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A Comparative Study on the Behavioural Ecology and Conservation of the Southern Gelada (*Theropithecus gelada obscurus*) in and around Borena Sayint National Park, Ethiopia

By

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NAME AND SIGNATURE OF EXAMINING COMMITTEE

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ABSTRACT

A Comparative Study on the Behavioural Ecology and Conservation of the Southern Gelada (*Theropithecus gelada obscurus*) in and around Borena Sayint National Park, Ethiopia

Zewdu Kifle Aweke, Doctoral degree

Addis Ababa University, 2018

The southern gelada (*Theropithecus gelada obscurus*) is an endemic little known subspecies of gelada that occur in northern central highlands of Ethiopia. The study was conducted for 18 months (May 2015–March 2017) to investigate the flexibility of southern geladas in terms of their behavioural ecology by comparing two bands (Selam and Tikure) that occupied different habitat types in and around Borena Sayint National Park (BSNP). The study also examined the magnitude of human-gelada conflict and assessed the attitude of local farmers toward the conservation of geladas. The population size of geladas was estimated, and their group sizes were also compared between fragments and BSNP. Total count method was employed to estimate the population size of geladas. Data on the activity budget, feeding ecology, ranging ecology and microhabitat use of the two bands were quantified using scan sampling method. Data on human-gelada conflict were collected using questionnaire interview method. The population size of geladas was 2786 individuals. The band size in the unprotected area was 40.07 while in BSNP it was 81.56. The overall time spent feeding, moving, resting, grooming and socializing between the two bands were not significant. Selam band spent significantly more time feeding during the dry season than the wet season ($p = 0.049$); however, for Tikure band the difference was not significant ($p = 0.112$). The trend of activity pattern of the two bands differed from each other. 74 plant species were identified as food for Selam band while Tikure band was found feeding on 36 plants. Food items consumption markedly varied between seasons. Cumulative aboveground herb consumption was higher for Tikure band than Selam band, and the difference was significant (p < 0.00l). Fruits accounted for 7.18% for Selam band and 0.22% for Tkure band. The similarities of food species of the two bands overlapped very weakly (Sørensen's coefficient = 0.19). The availability of green grasses was positively correlated with the consumption of grass blades and negatively correlated with underground grass item. The mean annual day path length for Selam band was 2438.35 m while it was 2512.64 m for Tikure band, but the difference was not significant ($p = 0.569$). Both bands used different home range sizes. Selam spent more time in open grazing plateau while Tikure spent in a long grassland plateau type of microhabitat. Overall, 42.41% of respondents had negative attitude towards geladas, and 92.13% considered them as crop pest. The result showed that southern geladas adapt anthropogenic habitat alterations by adjusting their ecological flexibility with respect to the habitat type. Thus, it is critical to consider the conservation value of human-altered landscapes.

Keywords: Activity budget, behavioural flexibility, BSNP, conservation, feeding ecology, southern gelada

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DEDICATION

This thesis is dedicated to my late mother, Turye Eshete, and my brother, Atele Kifle for their love, affection and contribution for my academic and personal advancement.

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1. INTRODUCTION

Habitat loss and fragmentation are the main threats facing many primate species in different part of the world because of human activities (Oates, 1996; Struhsaker and Siex, 1998). The human population growth and poverty in most primate range countries have contributed to clear, fragment, and degrade natural wildlife habitats. At present, 48% of all primate species are in danger of extinction (Isabirye-Basuta and Lwanga, 2008; Rylands *et al*., 2008; Estrada, 2013). Poaching, hunting and pollution are also threats that put many primate species in the danger of extinction (Cowlishaw and Dunbar, 2000; Chapman and Peres, 2001; Fedigan and Jack, 2001). Although the number of protected areas in many countries has increased over the recent decades, wildlife reserves did not encompass all primate populations (Estrada *et al*., 2012). As the result of this, many primate species live in human-dominated landscapes of unprotected areas (Isabirye-Basuta and Lwanga, 2008) and share resources with the local people. In addition, many primates are endemic to tropical countries in which preservation of primary forest and other habitat types is often viewed as conflicting with increasing human needs (Jha and Bawa, 2006; Mittermeier *et al.*, 2007).

Proximity of human settlements and activities near the habitats of primates has created negative, demographic and socioecological consequences on them (Bishop *et al*., 1981). The impact depends on the nature and scale of the disturbances. This impact brings the extent of ecological and behavioural flexibility on primates in response to changes and scale of disturbances (Bishop *et al*., 1981). Thus, feeding behaviour, time budget, ranging patterns and other socioecological behaviours may be changed in respective to habitat changes.

A high degree of ecological and behavioural plasticity is a characteristic of many primate species (Struhsaker, 2008). The behaviour of primate is dynamic, thus changing to suit local ecological and social circumstances (Strier, 2003). The study of primate adaptation to anthropogenic impacted habitats in particular would benefit from greater consideration of ecological and behavioural plasticity. A long-term ecological study across populations that live in different habitats is necessary to understand their behavioural responses to habitat disturbances (Chapman and Peres, 2001; Struhsaker, 2008), and is a necessary precursor to primate conservation programmes (Southwick and Blood, 1979). In addition, conservation plans that centre on the exclusion of human activities from primate habitats will be difficult to maintain in the presence of human population growth, urban development, mining and poverty. Thus, understanding the level of behavioural and ecological modifications and strategies of primate survival in anthropogenic habitats as well as the need of local people from the primate habitat is necessary for devising better conservation actions and strategies.

Human–wildlife conflict traditionally occurs when the needs of wildlife impact negatively on the goals of humans or when the goals of humans negatively impact on the needs of wildlife (Madden, 2004). This affects both the local farmers and wild animals of the area. Local farmers lose their crop as a result of crop damage by wild animals, and wild animals are killed in revenge by local people especially in unprotected areas. Crop damage by wild animals is a serious conflict between local farmers and wildlife managers adjacent to protected areas (Newmark *et al*., 1994; Ogra and Badola, 2008). It affects the livelihood of local farmers through crop damage (Osborn and Parker, 2003; Marchal and Hill, 2009). Primates are the major components in crop damage in many African subsistence farmers as the result of their complex behaviours (Hill, 1998) and traditional way of farming.

Ethiopia possesses very diverse set of ecosystems ranging from humid forest type, afroalpine and extensive wetland types to the desert of the Danakil depression in Afar Region, Ethiopia. The country has also great geographical diversity with high and rugged mountains, flat-topped plateau and deep gorges, incised river valleys and plains. These diverse set of geographical region harbour varieties of fauna and flora. The fauna and flora of Ethiopia are remarkable containing distinctive endemic species (Yalden, 1983; Yalden and Largen, 1992; Hillman, 1993).

Ethiopia is distinguished from all other African countries by its extensive highlands. About 80% of African highland areas i.e. above 3000 m altitude are located in Ethiopia (Yalden, 1983). The Ethiopian relief contains a range of altitudes from the lowest 125 m, the Danakil/Dallol depression, below sea level to 4620 m of the highest mountain peak, Ras Dejen, above sea level, 40% of the country consists of vast highlands about 2400 m above sea level (Afework Bekele and Corti, 1997). The altitudinal variation within Ethiopia produces a range of climate that helped to create isolated and varied ecological situations for diversification of animals and plants with a high level of endemism (Yalden *et al*., 1996). Many of the endemic animals are specifically associated with the high altitude moorland and grassland habitats.

There are 325 species of mammals, 872 species of birds, 200 species of fish, 240 species of reptiles, 71 species of amphibians in Ethiopia (Wilson and Reeder, 2005; Golubtsov and Darkov, 2008; Largen and Spawls, 2010; Afework Bekele and Yalden, 2013). Out of these, 57 species of mammals, 23 species of birds, 40 species fish, 15 species of reptiles, and 30 species of amphibians are endemic to the county. The country delineated 80, 223 km^2 of protected areas for the conservation of wildlife (EWCA, 2012). Recent information indicates that Ethiopia has more than 21 national parks (Young, 2012). Among these, Borena Sayint National Park is one of the recently established conservation areas where the diversity and abundance of wildlife is high. However, most of these conservation areas are threatened as the result of human population pressure, livestock rearing and poor management system. Thus, the wildlife populations in Ethiopia have diminished over the past three decades in diversity and distribution as a result of loss of habitat, illegal hunting for food and or medicine, disease, land clearing for farming and land degradation due to livestock overgrazing (Melaku Tefera, 2011).

Ethiopia harbours a great diversity of primates. To date, 13 species have been recognized belonging to two families and seven genera. If we add the subspecies of these primates, their number will increase. Among these, Bale monkey (*Chlorocebus djamdjamensis*) and gelada (*Theropithecus gelada*) are endemic to the county.

There are three subspecies of geladas. These are *Theropithecus gelada gelada*, *Theropithecus gelada obscurus* and the proposed *Theropithecus gelada aris* (Mori and Gurja Belay, 1990; Grubb, 2006; Gippoliti, 2010; Shotake *et al*., 2016). Currently, *T. g. gelada* and *T. g. obscurus* are commonly called the northern and southern gelada, respectively (Grubb, 2006), and *T. g. aris* commonly called the Arsi gelada. The focus of this study was on the southern geladas that live in and around Borena Sayint National Park.

Southern gelada is an endemic little known subspecies of gelada found in the northern central highlands of Ethiopia. They exist across a wide variety of habitat types and altitudinal ranges where sleeping cliffs are available with variable levels of degradations and alternations. Southern geladas live in areas where agriculture activities are intense. They also prefer to live near human settlement areas rather than wilderness habitats, and are considered as “human lover primate” (Personal observation, this study). Currently, they occupy only 10% of their original grassland habitat (Gippoliti, 2010) because of ongoing expansion of subsistence farming, human settlement and livestock grazing. In addition, as the result of living near human settlement areas, they are forced to raid cereal crops, resulting in potential conflict with local farmers. In turn, the local farmers harass and kill them to minimize crop raiding.

Southern geladas are vulnerable to future decline throughout their ranges due to their proximity of habitats to human settlement areas, loss of their original habitats by anthropogenic factors, competition with livestock on grazing pasture and conflict with the local farmers as the result of their crop raiding habit. Therefore, it is interesting to study the ecological and behavioural flexibility of survival of the southern geladas in such degraded and lowland habitats by comparing with intact and highland habitats, and their degree of conflict with the local farmers. The study encompasses a range of issues including their behavioural ecology, population size, attitudes of local farmers towards them, their conservation threats and impacts on the local farmers. Expanding such scientific knowledge on the behavioural ecology, population size and nature and extent of human-wildlife conflict is important in order to take appropriate conservation management actions.

1.1. Background

Geladas (*T. gelada*) are endemic primates to the highlands of Ethiopia. At present, geladas are found only in a few areas of the northern, northwestern, northern central Ethiopian highlands. In addition, few populations are found southern rift valley of Ethiopia. It is estimated that only about 50,000–60,000 population of geladas remain in the wild (Beehner *et al*., 2008). However, IUCN (2010) proposed about 150,000–200,000 individuals of geladas occurring in Ethiopia. However, the number is declining continuously as a result of habitat loss, degradation and fragmentation, disease, drought, killing and climate change (Dunbar, 1998). Even if geladas face those threats, they are considered “Least Concern” status by the World Conservation Union

(IUCN) and an Appendix II listing in the Convention of the International Trade in Endangered Species (CITES).

Scientific research on the biology and ecology of geladas started since 1965. The ecology, behaviour and other aspects of the northern geladas have been well studied in the Simien Mountains National Park by different scholars (Dunbar, 1986, 1992, 1998; Iwamoto, 1993; Beehner *et al*., 2008; Johnson *et al*., 2013; Cherkos Woldegeorgis and Afework Bekele, 2015). Recently, Fashing and others have initiated the study on behaviour, ecology and demographic structure of geladas in the Guassa Plateau, north Shewa (Fashing *et al*., 2010; Fashing *et al*., 2014; Eshetu Moges and Balakrishnan, 2015).

Research survey or monitoring work focusing on the southern gelada in Wollo is lacking (Gippoliti, 2010). Gippoliti (2010) recently also noted that population surveys and studies on the behavioural ecology and human disturbance are urgently needed for southern geladas in Wollo areas. There are reports on the crop damage of geladas throughout their ranges. Only few studies have also been undertaken on human-gelada conflict in Ethiopia (Mesele Yihune *et al*., 2008; Zewdu Kifle *et al*., 2013). However, the magnitude of conflict between local farmers and geladas is not fully documented.

In this dissertation, a long term study was conducted to compare and document the time budget, feeding ecology, ranging pattern and habitat use of two bands of southern geladas. This information allowed exploring the behavioural and ecological flexibility and strategies of survival in previously uninvestigated habitat types. In addition, the study compared the group size of geladas in terms of habitat types as well as the attitude of local farmers toward the conservation of geladas in and around BSNP. Thus, the project has 3 major components: behavioural ecology, human-wildlife conflict and population estimation of the southern geladas.

1.2. Research problems, objectives and research questions

1.2.1. Research problems

Primates that live in different habitats show intraspecific variations in their ecology, behaviour, group size, density and conflict with the local farmers. Anthropogenic habitat modification and other ecological changes have potential to alter the diet, activity, ranging, abundance and grouping pattern of primates (Riley, 2007, 2008). Primates with high behavioural and dietary plasticity have high chance of survival in an ever changing environment. Among primates, geladas exhibit the greatest degree of spatial overlap with humans. In addition, they are resilient to habitat disturbances. However, studies of behavioural and ecological responses as well as adjustment of group size to habitat alternation for southern geladas are lacking.

Hence, it was hypothesized that the southern geladas show intraspecific variations in population density, group size, time budget, feeding behaviour, ranging ecology and habitat use as well as conflict with the local communities across different habitat type and level of habitat alternations. It was also interesting to carry out a comparative study among these variables in contrasting habitats between the bands of southern geladas. To date, no comparative and substantial study has been carried out on the behavioural ecology of the southern geladas that live in and around BSNP. Therefore, this research is the first comparative study, and its main goal was to investigate how habitat alternation and habitat type influence behavioural ecology and population group size of southern geladas as well as human-gelada conflict impact on their conservation. By examining how southern geladas respond to human-altered habitat in terms of their behaviour, ecology and group size, it can achieve a better understanding of primate adaptability and plasticity to designing conservation plans.

1.2.2. General objective

The present study has two main components. The first component of this study was to study the behavioural ecology, human-gelada conflict and population size of the southern geladas in and around BSNP. The second component of this study was to compare parameters like feeding ecology, activity budget, ranging ecology and habitat use, as well as population parameters of the southern geladas that live inside and outside the Park in a fragmented habitat within the same year.

1.2.3. Specific objectives

- To get information on population size, density and social structure of southern geladas living in and around the BSNP
- To compare those population parameters such as population structure and group size between fragments and BSNP
- To examine and compare the influence of habitat alternation on the activity budget and pattern of the southern gelada
- To investigate the impact of anthropogenic habitat alternation on the diet and feeding ecology of the southern geladas living in two contrasting habitat types
- To assess the impact of habitat loss and degradation on the daily path lengths and ranging ecology of the southern gelada
- To examine the habitat use of southern gelada in response to anthropogenic habitat alteration
- To assess the phenology of grasses and herbs within the home range of the study bands and how their phenology affect the feeding ecology of geladas
- To examine the magnitude of human-wildlife conflict and its impact on the conservation of the southern gelada both in and outside BSNP

☞ To recommend conservation and management action for the southern geladas and their habitats.

1.2.4. Research questions

This project focuses on the following main research questions

1. What is the population size of southern geladas in and around BSNP?
    a. Is there any variation in the group size and social structure between those geladas that live inside and outside the Park?
    b. Does the group size of southern geladas vary in terms of altitude and habitat types?
    c. What is the density of southern gelada? Is there variation in density between sites?
2. How do anthropogenic habitat alternations affect the activity time budget of southern geladas in and around BSNP?
    a. How do geladas distribute their time across different activities?
    b. Are there differences in activity budgets between the bands, and if so what influences these differences?
    c. Does activity time budget vary across months and seasons within and between bands?
    d. Are there differences in the activity pattern between bands, and if so how do they respond to anthropogenic habitat alternations in adjusting their activity patterns?
3. How do the feeding ecology and diet of southern geladas change in terms of habitat type and alternation?
    a. What are the food species included in the diet of southern geladas and are they different between bands?
    b. What are the food items of southern geladas? Do they vary between bands?
    c. What is the contribution of different food species to the diet composition of geladas?

   d. What is the contribution of different food items to the total food categories in the diet of Selam and Tikure bands? Do they vary between bands?
   e. Does the contribution of different food items vary across months and seasons within and between bands?
   f. Does the food items included in the diet of southern geladas vary among months and between seasons?
   g. How does seasonality affect foraging ecology and what strategy do they follow during seasonal food shortage?
4. How do habitat loss and degradation affect the ranging ecology of geladas?
   a. What is the home range size of geladas in the bands? Is there variation between bands?
   b. What is the average daily path length of geladas? Are there differences between bands?
   c. Do the ranging pattern and daily path length vary monthly and seasonally and between bands of southern geladas that live within and outside the Park?
   d. What are the prominent factors for the variations of ranging pattern between these bands?
5. How do southern geladas use different microhabitats?
   a. Which microhabitats were mostly used by southern geladas?
   b. Does the microhabitat use vary throughout the study period for bands that live within and outside the Park?
   c. Is there monthly and seasonal variation in microhabitat use in both bands?
6. How does the magnitude of human-gelada conflict affect the conservation of the southern geladas in the study sites?

a. What is the attitude and perception of local farmers towards the conservation of southern geladas? Does the attitude of local farmers on the southern geladas vary between respondents who live near the periphery of the BSNP and in the unprotected site?
b. What socioeconomic factors affect the people’s attitude toward the conservation of southern geladas and their habitats?
c. What are the factors that contribute and intensify for the occurrence and magnitude of human-gelada conflict?
d. What are the conservation threats of the southern geladas in the study sites?
e. What are the problems faced on the local farmers as the result of gelada presence near their villages?
f. What are the hidden costs associated with human-gelada conflict within the study area.
g. What are the possible mitigation measures to minimize human-gelada conflict in the sites?

2. LITERATURE REVIEW

2.1. Physical description of geladas

Geladas are large-bodied, terrestrial primates that live in the highlands of Ethiopia. They are diurnal primates with pale, brown to near black of buff coarse pelage and with dark brown face. The pelage of geladas varies from one geographical area to the other and between sex and age of individuals. In adult males, a long and thick heavy cape of golden hair or mane is present at the back of the shoulder. The manes of some adult males are near white in colour. The most distinguishable characteristic of gelada is the presence of hairless hourglass-shaped or triangular patch of bare of bright colour skin located on the chest. The colour of this bare skin is pink or red depending upon the individual's age, sex, social position, hormonal and estrus state (Bergman and Beehner, 2013).

2.2. Taxonomy of geladas

Gelada was first discovered in 1835 by German naturalist and explorer Rüpell, who named it by the local name used by the inhabitants of Gonder region where he first observed (Last, 1982). Gelada is a species of Old World monkey (Family: Cercopithecidae, Subfamily: Cercopithecinae) (Jablonski, 1993). They are similar in morphology, size and appearance to true baboons (*Papio* spp.). Gelada sometimes called the bleeding-heart monkey or erroneously, gelada baboon. Although geladas are often mistakenly called "baboons", genetic evidence places them as a sister taxon to *Papio* spp. (Page *et al*., 1999; Page and Goodman, 2001).

Since 1979, it has been customary to place gelada in its own genus (*Theropithecus*), though some genetic research suggests that this primate should be grouped with its papionine (baboon) kin (Goodman *et al*., 1998). Other researchers have classified the species even farther distant from *Papio* as monkeys (McKenna and Bell, 1997). Gelada is the sole remaining species within its genus (Jolly, 2001). Currently, living geladas are divided into three subspecies: *Theropithecus gelada gelada*, *Theropithecus gelada obscurus and Theropithecus gelada arsi* (Gurja Belay and Mori, 2006; Gippoliti, 2010; Shotake *et al*., 2016).

2.3. Origin of geladas

Most scholars on biogeography of primates have found the centre of origin concept easy to justify in theory. However, in practice they have had difficulty to achieve consistent results and common consensus. Miller *et al.* (2005) exemplified the problem of primate centre of origin. Of these authors, two are more strongly inclined to identify the **African origin hypothesis**; the other one favours the **Indo-Madagascar hypothesis**. But still the centres of origin analyses of the living primates are questionable. On which continent did primates really originate? Biologists have been debating whether the true centre of origin of primates was in Africa, Asia or America for more than a century and so far the argument has never been resolved (Heesy *et al*., 2006). Fleagle and Gilbert (2006) supported Asia as centre of origin, but this was tentative. Some favoured Africa or India as centre of origin of primates; Silcox *et al.* (2007) suggested Europe; Bloch *et al.* (2007) supported North America or South America. However, currently the first documented fossils sharing the anatomical features of the primate order appeared simultaneously in Europe, North America and Asia at the boundary of the Palaeocene and Eocene Epoch, ~56 million years ago (Fleagle, 2013).

Primates originated most likely at Cretaceous-Paleogene (formerly Cretaceous-Tertiary) boundary around 66 million years ago (Wildman *et al*., 2004), or up to 80-90 million years (Martin, 2000; Bininda-Edmonds *et al*., 2007). Superfamily Cercopithecoidea (Old World monkeys) diverged from other primate groups in the early Miocene, at about 32 Ma. *Theropithecus* emerged from Old World monkeys from 3.5 to 4.5 million years (Roos *et al.*, 2011; Shotake *et al*., 2016).

Geladas are closely allied with the baboons (genus *Papio*), mangabeys (genera *Lophocebus* and *Cercocebus*) and mandrills (genus *Mandrillus*) (Page *et al*., 1999). Molecular and morphological studies suggest that these genera have a recent common ancestor. The morphological analysis has considered *Mandrillus* to be more closely related to *Papio* than *Theropithecus* (Hill, 1970). There are some morphological features showing a sister taxon relationship between *Mandrillus* and *Cercocebus*, as well as between *Papio* and *Theropithecus*. In addition, geladas are known to have hybridized with olive baboon (*Papio anubis*) and hamadryas baboon (*P. hamadryas*), in captivity and in the wild (Jolly *et al*., 1997).

2.4. Historical and present distribution of geladas

Gelada represents the monotypic or sole extant species of the genus *Theropithecus* once found throughout sub-Saharan Africa (Jolly, 1972). There are 5 described extinct species under genus *Theropithecus*. There are *T. darti*, *T. oswaldi*, *T. baringensis*, *T. quadratirostris*, and *T. brumpti* (Delson *et al*., 1993). These extinct species of fossils dated from 125,000 to 4 million years. *Theropithecus* had broad historical distribution. The fossil records indicate that genus *Theropithecus* was distributed throughout Africa and portions of India, Middle East and southern Europe (Delson *et al.*, 1993; Rook *et al*., 2004). Recently, the fossils of early *Theropithecus* were found from the Afar area, Ethiopia, date 3.6–3.8 million years ago (Frost *et al*., 2014). Hadar sample of *T. darti* from Ethiopia is the largest and the best preserved of its age so far found in Africa (Eck, 1993).

Although *Theropithecus* species once ranged across Africa, southwest Asia, and the Mediterranean, currently extant geladas are restricted only to the highlands of Ethiopia (Jablonski, 1993). They are distributed in three regional populations of Ethiopia. These include *T. g. obscurus* found south of Lake Tana and east of the Tekezie River in Wollo and Shewa areas, *T. g. gelada* found north of Lake Tana and west of the Tekezie River in Gonder and *T. g. arsi* another isolated population found in the Arsi area along the Wabe Shebelle gorges (Gurja Belay and Mori, 2006; Shotake *et al*., 2016). The distribution of geladas is mostly concentrated in the north central Ethiopian plateau.

2.5. Ecology and behaviour of geladas

Geladas are terrestrial, non-human primates with specialized adaptations for feeding and moving on the ground (Dunbar, 1983b, 1986). They feed and groom in the open plains during the days and spend the nights on cliff faces (Last, 1982). Sharp cliffs provide as sleeping sites and refugia from predators during the night time (Bergman and Beehner, 2013)**.** They use high montane grasslands associated with rocky gorges, precipices, open grassland and moorland for their feeding purpose during the daylight hours. They prefer grassland habitats with short grasses (Dunbar, 1977a; Iwamoto, 1979). They rarely use dense forest habitat types for foraging and any other activities. They spend much of their time of the day by foraging in grasslands along the edges and steep slopes of cliffs (Dunbar, 1977a). Geladas are found in a wide variety of habitats from mist afroalpine *Festuca* dominated grass species to warmer afromonetane lowland disturbed habitats. They live in altitudes from 1500 m to 4500 m above sea level where cliffs and escarpments occur (Bergman and Beehner, 2013).

