ feeding\ time\ of\ species\ i}{\%\ of\ total\ stem\ density\ of\ species\ i}$$

4.3.8. Ranging pattern

Total home range size and day range length was determined for each group based on the point to point movements of the group between consecutive GPS locations recorded (Di Fiore, 2003). Day range lengths were calculated based on full-day follows only (Kaplin, 2001) for each group from 07:00 to 17:00 hrs because sampling prior to 07:00 and after 17:00 was limited and the monkeys do not travel much before and after these periods. Each day range was drawn on a GIS-system generated map (ArcMap version 9.1) by connecting the consecutive GPS location records and the total distances traveled per day. These were calculated from the map by using measuring tools in the GIS software ArcGIS’9 (Defler, 1996; Di Fiore, 2003; Wong and Sicotte, 2007). Then mean day range lengths were calculated by averaging the wet and dry season day range lengths of the two groups as the sample size of full-day follows varies across months. The wet and dry season day range lengths were compared using Mann-Whitney U test.

The minimum convex polygon method (MCP) was used to determine the home range sizes of Bale monkeys. The MCP method has the advantage of not requiring independent data points and is a widely used method by many researchers (Swedell, 2002; Lehmann and Boesch, 2003; Williams-Guille´n, 2003; Barrett, 2005; Fashing *et al*., 2007b; Kumar *et al*., 2007; Wong and Sicotte, 2007). GIS software (ArcMap version 9.1) was used to determine the home ranges of the two study groups by simple minimum convex polygon method (Lehmann and Boesch, 2003; Pombo *et al.,* 2004; Barrett, 2005; Fashing *et al*., 2007b; Kumar *et al*., 2007; Wong and Sicotte, 2007). To estimate home range size, all day ranges were combined to generate a bounding polygon using 100% MCPs. The home ranges for both study groups was calculated by constructing a polygon around the outermost GPS locations used by each group during both wet and dry seasons (Wong and Sicotte, 2007). The seasonal and overall home range areas used during the course of the study period were calculated by GIS ArcView 9.1. The wet and dry season home range areas were compared using Mann-Whitney U test.

5. RESULTS

5.1. Vegetation

A total of 13 tree species, one shrub, five lianas, one epiphyte and two herbs were found within the study groups' home ranges. The stem density per hectare for species sampled in the study groups' quadrats is presented in Table 1.

Table 1. Plant species > 2 m tall trees including lianas, number and densities within the home range of Bale monkeys.

Local name	Species name	Family	Type	No. of Stem per ha (density)	% of stem density
Leemman	*Arundinaria alpine*	Poaceae	Tree (S)	14165	90.50%
Haliilaa	*Urera hypselodenron*	Urticaceae	Shrub (M)	220	1.40%
Tullaa	*Manilkara butugi*	Sapotaceae	Tree (S, M)	220	1.40%
Korraallaa	*Psychotria orohila*	Rubiaceae	Tree (M)	190	1.20%
Lallacaa	*Cypostemma adenocaule*	Vitaceae	Climber	150	1.00%
Allaafitree	*Thlophora lugardae*	Asclepiadaceae	Climber	150	1.00%
Ciroontaa	*Brucea antidysenterica*	Simarubaceae	Tree (S)	130	0.80%
Goraa	*Rubus apetalus*	Rosaceae	Climber	100	0.60%
Qrqooraa	*Mikaniopsis clematoides*	Asteraceae	Climber	70	0.40%
Anshaa	*Schifflera volcensii*	Araliaceae	Tree (M)	65	0.40%
Daannisa	*Dombeya torrida*	Sterculiaceae	Tree (L)	50	0.30%
Kombolcha	*Maytenus obscura*	Celastraceae	Tree (S, M)	40	0.30%
Horoqa	*Bersama abyssinica*	Melianthaceae	Tree (S)	30	0.20%
Heexoo	*Hagenia abyssinica*	Rosaceae	Tree	20	0.10%
Garambaa	*Hypericum revoltum*	Hypericeae	Tree (S, M)	20	0.10%
Xorsoo	*Jasminum abyssinicum*	Oleaceae	Climber	10	0.10%
Taruuraa	*Leggera sp.*	Asteraceae	Tree (M)	5	0.00%
Abaaraa	*Allophylus macrobothys*	Sapindaceae	Tree (M)	5	0.00%
Maraaroo	*Datura strrammonium*	Solanaceae	Tree (M)	5	0.00%
Herayyee	*Acanthopale pubescens*	Acanthaceae	Herb	0	0.00%
Garaabaa	*Bothrichloa radicans*	Poaceae	Herb	0	0.00%
Aanquu	*Embelia schimperi*	Embenaceae	Epiphyte	0	0.00%

Trees are classified based on their size as small (S), Medium (M) and large (L).

Other plant species, *Erythrococca sp.* (Euphorbiaceae), *Asplenium emmiforum* (Aspleniaceae) *and Crotalaria laburnifolia* (Fabaceae) that occurred in the study groups' home range were not included in the density analysis as they were not sampled as they did not occur within the vegetation transects. The home range areas on the average contained 15645 stems/ha including lianas taller than 2 m. The bamboo (*Arundinaria alpina*) with the highest stem density is a small sized tree. The plant species diversity in the home range of the study groups was found to be 0.54. The evenness of the study groups home range was 0.19. There was less diversity of plant species in the home range. Plant species that occurred in the home range of Bale monkeys were not evenly distributed.

5.2. Habitat preference

A total of 136 censuses were conducted along transect lines over a cumulative distance of 302.4 km in the three different habitat types. Sufficient transect sightings were made for Bale monkey group encounter rates (n=62). All Bale monkey group sightings occurred in the bamboo forest habitat. Bale monkeys were not observed in the tree-dominated forest and bushland habitat during transect walks (Table 2). Thus, Bale monkeys exclusively inhabit the bamboo forest and clearly preferred it over other habitat types in the Odobullu Forest.

Table 2. Sighting rates of Bale monkey groups along transects in different habitat types in the Odobullu Forest.

Transect name	Transect length (km)	No. of census	Distance surveyed (km)	Total groups sighted	Encounter rates (groups/km)	Habitat type
Otomena	3.2	16	51.2	26	0.47	Bamboo forest
Debello	1.8	16	28.8	19	0.63	Bamboo forest
Kensegnat	3.2	16	51.2	17	0.31	Bamboo forest
Head Quarter A	2	16	32	0	0	Tree dominated forest
Head Quarter B	2	16	32	0	0	Tree dominated forest
Head Quarter C	2	16	32	0	0	Tree dominated forest
Head Quarter D	2	16	32	0	0	Tree dominated forest
Jamma A	1.8	12	21.6	0	0	Bushland
Jamma B	1.8	12	21.6	0	0	Bushland
Total	19.8	136	302.4	62		

Similar to the transect sampling (encounter rates of monkeys), Bale monkeys also spent 100% of their time (based on scan samples) in the bamboo forest both during the wet and dry seasons that contains bamboo with big trees and homogeneous bamboo forest. They were never observed in the tree-dominated forest and bushland without bamboo plants. Thus, Bale monkeys use exclusively the bamboo forest as their primary habitat preference regardless of seasons.

5.3. Population estimate

The average group size of Bale monkeys counted during transect walks was 22.6 (SD±6.6) animals (range 14 - 46). In most group sightings, the group was composed of at least two males and three adult females, sub-adults, juveniles and infants which live in multimale-multifemale social organization.

The maximum reliable animal-observer distance was calculated for the three transects as the sighting distances were consistent with no significant difference between transects (Kruskal-Wallis H test, $P > 0.05$). The maximum reliable animal-observer distance was 40 m on either side of the transect. This resulted in a total of 58 sightings excluding four sightings which were beyond the fall-off distance (Fig. 7).

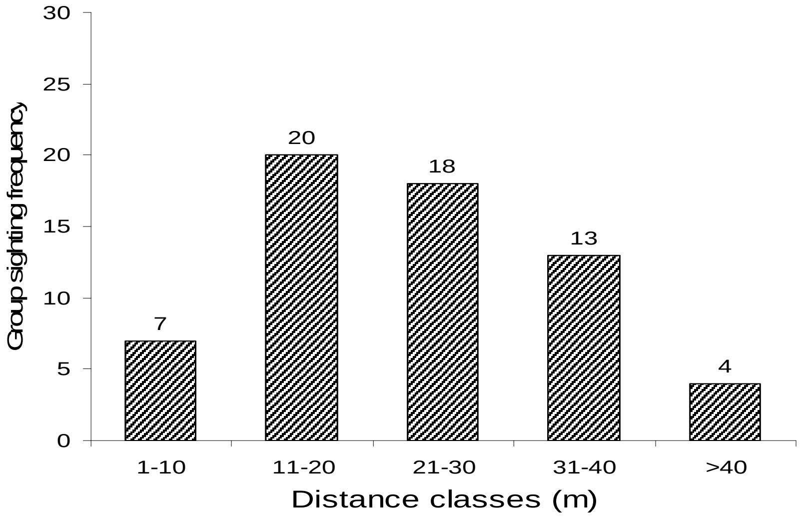

Figure 7. Frequency distribution of the maximum reliable animal-observer distances at 10 m class interval.

The highest encounter rate of Bale monkeys were recorded in the Debello transect (0.63 groups/km) both in the wet and dry seasons. The lowest encounter rate was recorded in the Kensengat transect with (0.27 groups/km). However, there was no statistical differences in the encounter rates between the three transects both in the wet and dry seasons (Kruskal Wallis H test, $P > 0.05$). Therefore, data were pooled in order to produce a single figure of Bale monkey density from the three transects (Brugiere, 2005).

The number of groups encountered varied from 0.31 to 0.63 per km transect walked with an average 0.44 groups/km (Table 3). The Bale monkey density was estimated only for groups sighted under the fall-off distance. Four sightings were excluded from density estimate analyses which were seen beyond the fall-off distance. The density estimates were made from 58 group encounters (Table 3). The average group density of Bale monkeys in the bamboo forest habitat was 5.53 groups/km^2 (range 3.91-7.81). The average individual density was found to be 124.69 individuals/km^2 (range 81.81-183.59 individuals per km^2) (Table 3).

Table 3. Encounter rate and density estimates of Bale monkeys in the Odobullu, bamboo forest transects during the wet and dry seasons.