The food of primate is largely determined by availability and the animal’s adaptability to what the environment has to offer (Kingdon, 1971). Diet has played an influential role in shaping the morphology, behaviour, and ecology of animals (Fashing *et al*., 2014). Geladas differ from their relatives (baboons) in their diet and physiology. Although, baboons are dietary generalists (Altmann *et al*., 1993; Barton *et al*., 1996), geladas are dietary specialists foraging entirely on grass blades (> 90% of their diet) (Dunbar and Bose, 1991; Hunter, 2001). Geladas are the only primates that are primarily graminivores (Iwamoto, 1993). Thus, the diet of gelada is unique among primates (Dunbar 1977b; Iwamoto, 1979; Fashing *et al*., 2014). It is the only member of the order which is a true grazer capable of competing with ungulates (Dunbar, 1977a). They eat soft blades, stems, roots and seeds of grasses. They also eat flowers, rhizomes and roots when available. They consume herbs, small plants, fruits, creepers, shrub flowers, bushes, thistles and fruits of trees (Iwamoto *et al*., 1996; Zewdu Kifle *et al*., 2013; Fashing *et al.*, 2014). Insects can be consumed, when they are available (Hunter, 2001; Fashing *et al*., 2010; Fashing *et al*., 2014). In addition, egg of birds, mollusks, earthworms and reptiles are occasionally added in the diet of geladas (Fashing *et al*., 2014). During the dry season, when grasses are dried, they prefer to eat food items like herb roots, rhizomes and bulbs (Zewdu Kifle *et al*., 2013). Geladas shift their feeding site daily to maximize energy gain (Personal observation, this study).

Geladas have some sort of digestive adaptation (Iwamoto, 1993). The chief method of digestion in gelada is thorough mastication of the vegetation to extract maximum nutrition (Dunbar and Bose, 1991), and consume more amounts of food items in their daily routine manner. They spend more time foraging than any other herbivorous primates (Bergman and Beehner, 2013).

Geladas use several types of relatively treeless, open and montane vegetation for foraging (Dunbar, 1976). Geladas spend the night on the ledges cliff faces. They leave the roosting site or cliffs at sunrise to ascend the top of the plateau and then start grooming and resting and then resume feeding activities (Dunbar and Dunbar 1974; Dunbar, 1977a; Iwamoto, 1993). Geladas feed by sitting upright for long period of time and foraging by both hands and use their elongated thumbs and shortened forefingers as pincers to pick short and long vegetation (Crook and Aldrich-Blake, 1968). The pieces are transferred to the mouth. Occasionally, they also use their teeth to graze very short food items like grasses and herbs. They also leap into the air to grab flying ants (Personal observation, this study). In addition, geladas dig the ground surfaces using both hands as shovels to forage on plant parts like herb roots, bulbs, and tubers and grass rhizomes or corms (Iwamoto, 1993).

Day travel length in geladas varies daily, monthly and seasonally but is closely related to its group size, ranging between 600-2160 m per day with larger groups moving longer distances (Kawai and Iwamoto, 1979; Iwamoto and Dunbar, 1983). Home ranges are also related to group size, with larger groups possessing larger home range sizes (Iwamoto and Dunbar, 1983). Resource availability of the area and intragroup competition over food are critical factors affecting variation in ranging ecology of geladas, both within and across bands (Grüter and Zinner, 2004). Differential use of the home range has been observed between the wet and dry seasons. As food availability is much greater in the highlands than in the lowlands, geladas move for only a short distance each day (Dunbar, 1986). Thus, the home range size of geladas is negatively correlated with the habitat quality of the areas (Iwamoto and Dunbar, 1983).

It is believed that social organization is evolutionarily shaped by the ecology of the respective taxon that adapt to certain habitats (Dunbar, 1980b; Kappeler and van Schaik, 2002). According to socioecological models of evolution of primate social systems, ecological factors such as food distribution and predator pressure (Grüter and Zinner, 2004), foraging patch size and mating opportunity (Johnson *et al.*, 2002) are among the most important factors that form social organization.

Geladas live in multi-level societies consisting of nested reproductive units within larger groups (Dunbar, 1984b). The dynamic and complex system of gelada is a nested; multi-level society with the hierarchy of social units similar to that of hamadryas baboons and snub-nosed monkeys (Kawai, 1979a; Dunbar, 1993b; Grüter and Zinner, 2004). Geladas live in a modular society with strong fission-fusion dynamics (Dunbar and Dunbar, 1975; Kawai, 1979). The society of gelada can be organized into five different levels or sizes: the reproductive units, all-male groups (AMGs), teams**,** bands, and herds/communities (Kawai *et al*., 1983; Dunbar, 1986; Grüter and Zinner, 2004). The first four social systems are the most stable kinds of social groups in geladas, thus fission-fusion patterns are rarely occurred.

The reproductive unit, also called *one-male units* (OMUs or "harems")**,** consists of an adult male, 1–12 adult females, variable numbers of offspring, and possibly 0–4 subordinate “follower” males that are found together 100% of the time (Crook, 1966; Dunbar and Dunbar, 1975; Gustison *et al*., 2012). A leader adult male has exclusive reproductive access to the females of his family. Leader males attend closely to their females, and they never attempt to steal or mate with females in other units (Dunbar, 1984a). In the reproductive unit there is a strong social bond which is shared by all the females (Dunbar, 1983a; Dunbar, 1986). These bonds between the females are established because of a high relatedness between them (Dunbar, 1986). Thus, Geladas are a female-philopatric species (le Roux *et al*., 2011). Females retain in their natal units for their entire life and they form stratified social relationships with each other. However, most males leave their natal units upon reaching sexual maturity (Ohsawa, 1979; Dunbar, 1993b). These dispersed males may congregate and then form their own AMGs or join with the member of other all-male unites. A reproductive unit of gelada breaks up when it becomes too large and competition for food outweighs (Iwamoto and Dunbar, 1983; Dunbar, 1993a). The most dominant juvenile male departs with some of the youngest sexually mature females during this time (Iwamoto and Dunbar, 1983) and forms their own family. The new unit usually stays close to the natal unit.

All-male group (AMGs) is an association between sub-adults and old males. Most all-male units consist of several subadults and one young adult, led by one male. Sometimes male juveniles become members of AMGs. Typically it consists of 3–15 individuals (Kawai *et al*., 1983; Dunbar, 1993b; Bergman and Beehner, 2013; Pappano, 2013). These individual cooperate each other to harass and overthrow the OMU leader males (Bergman and Beehner, 2013). Males remain in AMGs until they are able to successfully challenge and takeover a unit of their own. Eventually, a new male from these all-male groups becomes a new leader male in every occasion.

Two to four OMUs unite and spend at least 90% of their lifetime together to form the *team* (Bergman and Beehner, 2013). The team size consists between 18–50 individuals with 2–4 OMUs aggregation. They have strong relationship between individuals of each OMUs member in the team. An aggregate of 5–30 of OMUs into larger associations that spend at least 50% of their time together form a *band* (Crook 1966; Crook and Aldrich-Blake, 1968; Bergman and Beehner, 2013). Each harem in the band or team is led and controlled by a single adult male. The band may be an association between OMUs and AMGs (Kawai *et al*., 1983; Kingdon, 2004). The band size consists of ranges from 70–250 individuals (Bergman and Beehner, 2013). These bands cluster together on sleeping cliffs and often feed and move in a single dispersed group (Kingdon, 2004). Bands typically break apart every eight or nine years with a new band being formed in a new home range (Dunbar, 1980a). Between unites or their leaders comprising a band, there is no hierarchical order (Mori *et al*., 1997). The size of teams and bands varies depending on the habitat types.

Bands that come together for sleeping or foraging are called a *community* (Kawai *et al*., 1983; Snyder-Mackler *et al*., 2012) also called a *herd*. It is a temporarily group that remains for a few hours to days. The community shares a home range and spends at least some time together (Kawai *et al*., 1983; Snyder-Mackler *et al*., 2012). A community consists of members from several bands (Kawai *et al.,* 1983). The size of a herd might reach up to 1,200 individuals (Crook 1966; Crook and Aldrich-Blake, 1968; Gustison *et al*., 2012; Bergman and Beehner, 2013). The availability of diet in a certain place most likely facilitates these extremely large social aggregations of geladas. Thus, the size and number of herds vary by region and between seasons and availability of food. While membership in unites and teams is stable, fission and fusion are common at the levels of band and community.

Grooming, playing and aggression are the most common social interactions in geladas. The function of grooming in geladas underwent an evolutionary change, altering its function from simple hygiene (the removal of ectoparasites) to strengthen social bonding. Grooming can be categorized into self-grooming (autogrooming), social grooming (allogrooming) and mutual grooming (Ventura *et al*., 2005). Wrestling, mock-biting, vocalization, chasing, skating, shaking trees/shrubs and dismantling rocks and others can be forms of playing in geladas. Skating type of play typically occurs among immature and juveniles in sloppy bare soil (Personal observation, this study). Playing in females occurs through vocalization rather chasing with each other or other member group (Personal observation, this study).

In geladas, the majority of aggression is directed outward towards non-unit individuals, but aggression within a reproductive unit is low (Dunbar and Dunbar, 1975). As aggression can result in costly injuries to both winners and losers, individuals should display before fighting to resolve conflicts at the lowest possible cost. There are various forms of aggressions in geladas. Biting, grabbing, attacking, chasing, facial threats, eyebrow lifting and lipsmacking are forms of aggression behaviours preformed by the aggressor individuals. Fleeing, crouching, crying, grimacing, presenting, defencing and protect fighting are the form of submissive behaviours performed by the aggressee individuals. When aggressions become so intense, member of geladas cooperate each other to protect the victim from death (Personal observation, this study).

Geladas have diverse repertoire of discrete vocalizations, including contact, appeasement, solicitation, ambivalence, predator alarm, defensive vocalization (Kawai, 1979b; Aich *et al*., 1990), welcoming and calling. Southern geladas show a high rate of aggressive defense against predators, but to the contrary, northern geladas usually prefer to flee (Dunbar and Dunbar, 1974). Geladas have anti-predator behaviour using mobbing and counter attacks (Iwamoto *et al*., 1996). When they observe a predator like leopard, they leave the area and divert the directions of their movement. Sometime adult males try to chase the predators like leopards and domestic dogs (Personal observation, this study).

The mating system of gelada may be characterized as female defense polygyny. Female geladas, like many other Old World monkeys, have sexual swellings around the time of ovulation (Dunbar and Dunbar, 1974). However, unlike other monkeys, sexual swellings are situated around a patch of exposed skin on the chest. They also have perineal swellings; however, these swellings are smaller and less variable in colour and size than those of other primate species. The skin on the chest prominently changes its colour from a dull pink to bright red and is lined by swollen, bead-like vesicles during the periovulatory period (Dunbar and Dunbar, 1974). It undergoes changes in colour from pink to red during pregnancy and lactation (McCann, 1995). Chest patch colour is thought to be a sexually selected signal among male geladas (Bergman *et al*., 2009). Dominant males possess the reddest chests, although it is unknown if redness is associated with male-male competition, female choice, or both (Bergman *et al*., 2009). Sub-adult males possess somehow pale coloured chests.

The estrus female usually copulates 2 to 5 times per day (Mori, 1979b). Mating can occur at any time in the estrus cycle; however, copulation frequently increases around ovulation time (Dubar, 1984b; McCann, 1995). Copulation occurs only between the male unit leader and unit females (Mori, 1979b). Both sexes initiate sexual interactions. When more than one estrus females are found in the group, they compete for copulation with the leader by presenting their posterior quarters to him. During this time, the leader mates the estrus females one by one (Personal observation, this study).

Transfer between geladas is limited to males seeking mating success in a new reproductive unit of their own (Dunbar, 1980a). There are two main ways in which the breeding male can change within a reproductive unit. These are through takeover of a reproductive unit or through joining as a subordinate and eventually breaking off with some females as a new reproductive unit (Dunbar, 1986). Takeover occurs through several fighting between the father and the new comers. It takes several hours of fighting and intense injuries. Soon after takeover, females of the harems acknowledge the new adult male by presenting to him (Mori and Dunbar, 1985).

Reproduction in gelada occurs throughout the year and the species does not display a specific reproductive season. However, in some areas, there are birth peaks (Mori, 1979a; Dunbar *et al*., 2002). Females reach puberty at three years of age, but usually give the first birth when four years old (Dunbar and Dunbar, 1975; Dunbar, 1984a). The interval between births on average is 2.1 years (Dunbar and Dunbar, 1975; Dunbar, 1984b). After a gestation period of 150 to 180 days, females give birth to one infant (Dunbar, 1980b). Recent genetic analyses show that 100% of infant paternity is within the group. If there are multiple males in the group, all offspring are fathered by either the leaders (83%) or their followers (17%) of that group (Snyder-Mackler *et al*., 2012).

Infanticide following a male takeover occurs in geladas and is a real threat for females with dependent offspring (Mori *et al*., 1997; Beehner and Bergman, 2008; Personal observation, this study). Recent work on geladas indicates that infanticide is the leading cause of infant mortality in a population of wild geladas living in the Simien Mountains National Park of Ethiopia (Beehner and Bergman, 2008).

2.6. Major threats of gelada

In Ethiopia, geladas are protected only in the Simien Mountains National Park, Borena Sayint National Park, Abune Yosuf Mountain and Guassa Community Conservation Areas. But many other populations of geladas are found in unprotected areas of central and northern highlands of Ethiopia. Degradation and human-induced habitat loss seriously affect the habitat of gelada especially in the unprotected areas. The major threats are habitat loss for agricultural purposes, soil erosion, human settlement and competition with livestock forcing geladas into less productive area. Most of the preferred habitats of geladas are used for agriculture in most part of their ranges. Shooting by local farmers as a result of their crop raiding behaviour is also threat for geladas. In addition, planting of invasive alien species *Eucalyptus globulus* trees on their foraging grassland habitats is another threat of geladas. These trees inhibit the growth of grasses.

Human densities on the Ethiopian plateau are among the highest in Africa and as a result there is a high potential conflict over habitat use (Dunbar, 1993a). Agriculture is so extensive throughout the habitats of geladas and in some places all the accessible slopes that are too steep for ploughing are cultivated by hand using shovels (Zewdu Kifle *et al*., 2013). As the preferred habitat is destroyed, geladas likely move to marginal areas, reducing their population densities (Dunbar, 1977b). Due to their specialized food habits, geladas do not usually crop raid in the Siemen Mountains National Park (Dunbar, 1993a). However, during harvesting season, geladas are the major crop raiding primates near their ranging areas (Mesele Yihune *et al*., 2008; Zewdu Kifle *et al*., 2013).

Predators of geladas are leopards, domestic dogs, jackals, foxes, hyaenas, servals and raptors such as lammergeyers (Dunbar and Dunbar, 1975; Ohsawa, 1979; Mori *et al*., 1997). Cases of death of individuals from juvenile to adults are predominantly due to parasites (Ohsawa, 1979). Tapeworm parasite (*Taenia serialis*) is one of the most important causes of mortality among geladas (Ohsawa, 1979; Schneider-Crease *et al*., 2013). This is observed as a small to large swelling in various parts of the gelada's body.

2.7. Human-wildlife conflict

Ecosystems and habitats are fast becoming human dominated and more species, including primates, are compelled to exploit new human resources to survive. High rates of human population growth around the globe lead to the expansion of agriculture and encroachment upon wildlife habitats, thus increasing the occurrence of human-wildlife conflict. Various forms of human-wildlife conflicts occur with various negative results, including damage to crops and property, habitat destruction, injuries and death of people and wildlife, and livestock depredation. Crop damage is caused by several wild animals like insects, birds, rodents, primates, antelopes, elephants and other wild animals.

The success of primates as crop raiding is largely attributed to their possession of a complex social organization, their ability to utilize both terrestrial and arboreal habitats, and their reliance on non-specialized and omnivorous diets. The extent to which crop raiding is a problem depends on the location of crops in relation to primate habitats and the distance of the crops from such habitats, the types of crops grown, and people's ability to protect their crops from the invading animals (Hill, 1997; Naughton-Treves *et al*., 1998).

3. STUDY SITES AND METHODS

3.1. Description of the study area

The study area is located within the South Wollo zone in the Amhara Regional State, north central Ethiopia. Within the study area, two sites, one in Borena Sayint National Park (BSNP) and the other at Kosheme, near Mekaneselam town were selected. The study sites are about 18 km far apart from each other, and are found in different topography, climatic condition, altitudinal ranges, habitat and vegetation types, human disturbances and conservation status.

3.1.1. Borena Sayint National Park (BSNP)

BSNP is located at coordinate between 0464066–483640 UTM N latitudes and 1199663–1204560 E longitudes (Fig. 1). It is the only officially protected area in the north central highlands of Ethiopia. The primary aim is to protect the biodiversity of the Park. The Park is located at about 600 km north of Addis Ababa and 215 km from Dessie to the west, and about 16 km from Mekaneselam (the town of Borena Woreda) to the northwest. The Park is bordered by Borena Woreda in the south and southwest, Mahelsayint in the west and northwest, and Sayint in the northwest and Legambo to the east. Currently, the Park is extended further toward the northeast direction to include the afroalpine ecosystem.

BSNP was recognized as protected forest during the reign of Zara-Yakob in the 15th century (Bahru, 1998). During this time, the forest was extended to the edge of Abbay River compared to the present cover. The study area was recognized as an important biodiversity area in 1952. In 2003, it became the Amhara Regional State Forest Priority Area. Finally, the area was established as a National Park in 2009. Currently, BSNP covers an area of ca. 4,375 ha excluding the present extended part of the Park. The altitudinal range of BSNP is from 2,265 m to 3,732 m above sea level. The landscape of the Park consists of rugged topography, gorges, deeply incised valley, extremely steep escarpments, strip of plateau, mountains and cliffs.

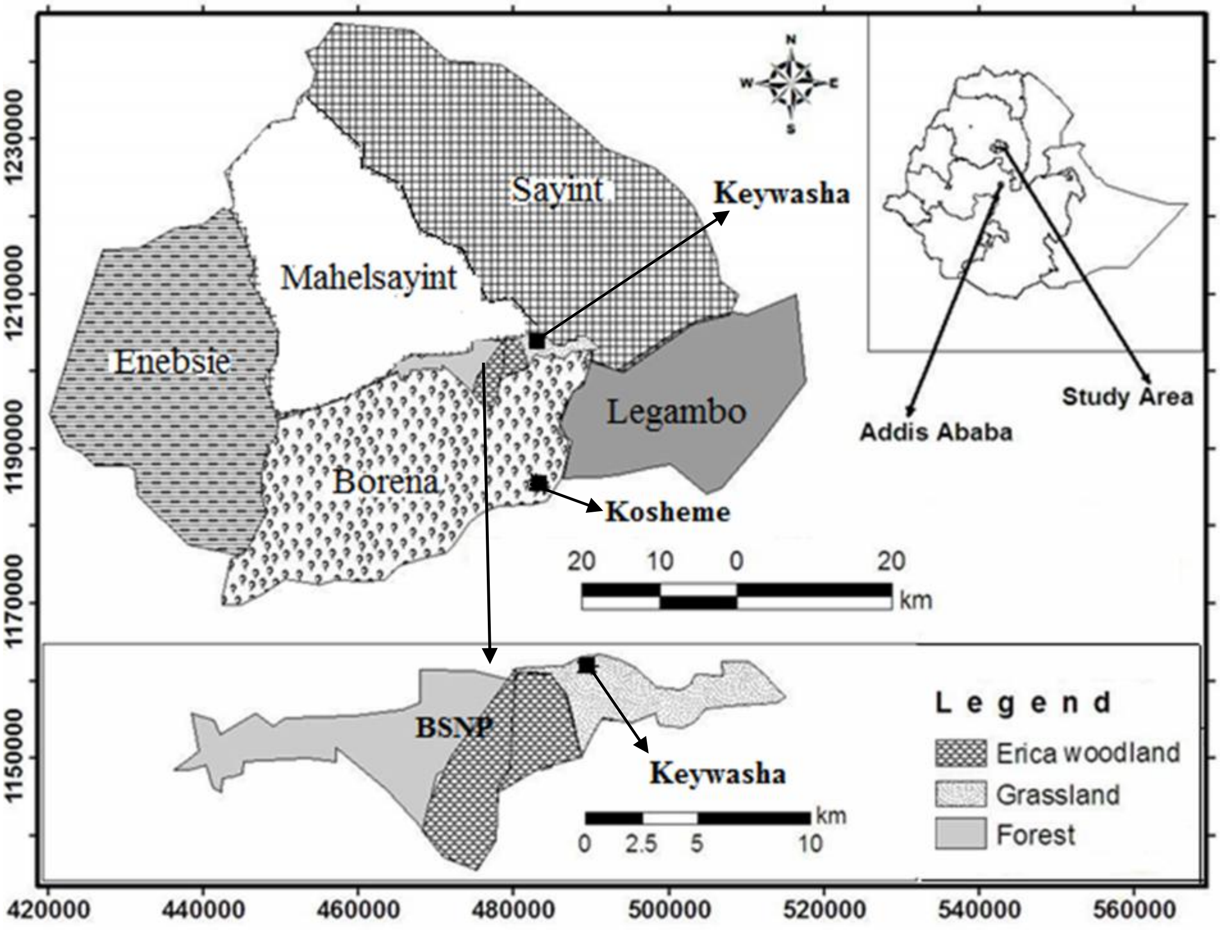

Figure 1. Map of Borena Sayint National Park, study sites and surrounding Woredas.

The Park is narrower in width and longer in length that makes the Park difficult for the conservation of wildlife. The periphery of the Park is heavily populated by humans with widespread cultivation of cereal crop and grazing pasture for livestock. Roughly, below 3329 m asl there is dense forest up to the lower end of the Park. This dense forest is locally called “Denkoro”. Above this altitude, there is dense *Erica* woodland and a splendid plateau with Afroalpine vegetation dominated by *Festuca macrophylla*, *Festuca abyssinica* and giant lobelia (*Lobelia rhynchopetalum).*

Currently, the adjacent highland areas are included to the Afroalpine part of the BSNP. Tabor Mountain (roughly about 4,247 m asl) in the Sayint Woreda and additional areas in the Legambo, Mekedella and Tenta Woredas are included to expand the National Park. Golate, peaking 4,280 m asl is the courtyard formed by the edges of the latter four Woredas. The proposed expansion plan will increase the total area of BSNP to 15,262 hectares. According to the experts of the Park, the expansion would lead to its redefinition and denomination as a new name called Borena Sayint Werehimenu National Park. But this new name is not approved by the proclamations so far.

Within the Park, research on the behavioural ecology of the southern geladas was carried out at Keywasha (0479203 UTM N latitude and 1203850 UTM E longitude) which consists of splendid plateau to the northeast direction with long *Festuca* grass spp, giant lobelia and *Erica* forest. The plateau is 3460 meters high and is well defined on the west by the main escarpment and sleeping cliff of the habituated gelada band. Below this cliff, there are human settlements and agricultural lands, where the band's home range overlaps. In the south, there is a dense *Erica* woodland, in the north and northwest there are human settlements with their livestock and agricultural lands and in the east there is long *Festuca* spp. Domestic stocks are prevalent in the buffer zone of Keywasha area. Geladas compete for food resources with these stocks in the buffer zone which is part of the home range area of the habituated band.

BSNP can be classified based on ambient heat intensity, moisture regime and high variation of altitude of the area. It has three broad agro-climatic zones known as Weina-dega (cool, sub-humid), Dega (cool and cold humid) and Worch (cooler, colder humid). The rainfall and the maximum and minimum daily temperatures data were measured for 12 months (from May 2015 to April 2016) using wireless rain gauge with indoor/outdoor thermometer placed at

Keywasha site during the study period. The average monthly temperature at Keywasha during the recording period was 11.41^{0}C (Fig. 2). Mean monthly low and high temperatures were 7.71^{0}C and 15.10^{0}C, respectively. Annual rainfall was 1714.5 mm (Fig. 2). Rainfall was strongly seasonal exhibiting a unimodal peak during August.