Transect name		Transect length (km)	Total census	Total distance surveyed	Groups sighted	Mean group size	Transect width	Encounter rates	Group Density	Population Density (Ind./km2)
Otomena	Wet	3.2	8	25.6	11	22.3	0.08	0.43	5.37	119.6
	Dry	3.2	8	25.6	13	24.2	0.08	0.51	6.35	153.8
	Mean	3.2	8	25.6	12	23.3	0.08	0.47	5.86	136.2
Debello	Wet	1.8	8	14.4	9	20.9	0.08	0.63	7.81	163.2
	Dry	1.8	8	14.4	9	26.1	0.08	0.63	7.81	204.0
	Mean	1.8	8	14.4	9	23.5	0.08	0.63	7.81	183.6
Kensegnat	Wet	3.2	8	25.6	9	19.9	0.08	0.35	4.39	87.4
	Dry	3.2	8	25.6	7	22.0	0.08	0.27	3.42	75.2
	Mean	3.2	8	25.6	8	20.9	0.08	0.31	3.91	81.81

The total area of suitable bamboo forest habitat in the Odobullu Forest calculated by satellite image analysis was 14 km^2. Therefore, the total population of Bale monkeys in the Odobullu, bamboo forest habitat was estimated to be 1746 individuals.

5.4. Distribution pattern

In Odobullu Forest, the Bale monkeys were exclusively found in the bamboo forest. The monkeys were observed in the mixed bamboo forest and homogeneous bamboo forest near to big trees. However, monkeys were not observed in the southern tip of the homogeneous bamboo forest that crossed the 1 km Otomena transect.

Surveys of bamboo forest in the Bale Massif revealed four Bale monkey localities (Fig. 8). Of these, one known population is found in the Bale Mountains National Park, at Rira and Kacha area. The Odobullu populations were discovered by Anagaw Atickem (pers. comm.) during Mountain nyala (*Tragelaphus buxtoni*) survey. The Shedem, Woge and Gamma populations were discovered during the present study which has not been reported before. All these populations were found exclusively in the bamboo forest. However, Bale monkeys were not found in West Shewa, Jibat bamboo forest.

The Odobullu and Shedem populations are not found in the vicinity of the villages but surrounded by other tree dominated forest in the mountainous terrain whereas the Woge and Gamma populations are found near the vicinity of the local people. In the Woge and Gamma populations, the group sizes ranged from 15-30 individuals. A rough count from two groups was found to be 22 and 28 individuals. In the Woge and Gamma area, the local peoples were settled inside the forest. Bale monkey populations are found in the fragmented bamboo forest habitats. Local people consider Bale monkeys as crop pests even though they are not as series as anubis baboon (pers. comm.). During the survey of Bale monkeys, the highest altitude was 3200 m asl was recorded in the Woge area. The monkeys were not observed in the bamboo forests less than 2400 m asl.

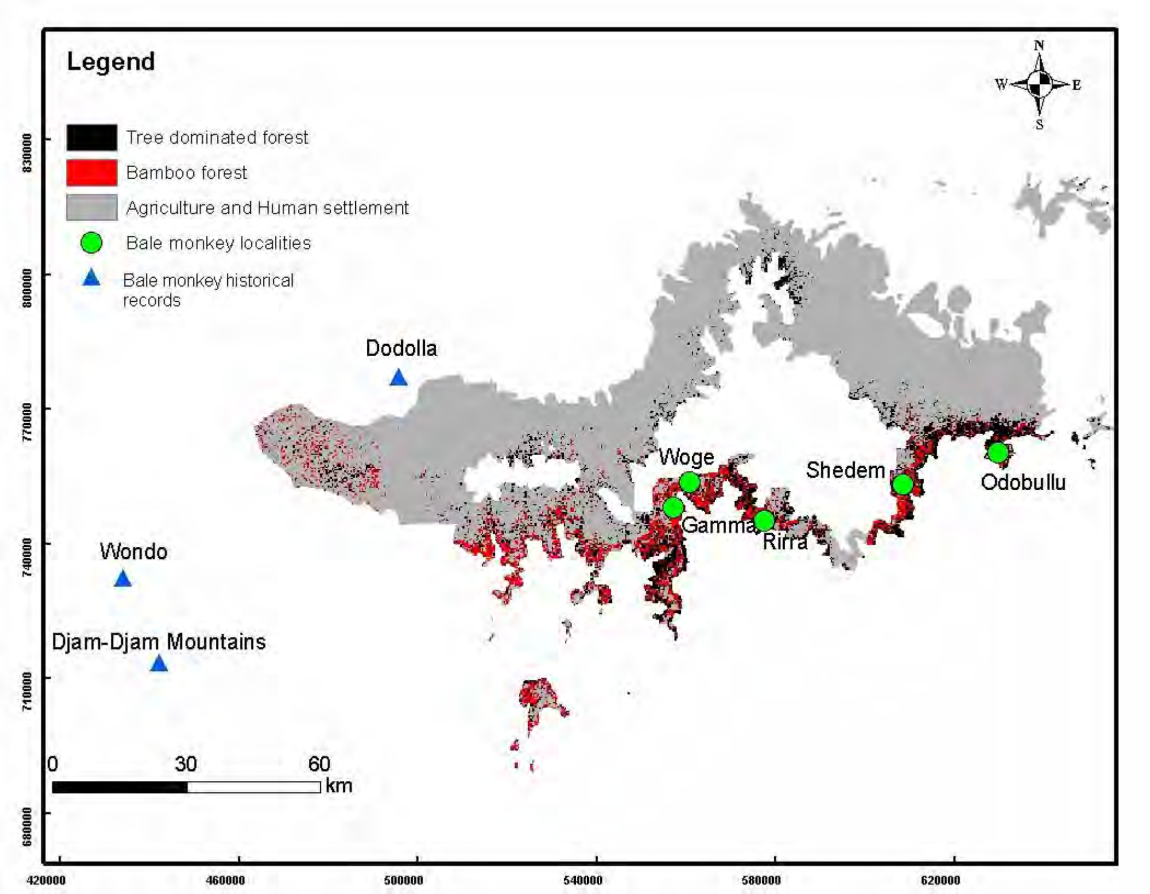

Figure 8. Map of the Bale monkey localities across the Bale Massif bamboo forest and their historical records.

5.5. Activity time budget

Approximate total count for the selected study Groups A and B was undertaken opportunistically when they crossed a narrow forest gap or existing animal tracks in the bamboo forest. Based on repeated counts, the total number of Group A was between 55-60 individuals and Group B was 46-50 individuals. It was impossible to precisely determine the group composition as there is relatively poor visibility in the thick bamboo forest. Each group contained at least 4-6 adult males and they exhibit a multimale-multifemale social organization. The study groups occupy mountainous terrain that varies from 2695–2900 m asl from north to south.

A total of 11393 individual behavioural observations were recorded from 2830 group scans for a total of 86 days. Of these, 42 days were from Group A and 44 days were from Group B. The overall activity time budget of Bale monkeys from the combined study groups is presented in Figure 9.

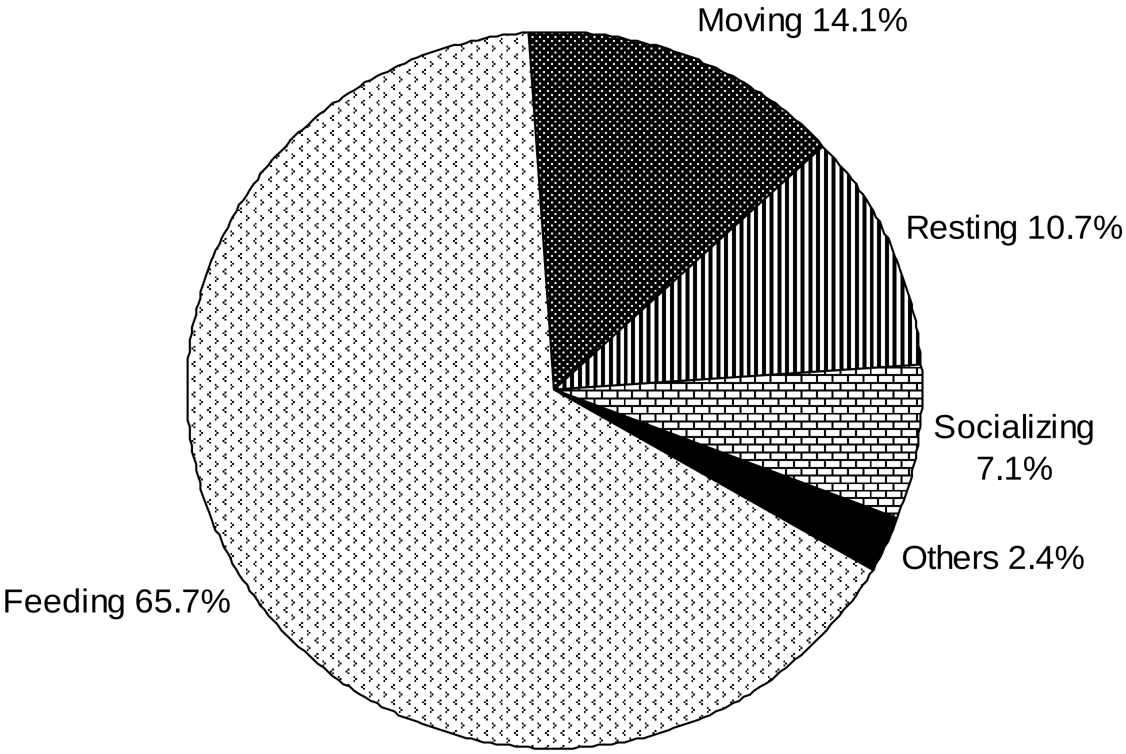

Figure 9. Overall activity time budget of Bale monkeys in the Odobullu Forest during the course of the study period.

On average, the monkeys spent 65.7% (range 58.9-72.0%, SD±4.1%) of their time feeding, 14.1% (range 10.9-16.3%, SD ± 1.8%) moving, 10.7% (range 7.9-13.9%, SD±1.8%) resting, 7.1% (range 5.2-9.1%; SD±1.1%) engaging in social activities such as 1.8% playing, 1.7% aggression, 2.7% grooming and 0.9% sexual activity, and 2.4% (range 1.2-4.0%, SD±1.0%) other activities such as vocalization, looking at the observer and defaecating.

Bale monkeys on average spent more time feeding (68.5%, SD±2.9%) during the wet season than the dry season (62.9%, SD±3.1%). The monkeys on the average spent more time moving (15.5%, SD±1.2%) and resting (11.4%, SD±1.9%) during the dry season than the wet season (12.8%, SD ± 1.2%) and (10.0%, SD±1.8%) respectively. They also spent on average more time engaged in social activities during the dry season (7.8%, SD±1.1%) than the wet season (6.5%, SD±1.0%) (Fig. 10).

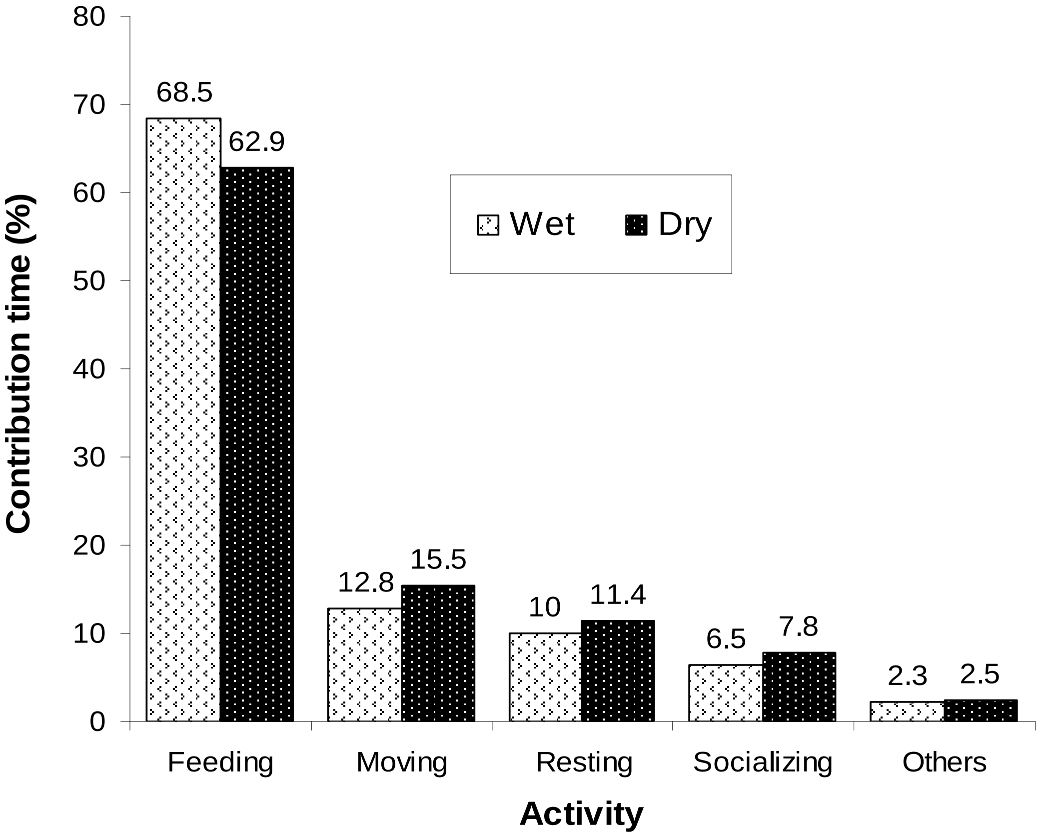

Figure 10. Seasonal activity time budget of Bale monkeys in the Odobullu Forest.

Mann-Whitney U tests showed significant differences between seasons in time spent feeding (*P* < 0.05), moving (*P* < 0.05), resting (*P* < 0.05) and social activities (*P* < 0.05). However, there was no significant difference between seasons in other activities (*P* > 0.05). Bale monkeys spent similar time during the wet and dry seasons engaged in other activities such as vocalization, looking the observer, and defaecation.

The monthly feeding time of Bale monkeys during the study period varied across months ranging from 58.9% during February to 72.8% during September. Moving ranged from 10.9% (September) to 16.3% (November) and resting ranged from 9.1% (September) to 13.9% (February). Social activities were highest during February (9.15%) and lowest during September (5.2%) (Fig. 11). However, there was no significant difference in the time spent for all activities across months (Kruskal-Wallis H test, *P* > 0.05).

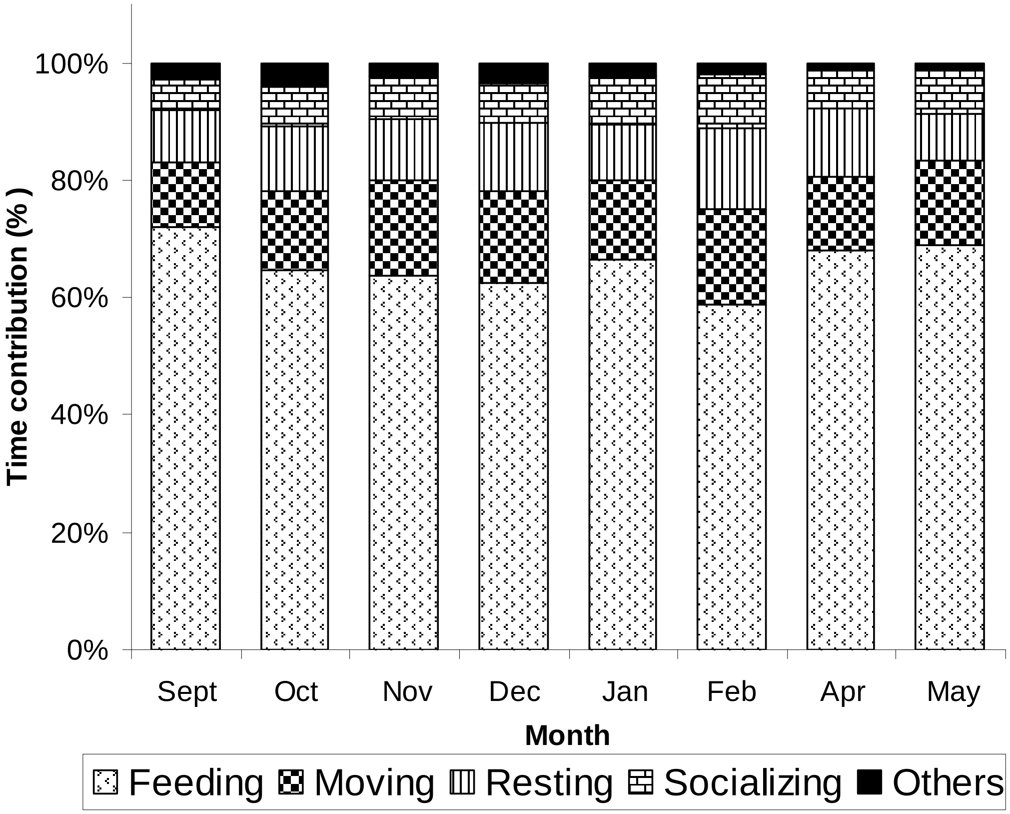

Figure 11. Monthly variation in the time spent for various activities.

5.6. Feeding ecology

Diet composition

A total of 7223 feeding behavioural records were obtained from scan sampling of the two combined study groups of 86 days. The overall diet of Bale monkeys during the study period is presented in Figure 12. Young leaves contributed 80.2% (SD±4.1%) of the overall diet of Bale monkey. Fruits and flowers made the second and third largest contributions to the overall diet of Bale monkeys at 9.6% (SD±6.9%) and 3.1% (SD±4.1%), respectively. Bale monkeys also consumed animal foods, especially insects, which accounted for 2.3% (SD±1.0%) of their overall diet. Mature leaves, roots, stems and shoots were consumed rarely (Fig. 12).

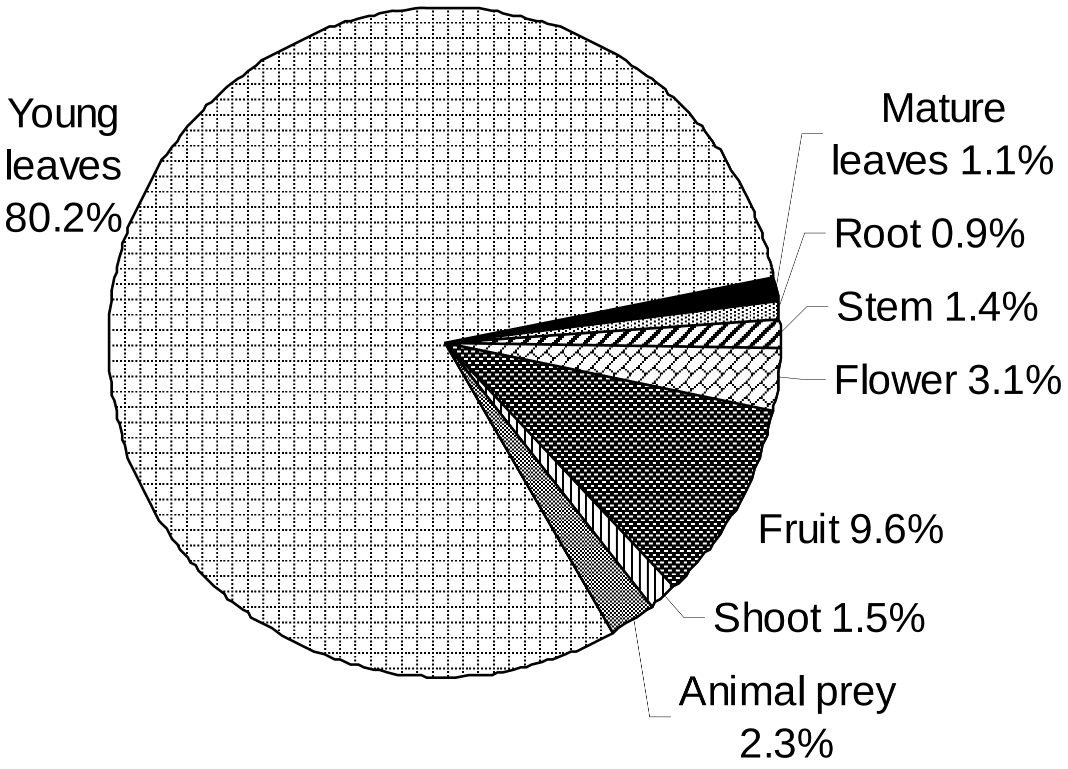

Figure 12. The overall percentage contribution of feeding time devoted to different types of food items by Bale monkeys.