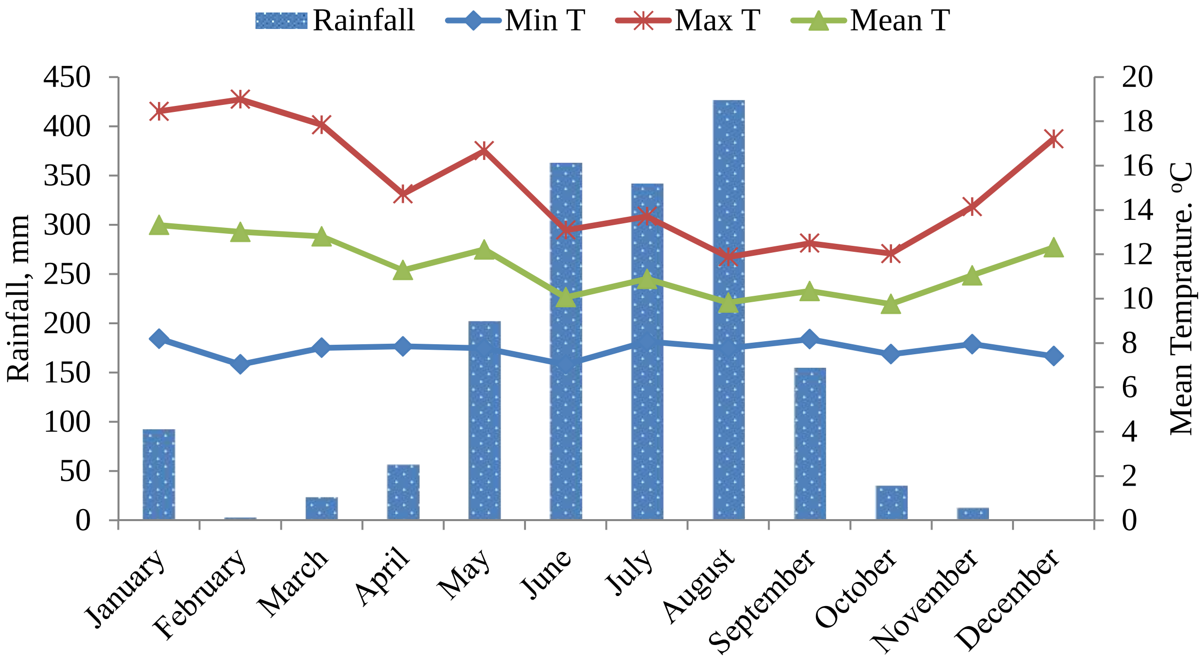

Figure 2. Weather data at Keywasha, BSNP (2015–2016). Mean daily maximum, minimum and average temperatures and rainfall (mm) for each month.

Based on descriptions of the geological structure of the highlands of Ethiopia, the study area comprises Crystalline Basement which is pre-Cambrian and Jurassic in origin (Friis *et al.*, 2011). The Ethiopian highlands are the result of slow volcanic outpouring during the Oligocene Period (40-25 mya) that produced a series of Trappean basalt layers up to 3000 m thick (Hurni, 1988). Tertiary extrusive and intrusive basaltic rocks of varying thickness formed as a result of the volcanic activity and dramatic uplift of the highlands dominate the geological structure. The volcanic rocks that include rhyolites, trachytes, tuffs, ignimbrites, agglomerates and basalts date mainly from the Tertiary (the Trap Series). Cambisols, Andosols, Lithosols and black Vertisols are the major soil types (Hurni, 1988).

BSNP is an ideal place in the northern central Ethiopia for water catchment system. It is one of the water towers from which more than 15 rivers flow in different directions. These provide water for thousands of people and their livestock, wildlife and riparian vegetation in the lowlands. The afroalpine ecosystem is the origin of nine main rivers flowing down into the Abbay River, one of the longest rivers in Africa, or its tributaries. Denkoro River has its source at the summit of afroalpine ecosystem, and it runs westwards through the Denekoro Forest and eventually joins Abbay River. On the Borena side, additional six rivers namely Legekora, Endras, Kulbit and Boreda flow down into the Yeshume River, one of the tributaries of Abbay River whereas Legedaba and Gebriel rivers independently flow directly to Abbay River. On the Sayint Woreda side, two other rivers, the Dendewa and Chilga, both start from the afroalpine part of the park. Chilga River flows down into the Beshilo River, one of the main tributaries of the Abbay River. Dendewa River independently flows directly to Abbay River.

The area is part of the Eastern Afromontane Hotspot with high species diversity and endemism in which more than 70% of its original habitat is already lost because of human encroachment. Due to the clearly seen altitudinal ranges (from 2265-3732 m asl), it comprises afromontane forest in the lower and subafroalpine habitats in the middle and afroalpine vegetation types in the upper part. Thus, the Park’s flora can be generally classified into three major vegetation types based on altitudinal variations. The lower evergreen afromontane forest is characterized by different big trees, shrubs, climbers and dominant trees like *Juniperus procera, Ekebergia capensis, Myrica salcifolia, Prunus africana, Podocarpus falcatus, Olea europaea, Olinia rochetiana, Carissa spinarum, Acokanthera schimperi, Clematis simensis* and

Convolvulus kilimandschari. At a middle altitude, *Hagenia abyssinica* and *Dombeya torrid,* and at the top subafroalpine and afroalpine ecosystem *Erica arborea, Hypericum revolutum, Festuca* spp., *Lobelia rhynchopetalum* and *Kniphofia* spp become the dominant plant species (Hussien Adal, 2014).

In general, even if BSNP is small in size and remnant, it is an important peculiar biological area. It is of considerable significance as a hotspot area for the conservation of biodiversity. It contains the greatest amount of indigenous forest and diverse flora and fauna in the northern central Ethiopia. It is endowed with 354 vascular plant species representing 265 genera and 95 families have been identified within the Park (Hussien Adal, 2014). The Park is endowed with diverse fauna. It supports different species of invertebrates, amphibians, reptiles, birds and mammals. So far, 30 mammalian species (23 medium and large size mammals and 7 small mammals) were recorded within the Park (Meseret Chane and Solomon Yirga, 2014). In addition, the Park is endowed with varieties of bird species.

In the past, the local farmers used the Park for raising livestock to collect milk and meat. However, the Park is totally closed for farmers since 2004. The surrounding areas of the Park have been highly modified by human settlement, and are dominated by eucalyptus plantations, farmlands and pasturelands for livestock. Local farmers claim that their livestock declined extremely in number as a result of lack of grazing pastures and the enclosure of the Park for grazing purposes.

Cereal crops like barley *(Hordeum vulgar)*, wheat *(Triticum* spp.) and Ethiopian oat (*Avena abyssinica)* are a major part of the family's income in the afroalpine and semi-afroalpine ecosystem of surrounding areas of the Park. Recently, maize *(Zea mays)* and potato (*Solanum tuberosum)* cultivation have been initiated. The majority of the local farmers who settled near the

Park periphery also harvest honey. The Park is vulnerable due to high human pressure leading to illegal timber production, firewood collection, livestock grazing, cutting of hay grass for livestock fodder and cutting of *Festuca* grass for construction, marketing, rope and floor covering. The rich biodiversity of the Park is surrounded by highly degraded environment with intensive agricultural activities and human settlements near its periphery (Plate 1).

Plate 1. Human settlement, agricultural expansion and degradation of habitat near the proximity of BSNP (Photo: Zewdu Kifle, 2016).

BSNP is not as well-known as one of the attractive Ethiopian national Parks both at national and international level. However, it is recognized as one of the best locations in the region for viewing caves, unique landscape, dense forest, long *Festuca* grasses, giant lobelia, southern geladas, birds and others (Plate 2). The area is also a good place for hiking through dense forest and long *Festuca* grass both at the lowland and highland parts of the park. Currently, the Park officials allow the local farmers to collect *Festuca* (every three years) and hay grasses (every year or every six months) from the Park. This permission may develop a positive attitude toward the designation of the Park among most local residents.

Plate 2: View of the afroalpine ecosystem of the BSNP with Tikure band, long *Festuca* grasses, giant lobelia and *Erica* forest (Photo: Zewdu Kifle, 2016).

3.1.2. Kosheme site

Kosheme site is located along the south direction of BSNP. It is far from the Park at about 18 km to the south. The area is specifically found in Borena Woreda, South Wollo, just near Mekaneselam (the town of Borena Woreda). Kosheme site occurs about 2.5 km in southeast direction from the main office of the BSNP, which is located in the town of Mekaneselam. Its geographical location is 0476380 UTM N latitude and 1186254 UTM E longitude. It is part of the watershed area of Yeshume River, the tributary of Abbay River. Borada River that flows from BSNP passes down through the Kosheme site to Yeshume River. The area is unprotected but basic drainage activities are carried out by the local communities.

The area is part of Abbay River drainage system. The terrain comprises steep escarpments, steep rugged cliffs, gorges and strip of plateaus with tiny bushy land in the gorges and escarpment sides. The altitudinal range of the area/gorge is approximately 1560–2500 m asl, an unusually low altitude for geladas compared to Keywasha site. Agriculture is the main activity in the area, followed by livestock rearing. Almost all of the accessible areas of the site are commonly used for agricultural purposes, human settlement and livestock rearing in both above and below the sleeping cliffs of geladas. There are permanent and intermittent streams like Boreda and Kulbit rivers that arise from BSNP to drain down into Yeshume River. The local farms divert these rivers during the dry season to their compounds and farmlands for household and irrigation purposes like sugarcane, chat, cabbage, and onion and for drinking purpose.

The climate of the area can be described as temperate. It is possible to divide the climate of Kosheme site into two main seasons as the wet season from June to September and the long dry season from October to May (Fig. 3). However, there may be a little rain in some part of dry months in January, April and May. This small rain is erratic and highly variable. Temperature and rainfall data for Kosheme site were taken from Mekaneselam Meteorological Station (Fig. 3), about 2.5 km away from the home range of Selam band. A mean annual maximum and minimum temperature 22.61°C and 11.32°C, while annual rainfall of 1004.27 mm have been recorded over the years.

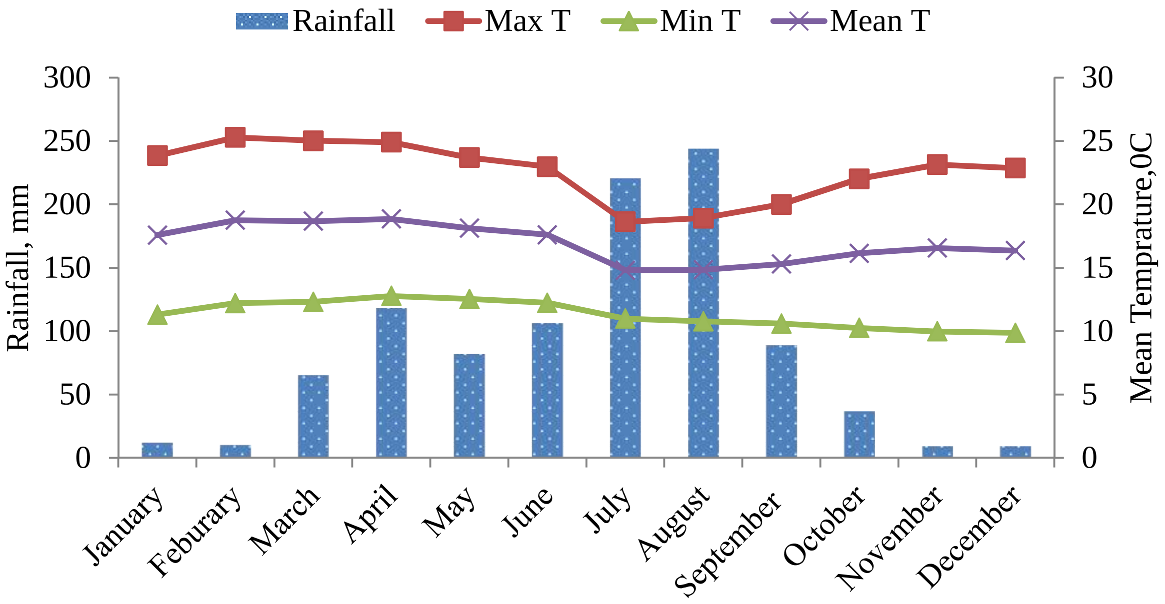

Figure 3**.** Weather data at Mekaneselam (2007–2016). Mean monthly maximum, minimum and average temperatures and rainfall (mm) for each month (Data source: National Meteorological Agency of Ethiopia, Addis Ababa, 2017).

In the lower altitude of the gorge, there are stocks of limestone. The type of soil in the area is composed of Lithosols. This has heavy texture from clay to sandy soil type. The erodibility of the soil is very high especially along the areas that are used for agricultural purposes in sloppy lands. Lava from the area hardened and formed rocks. The cooling of the basalt, combined with tectonic movement, lead to cracks. This opened the way for high rates of natural erosion during the Pleistocene ice ages when the massif experienced glaciations and high precipitation (Hurni, 1988). The cracks widened and deepened to produce the present landscape of the area.

Kosheme possesses an afromontane type of ecosystem and contains steepy cliffs, sparsely distributed of some species of trees, bushlands, grasslands, cultivated lands, valleys and gorges. Natural vegetation varies greatly across the altitudinal range of the valley, and has been affected drastically by human activity at all altitudes. In the lowlands, a few *Acacia*, *Euphorbia* and other trees remain in the most inaccessible gorges. The upper part of this site is also dominated by *Acacia* trees that are found near and in the farmlands. Indigenous trees of the area have been reduced dramatically due to farming and human fuel-wood needs. Vegetation composition in the study site is heterogeneous (Appendix 1).

The fauna of Kosheme includes different invertebrates, amphibians, reptiles, birds and mammals (Appendix 2). Southern gelada, olive baboon and grivet monkey are the dominated large mammalian species and are commonly seen in the study site. The wild animals of the area are highly harassed and killed by the local residents. They considered especially the aforementioned primates as pest of crops. In addition, olive baboon considered as pests of young livestock of goats and sheep.

The livelihood of the local people is highly dependent on subsistence farming that included varieties of crop production and livestock rearing. The small holder farming communities live by combining traditional animal husbandry and agricultural activities on narrow plain and degraded hillsides with supplementary irrigation using river water that passes through their surroundings. Cattle, sheep, goats, donkeys, horses, mules and poultry are the stock of the area. According to the local farmers recently the livestock of the area has extremely declined in number as a result of lack of grazing pastures, restricting programme of the government to stop uncontrolled grazing, and the protection of the remaining patchy grazing land for watershed to rehabilitate the degraded lands of the area.

3.2. Methods

3.2.1. Study population

This research project focused on the two populations (bands) of the southern geladas that live in and around BSNP to study the behavioural ecology (time budget, feeding ecology, ranging ecology and habitat use). Two bands of gelada populations (one of the bands lived inside the Park and the other lived outside in fragmented area) were selected and habituated to human observers by approaching step by step without any bait in recording their behavioural ecology. During this time, the home ranges of the bands were ascertained. The behavioural ecology of the bands were compared where their habitats differed in regard to ecological type, altitude, habitat alternation, vegetation type, human disturbance, climate, landscape and other factors.

The observer named Selam (the observer derived this name from the town of Mekaneselam, the town of Borena woreda, selam in English means peace) band for the southern gelada population that live outside the Park at Kosheme site, and Tikure (the observer named it by the local name used by the inhabitants of the study area) band for those that live inside the BSNP at Keywasha site. The observer considered the level of modification of the habitat and the good visibility of their home range to select those study bands. Selam band occupied relatively lowland (2200–2510 m asl) in the heavily human-altered habitat, and Tikure band in the highland (3350–3565 m asl) which has less altered habitat. Both bands also differed in group size (Selam band 31–42 while Tikure band 75–147 in number during the study period). The band size of Selam band varied as the result of birth, death and takeover and emigration, while the band size of Tikure band varied as the result of birth, death and emigration as well as aggregation and breaking apart.

Since, this project was the first to study the ecology and behaviour of the southern geladas at the chosen field sites, the observer spent 3 months (from February 2015 to April 2015), prior to starting actual and systematic data collection to habituate the two bands to the point of tolerating human presence at a distance of less than 5–10 m and until all fleeing and defensive behaviours disappeared, and travel and feeding behaviours took place in a relaxed manner.

During these field sessions, the observer collected preliminary behavioural data from both bands. Actual data were collected for a period of 18 months (May 2015–March 2017) after habituating each band.

3.2.2. Climate data

Weather data was recorded in the study site of the Park during the first one year study period. The rainfall and maximum and minimum daily temperature data was measured using General Tools and Instruments Wireless Rain Gauge with Thermometer placed in a permanent area at about 300 m from the home range of Tikure. The average mean monthly rainfall and maximum and minimum temperature was calculated for each month of the study period. Climate data for Kosheme site was taken from Mekaneselam Meteorological Station, which is about 2.5 km from the sleeping site of the band.

3.2.3. Population estimation

A census was conducted to determine the population size, and group size and composition of the southern geladas as well as their distribution in the BSNP and surrounding areas. Line transect methods are the most common methods for counting primate populations (Varman and Sukumar, 1995; Peres, 1999; Fashing and Cords, 2000; Plumptre and Cox, 2006). However, the topography of the BSNP and its surroundings make them difficult to undertake systematic survey using standard line transects. As the landscape of the study area is unique in its terrains, transect method is not appropriate for population census of wildlife like geladas (Sutherland, 2006; Beehner, *et al*., 2008). Instead, when the area is open, small, good visibility and undulating landscapes such as cliff and gorges, and for patchily distributed species, total count method with sweep census is recommended (National Research Council, 1981; Sutherland, 2006; Beehner, *et al*., 2008). Thus, total count method was applied to estimate the population size of southern gelada in and around BSNP. Population census was carried out by classifying the possible detached or separated gelada's sleeping sites/cliffs into different census blocks. Two individuals were deployed to each block and counted all southern geladas that occur in the area by identifying individual geladas from group size. Morning count started when all gelada groups left their sleeping cliffs and moved to the plateau for foraging (Hunter, 2001).

During population census, group size was recorded and categorized based on social organization as harems, bands and all-male unites following Dunbar (1993b). Each individual in the group was categorized into their respective age and sex structure as adult males, adult females, sub-adult males, juveniles, yearlings and infants based on body size, genital, red patches on the anogenital region, bulges on the buttock, pelage colour, size of mantle and whisker following Mori *et al*. (1999) and Beehner *et al*. (2008). Adult males were defined as males with visible manes and overall size about twice that of adult females with or without mating families. Sub-adult males were defined as males similar in size to adult females with the beginnings of a visible mane without mating females. Adult females were defined as females with visible red collachile and visible breasts with or without infants and carry out mating with adult males. Juveniles were defined as individuals about half of adult females in body size and bigger than yearlings and constitute both sex groups and approximately more than two and less than three and half years in age. Infants were defined as individuals with black colour and were carried by their mothers and approximately less than one year in age. Yearlings were defined as individuals who are somehow independent from their mothers and between infants and juveniles in size.

To avoid double count, the observers moved in the same direction from east to west or west to east and in some blocks from south to north or north to south. This depended on the position of sleeping cliffs. An intensive effort was made to obtain a complete census of all encounter groups of gelada in each census blocks. Birth rate/index was estimated for each group as the number of infants per adult female at the time of the survey. The distribution of southern geladas was assessed using presence/absence survey during the population census at different locations in and around BSNP. At each population survey area, when southern geladas were encountered, GPS location, weather condition, altitude and habitat types were recorded to determine their distribution in and around BSNP. Group size was defined as the total number of all individuals within a social group. Group composition was defined by sex and age categories.

A total of 3 census sessions were conducted in each block to estimate the population size and social structure of southern gelada. Censuses occurred in November (2016) and January (2017) when geladas were clearly seen on the nearby farmlands to raid crops, and in May (2017) when geladas were clearly seen on the open grassland plateau.

Data analysis: All of the results from each counting blocks were added to determine the number of geladas inside and outside Park areas. The all-male unit groups were included under sub-adult males for analysis. Group size was compared between the populations of geladas living in the unprotected area with the populations of the Park. Densities (individual/ha) of the unprotected and the Park populations were computed based on the home range size of the study bands (Boyle *et al.*, 2009). Ecological density also computed within the Park of gelada populations.

Statistical analysis: All tests were two-tailed with significant level at $p \leq 0.05$. For comparisons of population estimation variables (comparing mean group size, number of adult males, adult females, and immature and age/sex ratios) between the unprotected and the Park sites, independent sample t-test was used; otherwise, Mann–Whitney U tests has been run if the data could not be transformed to meet the assumptions of a t-test. Pearson rank correlation coefficient was used to determine differences in group size across altitudinal variations in BNSP.

3.2.4. Grass phenology

Phenological data on grasses and herbs greenness within each bands' home range was monitored monthly throughout the study period to evaluate temporal changes in food availability at each site. These phenological data were collected from the randomly selected permanent plots (each 50 x 50 cm) in each home range area of the band to assess the greenness and desiccation of herbs and grasses. The phenology of grasses and herbs was checked visually and then photographs were taken at monthly intervals. Those plant phenology monitoring were tightly correlated with behavioural observations of each study band. Depending upon their temporal greenness changes, each plot was assigned a score from 0-3, where 0 = 0% (absence of green grass or/and herb), 1 = <25% (brown grass or/and herb), 2 = 26-50% (light green grass or/and herb), and 3 = >51% (strictly green grass or/and herb) using visual inspection. The observer constructed 44 plots (22 plots per study site) in each home range areas of the bands to follow the phenology of grasses and herbs. A total of 792 censuses (44 surveys per month) distributed at different habitats were conducted in randomly selected plots.

Data analysis: In each month the level of greenness was added to determine the phenology of grasses and herbs, and to estimate grass blade and herb leaf availability at each area. Proportion of greenness score of each month in each site was calculated by dividing the number of each plot assigned to the particular score to the total number plots and then multiplied by hundred.

Statistical analysis: Monthly uniformity proportion of greenness scores of both sites were examined using Shapiro–Wilk test. The Kruskal–Wallis H test was used to examine whether greenness differed between the two sites. Pearson rank correlation coefficient (*r*) was calculated to determine whether monthly greenness scores were related with the type of food item consumed by bands in each month.

3.2.5. Activity time budget

Following habituation, data on the activity time budget and activity pattern (i.e., the diurnal hour of distribution for performing activities of different behavioural categories) were collected every month from May 2015–April 2016, and from May 2016–March 2017 on a bimonthly basis form each band living in different habitat types for a total of 18 months. Data were collected on a total of 180 complete focal band follow up days after habituating the bands to the human presence. During data collection periods, the observers wore the same matching uniforms of yellow clothing, so that the bands could distinguish between researchers and those local communities more easily.

Data on the activity budget were collected using the instantaneous scan sampling method (Altmann, 1974) on two bands for five consecutive days per month. Instantaneous behavioural sampling of a group of individuals at set time intervals is a standard method of unbiased behavioural sampling that is not subject to under or over-representing natural behaviours in a wild setting (Altmann, 1974). Data were collected at 15 minute intervals in order to maintain data independence for up to 5 minutes duration on the first five visible individuals from each band left to right (Fashing, 2001; Di Fiore, 2003; Fashing *et al*., 2014; Mekonnen *et al*., 2017) to avoid eye caching and possible biases by following them throughout the daylight hours. Day follows began during active period, when geladas left their cliff and climbed to the top of the cliff or at their cliff at early morning (06:30 to 07:00 a.m.) and ended when the band settled in its sleeping cliff at dusk (06:00 to 6:45 p.m). One hour comprised 4 scan samplings. One observation day comprised a minimum of 45 (when the scan started at 7:00 a.m. and ended at 6:00 p.m.) and a maximum of 50 (when the scan started at 6:30 early in the morning and ended at 6:45 early evening) scan samplings. Every attempt was made to keep data collection consistence and balanced between bands and across months. During each scan sample, the following mutual exclusive behavioural categories were recorded (Table 1): feeding, moving, resting, grooming, agonistic, playing, mating or other activities (Fashing, 2001; Riley, 2007; Mekonnen *et al*., 2017).

Table 1. Description of behavioural categories in and around BSNP.

Category	Description
Feeding	When the geladas were picking, grazing, handling, foraging, chewing or excavating and manipulating any potential food items.
Moving	When the geladas were walking, running or changing spatial position in any directional movement that contains at least five walks without feeding.
Resting	When the individual gelada was lying down or sitting or standing without performing any other apparent activity or remained inactive or immobile in quadrepedal standing or auto-grooming.
Grooming	When a gelada manipulates hair of another gelada or being manipulated by another gelada's with hands or mouth.
Agonistic (aggression/submission)	When an aggressive behaviour was displayed by an individual gelada and an aggressive or non-aggressive response by the aggressee.
Playing	When an individual gelada made mock-chasing or mock-fighting or others with other individual's.
Mating/Sexual behaviour	When adult male mounting the adult female and copulate with or without ejaculation.
Other	Behaviours that did not fit the above descriptions. This category included drinking water, urinating/defecating and predator alarm.

Data on the time budget was collected from different age/sex groups. The observer recorded the first activity that sustained for at least 3 seconds upon viewing each individual (Di Fiore, 2003; Fashing *et al*., 2014; Mekonnen *et al*., 2017). Behaviour was not recorded for five seconds after an individual was spotted, in order to remove the bias of recording movement as the behavioural state. An individual was scored no more than once per a particular scan period.

Yearlings and infants dependent on their mother were not sampled since their behaviour is strongly influenced by their mother.

Data analysis: The activity budget of each category was analysed in percentage. The proportions of time spent on different activities were calculated as follows: % activity = $(n_1 \times N)/100$. Where n_1 the number of behavioural records for each activity category and N is the total number of activity records. Behavioural records of the bands were then used to calculate the activity budgets per day and averaged within each month to construct monthly activity budgets. Daily activity budget was calculated by averaging the values from all scans within each day. Data were compared across months to identify temporal differences. Monthly activity budget was computed by averaging daily value with each 5 day follow. The grand mean proportions of monthly budgets provided the wet and dry seasons and the annual activity budgets for the entire study period. For data analysis, grooming was treated apart because it occurred in large proportion in the activity time budget of the southern geladas. However, agonistic, playing and mating activity of behavioural categories were pooled together as "socializing" for the purpose of data analyses because some of these individual behaviours accounted for < 1.00% of the total daily, monthly, seasonal and annual activity budget. Comparisons of time budgets between bands were performed on daily, seasonal and annual overall basis. In addition, the time budget for each band was analysed on daily, monthly, seasonal and annual basis for better understanding of their activities. The daily scans were considered as independent events for daily analysis, and the monthly scans for monthly, seasonal and annual analyses.

To examine the possible seasonal variation, the activity budgets of gelada were partitioned into the dry season and the wet season records. For seasonal analysis, the months of October through April were included as the dry season, and months from May through September were considered as the wet season at Kosheme site. Although the month of May typically is known as a dry season in the site, the researcher included it into the wet season as the result of unusually heavy rains during both the years of the study. At Keywasha site, the months from November through April were considered as the dry season, and months from May through October were considered as the wet season.

The average percentage of time allocated for each of the 4 main activities (feeding, resting, moving and grooming) in hourly classes was calculated to express and analyse the diurnal activity patterns. Thus, for analysis of daily activity pattern, data were divided by daylight hours into 6 blocks at 2 hours intervals. The division of daylight into 2 hour blocks provides a suitable separation for statistical comparison (Vasey, 2005). All time points that fell within the following time blocks were used for analysis: early morning (B1) 0600–0800, late morning (B2) 0800–1000, midday (B3) 1000–1200, early afternoon (B4) 1200–1400, midafternoon (B5) 1400–1600 and late afternoon (B6) 1600–1800. Any behavioural scan activities happened before 0600 and after 1800 were included in the early morning and late afternoon blocks, respectively. Daily activity patterns were compared between bands and seasons.

Statistical Analysis: All statistical tests were carried out using the SPSS version 20 software. All tests were two tailed with significance level $p \leq 0.05$. Data were tested for normality using the Shapiro–Wilk test and homogeneity of variances using the Levene test ($p > 0.05$). Daily variation in activity budget of each band and between bands was tested using One-way ANOVA models followed by Tukey's honest significant difference (HSD) post hoc test. Monthly variation in activity budget of each band was examined using Chi-square goodness of fit model. One-way ANOVA models followed by Tukey's HSD *post hoc* test were used to test the differences in daily, seasonal and annual activity budgets in each band. One-way ANOVA techniques were also used to examine the impact of habitat alternation and habitat type on activity budgets between the two bands, using the monthly mean as the unit of comparison. When the assumptions of parametric tests on the proportional activity data (daily, seasonal and annual data) did not meet, arcsine square root transformations were performed prior to statistical analysis to fulfill those assumptions (Sokal and Rohlf, 1981). If the data could not be transformed to meet the assumptions of ANOVA, Kruskal-Wallis models followed by Pairwise *post hoc* comparisons were used to analyse those data. Kruskal–Wallis models were performed to test those differences in activity pattern in daylight hour blocks within a band and between bands. Paired t-test was used to determine if there was difference between two years data collected in similar months.

After testing for normality and homogeneity of variances, Pearson rank correlation coefficient models were used to investigate associations between different activities with each other in each band. To assess whether monthly and seasonal variation in activity budgets associated with changing in grass and herb phenological conditions, Spearman rank correlation coefficient (r_s) tests were used to examine the relationships.

3.2.6. Feeding ecology

The feeding ecology of Selam and Tikure bands were collected for 5 days in each month from May 2015 to March 2017. The first 12 months of the data were collected every month, and the last 6 months feeding data were collected on bimonthly basis from each band. During each activity scan sampling, when geladas were feeding, the type of food items, species and growth form/habit consumed were recorded every 15 minutes (Iwamoto, 1979; Di Fiore, 2004; Fashing *et al.*, 2014) by following each band closely throughout the daylight hours. Whenever possible, food plants were identified at species level *in situ*. When the food items were unknown in the field, voucher specimens were collected and taken to the National Herbarium of Addis Ababa

University for later taxonomic identification at species level. The food items were generally categorized as grasses/sedges (blades, rhizomes, seed/head, corms or bulb), herbs (leaves/stems, flowers, roots, or bulbs), shrubs (flowers, fruits or buds/pith), trees (fruits or buds/pith), animal preys (ants, termites, caterpillars or flying insects) (Dunbar, 1977a; Iwamoto, 1979; Fashing *et al.*, 2014) and exudates/gums of plants or others.

Grasses/sedges included items identified as “blades” that consisted of both tall and short grass and sedge leaves. “Grass heads/seeds” were the seed of grass or sedges. “Rhizomes” were the underground creeping root stalks stems of grasses, and “corms” were the underground swollen storage organs of grasses or sedges. “Herbs” were any seed-bearing plant that does not belong to grasses or sedges without woody stem and dies down to the ground after flowering. “Bulbs” were underground food storage swelling part of herbs or grasses. “Fruits” were items of the seed-bearing structure collected either from trees or shrubs. “Cereal crops” were items of cultivated crops that were consumed by geladas at sowing time, seedling and fruiting periods or after post-harvesting period. “Gums” were exudates of trees or shrubs. “Others” were non-plant items in which the geladas obtained through digging like limestone. In many cases, a local name was used for plant species to simplify registering on the data sheet, and later its scientific name was assigned from the herbarium or other sources.

Data Analysis: Diet composition was evaluated by determining the proportion of different food items consumed by southern geladas. The relative proportion of each species consumed was calculated using the percentage of scans spent feeding on each different species. The daily food items consumed by each band were summed within each month to construct monthly proportion of food item consumed. The mean seasonal and annual dietary composition was obtained by averaging the monthly percentage proportions. Diet composition of the bands was calculated as follows: $y = (n_y/N) \times 100$. Where n_y is the number of feeding records of item y, and N is the number of feeding record for each diet item with the total number of feeding records.

Seasonal and annual variation in dietary diversity was measured using Shannon–Wiener index, H’ and evenness was assessed by the evenness index, J (Krebs, 1999). Shannon–Wiener index was calculated as follows: $H' = -\sum(pi*\ln [pi])$, where $p_i = n_i/N$ or the proportion of the total number of individuals (N) that belong to species or diet item *i*, where ln is the natural log, and where n_i is the number of individuals that belong to species or diet item *i*. Whereas, dietary evenness index was calculated as follows: $J' = H'/\ln(S)$, where H' is the Shannon–Wiener diversity Index score, ln is the natural log and S is the total number of species or diet items consumed in the particular period.

The dietary similarity was compared in the respective habitats (Krebs, 1999). Similarity of species in the dietary composition of the two bands was compared across the two habitats. In addition, the similarity of diet items included in both bands was compared across the wet and dry seasons. Sørensen’s Index is one of the most commonly used similarity measures between two or more communities (Krebs, 1999). Thus, the dietary similarity of the two bands was compared in their respective habitats and seasons using the Sørensen’s Index of Similarity (*Ss*) as defined by: $Ss = 2a/(2a + b + c)$; where *a* is the number of species shared by the two bands or number of diet items present in both seasons, *b* is the number of species appearing in Selam band but not in Tikure band, and *c* is the number of species present in Tikure band but not in Selam band; or a is the number of diet items present in both the wet and dry seasons, *b* is the number of diet items appearing during the wet season but not during the dry season, and *c* is the number of species present during the dry season but not during the wet season.

Statistical Analysis: All statistical tests were carried out using SPSS version 20 software. All tests were two tailed with significance level $p \leq 0.05$. Data were tested for normality using the Shapiro–Wilk test and homogeneity of variances using the Levene test ($p > 0.05$). One-way ANOVA models followed by Tukey's HSD *post hoc* test were used to test the differences in seasonal and annual diet in each band. One-way ANOVA techniques were also used to test the differences in seasonal and annual food item contributions between the two bands. When the assumptions of parametric tests on the proportional food item did not meet, arcsine square root transformations were performed prior to statistical analysis to fulfill those assumptions (Sokal and Rohlf, 1981). If the assumptions of normality and equal variances were not possible after transformations, Kruskal–Wallis models followed by Dunn’s *post hoc* comparisons (Siegel and Castallan, 1988) were used to analyse those data.

Spearman rank correlation coefficient test (Zar, 1999) was used to test the relationships between the time spent consumption of different food items.

3.2.7. Ranging ecology

GPS coordinate points at the centre of the study band were recorded every half hour intervals (Di Fiore, 2003; Riley, 2008) to study the daily travel distance and the ranging ecology of southern geladas in the study area by following each band throughout the daylight hours. The GPS waypoints were recorded when the bands move from point to point using a handheld Garmin *eTrex* Global Positioning System unit. Coordinates were only recorded if the GPS unit was receiving a signal at the accuracy of three meters. Since most of the time geladas spend their time in open grassland, it is not difficult to receive a strong satellite signal with the accuracy of three meters.

Data Analysis: A mean day range length for each month of both study sites was calculated by adding up the mean half-hourly distances travelled during the day. The GPS locations of the bands recorded were used to estimate the daily travel distances and home range areas utilized by the groups using ArcGIS. The day travel lengths and home range sizes of each band were calculated using ranges7 (Anatrack Ltd.) and mapped via ArcGIS version 10.3 software. The home range sizes of the study bands were determined by using the minimum convex polygon (MCP) method with harmonic means centers as well as fixed kernel density estimates (KDEs) (Fashing *et al.,* 2007). To estimate the home range, all day ranges were combined to generate 100%, 95%, 90% and 50% MCPs, and 95% and 50% KDE estimates. Thus, the observer used two methods for estimating home range area of each band: MCP and KDE. Home range areas for each band were calculated using these methods and then compared between bands. Thus, owing to the variability in methods used to estimate animal home range size, and the controversy regarding which is the most accurate, the observer used the above two different methods for this study (Seaman and Powell, 1996; Boyle *et al*., 2009).

Statistical Analysis: All statistical tests were carried out using the SPSS version 20 software. All tests were two tailed with significance level $p \leq 0.05$. Data were tested for normality using the Shapiro–Wilk test and homogeneity of variances using the Levene test ($p > 0.05$). One-way ANOVA models were used to test the differences in mean seasonal and annual home range size and daily path length in each band. One-way ANOVA models were also used to compare daily path length and mean monthly travel length for the two bands, and to test for seasonal differences in these variables. When the assumptions of parametric tests on the daily length and home range size did not meet, arcsine square root transformations were performed prior to statistical analysis to fulfill those assumptions (Sokal and Rohlf, 1981). If the assumptions of normality and equal variances were not possible after transformation, Kruskal–Wallis models (Siegel and Castallan, 1988) were used to analyse those data. Pearson rank correlation coefficient test was used to test the relationship between monthly travel length and the time spent consumption of different food items.

3.2.8. Habitat use

The available microhabitat types of each study site were recorded every 15 minutes throughout the daily follows for each study band. Six microhabitat types were identified at Kosheme site, and classified as grazing plateau (GP), bush plateau (BP), gorge bush (GB), cliff (CL), farmland (FL) and escarpment side (ES). A microhabitat is defined as a "grazing plateau" when the area was opened and covered dominantly by grass species and found above the sleeping cliffs of geladas; "bush plateau" was an area dominantly covered by bushes and *Acacia* trees and located above the sleeping cliffs of geladas; "gorge bush" was tree with bush dominated area that are found below the sleeping cliff of geladas; "cliff" was defined or characterized by vertical rock faces and absence of vegetation, and used by the geladas as sleeping sites or refugia; "escarpment" was defined by inclined area of the cliff with grasses and other plant species; "farmland" habitat type represented the unnatural habitat as it constitutes cultivated cereal crop fields near the habitat of geladas.

At Keywasha site, another six microhabitat types were identified within the home range of Tikure band. These were classified as long grassland plateau (LGP), cliff (CL), escarpment (ES), grazing open grassland (GOP), *Erica* dominated forest (EDF) and farmland (FL). "Long grassland plateau" was defined as microhabitat dominated by long *Festuca* grass species or *Kniphofia* spp within the Park and buffer zone of the Park including the vehicle road that passes through the Park; "grazing open grassland" area dominated by short *Festuca* and other grasses and herb species or *Kniphofia* spp. that is found outside the Park boundary or buffer zone of the Park; "*Erica* dominated forest" was defined as area with scattered or dense dominated *Erica* and some other trees and shrubs.

Data Analysis: Habitat use of the study bands were analyzed from habitat types recorded during scan sampling by the proportion of the use of areas with respect to the availability of habitat types (Wallace, 2006). Thus, the habitat use of geladas was calculated by the proportion of the number of scans where each band spends with the respective available habitat types in their home ranges (Wallace, 2006; Riley, 2008; Tesfaye, 2013). Analyses of habitats occupied by the band were based on the proportion of the number of records in each habitat types. Data were compared across months, seasons and annually to identify temporal habitat use differences.

Statistical Analysis: All statistical tests were carried out using SPSS version 20 software. All tests were two tailed with significance level $p \leq 0.05$. Data were tested for normality using the Shapiro–Wilk test and homogeneity of variances using the Levene test ($p > 0.05$). Monthly variation in the habitat use for each band was examined using chi-square tests. One-way ANOVA models followed by Tukey's HSD *post hoc* test were used to test the differences in seasonal and annual habitat use in each band. When the assumptions of parametric tests did not meet, arcsine square root transformations were preformed prior to statistical analysis to fulfill those assumptions (Sokal and Rohlf, 1981). If the assumptions of normality and equal variances were not possible after transformation, Kruskal–Wallis models followed by Pairwise *post hoc* comparisons were used to analyses those data.

3.2.9. Human-gelada conflict and the attitude of local community towards gelada

Human-gelada conflict was assessed using questionnaire survey methods. The questionnaire had a combination of both open-ended and fixed response questions with different variables

(Appendix 7). It was designed to elicit information on factors that shape the attitudes of the local community, the cause of conflicts, threat of geladas, crop protection measures adopted and other variables affecting the conservation of southern geladas. A series of supplementary questions on the socioeconomic and demographic variables such as household size, age, sex, religion, household wealth status (farmland and livestock size) and level of education were also gathered from each respondent (Campbell-Smith *et al*., 2010). At the beginning of each potential interview, the aim of the research was briefly explained by the interviewer for each respondent. A pilot study was conducted in the area, before the actual data collection periods. During the pilot survey, 20 farmers were interviewed in the study site. Based on the results from the pilot survey, the questionnaire was revised as appropriate for actual study.

Human-gelada conflict was collected through questionnaire survey in comparative approach from the villagers near the BSNP and from the unprotected area far from the BSNP. Thus, the study was conducted in two sites, namely, in the periphery of the Park and unprotected sites. These sites were classified based on the conservation status of the area. These two sites were approximately 20 km far apart. The unprotected site was found south of the BSNP in the Borena Woreda. Questionnaire surveys were conducted in a total of 11 villages, 6 of them were found near the BSNP and they were directly connected to the Park whereas the other 5 were found far away from the BSNP and had no any connection to the Park. All of the villages had direct encounter with gelada through crop raiding and other related issues. Interview was conducted from January–March 2016 in the unprotected site and from April–May 2016 in the Park surroundings.

The interviewees were selected on the basis of chance encounter by the interviewer (Newmark, *et al*., 1994). The interviews were undertaken with either the household head or wife head or other adult ≥ 18 years. A total of 165 from the unprotected site and 191 form the Park boundary were interviwed for the study. The information gathered from the respondents was used only for this proposed project work.

Data analysis: The questionnaire data of each category were analysed in percentage. The response "do not know/neutral" responses were considered as missing values for some analyses. The unit of sampling for analysis was individual farmers. The data from each villages were combined together into each respective study sites. The total ages of the respondents was classified into three groups: 18-35 (n = 87), 36-50 (*n* = 109) and 51-90 (*n* = 160) for some analyses.

Statistical Analysis: All statistical analysis was performed using SPSS version 20, and data were presented with p-values and confidence intervals set at 95%. The chi-squared test for goodness of fit was used to examine the proportion of cases that fitted into different categories of a particular variable, while the chi-square test for independence was employed to assess whether the categorical variables were related. A logistic regression model was performed to investigate the attitude and conservation variations on geladas using age, settlement site, gender and educational level as predictors.

4. RESULTS

The results of the present study are divided into six sections. Those chapters included population estimation, activity budget and pattern, feeding ecology, daily path length and ranging ecology, habitat use and human-gelada conflict. Each of the results of those section parameters is presented as follows:

4.1. Population estimation

The overall results from the southern gelada count across different age and sex groups from the total of 16 counting blocks are listed in Table 2. A total of 2786 southern geladas belonging to 59 groups (bands, one-male units and all-male units) were counted in the entire survey area of the 16 census blocks. A total of 1251 southern geladas in 35 distinct groups were counted in the area outside the BSNP, and 1535 in 24 distinct groups in the BSNP during the census period. The maximum number of southern geladas was counted in Chefiafaf–Kobo–Sefatira and Degamagola–Abota–Kulbit areas, and the lowest was in Durame–Dire area. From the census blocks of the BSNP, the maximum number of southern geladas was counted in Godel (274 individuals) in a single band and the second highest was recorded in Keywasha–Dikulabar area (291 individuals) in two bands excluding all-male groups (Table 2). Both of these blocks were located in the afroalpine ecosystem of the Park. The minimum number of geladas was recorded at Sedeta area which is found in the middle altitude of the BSNP. Thus, the group size of geladas was not uniformly distributed in the BSNP.

In BSNP, the overall number of adult males per group (including bands and harems) ranged from 1 to 17 individuals (mean = 5.68, SD = 3.94); whereas the number of adult males per group in the unprotected site ranged from 1 to 6 individuals (mean = 3.09, SD = 1.35). In BSNP, the overall number of adult females per group (including bands and harems) ranged from

Table 2. Demographic characteristics and population parameters (N=number of band and/or OMU, AM=adult male, AF=adult female, SM=subadult male, JV=juvenile, YR=yearling, IN=infant) in the unprotected site and in the BSNP.

Area/block name	Location	N	AM	AF	SM	JV	YR	IN	Total
Unprotected site									
Mendoye/Mekedella/Tewa	Outside	6	23	83	20	30	26	38	220
Denesa/Kereba	Outside	3	7	36	11	14	10	17	95
Durame/Dire	Outside	2	5	23	4	13	5	11	61
Kunto/Neno/Lankesa	Outside	7	18	87	29	39	32	35	240
Jimaye	Outside	1	6	29	5	12	7	12	71
Degamagola/Abota/Kulbit	Outside	6	19	107	38	51	26	41	282
Chefiafaf/Kobo/Sefatira	Outside	7	21	111	28	46	33	43	282
Total count for the area		32	99	476	135	205	139	197	1251
Mean/group		-	3.1	14.9	4.2	6.4	4.3	6.2	39.1
Proportion		-	0.08	0.38	0.11	0.16	0.11	0.16	-
BSNP									
Godel	Inside	1	17	96	51	53	34	42	293
Keywasha/Dikulabar	Inside	2	22	108	27	60	39	48	304
Sako	Inside	1	3	19	4	4	3	10	43
Alebachew Washa	Inside	1	7	34	6	19	10	12	88
Sekedereba/Dabograre	Inside	4	15	69	26	32	19	32	193
Bukie	Inside	2	13	66	26	31	25	23	184
Guba	Partial inside	2	10	44	9	32	10	20	125
Menegash/Kedmemariyam	Inside	5	18	100	21	58	34	37	268
Sedeta	Partial inside	1	3	14	5	4	6	5	37
Total count for the area		19	108	550	175	293	180	229	1535
Mean/group		-	5.7	28.9	9.2	15.4	9.5	12.1	80.8
Proportion		-	0.07	0.36	0.11	0.19	0.12	0.15	-

5 to 96 individuals (mean = 28.95, SD = 21.06); whereas the overall number of adult females per group in the unprotected site ranged from 5 to 29 individuals (mean = 14.87, SD = 6.16). From

the habituated bands, the number of females per adult male varied from 2 to 6 in the unprotected site and from 3 to 11 in the BSNP during the study period. The highest number of females per adult male was recorded in the afroalpine area of the BSNP. Thus, the number of females per adult male varied from harem to harem. Similarly, the reproductive unit has only one adult male. However, in some occasion, old adult males lived within the bands or harems. In BSNP, number of immature (yearlings and infants) per group including in bands and harems ranged from 2 to 76 individuals (mean = 21.53, SD = 17.02); whereas the overall number of immature per group in unprotected site ranged from 3 to 20 individuals (mean = 10.50, SD = 4.27).

There were higher significant differences in the mean number of adult males (Mann–Whitney U-test: $U = 157.00$, $N_1 = 19$, $N_2 = 32$, $p = 0.004$), adult females ($U = 138.50$, $N_1 = 19$, $N_2 = 32$, $p = 0.001$) and immature ($U = 128.50$, $N_1 = 19$, $N_2 = 32$, $p = 0.001$) per group in BSNP than in the unprotected site (Table 2). However, the proportions of adult male and adult female (t-test: $t = 0.452$, $df = 49$, $p = 0.510$) and adult female and immature ($U = 281.00$, $N_1 = 19$, $N_2 = 32$, $p = 0.654$) did not differ significantly between the BSNP and unprotected sites of the southern gelada populations.

BSNP comprised a total of 4,375 ha (43.75 km^2). The crude density of southern gelada in BSNP was 0.3 individuals per hectare or 35.60 individuals/km^2. The ecological density taken from the home range area of Tikure band was 37.66 individuals/km^2 using 95% KDE and 38.32 using 95% MCP. Similarly, the ecological density taken from the home range size of Selam band was 26.53 individuals/km^2 using 95% kernel density estimation and 18.72 individuals/km^2 using 95% MCP. Thus, southern geladas were found in lower density in the unprotected area compared to protected area.

The location, mean and range of group sizes are presented in Table 3. The altitudinal locations of the population of southern geladas in the unprotected area were almost linear; however, there was distinctive altitudinal variation in the distribution of southern geladas in the BSNP. In addition, the distribution of southern geladas was not uniform throughout the Park. Rather, their distribution is restricted in the periphery part of the Park (Fig. 4). A total of 24 and 35 southern gelada groups as OMU, AMU and band were recorded in the BSNP and the surrounding unprotected site, respectively.

Table 3. Comparison of population parameters in the BSNP and unprotected site of the surrounding landscapes (AMU=Adult male unit, OMU=One male unit).