Bale monkeys spent more time feeding on young leaves (81.7%, SD±3.8%) and flowers (3.9%, SD±6.2%) during the wet season than the dry season (78.8%, SD±4.3%) and (2.3%, SD±3.7%), respectively. The monkeys spent more time feeding on fruit (14.9%, SD±4.1%) during the dry season than the wet season (4.3%, SD±4.3%). Roots and shoots were consumed during the wet season only, while mature leaves were consumed irregularly both during the wet and dry seasons (Fig. 13). Mann-Whitney U tests showed that there was a significant difference in time spent feeding on fruits ($P < 0.05$) and shoots ($P < 0.05$) between the seasons. However, there were no significant differences between seasons in the time spent feeding on young leaves ($P > 0.05$), mature leaves ($P > 0.05$), root ($P > 0.05$), flower ($P > 0.05$), stem ($P > 0.05$) and animal prey ($P > 0.05$). The monkeys spent similar amounts of time feeding during the wet and dry seasons on young leaves, mature leaves, stems, root, flower and animal prey.

Figure 13. Seasonal percentage contribution of food items selected by Bale monkeys in Odobullu Forest.

The monthly time spent feeding on different food items by Bale monkeys is shown in Table 4. Feeding time on young leaves was high in all months. The minimum time spent feeding on young leaves was recorded during February (72.9%) and the maximum was during April (86.7%). The monkeys spent more time feeding on fruit during February (20.0%) while no fruit diet was recorded in September. The monkeys spent more time feeding on flower at the end of the wet season (October, 13.1%) while flower diet was not recorded from January to May. During the study period, shoots were heavily consumed during the early wet season, May (8.3%) (Table 4). Kruskal-Wallis H tests showed that there were no significant differences in the time spent feeding on all food items across months ($P > 0.05$).

Table 4. Monthly variation in percentage contribution of food items.

	Percentage of diet								
Month	Young leaves	Mature leaves	Root	Stem	Flower	Fruit	Shoot	Animal prey	Total
Sept	82.1	2.6	1.2	5.4	2.5	-	2.6	3.8	100
Oct	80.6	0.7	-	0.7	13.1	2.3	0.8	1.8	100
Nov	80.0	-	-	-	7.7	10.5	-	1.8	100
Dec	83.2	-	-	1.2	1.4	12.8	-	1.5	100
Jan	78.9	1.4	-	2.2	-	16.3	-	1.2	100
Feb	72.9	1.9	-	1.4	-	20.0	-	3.7	100
Apr	86.7	0.7	-	0.4	-	10.1	-	2.1	100
May	77.5	1.3	6.0	-	-	4.8	8.3	2.1	100
Mean	80.2	1.1	0.9	1.4	3.1	9.6	1.5	2.3	100

During the study period, Bale monkeys consumed a total of 11 plant species which accounted for 97.7% of their diet over the course of the study period. The percentage contribution and the food items consumed in each species of plants are presented in Table 5. From the 11 plant species contributing to the overall diet of Bale monkeys, three species were trees, four were climbers or lianas, one was an epiphyte, one was a shrub and two were herbs.

Table 5. List of plant species, food items consumed and percentage contribution of the diet of Bale monkeys during the study period.

Local name	Species consumed	Family	Type	Food items consumed	% contribution
Leemman	*Arundinaria alpina*	Poaceae	Tree	YL, ML, R, S, SH	76.7%
Korraallaa	*Psychotria orohila*	Rubiaceae	Tree	YL, FR	10.6%
Daannisa	*Dombeya torrida*	Sterculiaceae	Tree	FL	3.1%
Qrqooraa	*Mikaniopsis clematoides*	Asteraceae	Climber	YL	2.6%
Haliilaa	*Urera hypselodenron*	Urticaceae	Shrub	YL, S	1.4%
Herayyee	*Acanthopale pubescens*	Acanthaceae	Herb	S	1.2%
Garaabaa	*Bothrichloa radicans*	Poaceae	Herb	YL	0.9%
Aanquu	*Embelia schimperi*	Embenaceae	Epiphyte	FR	0.6%
Lallacaa	*Cypostemma adenocaule*	Vitaceae	Climber	FR	0.3%
Alafitre	*Thlophora lugardae*	Asclepiadaceae	Climber	YL	0.3%
Goraa	*Rubus apetalus*	Rosaceae	Climber	FR	0.1%
Total					97.7%

YL = Young leaves; ML = Mature leaves; R = Root; S= Stem; FL = Flower; FR = Fruit; SH = Shoot

The top five most consumed plant species accounted for 94.3% of the overall diet of Bale monkeys (Fig. 14). Based on the overall percentage contribution of food items consumed, bamboo (*Arundinaria alpina*) was the most consumed food species which accounted for 76.7% (range 68.1-84.2%, SD ± 5.8%) for the overall diet of Bale monkeys. *Psychotria orohila* tree ranked second and *Dombeya torrida* tree ranked the third plant species accounting for 10.6% (range 2.8-20.7%; SD±6.6%) and 3.1% (range 0-13.1%; SD±4.8%) of the overall Bale monkey diet, respectively.

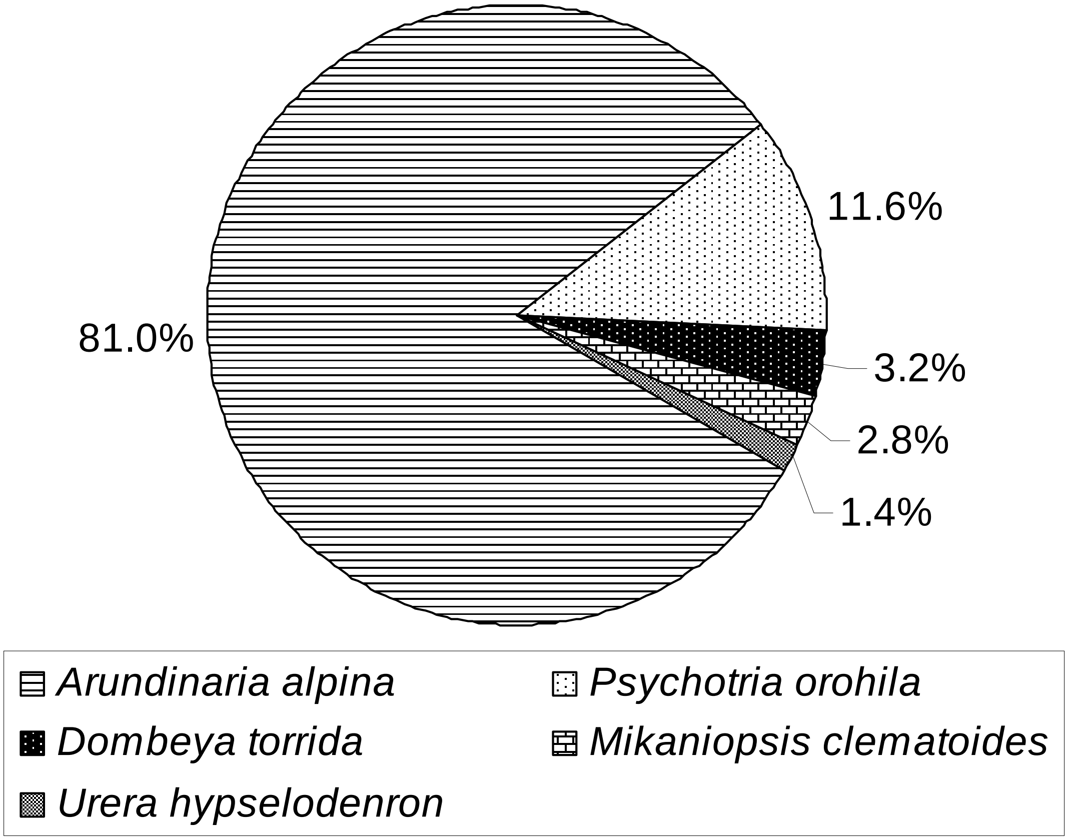

Figure 14. The major 5 plant species consumed by Bale monkeys during the study period

The main food item consumed during the study period was the young leaves of bamboo *(Arundinaria alpina)* which comprised 73.0% of the diet while bamboo mature leaves, roots, stems and shoots together accounted 3.7 % of the diet. *Psychotria orohila* contributed fruits (8.9%) and young leaves (2%) and *Dombeya torrida* contributed flowers (3%) to the diet of Bale monkeys (Table 6). The percentages for each plant species were calculated from the total percentage of feeding contribution during the study period as independent samples rather than depending on the average samples each month.

Table 6. The overall percentage of time spent feeding on specific food items in each plant species and animal prey during the study period.

Species	Percentage of diet								
	Young leaves	Mature leaves	Root	Stem	Flower	Fruit	Shoot	Animal prey	Total
Arundinaria alpina	73	1.1	0.8	0.3	-	-	1.3	-	76.5
Psychotria orohila	2.0	-	-	-	-	8.9	-	-	10.9
Dombeya torrida	-	-	-	-	3.0	-	-	-	3.0
Mikaniopsis clematoides	2.6	-	-	-	-	-	-	-	2.6
Urera hypselodenron	1.3	-	-	0.1	-	-	-	-	1.3
Acanthopale pubescens		-	-	1.2	-	-	-	-	1.2
Bothrichloa radicans	0.8	-	-	-	-	-	-	-	0.8
Embelia schimperi	-	-	-	-	-	0.7	-	-	0.7
Cypostemma adenocaule	-	-	-	-	-	0.3	-	-	0.3
Thlophora lugardae	0.3	-	-	-	-	-	-	-	0.3
Rubus apetalus	-	-	-	-	-	0.3	-	-	0.1
Animal prey	-	-	-	-	-	-	-	2.2	2.2

Bale monkeys on average spent more time feeding on bamboo (*Arundinaria alpina*) (80.3%, SD±5.4%) and *Dombeya torrida* (3.9%, SD±6.2%) during the wet season compared to the dry season (73.2%, SD±4.0%) and (2.3%, SD±3.7%), respectively (Table 7). They showed significant difference in the time spent feeding on *Psychotria orohila* (Mann-Whitney U test, $P < 0.05$) during the dry season compared to the wet season. They spent more time feeding on *Psychotria orohila* fruit during the dry season. They also showed significant difference consuming relatively more of *Bothrichloa radicans* young leaves (Mann-Whitney U test, $P < 0.05$) and *Urera hypselodenron* young leaves (Mann-Whitney U test, $P < 0.05$) during the wet season compared to the dry season. However, Bale monkeys did not show significant seasonal difference in the time spent feeding on Bamboo (*Arundinaria alpina*) (Mann-Whitney U test, $P > 0.05$) as bamboo is available throughout the year. In addition, there was no significant difference between seasons in the rest of plant species consumed by Bale monkeys (Mann-Whitney U test, *P* > 0.05).