Block name	GPS Location		Altitude	Social system	No of groups	Group size range	Mean group size
	Latitude	Longitude					
Unprotected site							
Mendoye/Mekedella/Tewa	460288	1182673	2363	Band	6	17-65	35.83
				AMU	1	5	5
Denesa/Kereba	467668	1180660	2363	Band	3	25-41	31.67
Durame/Dire	470559	1182460	2345	Band	2	25-36	30.55
Kunto/Neno/Lankesa	472279	1185659	2503	Band	6	22-53	36.67
				OMU	1	13	13
				AMU	1	7	7
Jimaye	475137	1184834	1977	Band	1	71	71
Degamagola/Abota/Kulbit	482216	1185193	2463	Band	6	26-58	45.67
				AMU	1	8	8
Chefiafaf/Kobo/Sefatira	465507	1192341	2256	Band	6	26-68	44.33
				OMU	1	16	16
Overall				Band	30	17-71	40.07
				OMU	2	13-16	14.5
				AMU	3	5-8	6.67
BSNP							
Godel	483669	1204560	3529	Band	1	274	274

				AMU	1	19	19
Keywasha/Dikulabar	479254	1203837	3392	Band	2	136-155	145.50
				AMU	1	13	13
Sako	480819	1201319	3424	Band	1	43	43
Alebachew Washa	476559	1201688	3200	Band	1	88	88
Sekedereba/Dabogirar	468331	1199777	2782	Band	4	41-47	44.80
				AMU	1	14	14
Bukie	465914	1199663	2575	Band	2	87-97	92
Guba	464066	1201586	2328	Band	2	53-72	62.50
Menegash/Kedmemariyam	464325	1202387	2663	Band	4	38-91	62.75
				OMU	1	10	10
				AMU	1	7	7
Sedeta	471022	1203358	2831	Band	1	33	33
				AMU	1	4	4
Overall				Band	18	33-274	81.56
				OMU	1		
				AMU	5	4-19	11.40

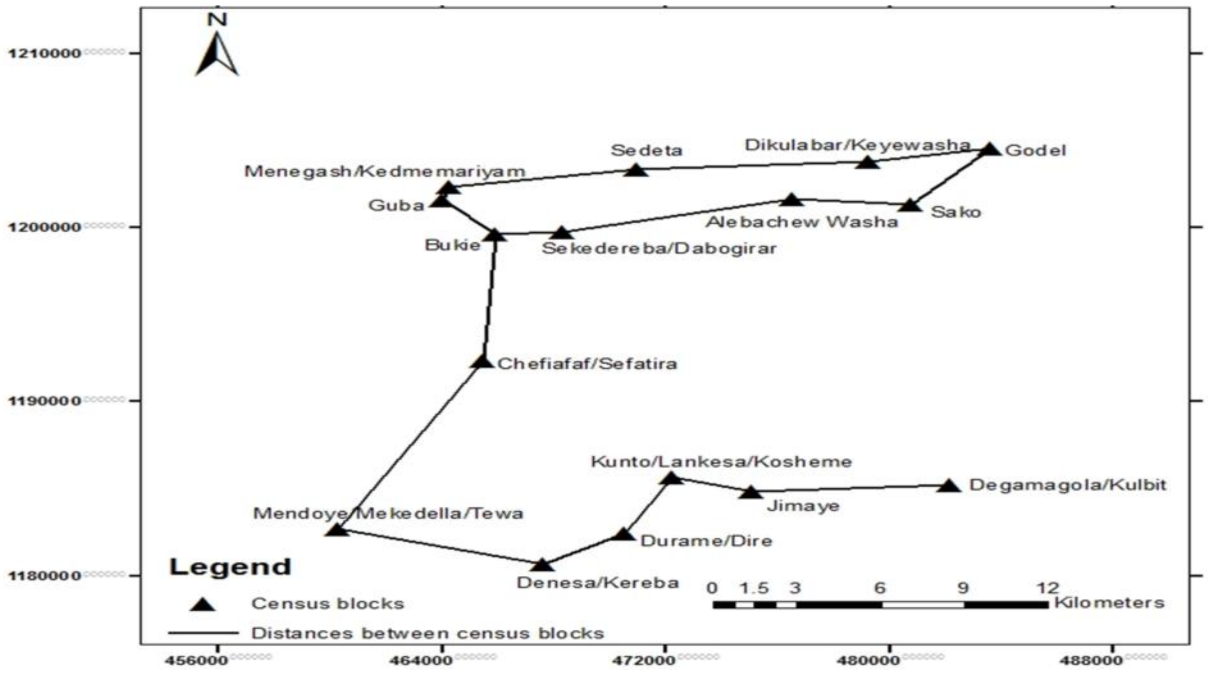

Figure 4. Census blocks and distribution of southern geladas in and around BSNP.

In unprotected area, 85.71%, 5.72% and 8.57% of the population was recorded in a band, OMU and AMU type of social systems, respectively. Similarly in BSNP, nearly 75.00%, 4.17% and 20.83% were recorded in a band, OMU and AMU social system type, respectively. In unprotected area, the overall band size ranged from 17 to 71 individuals (mean = 40.07, SD = 14.10); whereas the overall band group size ranged from 33 to 274 individuals (mean = 81.56, SD = 59.06) in BSNP (Table 3). The band size of geladas in BSNP was significantly higher than in the unprotected site (Mann–Whitney U-test: $U = 92.00$, $N_1 = 30$, $N_2 = 18$, $p = 0.001$). Similarly, the mean band size of geladas in the Park of each block was significantly higher than the mean band size in the unprotected site ($U = 12.00$, $N_1 = 7$, $N_2 = 9$, $p = 0.039$). There was larger size of AMU in BSNP (mean = 11.40) than in unprotected fragmented site (mean = 6.67).

The group composition of southern geladas in the unprotected site and BSNP are shown in Figures 5 and 6, respectively. Females comprised the highest percentage in both the unprotected and BSNP gelada population; whereas adult males were the lowest in number in both study sites. From the total population size counted in the unprotected site, there were 38.05% adult females and 26.86% immature (yearlings and infants). Similarly, from the total population in the BSNP, there were 35.83% adult females and 26.64% immature (yearlings and infants). The overall population counted in both study sites comprised adult males (7.43%), adult females (36.83%), sub-adult males (11.13%), juveniles (17.88%) and immature (26.73%).

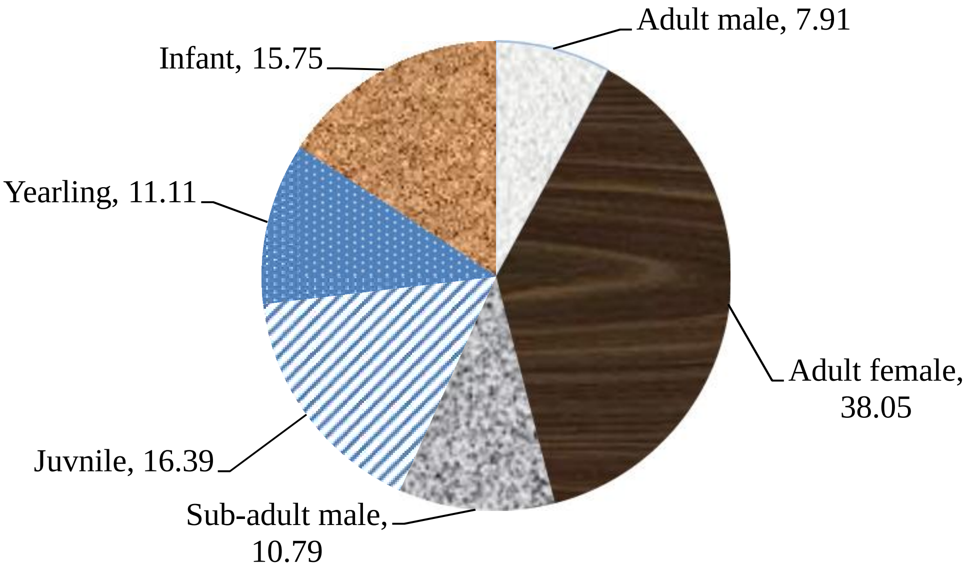

Figure 5. Group composition of southern geladas in unprotected area.

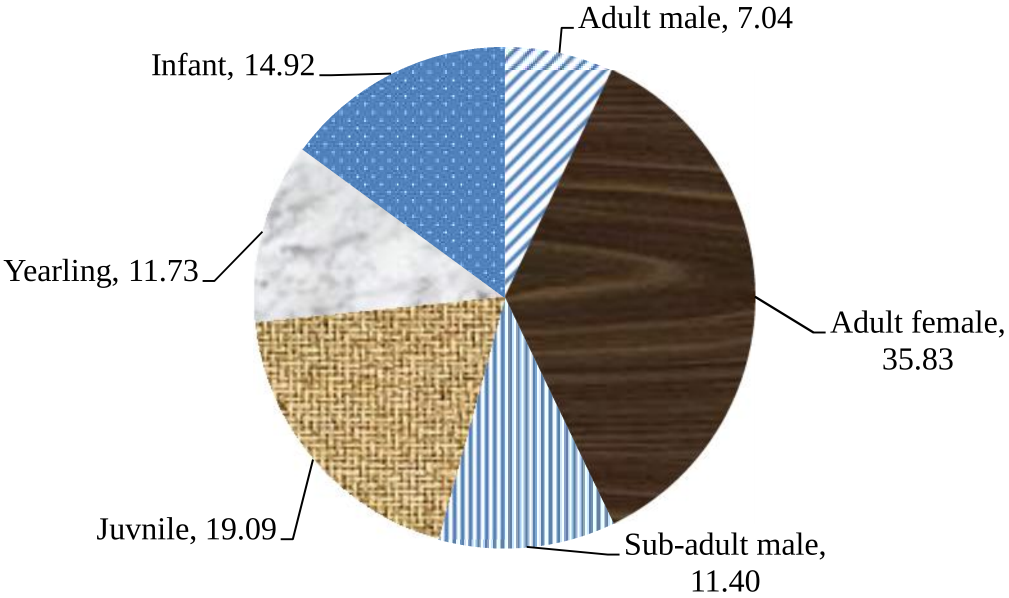

Figure 6. Group composition of southern geladas in BSNP.

***Sex and age ratio**:* The number of females per adult male differed from harem to harem. The average sex ratio of adult male to adult female ranged from 1:4.40 to 1:6.33 in BSNP and 1:3.61 to 1:5:63 in the unprotected site in each block. The overall average adult male to female ratio in unprotected area was 1:4.81. For each adult male, there were 4.81 females in the population (Table 4). However, adult male to female ratio in the BSNP was 1:5.09. There was no significant difference in adult male and adult female sex ratio between the unprotected and BSNP (t-test: t = 0.664, df = 49, p = 0.510). On the other hand, the overall mean male (adult male and sub-adult male) to adult female sex ratio in the unprotected site was 1:2.03 and 1:1.94 in BSNP.

Table 4. Comparison of sex and age ratio between sites (AM=Adult male, AF=Adult female, YR=Yearling, IN=Infant, SAM=Sub-adult male, M=Adult male and sub-adult male).

Site	Sex ratio			Age ratio		
	AM:AF	SAM:AF	M:AF	AF:YR	AF:IN	AM:SAM
BSNP	1.00:5.09	1.00:3.53	1.00:1.94	1.00:0.32	1.00:0.42	1.00:1.63
Unprotected	1.00:4.81	1.00:3.53	1.00:2.03	1.00:0.29	1.00:0.41	1.00:1.36

The index of reproduction (*i.e.* average number of infant or yearling per adult female) in the unprotected area of the population corresponded to 0.43 for adult female to an infant, i.e. 43% of adult females had infants, and 0.30 for a yearling, 30% of the adult females had yearlings. The overall index of reproduction of adult females to immature (infants and yearlings) was 0.73 in unprotected site. Similarly, the index of reproduction in BSNP population was 0.43 for adult females and infants, and 0.34 for yearlings. The overall index of reproduction of adult females to immature (infants and yearling) was 0.77 in BSNP. There was no significant difference between the unprotected site and BSNP population on index of reproduction (U = 281.00, N_1 = 19, N_2 = 32, p = 0.654).

The distribution of gelada in different habitat type of BSNP was not uniform in group size. Large group sizes were found in afroapline habitat types compared to lowland areas. Band size was significant and positively correlated with the altitude of the habitat (Pearson rank correlation coefficient: $r = 0.568$, N = 19, p = 0.011). Thus, as the altitude increases the band size of geladas also increases.

4.2. Activity time budget and pattern

A total of 21,135 individual behavioural activities with the mean of 1174.17 ± 24.75 per month from 4,227 group scans with the mean of 234.83 ± 4.95 per month for a total of 1056.75 hours across 90 days were collected from Selam band. For Tikure band, 20,770 individual behavioural scans with the mean of 1153.89 ± 16.94 per month from 4,154 group scan samples with the mean of 230.78 ± 3.39 per month were recorded during 1038.50 hours across 90 days. This study yielded a total of 41,905 individual activity scan samples, 8,381 group scans, 2095.25 hours across 180 days from both bands.

Daily activity time budget: Southern gelada exhibited wide daily fluctuation in time budget. Selam band at Kosheme spent daily feeding time ranging from 22.67–69.80%, resting 4.49–35.32%, moving 7.39–27.08%, grooming 4.68–25.11%, agonistic 0.00–3.11%, mating 0.00–4.26%, playing 0.00–5.78% and other 0.00–2.98% during the observation days. Similarly, Tikure band at Keywasha in BSNP spent daily feeding time ranging from 33.19–66.52%, resting 5.96–43.40%, moving 7.11–26.67%, grooming 4.35–24.00%, agonistic 0.00–4.35%, mating 0.00–3.04%, playing 0.00–4.44% and other 0.00–3.91%.

Feeding, moving, resting and grooming were the main behavioural categories for both Selam and Tikure bands. Daily time budgets of Selam band differed significantly among the main behavioural categories (Kruskal–Wallis H test, H = 221.14, df = 3, $p < 0.001$). Follow-up post hoc tests of pairwise comparison indicated that a significant difference was observed in feeding compared with moving, resting and grooming ($p < 0.001$), grooming with moving (p =

0.001) and resting ($p < 0.001$). However, there was no significant difference between moving and resting ($p = 0.368$).

Similarly, daily time budgets of Tikure band differed significantly among the main behavioural categories ($H = 223.84$, $df = 3$, $p = 0.001$). Follow-up post hoc tests of pairwise comparison indicated that a significant difference was observed in feeding compared with moving, resting and grooming ($p < 0.001$), grooming with moving ($p < 0.001$) and resting ($p = 0.003$). However, there was no significant difference between moving and resting ($p = 0.072$) during the 90 days of observation periods at Keywasha in BSNP.

The two bands did not differ in the proportion of daily records devoted to feeding, resting, grooming, socializing and other activities. However, Tikure band spent a higher percentage of daily records for moving than Selam band. Thus, there was no significant difference in the time spent in behavioural category within the 180 days of sampling period comparison between Selam and Tikure bands (Feeding: ANOVA, $F_{1,178} = 0.44$, $p = 0.509$; grooming: $F_{1,178} = 0.06$, $p = 0.804$; socializing: $F_{1,178} = 0.01$, $p = 0.981$; resting: $H = 2.50$, $df = 1$, $p = 0.114$; other: $F_{1,178} = 3.33$, $p = 0.070$). However, there was significant difference in the time spent moving within the 180 days of sampling period between Selam and Tikure bands (ANOVA, $F_{1,178} = 5.81$, $p = 0.017$).

Monthly activity time budget: Southern gelada exhibited wide monthly fluctuation in time budget. The study showed that both Selam and Tikure bands spent most of their monthly time feeding followed by either moving or resting or grooming. The monthly activity budget of Selam band is presented in Table 5. Selam band at Kosheme spent monthly feeding time ranging from 36.52–58.35%, resting 10.63–26.87%, moving 11.38–23.00% and grooming 7.78–18.58%. The band used the longest and shortest time spent feeding in April and July 2015, respectively.

Grooming activity was highest in June and least in November during the study months. Selam band also spent their highest time in January 2017 for moving and least in July 2016 of their monthly time budget.

Table 5. Monthly activity time budgets for Selam band at Kosheme from May 2015–March 2017 (N=activity records).

Month	N	Frequency of occurrence of activities (%)							
		Feeding	Grooming	Moving	Resting	Agonistic	Mating	Playing	Other
May 2015	1155	44.33	16.80	14.11	17.06	1.04	2.16	2.86	1.65
Jun 2015	1130	40.45	18.58	16.46	20.44	0.71	0.00	2.83	0.53
Jul 2015	1150	36.52	15.74	16.78	26.87	0.43	1.74	1.83	0.09
Aug 2015	1155	45.71	17.32	13.77	18.10	1.47	1.64	1.82	0.17
Sep 2015	1145	43.41	14.93	16.77	19.13	1.05	1.57	2.62	0.52
Oct 2015	1165	56.91	12.02	12.88	14.51	1.37	0.17	1.03	1.12
Nov 2015	1160	42.76	15.34	17.76	20.34	1.03	0.78	1.29	0.69
Dec 2015	1185	53.92	15.78	16.88	10.63	0.68	0.42	0.93	0.76
Jan 2016	1185	45.91	12.91	17.38	17.55	1.60	1.35	2.45	0.84
Feb 2016	1200	55.42	9.75	16.75	13.75	1.00	0.17	1.67	1.50
Mar 2016	1190	56.39	11.09	13.70	15.63	0.59	0.17	1.09	1.34
Apr 2016	1215	58.35	11.69	13.74	13.66	0.58	0.00	1.07	0.91
May 2016	1220	56.64	10.16	14.75	15.41	0.57	0.58	1.39	0.49
Jul 2016	1160	54.05	11.81	11.38	20.69	0.69	0.09	1.03	0.26
Sep 2016	1185	47.59	12.32	13.67	23.63	0.68	0.17	1.10	0.84
Nov 2016	1170	52.74	7.78	18.80	17.52	0.68	0.00	1.28	1.20
Jan 2017	1165	45.75	10.47	23.00	17.51	0.43	0.26	1.37	1.20
Mar 2017	1200	53.17	9.08	22.75	12.08	0.75	0.00	0.50	1.67

The proportion of behavioural activities varied monthly. There was significant difference in the time spent in each behavioural category of time budget among the 18 months of the sampling period (Chi-square goodness of fit, feeding: $\chi2 = 219.16$, df = 17, $p < 0.001$; resting:

$\chi 2 = 168.59$, df = 17, $p < 0.001$; moving: $\chi 2 = 123.29$, df = 17, $p < 0.001$; grooming: $\chi 2 = 131.15$, df = 17, $p < 0.001$; socializing: $\chi 2 = 137.21$, df = 17, $p < 0.001$ and other: $\chi 2 = 54.97$, df = 17, $p < 0.001$) for Selam band (Table 5).

Selam band spent more time on feeding activity. In turn, the band reduced its grooming and resting activities. Feeding activity was significant and negatively correlated with monthly grooming (Pearson correlation coefficient: $r = -0.674$, N = 18, p = 0.002) and resting activity ($r = -0.733$, N = 18, p = 0.001). In the contrary, there was no significant correlation between resting and grooming ($r = 0.358$, N = 18, p = 0.145) and moving activity ($r = -0.162$, N = 18, p = 0.521). In addition, there was no significant correlation between moving and feeding ($r = -0.246$, N = 18, p = 0.326) and grooming activity ($r = -0.268$, N = 18, p = 0.283).

Tikure band at Keywasha spent monthly feeding time ranging from 42.13–56.02%, resting 12.26–26.53%, moving 13.13–21.90% and grooming 9.18–17.04% (Table 6). The band spent the longest and shortest time feeding in February 2016 and June 2015, respectively. Grooming activity was longest in December 2015 and the least was recorded in January 2017. The highest mating activity was registered in May 2015 and March 2017.

There was significant difference in time spent in each behavioural category within the 18 months of study period (Chi-square goodness of fit, feeding: $\chi 2 = 74.96$, df = 17, $p < 0.001$; resting: $\chi 2 = 186.83$, df = 17, $p < 0.001$; moving: $\chi 2 = 83.62$, df = 17, $p < 0.001$; grooming: $\chi 2 = 86.91$, df = 17, $p < 0.001$; socializing: $\chi 2 = 96.80$, df = 17, $p < 0.001$ and other: $\chi 2 = 27.66$, df = 16, $p < 0.001$) for Tikure band (Table 6).

Table 6. Monthly time budgets for Tikure band from May 2015–March 2017 (N=activity record).

Month	N	Frequency of occurrence of activities (%)							
		Feeding	Grooming	Moving	Resting	Agonistic	Mating	Playing	Other
May 2015	1150	47.04	14.70	18.52	12.26	1.91	1.74	2.70	1.13
Jun 2015	1125	42.13	15.02	21.69	15.47	0.89	1.42	2.67	0.71
Jul 2015	1145	42.53	15.98	17.55	20.52	1.83	0.00	1.22	0.35
Aug 2015	1155	44.85	11.69	19.13	22.34	0.52	0.26	1.04	0.17
Sep 2015	1145	49.34	12.58	18.17	15.72	0.96	0.00	2.36	0.87
Oct 2015	1135	51.72	15.42	13.48	14.89	1.32	0.35	2.56	0.26
Nov 2015	1150	49.65	14.78	14.96	17.48	0.78	0.17	1.83	0.35
Dec 2015	1150	45.13	17.04	13.13	19.91	1.65	0.52	1.83	0.78
Jan 2016	1160	52.07	10.86	18.19	16.03	0.86	0.52	0.95	0.52
Feb 2016	1180	56.02	12.88	15.00	12.71	0.85	0.93	0.85	0.76
Mar 2016	1160	53.97	13.02	16.12	12.93	0.78	1.21	1.20	0.78
Apr 2016	1175	45.87	16.17	19.49	15.66	0.85	0.60	0.51	0.85
May 2016	1180	47.54	12.71	14.83	21.69	1.02	0.68	1.02	0.51
Jul 2016	1180	42.88	13.81	15.00	26.53	0.59	0.42	0.76	0.00
Sep 2016	1145	53.89	9.78	19.91	13.71	0.79	0.79	0.61	0.52
Nov 2016	1125	52.89	9.69	20.53	14.67	0.62	0.18	0.44	0.98
Jan 2017	1155	50.22	9.18	21.90	14.98	1.39	0.52	0.87	0.95
Mar 2017	1155	48.23	10.91	21.21	14.89	0.78	1.73	0.87	1.39

Tikure band spent more time on feeding activity, reducing its grooming and resting activities. Within the study periods, feeding activity was significant and negatively correlated with monthly grooming (Pearson correlation coefficient: *r* = -0.530, N = 18, p = 0.024) and resting activity (*r* = -0.659, N = 18, p = 0.003). Similarly, monthly moving activity was significantly negatively correlated with grooming (*r* = -0.542, N = 18, p = 0.020). Contrary to this, there was no significant correlation between resting and grooming activity (*r* = 0.226, N =

18, p = 0.366) and moving (*r* = -0.337, N = 18, p = 0.171). Similarly, there was no significant correlation between feeding and moving activity (*r* = -0.075, N = 18, p = 0.768).

Relationship between grass phenology and time budget: The monthly pattern of greenness level of grasses and herbs affected the time budget of the southern geladas at Kosheme (Table 7). The higher percentage availability of strictly green grass plots was significantly positively correlated with the monthly percentage of resting (Spearman rank correlation coefficient: r_s = 0.653, p = 003) and grooming activities (r_s = 0.541, p = 021). Contrary to this, it was significantly negatively correlated with the monthly percentage of feeding activity (r_s = -0.493, p = 0.038). Monthly percentage of resting and grooming activity was significantly negatively correlated with higher percentage availability of non-green plots (resting: r_s = -0.588, p = 0.010; grooming: r_s = -0.594, p = 0.009). However, monthly percentage of moving activity was significantly positively correlated with the presence of higher percentage of non-green plots (r_s = 0.517, p = 0.028).

Table 7. Relationship between the level of greenness and time budget for Selam band.

Level of greenness		Feeding	Moving	Resting	Grooming
Strictly green	r_s	-0.493	-0.351	0.653	0.541
	p	0.038	0.153	0.003	0.021
Light-green	r_s	0.353	0.035	-0.318	-0.162
	p	0.151	0.890	0.199	0.522
Brown	r_s	0.414	0.283	-0.485	-0.468
	p	0.088	0.256	0.041	0.050
Nongreen	r_s	0.339	0.517	-0.588	-0.594
	p	0.169	0.028	0.010	0.009

Monthly pattern of greenness level of grasses and herbs affected the time budget of the southern geladas at Keywasha (Table 8). Higher percentage availability of strictly green grass plots was somehow significantly negatively correlated with the monthly percentage of feeding (Spearman rank coefficient correlation: r_s = -0.461, p = 0.054). Time budget of moving, grooming and resting of the southern geladas at Keywasha were not associated with level of greenness.