Table 7. Seasonal percentage contribution of plant species consumed by Bale monkeys.

Species consumed	Wet season (%)	Dry season (%)
Arundinaria alpina	80.3	73.2
Psychotria orohila	4.9	16.3
Dombeya torrida	3.9	2.3
Mikaniopsis clematoides	2.1	3.0
Urera hypselodenron	1.7	1.0
Acanthopale pubescens	1.2	1.2
Bothrichloa radicans	1.7	0.1
Embelia schimperi	0.6	0.6
Cypostemma adenocaule	0.7	0.0
Thlophora lugardae	0.4	0.1
Rubus apetalus	0.1	0.0
	97.5	97.9

The monthly percentage contribution of each plant species is presented in Table 8. The contribution of bamboo *(Arundinaria alpina)* to the diet of Bale monkeys was regular in all months ranging from the smallest 68.1% in February to 84.2% in May. Bamboo was the most frequently consumed species providing different food items even though young leaves are dominant. Bamboo shoots were available following the early wet rainy season during May. During this time, the monkeys forage on the newly emerging shoots and roots as well. *Psychotria orohila* was consumed in all months ranging from a minimum of 2.8% in September to a maximum of 20.7% in February. However, the comparison of plant species contribution across each month by Kruskal-Wallis H tests showed no significant differences in the time spent feeding on different species of plants (*P* > 0.05).

Table 8. Monthly percentage contribution of plant species consumed by Bale monkeys.

Species consumed	Sept	Oct	Nov	Dec	Jan	Feb	Apr	May	Mean
Arundinaria alpina	84.1	72.7	73	77.9	73.9	68.1	80	84.2	76.7
Psychotria orohila	2.8	4.5	13.9	15.5	15.4	20.7	7.5	4.7	10.6
Dombeya torrida	2.5	13.1	7.7	1.4	-	-	-	-	3.1
Mikaniopsis clematoides	1.8	3	2.3	2.1	3.7	4.1	2	1.6	2.6
Urera hypselodenron	1.2	2.4	1.3	0.5	0.9	1.1	1.8	1.6	1.4
Acanthopale pubescens	2.5	0.7	-	1.2	2.2	1.4	0.4	1.5	1.2
Bothrichloa radicans	1.5	1.8	-	-	0.3	0.2	1.5	1.7	0.9
Embelia schimperi	-	-	-	-	2.2	0.4	2.5	-	0.6
Cypostemma adenocaule	-	-	-	-	-	-	-	2.7	0.3
Thlophora lugardae	-	-	-	-	0.3	0.3	1.5	-	0.3
Rubus apetalus	-	-	-	-	-	-	0.6	-	0.1

Diet variation

The mean monthly Shannon-Wiener index (H') for food species diversity was 0.74 (range 0.58-0.94; SD±0.14) (Table 9).

Table 9. Food species diversity and evenness index for each month during the study period.

Month	Shannon-Wiener Diversity index, H'	Evenness index, J
Sep	0.60	0.31
Oct	0.94	0.48
Nov	0.58	0.52
Dec	0.65	0.39
Jan	0.87	0.42
Feb	0.88	0.42
Apr	0.79	0.36
May	0.64	0.33
Mean	0.74	0.40

Dietary diversity was relatively highest in October and lowest in September. In general, the diet of Bale monkeys was not diverse and showed little variation during the study period. The dietary evenness index, J, was calculated each month and the mean monthly evenness index was found to be 0.40 (SD±0.07). Evenness index ranged from 0.31 in September to 0.52 in November (Table 9).

Diet selection

The dietary preference or selection ratio for food species consumed during the study period in the home range of Bale monkey groups is presented in Table 10.

Table 10. Dietary preference of Bale monkeys based on stem density for plant species consumed.

Rank	Species name	Family	Habit	Stem Density (%)	% diet	Selection ratio
1	*Arundinaria alpina*	Poaceae	Tree	90.5	76.7	0.9
2	*Psychotria orohila*	Rubiaceae	Tree	1.2	10.6	8.7
3	*Dombeya torrida*	Sterculiaceae	Tree	0.3	3.1	9.7
4	*Mikaniopsis clematoides*	Asteraceae	Climber	0.4	2.6	5.8
5	*Urera hypselodenron*	Urticaceae	Climber	1.4	1.4	1.0
6	*Acanthopale pubescens*	Acanthaceae	Herb	-	1.2	-
7	*Bothrichloa radicans*	Poaceae	Herb	-	0.9	-
8	*Embelia schimperi*	Embenaceae	Epiphyte	-	0.6	-
9	*Cypostemma adenocaule*	Vitaceae	Climber	1.0	0.3	0.3
10	*Thlophora lugardae*	Asclepiadaceae	Climber	1.0	0.3	0.3
11	*Rubus apetalus*	Rosaceae	Climber	0.6	0.1	0.2

Rank is presented in the order of percentage contribution of overall diet. Dietary preference for herbs and an epiphyte was not calculated.

Based on the dietary preference ratio, *Dombeya torrida* was the most selected plant species by Bale monkeys with a selection ratio of 9.7. *Psychotria orohila* tree was the second and *Mikaniopsis clematoides* was the third most selected plant species with dietary selection ratios of 8.7 and 5.8, respectively. Bamboo (*Arundinaria alpina*) had a low selection ratio 0.9 even though it was by far the top species in percentage contribution of the overall diet of Bale monkeys. Other common species such as *Manilkara butugi, Schifflera volcansii, Maytenus obscura and Hagenia abyssinica* were found in the study groups home range but not consumed by the monkeys (Table 1).

5.7. Ranging pattern

Home range

The overall home range areas of group A and B based on minimum convex polygon method during the course of the study period was found to be 18.1 and 12.3 ha, respectively (Fig. 15). The wet and dry season home range areas of the study groups are depicted in Table 11.

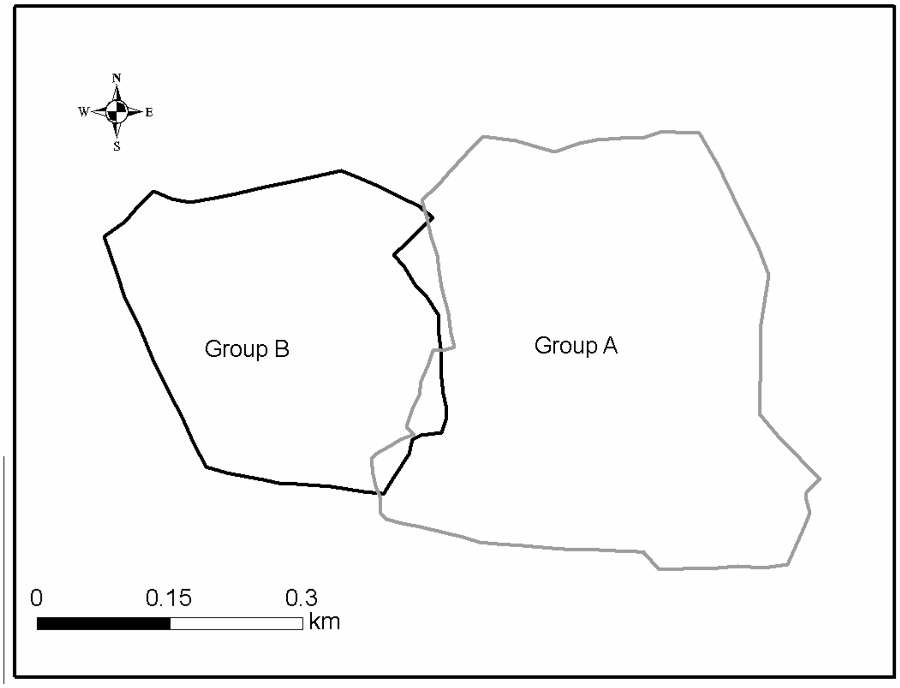

Figure 15. The overall home range size of the two groups of Bale monkeys using the minimum convex polygon (MCP) method.

The home range areas of the study groups were extended during the dry season than the wet season. Mann-Whitney U test showed significant difference in the home range areas used by the study groups between seasons ($P < 0.05$). The two study groups occupied their own home range area throughout the year regardless of seasonal variation. There was only slight home range overlap of 0.5 ha between neighbouring study groups. The overlap was 2.8% from group A and 4.1% from group B home range.

Daily range lengths

The average daily range length for groups A and B during the 8-month study period based on a total of 25 and 23 full day follow up for each group was 956 m (range 759-1288 m, SD±149.6) and 898 m (range 724-1207 m, SD±109.0), respectively. The mean daily range lengths of the two study groups combined were found to be 928 m. The average daily range lengths for the wet and dry seasons for the study groups are shown in Table 11. The Mann-Whitney U test showed significant difference in the daily range lengths of Bale monkeys between the wet and dry seasons ($P < 0.05$).

Table 11. Mean daily travel distance and home range size of group A and B during wet and dry seasons.

Season	Group	Mean daily travel distance (m)		Home range area (ha)
		Mean (n)	SD	
Wet	A	897 (13)	129.2	8.8
	B	853 (11)	78.1	7.3
Dry	A	1021 (12)	147.6	17.3
	B	939 (12)	120.0	11.3

6. DISCUSSION

To date, there is no detailed published information on the habitat preference, distribution pattern, feeding ecology, activity pattern and ranging behaviour of Bale monkeys. Therefore, the ecology of Bale monkey will be compared with the members of the *Cercopithecus* monkeys or guenons studied elsewhere in other sites or countries. Comparisons of Bale monkeys with guenons should be considered with caution due to differences in species, methodology and forest composition in different studies. However, this can give some information how Bale monkeys are similar or different with their phylogenetic relatives.