Table 8. Relationship between level of greenness and percentage of time budget for Tikure band.

Level of greenness		Feeding	Moving	Resting	Grooming
Strictly green	r_s	-0.461	-0.130	0.408	0.241
	p	0.054	0.608	0.092	0.336
Light-green	r_s	0.372	-0.076	-0.224	-0.080
	p	0.129	0.764	0.329	0.751
Brown	r_s	0.420	0.290	-0.448	-0.339
	p	0.083	0.244	0.062	0.169
Nongreen	r_s	0.250	0.308	-0.353	-0.222
	p	0.317	0.213	0.150	0.375

For Selam band, there was no significant difference in the time spent feeding (44.89 vs. 51.66%: paired t-test, t = -2.10, df = 5, p = 0.090), moving (16.08 vs. 17.39%: t = -0.60; df = 5, p = 0.576) and resting (19.43 vs. 17.81%: t = -1.10, df = 5, p = 0.323) between the two years data collected in similar months. However, there was a significant difference in time spent grooming (14.47 vs. 10.27%: t = 4.37, df = 5, p = 0.007) and socializing (4.28 vs. 1.93%: t = 4.61, df = 5, p = 0.006) between the two years. Similarly, for Tikure band there was no significant difference in the time spent feeding (49.10 vs. 49.28%: paired t-test, t = -0.12, df = 5, p = 0.912), moving (17.25 vs. 18.90%: t = -1.02; df = 5, p = 0.353), resting (15.82 vs. 17.75%: t = -0.96, df = 5, p = 0.380) and socializing (3.50 vs, 2.35%: t = 1.94; df = 5, p = 0.110) between the two years data collected in similar months. However, there was a significant difference in time spent grooming (13.65 vs. 11.01%: t = 5.15; df = 5, p = 0.004) between the two years.

Seasonal activity time budget: Across the study period, feeding activity was the most frequent behavioural activity in both the wet and dry seasons for both Selam and Tikure bands. Selam band spent time feeding ranging from 36.52–56.64%, moving (11.38–16.78%), resting (15.41–26.87) and grooming (10.16–18.58%) during the wet season (Fig. 7). The band also spent time feeding ranging from (42.76–58.35%), moving (12.88–22.75%), resting (10.63–20.34%) and grooming (9.08–15.78%) during the dry season.

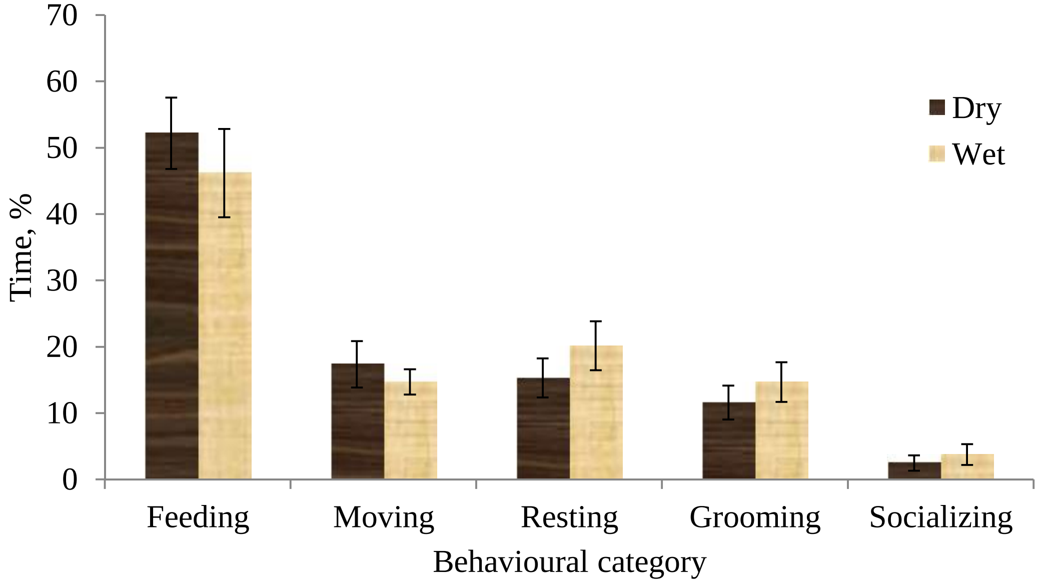

Figure 7. Seasonal differences spent in each behavioural category of time budget for Selam band during the wet and dry seasons; values represent the mean ± SD (standard deviations).

The time budget of Selam band differed significantly among the main behavioural categories (ANOVA, $F_{3,28} = 102.31$, $p < 0.001$) during the wet season (Fig. 7). Using the Tukey HSD post hoc test, a significant difference was observed in feeding compared to moving, resting and grooming ($p < 0.001$) during the season. However, there was no significant difference between moving and grooming ($p = 1.000$), moving and resting ($p = 0.066$), resting with grooming ($p = 0.066$) during the wet season at Kosheme. Similarly, the time budget of the Selam band differed significantly among the main behavioural categories (ANOVA, $F_{3,36} = 250.45$, $p < 0.001$) during the dry season. Using the Tukey HSD post hoc model, a significant difference was observed as feeding compared with moving, resting and grooming ($p < 0.001$) and moving with grooming ($p = 0.008$). However, there was no significant difference between moving and resting ($p = 0.621$) and resting with grooming ($p = 0.139$) during the wet season at Kosheme.

Similarly, Tikure band spent time feeding ranging from (42.13–53.89%), moving (13.48–21.69%), resting (12.26–26.53%) and grooming (9.78–15.98%) during the wet season (Fig. 8).

The band also spent time feeding ranging from (45.13–56.02%), moving (13.13–21.21%), resting (12.71–19.91%) and grooming (9.18–17.04%) during the dry season. The time budgets of Tikure band also differed significantly among the main behavioural categories (H = 23.92, df = 3, $p < 0.001$) during the wet season. Follow-up post hoc tests of pairwise comparison indicated that a significant difference was observed when feeding compared to grooming ($p < 0.001$), moving (p = 0.002) and resting (p = 0.002). However, there was no significant difference between moving and resting (p = 1.00) and between grooming and moving (p = 0.075) and resting (p = 0.075) at Keywasha in BSNP during the wet season. Similarly, the time budget of Tikure band differed significantly among the main behavioural categories (ANOVA, $F_{3,32}$ = 311.28, $p < 0.001$) during the dry season. Using the Tukey HSD test, a significant difference was observed in feeding compared to moving, resting and grooming ($p < 0.001$) and moving with grooming (p = 0.005). However, there was no significant difference between moving and resting (p = 0.357) and resting with grooming (p = 0.232) during the dry season.

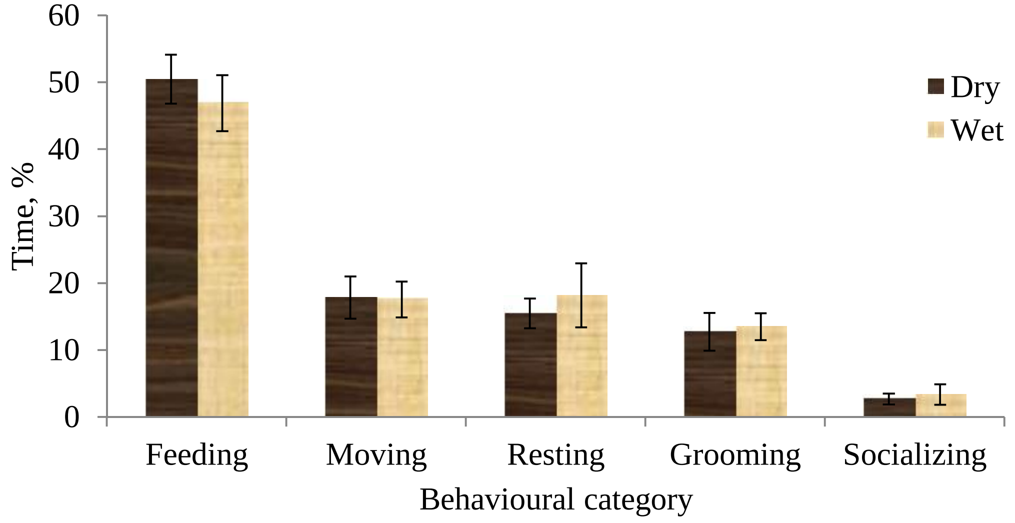

Figure 8. Seasonal differences spent in each behavioural category of activity time budget for Tikure band during the wet and dry seasons; values represent the mean ± SD.

Selam band at Kosheme spent significantly more time during the dry season than the wet season in feeding (52.18 vs. 46.19%, ANOVA, F1,16 = 4.53, p = 0.049). However, even if Tikure band showed an increase in time spent feeding from 46.87% during the wet season to 50.45% during the dry season, the difference was not significant (paired-samples t-test: t = 1.79, df = 8, p = 0.112). Thus, southern geladas spent more time for feeding when the availability of food is low during the dry season than during the wet season. Selam band also spent significantly more time during the wet season than the dry season for resting and grooming activities (resting: 20.14 vs. 15.29%, $F_{1,16}$ = 9.65, p = 0.007; grooming: 14.66 vs. 11.58%, $F_{1,16}$ = 5.69, p = 0.030). Contrary to this, there was no significant difference in resting and grooming between the dry and wet seasons for Tikure band (resting: 15.47 vs. 18.18%, t = 1.32, df = 8, p = 0.222; grooming: 12.74 vs. 13.51%, t = 0.88, df = 8, p =0.404). Although, Selam band spent more time moving during the dry season than the wet season, the difference was not significant. Thus, for both bands, there was no significant difference between the dry and wet seasons in moving (Selam: 17.36 vs. 14.70 %; $F_{1,16}$ = 3.70, p = 0.072; Tikure: 17.83 vs. 17.57%; t = 0.14, df = 8, p = 0.891) and socializing (Selam: 2.47 vs. 3.74%, $F_{1,16}$ = 4.06, p = 0.061; Tikure: 3.37 vs. 2.70%; t = 1.28, df = 8, p = 0.236).

A comparison of seasonal time budget between the two bands is presented in Figure 9. The study revealed that most of the seasonal behavioural categories of activity time budget were more or less similar. There was no significant difference for feeding between Selam and Tikure bands during both the dry and wet seasons (wet: 46.19 vs. 46.87%, $F_{1,15}$ = 0.09, p = 0.770; dry: 52.18 vs. 50.45%, $F_{1,17}$ = 0.62, p = 0.443). Tikure band devoted significantly high proportion of time compared to Selam band in moving (17.57 vs. 14.70%, $F_{1,15}$ = 6.41, p = 0.023) during the wet season. However, there were no significant differences in the time spent moving (17.83 vs.

17.36%, $F_{1,17} = 0.09$, p = 0.762) between the two bands during the dry season. Similarly, there were no significant differences in the time spent resting during both the wet and dry seasons (wet: 20.14 vs. 18.18% $F_{1,15} = 0.95$, p = 0.346; dry: 15.29 vs. 15.47%, $F_{1,17} = 0.02$, p = 0.899), grooming (wet: 14.66 vs. 13.51%, $F_{1,15} = 0.95$, p = 0.346; dry: 11.58 vs. 12.74%, $F_{1,17} = 0.85$, p = 0.371) and socializing (wet: 3.74 vs. 3.37%, $F_{1,15} = 0.25$, p = 0.626; dry: 2.47 vs. 2.70%, $F_{1,17} = 0.23$, p = 0.634) between the two bands.

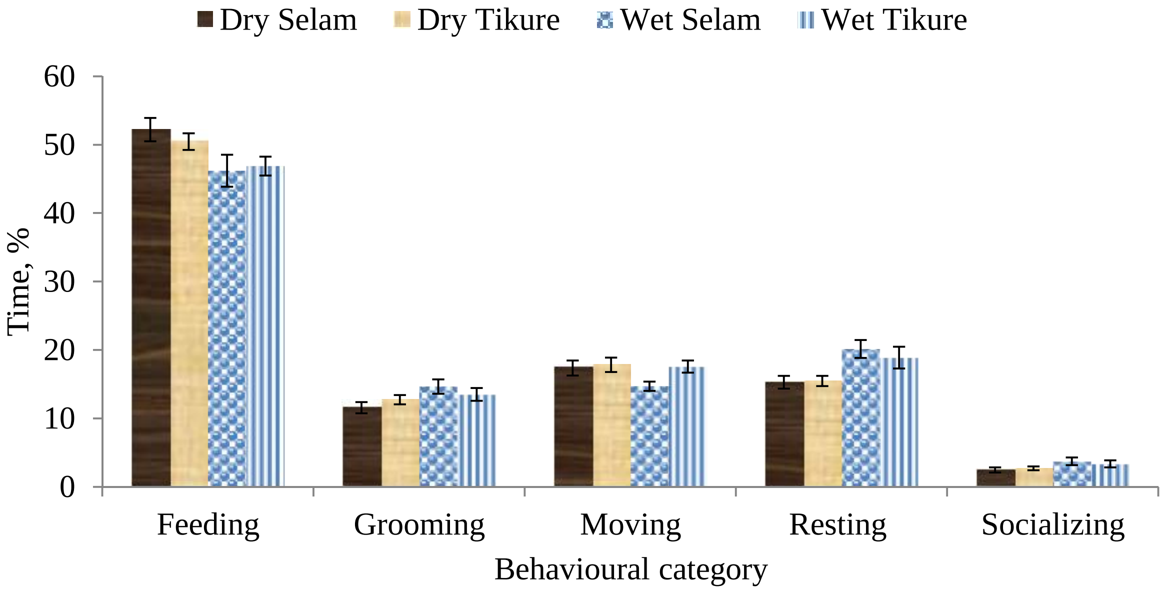

Figure 9. Seasonal differences of each behavioural category of time budget spent between Selam and Tikure bands; Error bars represent the standard error of the mean.

Activity time budget of southern geladas at Kosheme among the four seasons is presented in Table 9. Selam band spent more feeding time during the wet season II than wet season I (52.76 vs. 42.08%). Similarly, southern geladas at Kosheme spent grooming 16.67% during the wet season I and 11.43% during the wet season II. The time budget of Selam band for feeding during the two dry seasons was more or less similar (52.81 vs. 50.55%).

Table 9. Activity time budget of Selam band in four seasonal blocks (n = months).

	Behavioural category, %					
Season	Feeding	Grooming	Moving	Resting	Socializing	Other
Wet I n=5	42.08	16.67	15.58	20.32	4.76	0.59
Wet II n=3	52.76	11.43	13.27	19.91	2.10	0.53
Dry I n=7	52.81	12.65	15.58	15.16	2.78	1.02
Dry II n=3	50.55	9.11	21.52	15.70	1.76	1.36

Activity time budget of southern geladas at Keywasha among the four seasons is presented in Table 10. Tikure band spent more feeding time during the wet season II than the wet season I (48.10 vs. 46.27%). Similarly, Tikure band spent resting 16.87% during the wet season I and 20.65% during the wet season II.

Table 10. Activity time budget of Tikure band in four seasonal blocks (n=months).

	Behavioural category, %					
Season	Feeding	Grooming	Moving	Resting	Socializing	Other
Wet I n=6	46.27	14.23	18.09	16.87	3.96	0.58
Wet II n=3	48.10	12.10	16.59	20.65	2.22	0.34
Dry I n=6	50.45	14.13	16.15	15.78	2.82	0.67
Dry II n=3	50.45	9.93	21.21	14.84	2.46	1.11

Annual activity time budget: On the basis of overall annual time budget of the 18 months data, Selam band spent on average 49.54% of the daytime feeding followed by resting (17.43%). The other activities agonistic, playing, mating and other comprised 0.85%, 1.56%, 0.62% and 0.88%, respectively during the study period (Fig. 10). For Selam band, there was a significant difference among the annual activity time budget of behavioural categories (Kruskal–Wallis H test, H = 73.01, df = 4, $p < 0.001$). Using the pairwise comparison of Dunn's test, a significant difference was observed in feeding compared with moving, grooming and socializing ($p < 0.001$) and resting ($p = 0.001$), socializing with moving and resting ($p < 0.001$) and grooming ($p = 0.003$), and resting with grooming (p = 0.036). However, there was no significant difference between moving and resting (p = 0.536), moving and grooming (p = 0.139).

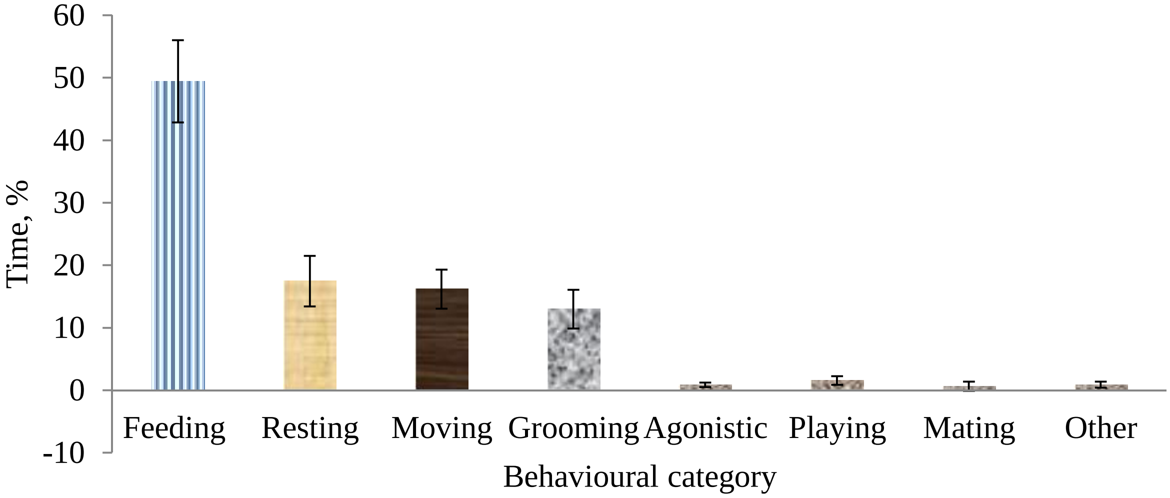

Figure 10. Percentage accounted by different behavioural category in the annual activity time budget of southern geladas at Kosheme; values represent the mean ± SD.

Similarly, Tikure band spent on average 48.67% of the daytime feeding followed by moving (17.70%). Agonistic, playing, mating and other activities comprised 1.02%, 1.34%, 0.67% and 0.66%, respectively of its annual time budget (Fig. 11).

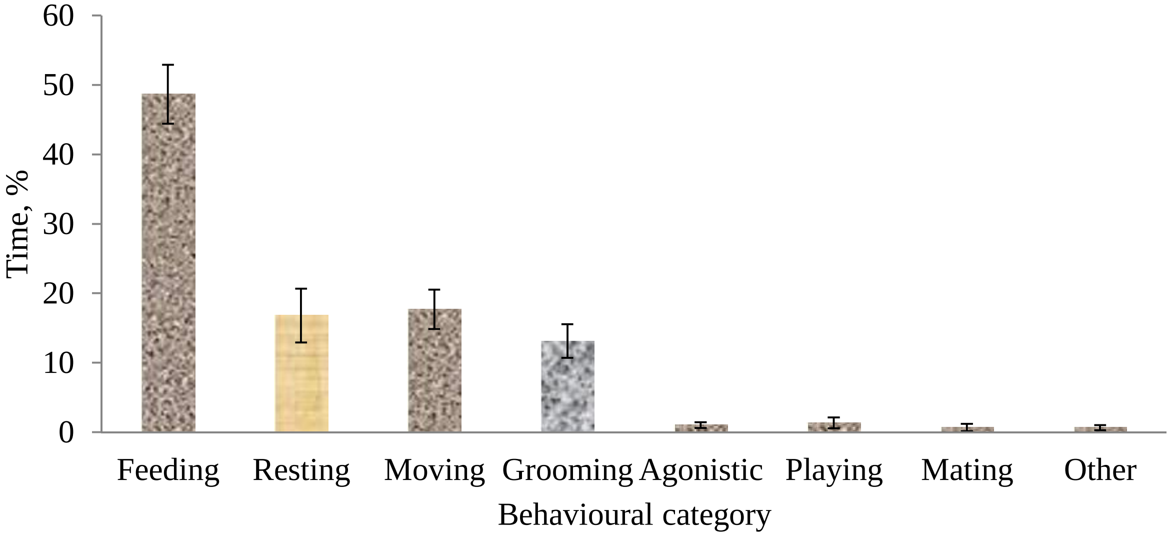

Figure 11. Percentage accounted by different behavioural category in the annual activity time budget of the southern geladas at Keywasha; values represent the mean ± SD.

For Tikure band, there was significant difference among annual behavioural categories ($F_{4,85} = 481.23$, $p < 0.001$). Using the Tukey HSD test, a significant difference was observed in feeding compared to moving, resting, grooming and socializing ($p < 0.001$), moving with grooming ($p < 0.001$), resting with grooming ($p = 0.003$) and socializing with resting, grooming and moving ($p < 0.001$). However, there was no significant difference between moving and resting ($p = 0.874$).

The overall mean annual comparison percent time spent between the two bands in the different activities during the course of the study is presented in Figure 12. Selam and Tikure bands spent non-significant differences in the percentage of time feeding (49.54 vs. 48.67%; H = 0.44, df = 1, $p = 0.506$) in their overall annual time budget. Similarly, there was no significant difference in moving (16.19 vs. 17.70%; $F_{1,34} = 2.35$, $p = 0.134$), resting (17.43 vs. 16.82%; $F_{1,34} = 0.26$, $p = 0.615$), grooming (12.94 vs. 13.12%; $F_{1,34} = 0.25$, $p = 0.875$) and socializing (3.02 vs. 3.03%; $F_{1,34} = 0.26$, $p = 0.613$) between the two bands.

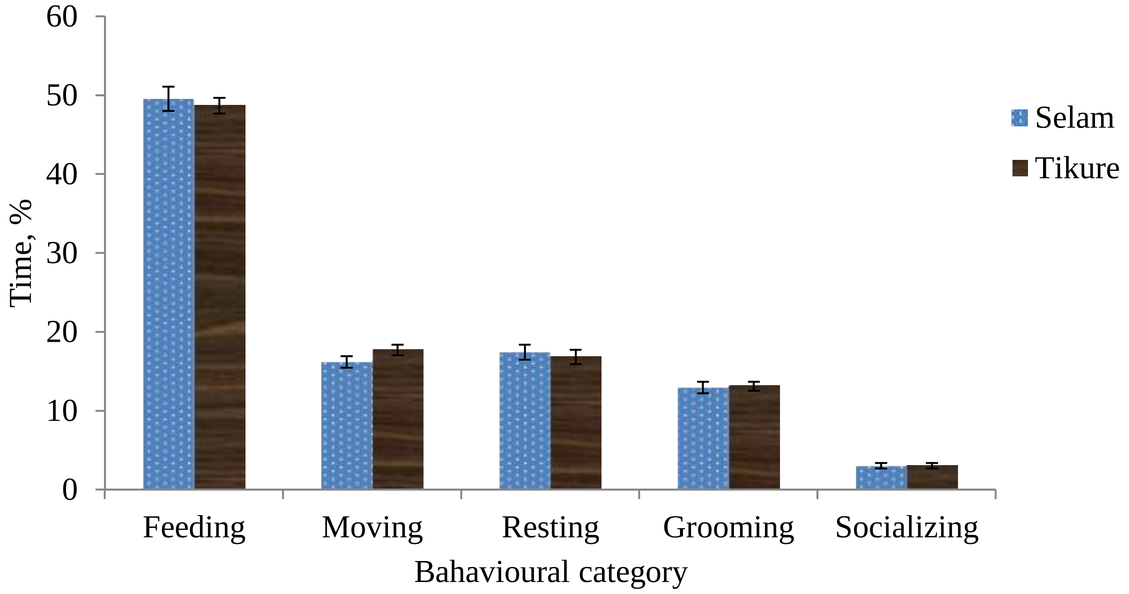

Figure 12. Percentage accounted by different behavioural category in the annual activity time budget of Selam and Tikure bands; values represent the mean ± SE.