From the results obtained during census walk, Bale monkeys were frequently encountered in the three Bamboo forest transects but never observed in the tree dominated forest and bushland habitat. In addition, from the result obtained from scan sampling of the two studied groups, they spent 100% of their time exclusively in the bamboo forest especially in the homogenous bamboo and bamboo with mixed trees. They were observed both during the wet and dry seasons using their home range area throughout the study period. The association of Bale monkeys in the bamboo forest may be correlated with their primary habitat preference of the bamboo forest. Thus, the results of this study suggest that Bale monkeys use their habitat throughout the year regardless of seasonal variation. As a result, Bale monkeys are considered as habitat specialists at Odobullu Forest. This similar trend was observed in golden monkeys (*Cercopithecus mitis kandti)* that preferred bamboo and bamboo with mixed tree habitats at Mgahinga Gorilla National Park, Uganda (Twinomugisha *et al*., 2003) and red howler monkeys that have a habitat specialist behaviour at least part of the year in Terra Firme forests, south-eastern Colombia (Palacios, and Rodriguez, 2001; Palacios and Peres, 2005).

The habitat preference of Bale monkeys at Odobullu Forest may be associated with the availability and abundance of preferred resources, predation risk avoidance and availability of sleeping trees (Nakagawa, 1999; Wallace, 2006). Therefore, the habitat adaptability of the Bale monkeys to the bamboo forest may be associated with the dietary species specialist nature of the monkeys that depended on bamboo. In addition, bamboo is more abundant and provides year round suitable food sources for the monkeys than other food species. Their adaptation may also be correlated with their digestive ability to consume bamboo leaves similar to howler monkeys that consume and digest foliage (Haugaasen and Peres, 2005).

Bale monkeys were never observed in the southern homogeneous bamboo forest about 1 km transect relatively lower in altitude less than 2600 m asl and relatively with short bamboo less than 7 m in height. The result of the present study suggests that even though the area has abundant bamboo leaves but have no or very few big trees where Bale monkeys usually need them as sleeping sites, rain sheltering and predation avoidance from leopard which is common in the study area. However, other factors may make them to avoid this area and this will need further research. It was observed that during heavy rain, the monkeys usually move to big trees for shelter and stayed inactive until the rain ceased. Bale monkeys mostly preferred the lower strata up to 10 m height for feeding mainly on bamboo. The preference of the lower strata may be an adaptation for predation avoidance from birds of prey. However, they also fed on trees up to 25 m in height on *Dombeya torrida* flower.

The habitat preference of Bale monkeys is different from other members of the genus *Chlorocebus.* Bale monkeys are habitat specialists of the bamboo forest. Whereas, other members of the genus *Chlorocebus* such as grivet and vervet monkeys are habitat generalists and inhabit a wide range of habitat types including savannah, woodland, forest, grassland, riverine and gallery forests (Kingdon, 1997; Nakagawa 1999; Zinner *et al*., 2002; Barrett, 2005). According to Yu and Dobson (2000), a species with narrow habitat tolerance is more vulnerable to extinction. Therefore, the narrow habitat preference or rigidity in the habitat use of Bale monkeys to the bamboo forest is a threat due to the current deforestation of the bamboo forest (pers. obser.). In general, understanding the habitat preference of animals is imperative for planning future conservation and management of the species (Balakrishnan and Easa, 1986; Worman and Chapman, 2006). Therefore, recognizing the bamboo forest as the habitat preference of Bale monkeys is basic to plan for future scientific conservation and management of the bamboo forest.

Density estimates rely on encounter rates of monkeys, group size and the method used in estimating transect width (Shah, 2003; Weghorst, 2007). Density estimates for forest dwelling and unhabituated primates may not be accurate because of the difficulty to count the group size reliably (Shah, 2003). In addition, it should be noted that counts during transect walks are likely to have been incomplete considering the relatively short time spent with these groups and the poor visibility characteristic of their bamboo habitat. However, to avoid this source of error, the group size of the monkeys were counted again by the local assistants during transect walking and after the census. The minimal group size recorded during transect walking may be associated with separation of the group during foraging which was common in the study groups during scan sampling. However, the group size of Bale monkeys is higher than their congenetic grivet monkeys (*Chlorocebus aethiops*) recorded in Eritrea (Zinner *et al*., 2002). The maximum reliable observer animal distance method of transect width estimation used for transect width estimation was more effective compared to mean reliable transect to animal distance method (Shah, 2003) and animal transect method (Fashing and Cords, 2000; Shah, 2003) which reduces transect width and causes over-estimation of population density. Therefore, the total population estimates of Bale monkeys calculated in the Odobullu thick bamboo forest is expected to be accurate (Chapman *et al*., 1988; Fashing and Cords, 2000; Shah, 2003).

Comparing density estimates of primates at different sites with various methods of analysis resulted in differences (Shah, 2003). However, comparison of the encounter rate and density estimates of Bale monkeys with other guenons gives some information. The encounter rate and density of Bale monkeys are comparable with golden monkeys (*Cercopithecus mitis kandti)* that specialize feeding on bamboo but higher than that of *Cercopithecus nictitans, Cercopithecus ascanius* and *Cercopithecus cephus* (Appendix 1). According to Chapman and Chapman (2002) and Wallace *et al*. (1998), the abundance and density of primates were related to food quality and availability. The high abundance and density of primates are associated with a combination of factors (Butynski, 1990; Wallace *et al*., 1998; Weghorst, 2007). The relatively high abundance and density of Bale monkeys in the Odobullu Forest may be related to the high abundance and productivity of bamboo, long wet season, less hunting pressure, low predation by raptors due to closed canopy, large group size of the troop to avoid predation from leopard, the difficult terrain they harbour and the existence of the monkeys far from the surrounding local people. In general, the presence of accurate data on the population estimate of animals is very crucial for determining future conservation and management of the species (Muoria *et al*., 2003). In addition, accurate population estimate will help to determine the status of the species. However, further research is recommended to assess the whole population of Bale monkeys across the Bale Massif. Therefore, the population estimate of Bale monkeys made in the Odobullu Forest gives insight for wildlife officials for planning the future conservation of the species.

From the result obtained during transect walks, the distribution of Bale monkeys were also found exclusively in the bamboo forest habitat. The result of the present study suggests that the distribution of Bale monkeys is strongly interlinked with top dominant diet species availability (Wallace, 2006). However, other factors such as altitude and the availability of sleeping trees may have a strong effect. The present study shows that the distribution of the Bale monkeys are related with the distribution the “keystone resource”, bamboo across the Bale

Massif. However, the whole bamboo forest that was identified by satellite image across the Bale Massif was not surveyed due to limited time and limitation of funding to survey the whole area. Therefore, the result of the present study suggests that other new populations may be discovered if the whole bamboo forest across the Bale Massif is surveyed. As a result, further research should be conducted to identify the whole distribution pattern of Bale monkeys in the Bale Massif.

According to Lehman (2004b), habitat generalist primates show wider geographical range while habitat specialists show limited geographical distribution. Therefore, Bale monkeys are the narrowly distributed members of the Genus *Chlorocebus* that restricted in the Bale Massif, in which they are habitat specialists. Whereas, their sister taxa are widely distributed across Africa. Vervet monkeys are distributed in the southern, central and eastern African countries (Kingdon, 1997; Barret, 2005; Groves, 2005). Vervet monkeys have the widest range of distribution of other guenons in Africa (Struhsaker, 1967). While grivet monkeys are distributed in central and northern Ethiopia, southeastern Sudan and Eritrea (Kingdon, 1997; Zinner *et al.,* 2002; Groves, 2005).

The amount of time spent for different activities in animals is an indication of balancing energy budgets for various activities. A monkey that can easily obtain food can spend more time for resting and grooming than feeding and moving (Pombo *et al.,* 2004). However, Bale monkeys spend larger portion of their time for feeding and moving than resting and socializing (Fig. 9). Even though Bale monkeys are social animals, they spend less time for social activities such as grooming, playing, sexual activities and aggression. Rresults of the present study suggest that they spend more time for feeding as they feed dominantly on leaves that may have low energy value. Therefore, as a folivore species they have to spend more time feeding on leaves to satisfy their daily energy requirements than social activities and resting. During the study period, inter-group aggression was observed in three occasions. One occasion was between group A and the neighbouring unstudied group. During this time, the two group members vocalize on both sides and both of them move to their home ranges. On the other two occasions, group B was encountered with the unstudied neighbouring group inside its own home range. In both cases, there was fighting between the groups that last for about 15 minutes. The two troop members especially females and juveniles were the main participants chasing one another in the agonistic interaction whereas adult males did not participate but simply vocalize with loud calls may be to frighten the new group. Then the intruding group was displaced by members of Group B. This may indicate that Bale monkeys are territorial which use their home ranges strictly.

There were significant differences between seasons in the activity time spent on feeding, moving, resting and social activities. These seasonal differences may be attributed to environmental and dietary variables (Shah, 2003; Williams-Guille´n, 2003). Bale monkeys spent more time for feeding and less for moving during the wet season than the dry season. This may be attributed to the fact that during the wet season the monkeys spend greater amount of time to feed on abundant young leaves to satisfy their daily energy requirements compared to the dry season, in which they travel more to obtain fruit. High feeding time during the wet season may be a result of the low energy value of the leaves than fruits (Williams-Guille´n, 2003). On the other hand, the monkeys spent relatively more time for moving, resting and socializing during the dry season than the wet season. This may be associated with that the monkeys spent more time for moving due to the relative scarcity of food resources and to forage on *Psychotria orohila* fruit. They spent more time for resting and social activities that may be correlated with feeding on fruit containing more energy than young leaves.

The activity time budget of Bale monkeys showed variation compared to other Cercopithecines or guenons (Appendix 2). Thus, the result of this study does not fall within the categories spent in different activities. Bale monkeys spent most of their time for feeding compared to other guenons listed in Appendix 2. On the other hand, they spent less time for resting and socializing compared to the time spent by vervets. Bale monkeys spent less time moving compared to *Cercopithecus lhoesti* and *C. mitis doggetti* while their movement activity is comparable with that of vervets. These differences may result from the folivore nature of the Bale monkeys that depended mainly on leaves.

The availability of data on the feeding ecology of the species is used to specify the proportion of the diet containing different food items and species consumed. Based on the main dietary item constituent, the monkeys can be classified as folivores, frugivores or insectivores (Chapman *et al.,* 2002b). Even though Bale monkeys consumed all food categories listed in (Table 4, Fig. 12), but leaves accounted 81.3% of their overall diet. Therefore, they can be considered as strictly folivores as they spend most of their time feeding on leaves.