Activity patterns: The daily diurnal activity pattern of Selam band showed that resting, moving and grooming activities were constant throughout the daylight hours (Fig. 13). Feeding time pattern of Selam band started at early morning around 0700 and increased spontaneous till its peak around 0830. This activity then started to decline and reached lower stage around 1130. Feeding activity again gradually increased from 1200 onwards until the band returned back to its sleeping site. However, most of resting and grooming activities were performed during the midday of the day. Moving as a diurnal activity took place linearly throughout the day and it did not show peaks and occurred any time of the day.

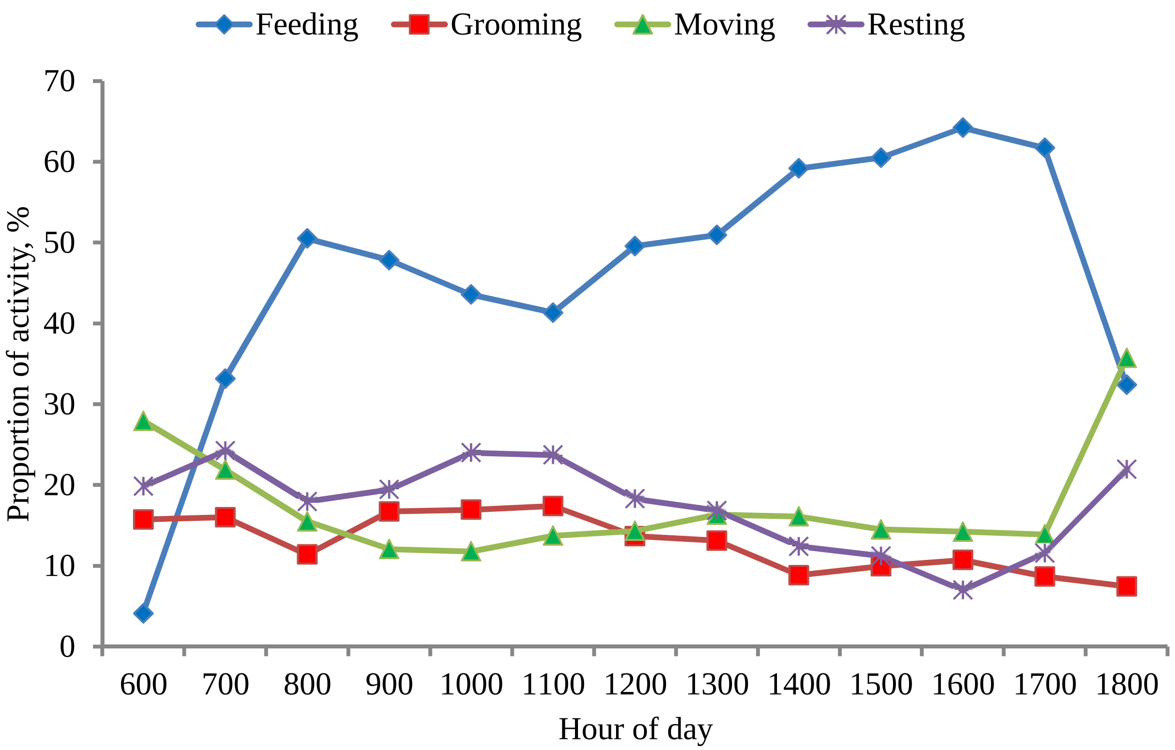

Figure 13. Annual daily activity pattern of Selam band.

For Selam band, the overall annual percentage of time allocated to feeding at different hours of the daylight blocks showed significant differences ($F_{5,102} = 12.17$, $p < 0.001$) during the study period (Table 11). Using the Tukey HSD test, a significant difference was observed in B1 compared to B2 ($p = 0.006$), B3 ($p = 0.007$), B4 ($p < 0.001$), B5 ($p < 0.001$) and B6 ($p = 0.002$). Similarly, a significant difference was observed in B2 compared to B5 ($p = 0.005$) for feeding. However, there was no significant difference between B2 and B3 ($p = 1.000$), B2 and B4 ($p = 0.308$) and B2 and B6 ($p = 1.000$) in feeding on the daily activity patterns. For the activity pattern of feeding, a significant difference was also observed in B3 compared to B5 ($p = 0.004$). However, there was no significant difference in B3 compared to B4 ($p = 0.279$) and B6 ($p = 0.999$). Similarly, there was no significant difference in B4 compared to B5 ($p = 0.587$) and B6 ($p = 488$). However, a significant difference was observed in B5 compared to B6 ($p = 0.012$).

For Selam band, the overall percentage of time allocated to grooming at different hours of daylight showed significant differences ($F_{5,102} = 4.45$, $p = 0.001$). Using the Tukey HSD test, a significant difference was only observed in B2 compared with B6 ($p = 0.003$) and B3 compared to B6 ($p = 0.018$). However there was no significant difference in daily activity pattern in grooming in B1 compared to B2 ($p = 0.889$). B3 ($p = 996$), B4 ($p = 0.673$), B5 ($p = 0.491$) and B6 ($p = 0.072$). Similarly, there was no significant difference in daily activity pattern in grooming when B2 compared to B3 ($p = 0.993$), B4 ($p = 0.115$) and B5 ($p = 0.058$), as B3 compared to B4 ($p = 0.353$) and B5 ($p = 0.214$), when B4 compared to B5 ($p = 1.000$) and B6 ($p = 0.793$), and as B5 compared to B6 ($p = 0.918$).

The overall percentage of time allocated to moving at different hours of the daylight showed significant differences (Kruskal–Wallis test, H = 36:08; df = 5, $p < 0.001$) for Selam band. Using the Post hoc pairwise comparison of Dunn’s test, a significant difference was observed in B1 compared to B2 ($p = 0.001$), B1 vs. B3 ($p = 0.012$), B1 vs. B5 ($p = 0.017$), B2 vs. B6 ($p < 0.001$), B3 vs. B6 ($p < 0.001$), B4 vs. B6 ($P = 0.001$) and B5 vs. B6 ($p < 0.001$). However there was no significant difference in daily activity pattern in moving when B1 compared to B4 (p = 0.079), B1 vs. B6 (p = 0.091), B2 vs. B3 (p = 0.349), B2 vs. B4 (p = 0.091), B2 vs. B5 (p = 0.287), B3 vs. B4 (p = 0.451), B3 vs, B5 (p = 0.898), B4 vs. B5 (p = 0.532).

Lastly, for Selam, the overall percentage of time allocated to resting at different hours of the daylight showed significant differences ($F_{5,102} = 5.91$, $p < 0.001$). Using the Tukey HSD test, a significant difference was only observed when B1 compared to B5 (p = 0.002), B2 vs. B5 ($p < 0.001$) and B3 vs. B5 (p = 0.001). However, there was no significant difference in daily activity pattern in resting when B1 compared to B2 (p = 0.989), B1 vs. B3 (p = 1.000), B1 vs. B4 (p = 0.404), B1 vs. B6 (p = 0.777), B2 vs. B3 (p = 0.998), B2 vs. B3 (p = 0.126), B2 vs. B3 (p = 0.383), B3 vs. B4 (p = 0.297), B3 vs. B6 (p = 0.657), B4 vs. B5 (p = 0.313), B4 vs. B6 (p = 0.992) and B5 vs. B6 (p = 0.094).

Table 11. Annual daily activity pattern for Selam band based on daylight hour blocks (B=hour block, B1=0600–0800, B2=0800–1000, B3=1000–1200, B4=1200–1400, B5=1600–1400, B6=1600–1800).

Activity	Activity pattern in different hours of daylight, hour blocks, %					
	B1	B2	B3	B4	B5	B6
Feeding	29.26	45.69	45.44	55.06	62.36	47.06
Grooming	14.37	16.83	15.53	10.97	10.33	8.06
Moving	21.77	11.92	14.03	16.22	14.36	24.81
Resting	20.67	21.72	21.00	14.61	9.11	16.75

Annual diurnal activity patterns of Tikure band showed that resting and grooming were dominant and reached their highest peak during the early morning sessions (Fig. 14). These behavioural activities then gradually declined starting from late morning and almost became zero after midday onwards. Feeding time started around 0900 and increased gradually/spontaneously until 1300, and then it reached its peak at 1400 and followed at constant trend until 1730. After this time, feeding activity declined gradually until the band returned back to its sleeping site.

Thus, Tikure band at Keywasha spent at least 3 hours for engaging in grooming and resting during the morning session. However, the remaining of the daylight hours was used for feeding followed by moving activities.

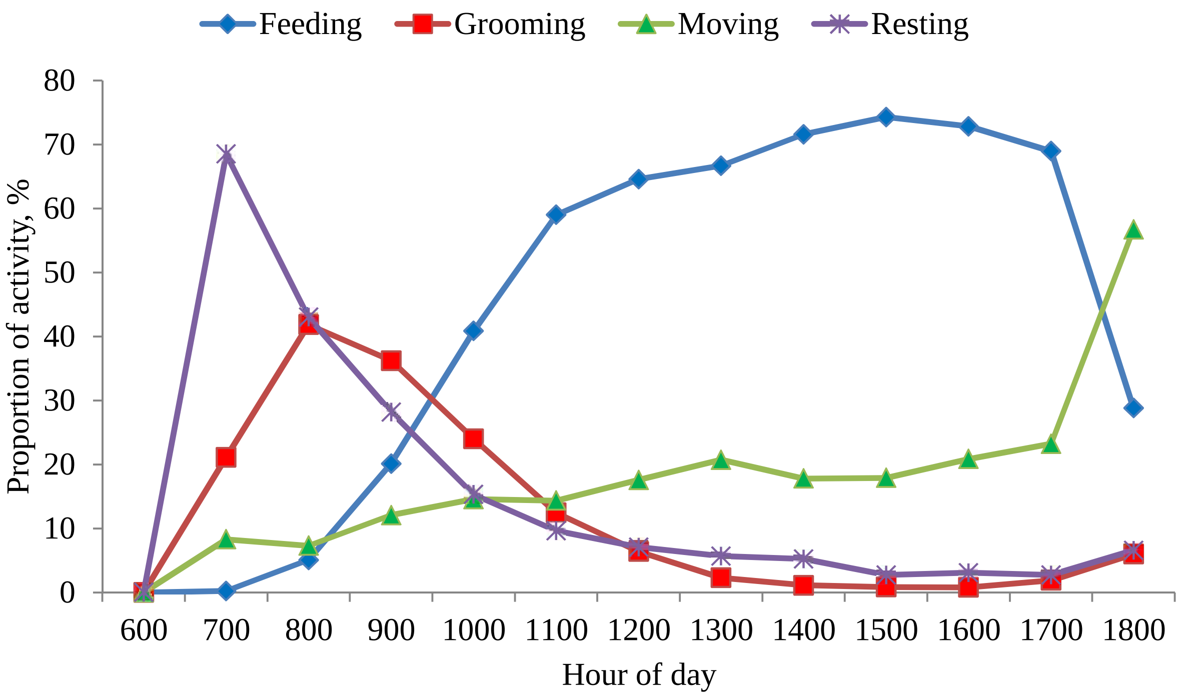

Figure 14. Annual daily activity pattern for Tikure band.

The activity time pattern of hourly block for Tikure band is presented in Table 12. Based on the daylight hour blocks, the overall percentage of time allocated to feeding for Tikure band showed significant differences (H = 87.26, df = 5, $p < 0.001$). Using the pairwise comparison of Dunn's test, a significant difference was detected in B1 compared to B2 ($p = 0.049$), B3 ($p < 0.001$), B4 ($p < 0.001$), B5 ($p < 0.001$) and B6 ($p < 0.001$), B2 vs. B3 ($p < 0.001$), B4 ($p < 0.001$) and B5 ($p < 0.001$), B3 vs. B5 ($p = 0.027$), B4 vs B6 ($p = 0.002$) and B5 vs. B6 ($p < 0.001$). However, significant differences were not observed in B2 compared to B6 ($p = 0.096$), B3 vs. B4 ($p = 0.208$), B3 vs. B6 ($p = 0.061$) and B4 vs. B5 ($p = 0.341$).

Similarly, for Tikure band, the overall percentage of time allocated in activity pattern to grooming showed significant differences (H = 82.97, df = 5, $p < 0.001$) across the daylight blocks. Using post hoc of the pairwise comparison, a significant difference was detected when B1 compared to B3 ($p = 0.002$), B4 ($p < 0.001$), B5 ($p < 0.001$) and B6 ($p < 0.001$), B2 vs. B3 ($p = 0.003$), B4 ($p < 0.001$), B5 ($p < 0.001$) and B6 ($p < 0.001$), B3 vs. B4 ($p = 0.006$), B5 ($p = 0.001$), B6 ($p = 0.042$) in grooming activity patterns of the daylight hours. However, there were no significant differences in activity pattern of grooming in daylight hour blocks when B4 compared with B5 ($p = 0.470$) and B6 ($p = 0.481$), and B5 vs. B6 ($p = 0.153$).

For Tikure band, the overall percentage of time allocated in activity pattern to moving showed significant differences ($F_{5,102} = 5.91$, $p < 0.001$) across the daylight blocks. Using the Tukey HSD test, a significant difference was only observed in B1 compared to B2 ($p = 0.002$), B3 ($p < 0.001$), B4 ($p < 0.001$), B5 ($p < 0.001$) and B6 ($p < 0.001$), B2 vs. B4 ($P = 0.007$), B5 ($p = 0.005$), and B6 ($p < 0.001$), B3 vs. B6 ($p < 0.001$), B4 vs. B6 ($p < 0.001$) and B5 vs. B6 ($p < 0.001$). However, there were no significant differences in activity pattern of moving in daylight hour blocks in B2 compared to B3 ($p = 0.498$), B3 vs. B4 ($p = 0.461$) and B5 ($p = 0.396$), B4 vs. B5 ($p = 1.000$).

In addition, the overall percentage of time allocated in activity pattern to resting showed significant differences (H = 73.85, df = 5, $p < 0.001$) across the daylight blocks. Post hoc pairwise comparison showed that significant differences between B1 and B2 ($p < 0.001$), B3 ($p < 0.001$), B4 ($p < 0.001$), B5 ($p < 0.001$) and B6 ($p < 0.001$), B2 vs. B3 ($p = 0.008$), B4 ($P < 0.001$), B5 ($p < 0.001$) and B6 ($p < 0.001$), B3 vs. B5 ($p = 0.027$). However, significant differences were not observed between B3 and B4 ($p = 0.133$) and B6 ($p = 0.265$), B4 vs. B5 (p

= 0.479) and B6 (p = 0.697) and B5 vs B6 (p = 0.272) in activity patterns of the daylight hour blocks.

Table 12. Annual daily activity pattern for Tikure band based on daylight hour blocks (B=block, B1=0600–0800, B2=0800–1000, B3=1000–1200, B4=1200–1400, B5=1600–1400, B6=1600–1800).

Activity	Activity pattern in different hours of daylight, hour block, %					
	B1	B2	B3	B4	B5	B6
Feeding	2.64	30.47	61.78	69.11	73.56	48.86
Grooming	31.47	30.11	9.42	1.69	0.81	3.94
Moving	7.78	13.31	15.94	16.62	19.36	39.97
Resting	55.75	21.72	8.33	5.44	2.89	4.64

A comparative study indicated that there was extreme variation in the trend of annual activity patterns in the major behavioural categories between Selam and Tikure bands. The variation of feeding pattern between Selam and Tikure bands is presented in Figure 15.

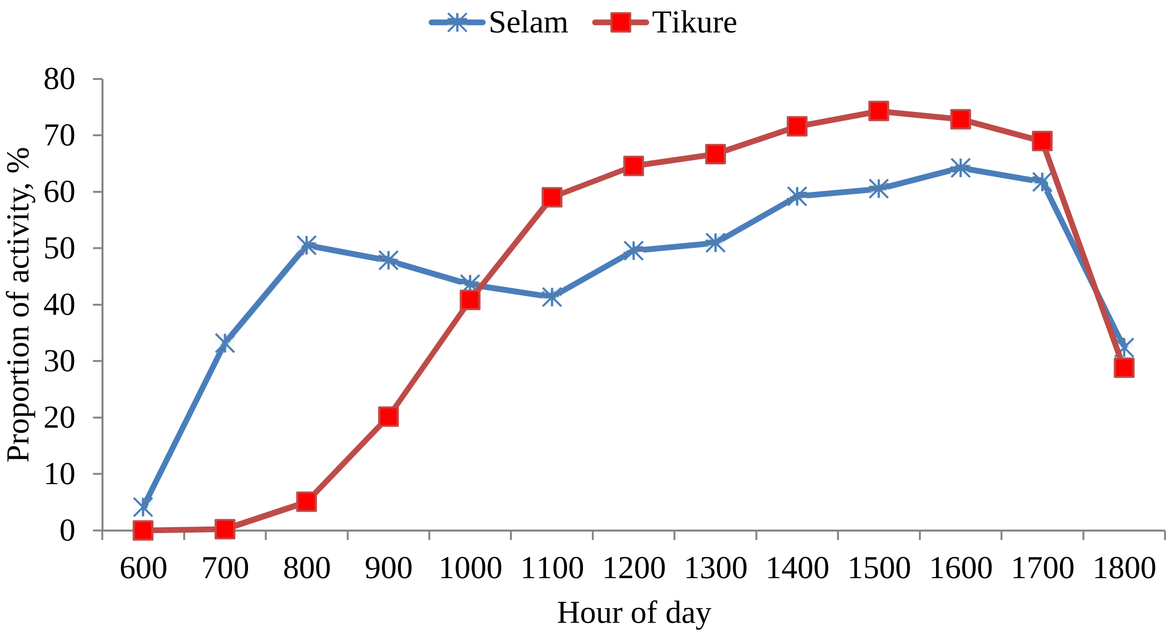

Figure 15. Overall distribution of feeding activity pattern over the daylight hours between Selam and Tikure bands.

Selam band tended to start feeding activity earlier in the morning compared to Tikure band. However, following resting and grooming activities, the feeding activity pattern for Tikure band started at late morning and then increased progressively throughout the daylight hours. Feeding activity pattern, except (1600–1800 h), showed significant differences between Selam and Tikure bands (Table 13).

Activity patterns comparison of grooming and resting between Selam and Tikure bands are depicted in Figures 16 and 17. The activities of grooming and resting for Tikure band were dominated in the early and late morning durations. These activities started to decline near the midday and became almost zero in the midafternoon. For Selam band, both grooming and resting were performed during the early morning. The patterns of resting and grooming activities seemed linear throughout the day for Selam band and did not reach at zero level like Tikure band. With only one exception (8000–1000 h), resting activity pattern differed significantly between Selam and Tikure bands during the daylight hours. Grooming activity pattern also showed significant differences between Selam and Tikure bands throughout the day (Table 13).

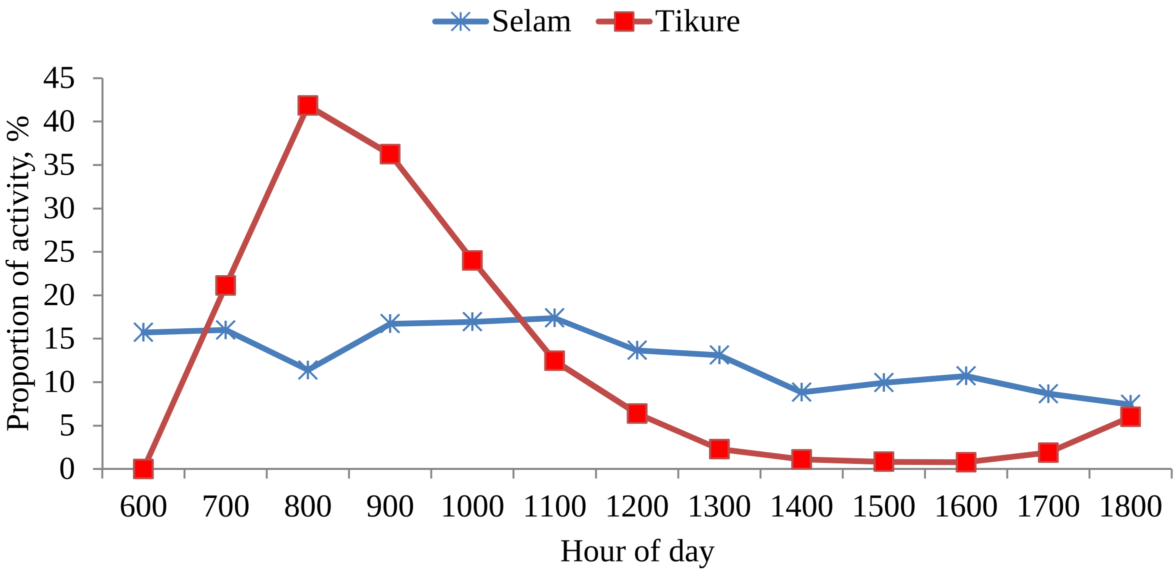

Figure 16. Overall distribution of grooming activity pattern between Selam and Tikure bands.

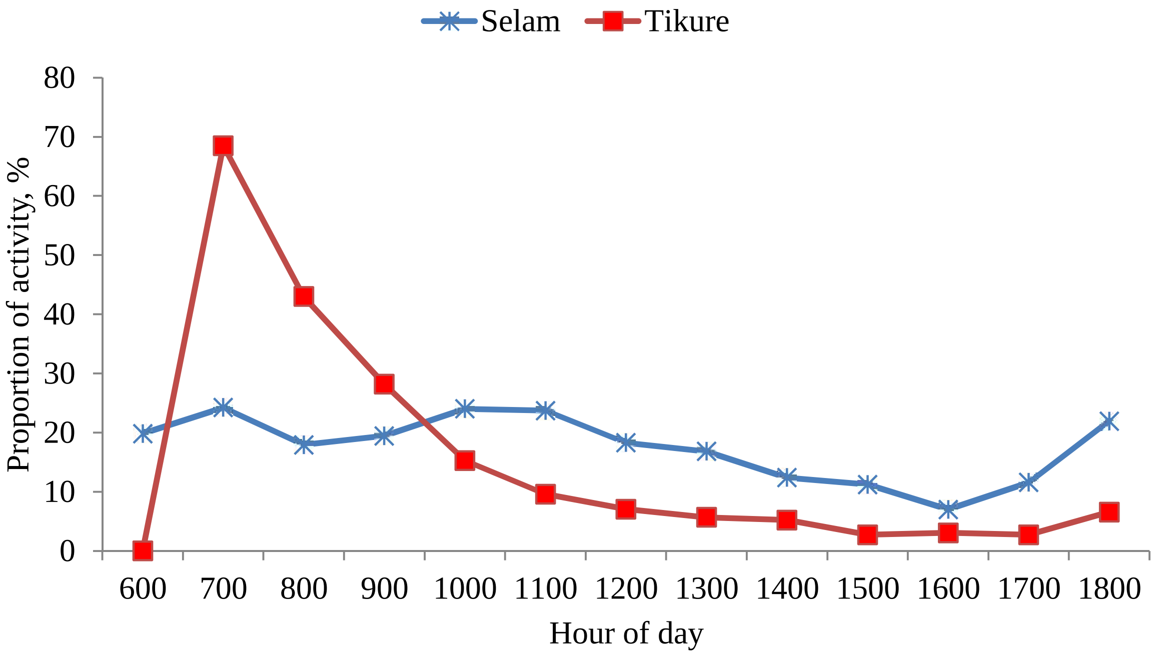

Figure 17. Overall distribution of resting activity pattern between Selam and Tikure bands.