Bale monkeys preferred younger leaves to mature leaves. Bamboo young leaves are the favourite foods of the monkeys and spend much of their time feeding on them. Studies showed that young leaves have more protein, low fibre content and are more digestible than mature leaves (Kaplin and Moermond, 2000; Chapman *et al*., 2002a; Vasey, 2005; Fashing *et al*., 2007a). However, further studies are needed to determine the nutritional content of young leaves consumed in the Odobullu Forest. They also spend portion of their time feeding on fruit and flower next to young leaves. Solanki *et al*. (2008) suggested that Capped langur (*Trachypithecus pileatus*) spent more time feeding on fruits during the dry season due to the high availability of fruit and low abundance of young leaves. Similarly, Bale monkeys spent relatively more time feeding on fruit during the dry season than the wet season which may be associated to compensate the relatively low abundance of bamboo young leaves during the dry season. In addition, fruits especially *Psychotria orohila* tree fruits were abundant and relatively have larger nutrient value than leaves. They also fed on flower of *Dombeya torrida* tree at the end of the late wet season (October) and the early dry season (November). Flowers are high quality food items that contain protein and macronutrient (Vasey, 2005). However, flower and fruits were seasonal food items and were not available throughout the year. In addition, they also spend a small portion of their time feeding on roots, shoots and stems. Bale monkeys spent relatively more time feeding on bamboo shoots during the early wet season (May) (Plate 4). They spent more time to search for the newly emerging shoots from the ground. Not only they fed on the shoot but also on the root of the bamboo as well.

Plate 4. Adult male Bale monkey feeding on the shoot of bamboo. (Photo: Addisu Mekonnen, May 2008).

Bale monkeys feed on animal prey during all months of the study period and this may be to fulfill their protein requirements. They spend more time to obtain insects by scratching tree bark, ferns and exposing dead leaves. In one occasion, they spent relatively more time feeding on insect during the outbreak of locust that invaded the home range area of the study groups for one day in February. During this time, they spent relatively more time feeding on insect than the usual time. They also spent more time for resting and socializing during this time as insects have high protein content. Even though this can not be evaluated in the long term, Bale monkeys may spend and feed more on the highly nutritious foods of insects if they find them in high abundance easily. However, searching insect seems cost intensive for them.

The diet of Bale monkeys consisted of 11 plant species during the study period (Table 5). The top five plant species accounted 94.3% of their overall diet. Of these, a single species, bamboo (*Arundinaria alpina*) dominated their overall diet. Bamboo was consumed throughout the year contributing 76.7% of their overall diet, of this, bamboo young leaves accounted 73%. Therefore, the result of the present study suggests that Bale monkeys are bamboo specialists. In addition, the result of this study indicates that Bale monkeys in the Odobullu Forest showed a narrow dietary niche or dietary rigidity that depended on few plant species dominated by bamboo young leaves. This dietary rigidity on a single species may be explained by a narrow distribution of the Bale monkeys that restricted themselves in a narrow habitat types and geographic range. According to Harcourt (2006), a species which has narrow geographical range with habitat and dietary specialization is considered as rare species. Therefore, Bale monkeys could also be considered as a rare species.

The habitat of Bale monkeys was not diverse in plant species and was dominated by a single species, bamboo (Table 1). According to Stoner (1996) and Silver *et al*. (1998), species diversity by itself is not sufficient to determine the quality of a given habitat. However, the density and relative abundance of the most commonly consumed plant species were considered as indicator of habitat quality in the study site. Therefore, the result of the present study suggests that the bamboo forest habitat with low species diversity dominated by the most utilized bamboo (*Arundinaria alpina*) species would be the best habitat for Bale monkeys (Table 1, Plate 5).

Plate 5. Bamboo forest in the home range area of the study groups in the Odobullu Forest. (Photo: Addisu Mekonnen, October 2007)

The availability of resources in their habitat throughout the year indicates the habitat quality of the forest to support the monkeys (Solanki *et al*., 2008). The area is characterized by long wet season that makes young leaves more abundant. Wallace *et al.* (1998) considers that the main dietary resources for the spider monkeys as a “keystone” resource. Thus, the bamboo plant for Bale monkeys can be considered as a keystone resource, in which the loss of this resource would have a great effect on the survival of the species.

The diet of Bale monkeys was not diverse and showed little variation during the study period. The dietary diversity calculated by Shannon-Weiner index (H’) consumed by Bale monkeys was less with mean 0.74. This small value may be due to the high proportion of bamboo young leaves consumption, in which other food items accounted for a small part of their monthly diet. Dietary diversity was relatively highest in October (0.94) and lowest in September (0.58). The variation in the dietary diversity across months may be correlated with the proportion of each food item and the number of species consumed each month. Dietary evenness index calculated by evenness index (J) showed that the dietary species were not evenly distributed. Evenness index ranged from 0.31 in September where the species diet was relatively more evenly distributed than November (0.52) where the species diet was relatively less evenly distributed.

The feeding ecology of Bale monkeys was compared with other guenons as shown in Appendix 3. Guenons are generally known mainly as frugivores that mostly feed on fruit (Chapman *et al*., 2002b). According to Chapman *et al.* (2002b), two related phylogenetic taxa will have more similar diets. However, Bale monkeys are strictly folivores that specialize feeding on bamboo while their nearest member of guenons such as *Cercopithecus lhoesti, C. mitis doggetti, C. pogonias, C. nictitans, and C. ascanius* are frugivores (Appendix 3). They spend large portion of their time feeding on fruit and flower compared with that of Bale monkeys. The animal prey or insects that Bale monkeys feed on is not comparable with the other members of guenons. Bale monkeys spent less amount of time feeding on insects or animal prey compared to others. They also consumed very small number of plant species compared with other guenons. Therefore, Bale monkeys are bamboo specialist folivores while the other guenons are generalist frugivores.

The highest selection ratio for the species suggests that a preference for the food items that the plant species provided while low selection ratio indicates the species is not preferred (Fashing, 2001b; Shah, 2003). Based on the result of dietary preference ratio, Bale monkeys primarily preferred *Dombeya torrida* tree flower and secondly *Psychotria orohila* tree mainly fruit (Table 10). However, bamboo with the top plant species in stem density and the proportion of time spent feeding has a low selection ratio of 0.9. This low selection ratio may be due to the extremely high density of bamboo in the home range of the study groups. The selection ratio that approaches to one indicates that the species was probably not preferred but frequently consumed because bamboo is common and available in the home range of Bale monkeys. On the other hand, other common species such as *Manilkara butugi, Schifflera volcansii, Maytenus obscura and Hagenia abyssinica* were found in the study groups' home range but not consumed during the study period which suggests that they are not suitable as food sources (Table 1). The monkeys use the *Hagenia abyssinica* tree for foraging insect from the bark and as a nesting site but did not consume any item of food from the tree. Fashing (2001b) suggested that dietary preference should be tested when different food species are abundant and available equally. Therefore, *Dombeya torrida* and *Psychotria orohila* trees may be preferred in the Odobullu bamboo forest as they are not abundant and available throughout the year. Even though *Dombeya torrida* and *Psychotria orohila* trees are the preferred food species at Odobullu Forest, Bale monkeys spent most of their time feeding on the top species in stem density, bamboo young leaves. Preference of food resources should be tested based on food resource availability and abundance throughout the year equally.

Studying the home range and day range length of animals are important to recognize the presence of feeding competition (Williams-Guille´n, 2003), determine niche adaptation (Defler, 1996), understand the relationship between ecological variables with ranging behaviour (Di Fiore, 2003) and identify the habitat preferences of the species (Nakagawa, 1999). Home range size is affected by different factors such as foraging competition and group size (Isbell, 1991), density of resource and dietary habits (Milton and May, 1976; Bocian, 1997; Shah, 2003; Merker, 2006) and abundance of dominant food source (Nakagawa, 1999). The home range areas of the two studied groups were larger during the dry season than the wet season (Table 11). The use of relatively larger areas during the dry season may be correlated to find extra fruit from *Psychotria orohila* trees that are found dispersed and due to relative scarcity of young leaves. Fruit availability was the main determinant of the ranging pattern of the Mangabey (*Cercocebus albigena*) (Olupot *et al*., 1997). Whereas, during the wet season, they used small area as the bamboo (*Arundinaria alpina*) young leaves are more abundant.

The overall home range area used by the studied groups during the study period was small compared to other members of the guenons (Appendix 4). These have been correlated with the preference of monkeys for the abundant and available leaf resources. In addition, being as folivores, they use small home range area than frugivores. According to Isbell (1991), primates with larger groups travel longer day range length and use larger home range areas. Bale monkeys with large group sizes did not travel longer and show intragroup feeding competition that may be related with the availability of resources. As a result, they may use small home range areas. The two studied groups use their home range area throughout the year consistently and defend their home range area.

The use of MCP for home range area calculation has a disadvantage in overestimating the area that includes areas not used by the group but within their home range (Williams-Guille´n, 2003; Fashing *et al.,* 2007b). According to Sprague (2000), topography with about 30^o elevations affected the day range lengths and home range area used by the Japanese macaques at Yakushima, Japan. On the average, it increased the day range length and home range area by about 10% and 20%, respectively when topography was taken into consideration. Therefore, the actual home range areas of the Bale monkeys used in the mountainous habitat in the Odobullu Forest were less than the calculated value that was considered as flat map during GIS mapping. In addition, many GPS locations collected during scan sampling were entered in ArcView 9.1 to superimpose the map (Merker, 2006). Therefore, the home range areas calculated by MCP method from the two study groups were accurate.

According to Bocian (1997), at Ituri Forest, Democratic Republic of Congo, *Colobus angolensis* traveled longer when their primary food items was less abundant. Similarly Bale monkeys traveled longer distance during the dry season than the wet season correlated to the need to search matured *Psychotria orohila* fruits.

The mean day range lengths of Bale monkeys are comparable with that of vervet monkeys *and Cercopithecus mitis kandti,* while smaller when compared with that of *Cercopithecus lhoesti* and *C. mitis doggetti* (Appendix 4). This variation may be associated with their feeding behaviour as folivores do not travel longer distances while frugivores travel longer to obtain fruits in their home range. In general, Bale monkeys travel short distances daily in search of food as bamboo is abundant throughout the year. The result of this study supports the idea that short distances are related to readily availability of food resources (Kumar *et al*., 2007). Even though Bale monkeys have small home range size, the average day range length they travel was higher in contrast to the small size of their home ranges. The average day range lengths for the two study groups were nearly twice of the diametre of their yearly home range sizes.

7. THREATS

According to Wieczkowski (2004), the major threat for primates is habitat destruction. Habitat destruction reduces the forest size leading to the reduction of food sources (Muoria *et al*., 2003). The habitat destruction of bamboo forest for local consumption and commercial purpose in the nearby towns is a big threat for the Bale monkeys. Legal harvesting of bamboo is a common phenomenon for the local people especially for the young ones. It is the main source of income next to agriculture. Twinomugisha and Chapman (2006) found out that the harvesting of bamboo in the same area year after year affected the growth of bamboo resulting in poor yield and low coverage. Similarly, harvesting of bamboo in the Odobullu Forest decreases the quality and abundance of bamboo.

Logging or anthropogenic disturbance of the forest increases the complexity and diversity of plant species for the blue monkeys (*Cercopithecus mitis stuhlmanni)* (Fairgrieve and Muhumuza, 2003) and *Hapalemur griseus* (Grassi, 2006) to utilize more alternative food sources. Forest disturbance may increase the variety of food species for those species having generalist diet but this may not be true for specialist species like Bale monkeys. Lee and Hauser (1998) suggested that the destruction of habitat result in the reduction of selected food species that may initiate local extinction of the species. Therefore, the legal harvesting of bamboo in the Odobullu Forest is a threat which increases the diversity and abundance of other plant species not selected by the monkeys. Thus, harvesting of bamboo would have a negative effect on the population of Bale monkeys that specialize feeding on bamboo. However, more detailed ecological investigations are needed to recognize how logging or harvesting of bamboo positively or negatively affect the Bale monkey populations.

In addition, the bamboo forest naturally becomes dry after producing seed changing the area to bare land (personal communication of local people) and as observed in the Woge area during survey (Plate 6). This would be a great threat for Bale monkey populations that specialize feeding on bamboo, if this trend occurs in other sites in the future. Therefore, further botanical research should be conducted to determine the root cause of bamboo forest decline.

Bale monkeys have narrow ecological niche with a bamboo habitat preference, narrow geographical range and diet specialization on a single plant species which may be a threat for the conservation and management of the species. Generally a species with narrow ecological niche is susceptible for extinction.

Plate 6. Bamboo forest decline after producing seed in the Woge area. (Photo: Addisu Mekonnen, March 2008).

Bale monkeys are the main source of food for leopard in the Odobullu Forest, a thick bamboo forest makes them vulnerable to predation. However, they are well-adapted for vocal communication in the thick bamboo forest by forming large groups as predation avoidance strategy similar to Bamboo lemur *(Hapalemur griseus)* (Grassi, 2006). Usually, they communicate through vocal communication as the bamboo forest is difficult for visual communication. When they become aware of the presence of leopard, they usually climb big trees. Bird raptor predation was not common in the Odobullu Forest. However, when the monkeys are aware of the presence of bird predators, they usually step down to the middle canopy, even adult males. This low predation rate by bird predator may be due to the closed canopy.

8. CONCLUSION AND RECOMMENDATIONS

- Bale monkeys showed preference for bamboo forest habitat ignoring other habitat types regardless of seasons in the Odobullu Forest and are bamboo forest habitat specialists.

- The distribution of Bale monkeys is strongly interlinked with the distribution of bamboo forests both in the main study area Odobullu Forest and across the Bale Massif. However, not all bamboo forests harbour Bale monkeys.

- The density and abundance of Bale monkeys in the Odobullu bamboo forest was high. This may be correlated with the abundance of year round food sources.

- Bale monkeys spend much of their activity time budget for feeding and moving than socializing and resting that may be interlinked with the folivores diet of the species and the quality of the preferred food sources.

- Bale monkeys consumed a total of 11 plant species throughout the study period. They spent most of their time feeding on young bamboo leaves and are bamboo specialist folivores. The dietary rigidity of the species might restrict the species to a narrow habitat and geographic range. Thus, Bale monkeys may not colonize habitats without bamboo plant.

- The home range areas and day range lengths used by the Bale monkeys are small compared to other guenons possibly related to folivores nature of the species and the abundance of food resource in their home range.

- The results of the present study have several conservation and management implications for the species and their habitat. Therefore, the survival of the species depends heavily on planning and implementing on the conservation and management of the bamboo forest habitat. The conservation of bamboo forest will ensure the existence of Bale monkeys in the future. To determine the status of the species in IUCN Red List category and to develop long-term conservation and management strategies, the distribution and population size of the whole Bale monkey population in the Bale Massif should be examined.

- The legal harvesting of bamboo by the local people for commercial purposes could impose threat to the Bale monkey populations in the future. If this current trend continues, the population of Bale monkeys could be affected in the future. Therefore, it is recommended that management action should be taken to conserve the most important food resources such as bamboo plants, *Psychotria orohila* and *Dombeya torrida* trees. In addition, big tree species such as *Hagenia abyssinia* also be conserved even though they are not food sources for the monkeys but used as nesting. In addition, further investigation should be conducted to determine the sustainable and beneficial level of bamboo harvest to integrate the local people in the conservation of the species and wildlife in general.

Appendix 1. Encounter rates and density estimates of guenons or Cercopthicenes at different sites in Africa.

Species	Group size	Encounter rate (group/km)	Density (Group/km^2	Density (Ind/km^2)	Method	Site, Country	Source
Chlorocebus djamdjamensis	22.6	0.44	5.53	124.7	MRSD	Odobullu, Ethiopia	This study
Cercopithecus mitis kandti	30.0	0.05	5.11	153.3	MRSD	Mgahinga Gorilla National Park, Uganda	Twinomugisha *et al*. (2003)
Cercopithecus nictitans	12.1	0.17	0.99	12.0	Effective distance, Whitesides	Lope reserve, Gabon	Brugiere (2005)
Cercopithecus mitis	-	0.15	2.7	-	Modified Kelker	Kibale National Park, Uganda	Worman and Chapman (2006)
Cercopithecus ascanius	-	0.58	9.1	-	Modified Kelker	Kibale National Park, Uganda	Worman and Chapman (2006)
Cercopithecus nictitans	6.0	0.31	1.93	11.6	MRSD	Mondica, R. of Congo	Shah (2003)
Cercopithecus cephus	6.0	0.28	1.38	8.3	MRSD,	Mondica, Central African Republic & R. of Congo	Shah (2003)

Method: Method of transect width estimation; MRSD: Maximum reliable sighting distance

Appendix 2. Percentage of activity time budget devoted to different activities by guenons from a variety of sites across Africa.

	% of time contribution						Site, Country	Reference
Species	F	FR	M	R	S	Os		
Chlorocebus djamdjamensis	65.7	-	14.0	11.0	7.1	2.4	Odobullu Forest, Ethiopia	This study
Chlorocebus aethiops (Verevts)	39.0	-	15.0	17.0	26.0	3.0	Blydeberg Conservancy, South Africa	Barret (2005)
Cercopithecus lhoesti	45.1	2.5	23.0	14.0	10.0	5.8	Nyungwe Forest Reserve, Rwanda	Kaplin (2001)
C. mitis doggetti	44.6	2.4	20.0	16.0	11.0	-	Nyungwe Forest Reserve, Rwanda	Kaplin (2001)

F = Feeding; FR = Foraging; M = Moving; R = Resting; S = Socializing; Os = Others

Appendix 3. Percentage of feeding time devoted to different plant parts by guenons from a variety of sites across Africa.

Species	YL	ML	TL	R	S	FL	FR	SH	AP	Seed	No. species	Site, Country	Reference
Chlorocebus djamdjamensis	80.0	1.1	81.3	1.0	1.4	3.1	9.6	2.0	2.3	-	11	Odobullu Forest, Ethiopia	This study
Cercopithecus lhoesti	-	-	35.2	-	-	4.0	24.5		8.8	17.8	83	Nyungwe Forest Reserve, Rwanda	Kaplin (2001)
Cercopithecus mitis doggetti	-	-	6.2	-	-	6.2	47.4		24.9	9.3	-	Nyungwe Forest Reserve, Rwanda	Kaplin (2001)
Cercopithecus pogonias	13.0	0.1	12.6	-	-	4.7	26.9	-	-	49.8	30 (Family)	Makand´e Forest, Gabon	Brugiere (2002)
Cercopithecus nictitans	10.0	0.1	10.3	-	-	4.1	35.5	-	-	50.2	31 (Family)	Makand´e Forest, Gabon	Brugiere (2002)
Cercopithecus ascanius	-	-	34.7	-	-	2.7	44.6	-	17.6	-	-	Kibale at Sebatoli, Uganda	Chapman *et al*. (2002b)
C. ascanius	-	-	28.2	-	-	3.7	35.7	-	31.2	-	-	Kibale at Kanyawara, Uganda	Chapman *et al*. (2002b)
C. ascanius	-	-	15.4	-	-	8.2	55.6	-	20.6	-	-	Kibale at Dura River, Uganda	Chapman *et al*. (2002b)
C. ascanius	-	-	12.8	-	-	11.6	59.7	-	14.5	-	-	Kibale at Mainaro, Uganda	Chapman *et al*. (2002b)

YL = Young leaves; ML = Mature leaves; TL= Total leaves; R = Root; S= Stem; FL = Flower; FR = Fruit; SH = Shoot.

(-) Data are not available

Appendix 4. Day range lengths and home range area of some Cercopithecines across Africa.

Species	Mean Day range length (m)	Total Home range (ha)	Site, Country	Reference
Chlorocebus djamdjamensis	928.0[a]	15.2[a]	Odobullu Forest, Ethiopia	This study
Chlorocebus aethiops (Vervet monkeys)	865.0	77.0	Blydeberg Conservancy, South Africa	Barret (2005)
Cercopithecus lhoesti	2091.5	117.0	Nyungwe Forest Reserve, Rwanda	Kaplin (2001)
C. mitis doggetti	1306.7	87.8	Nyungwe Forest Reserve, Rwanda	Kaplin (2001)
C. mitis kandti	898.0	67.5	Mgahinga Gorilla National Park, Uganda	Twinomugisha and Chapman (In press)

[a] mean from the two groups

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DECLARATION

I, the undersigned, hereby declare that this thesis is my original work; it has not been presented in other University, College or Institutions seeking for similar degree or other purposes. All sources of material used for the thesis have been duly acknowledged.

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