The activity pattern of moving for Selam band was high in the early morning sessions compared to Tikure band (Fig. 18). Contrary to this, the pattern of moving was greater during the late afternoon session. However, this activity was patterned in similar manner for both Selam and

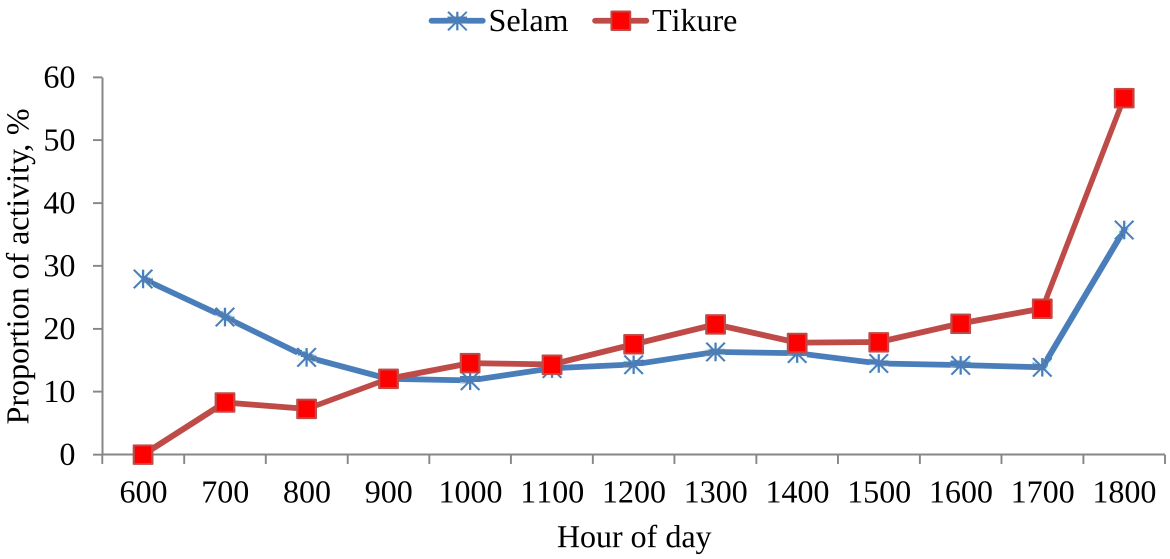

Figure 18. Overall distribution of moving activity pattern between Selam and Tikure bands.

Tikure bands in all other daylight hours. There were significant differences on the moving activity pattern at the early morning and late afternoon sessions between bands. However, there were no significant differences between bands on moving activity pattern in the remaining daylight hours (Table 13).

Table 13. Overall variations in diurnal annual activity patterns via Kruskal–Wallis H model between Selam and Tikure bands.

Hours	Feeding		Moving		Resting		Grooming	
	H	p	H	p	H	p	H	p
0600-0800	22.45	<0.001	18.53	<0.001	26.28	<0.001	24.38	<0.001
0800-1000	9.13	0.003	0.93	0.334	0.14	0.704	14.18	<0.001
1000-1200	9.52	0.002	1.53	0.217	12.91	<0.001	7.59	0.006
1200-1400	9.82	0.002	2.08	0.149	13.16	<0.001	23.09	<0.001
1400-1600	5.19	0.023	7.59	0.006	13.46	<0.001	25.45	<0.001
1600-1800	0.26	0.613	22.41	<0.001	17.09	<0.001	9.66	0.002

Seasonal variation in activity patterns: The schedule of activity pattern showed slight changes during the wet and dry seasons. For Selam band, during the wet season, feeding activity pattern delayed by 2 hours in the morning; however, during the dry season feeding activity started earlier in the morning (Fig. 19). During the dry season, there was morning and late afternoon feeding peaks. However, there was only late afternoon feeding peak during the wet season. During the wet season, feeding time increased gradually step by step from morning to the next hours of the day. Feeding activity pattern in the early morning (0600–800 h) and late morning (0800–1000 h) showed significant differences between the wet and dry seasons (Table 14).

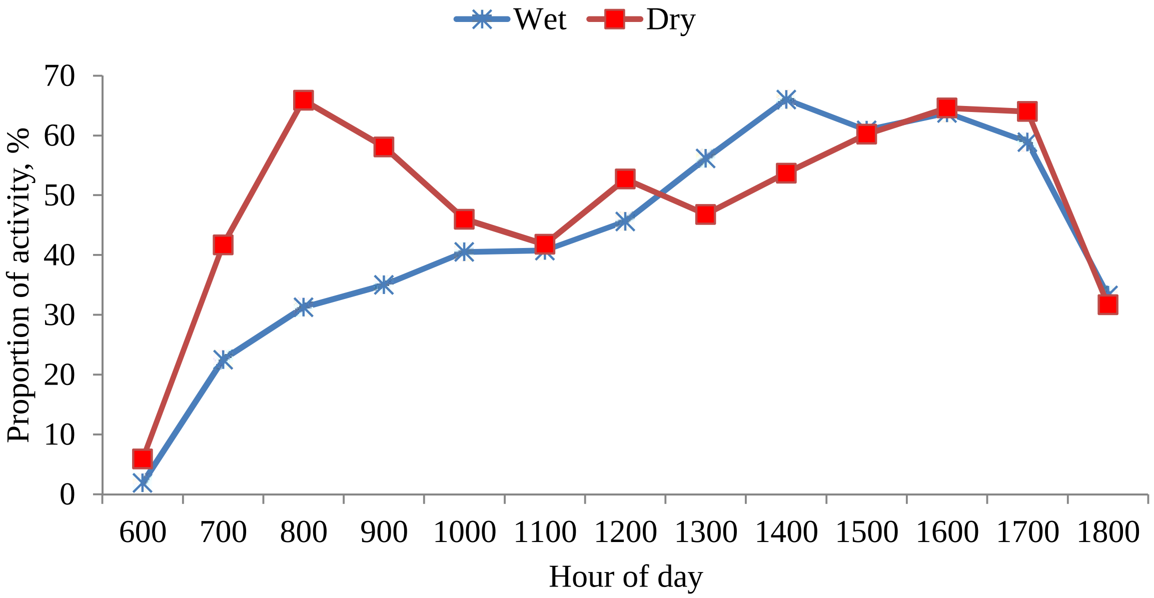

Figure 19. Feeding activity pattern during the dry and wet seasons for Selam band.

For Selam, grooming activity pattern showed variations in the morning during the wet and dry seasons (Fig. 20). During the wet season, there was grooming peak in the late morning; however, grooming reached its peak at midday during the dry season. During the dry season, short early morning grooming peak showed and declined dramatically in the late morning. Grooming activity showed significant difference between seasons during morning (Table 14).

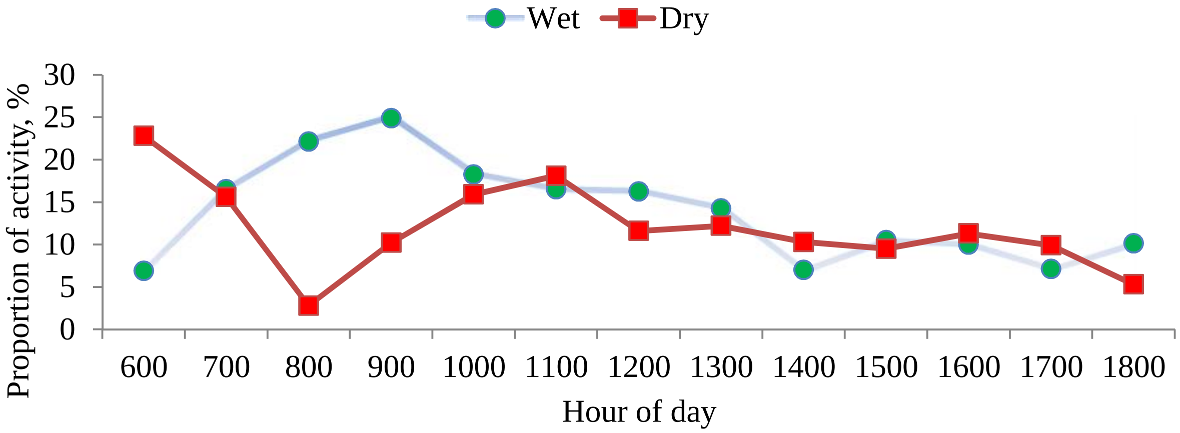

Figure 20. Grooming activity pattern during the dry and wet seasons for Selam band.

For Selam band, moving activity pattern was identical during the wet and dry seasons (Fig. 21). There were morning and late afternoon peaks during the dry and wet seasons. Although, seasonal moving pattern occurred in similar manner, the data revealed significant difference between the wet and dry seasons during early afternoon (1200–1400 h) of daylight hours (Table 14).

Resting activity pattern for Selam band showed variations in the morning during the wet and dry seasons (Fig. 22). During the wet season, there was moving peak in the late morning; however, during the dry season moving had 2 peaks in the early morning and midday. During the dry season, the short early morning moving peak declined dramatically during the late morning. After midday, moving pattern seemed identical during both the wet and dry seasons. Although, seasonal variations occurred in the morning session on activity pattern of resting, data showed no significant differences between the wet and dry seasons in any of the daylight hours (Table 14).

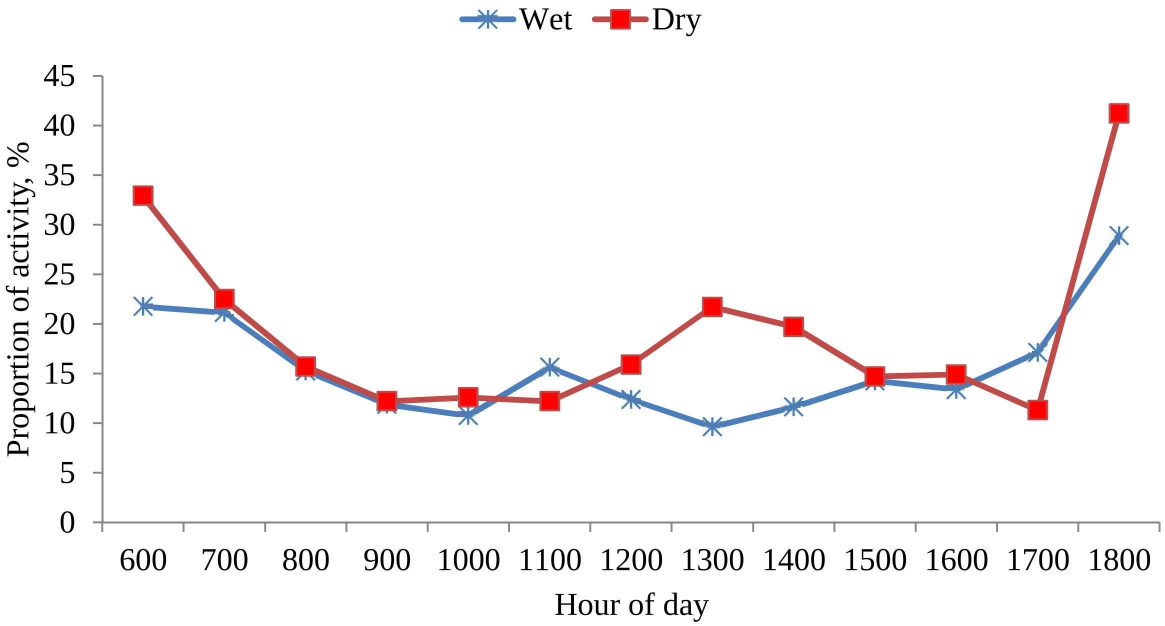

Figure 21. Moving activity pattern during the dry and wet seasons for Selam band.

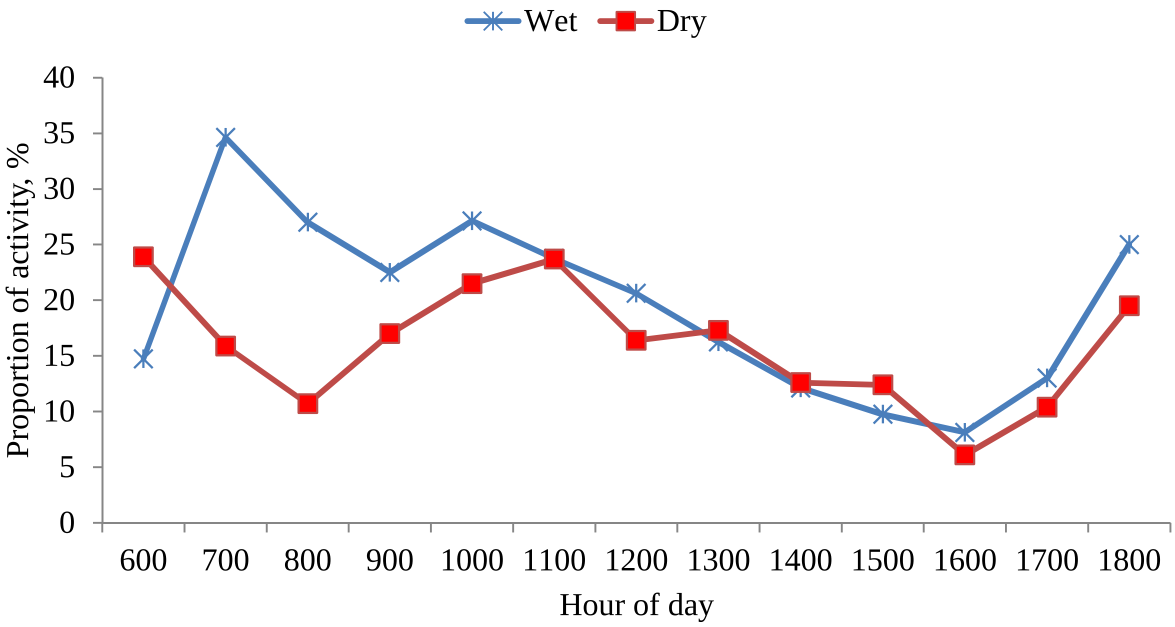

Figure 22. Resting activity pattern during the dry and wet seasons for Selam band.

Table 14. Seasonal variations in diurnal activity patterns via Kruskal–Wallis H test between the wet and dry seasons for Selam band.

Hours	Feeding		Moving		Resting		Grooming	
	H	p	H	p	H	p	H	p
0600-0800	6.88	0.009	2.85	0.091	1.78	0.183	0.24	0.625
0800-1000	6.64	0.010	0.20	0.656	3.33	0.068	4.18	0.041
1000-1200	0.87	0.350	0.51	0.476	0.24	0.625	1.05	0.306
1200-1400	2.42	0.120	6.91	0.009	0.24	0.625	0.02	0.894
1400-1600	0.02	0.840	0.39	0.534	1.33	0.248	1.05	0.305
1600-1800	0.10	0.756	1.35	0.246	0.64	0.423	0.02	0.894

For Tikure band, feeding activity pattern did not show any clear variation between the wet and dry seasons. For both the wet and dry seasons, there was a gradual increment of feeding activity starting from late morning (Fig. 23). This gradual increment of feeding pattern reached its peak point in the midafternoon hours. Feeding activity pattern did not show any significant difference between the wet and dry seasons throughout the daylight hours (Table 15).

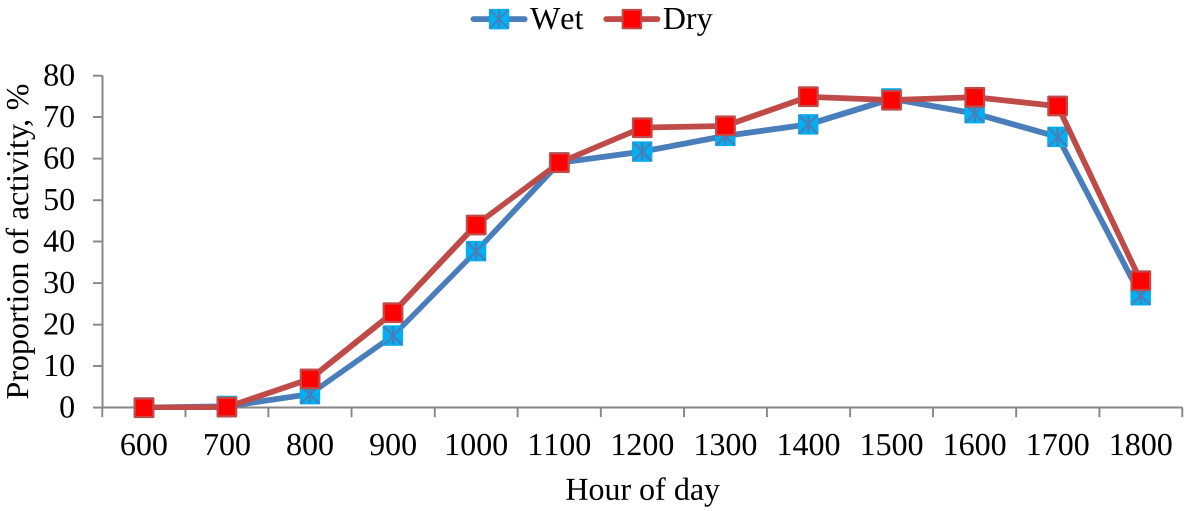

Figure 23. Feeding activity pattern during the dry and wet seasons for Tikure band.

Grooming activity pattern of Tikure band did not show any clear variations between the wet and dry seasons during the daylight hours (Fig. 24). For both the wet and dry seasons, there was morning grooming peaks, with reductions in grooming time after late morning throughout the midday and afternoon which reached lowest for grooming time. Grooming activity pattern did not show any significant difference between seasons throughout the day (Table 15).

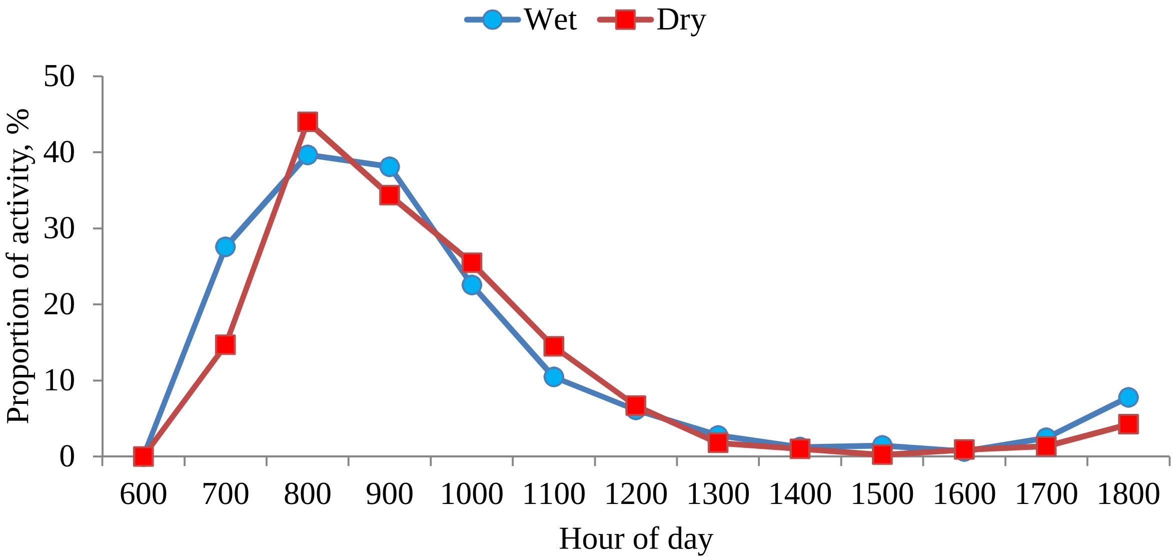

Figure 24. Grooming activity pattern during the dry and wet seasons for Tikure band.

For Tikure band, moving activity pattern was similar during the wet and dry seasons (Fig. 25). In both the dry and wet seasons, there were late afternoon moving peaks when the band returned back to sleeping cliff. Thus, for Tikure band, moving activity pattern did not differ significantly between the wet and dry seasons throughout the daylight hours (Table 15).

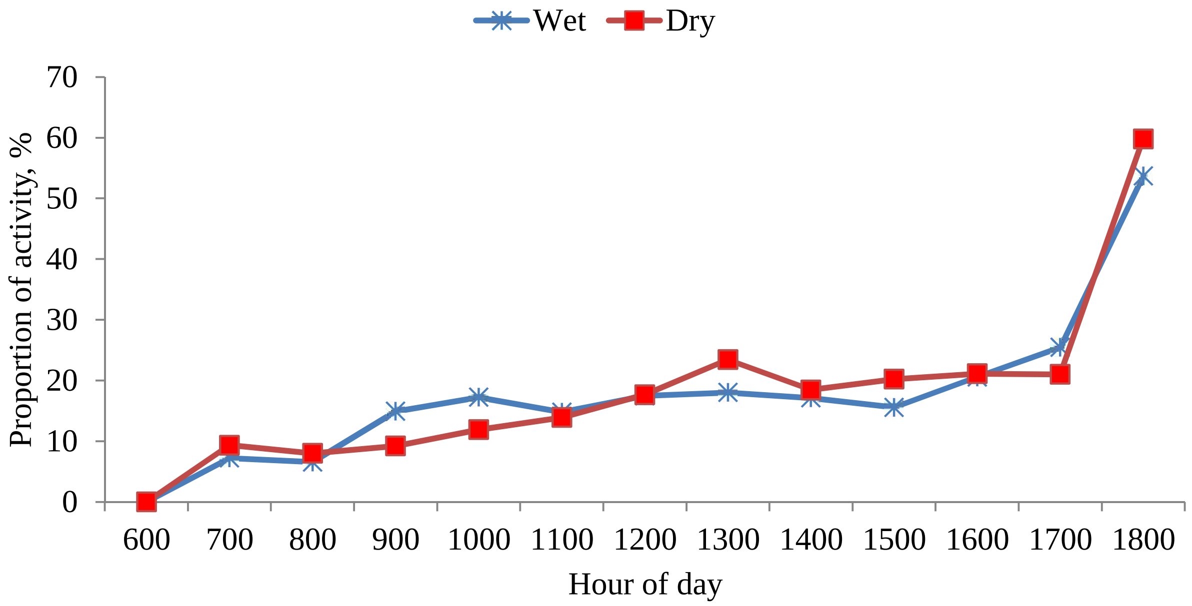

Figure 25. Moving activity pattern during the dry and wet seasons for Tikure band.

Resting activity pattern of Tikure band showed no clear seasonal variations during the wet and dry seasons (Fig. 26). For both the wet and dry seasons, there was morning grooming peaks, with reductions in resting time after late morning throughout the midday and afternoon which reached the lowest for grooming time. Although, seasonal resting pattern occurred in similar manner, the trend differed significantly between the wet and dry seasons in the early afternoon (1200–1400 h) and midafternoon (1400–1600h) of daylight hours (Table 15).

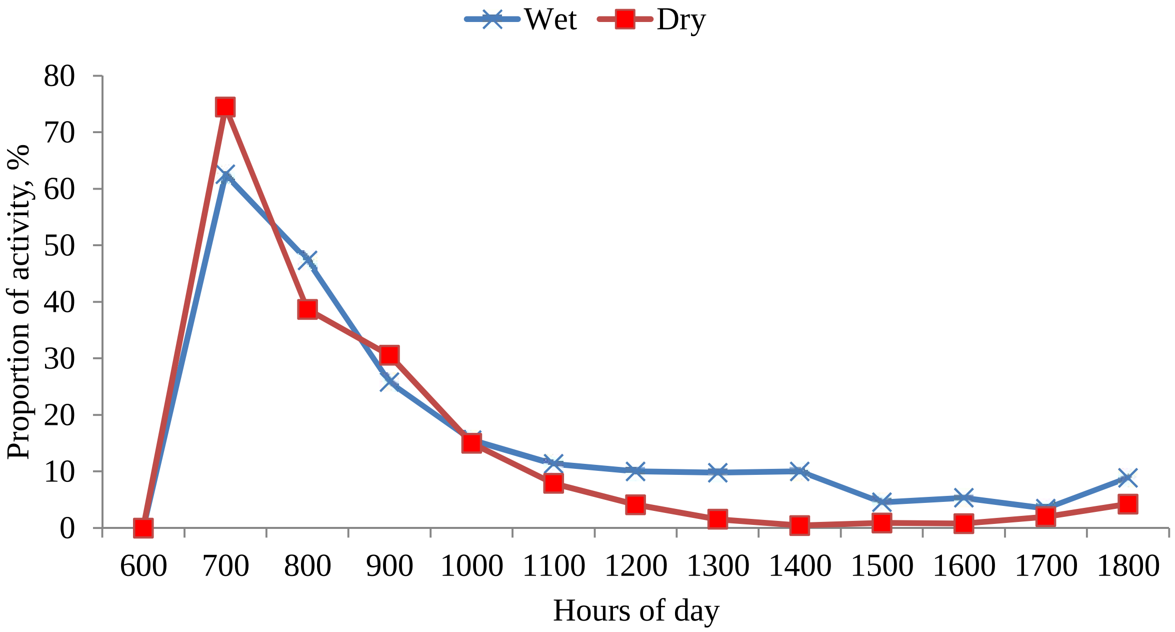

Figure 26. Resting activity pattern during the dry and wet seasons for Tikure band.

Table 15. Seasonal variations in diurnal main activity patterns using Kruskal–Wallis H test between the wet and dry seasons for Tikure band.

Hours	Feeding		Moving		Resting		Grooming	
	H	p	H	p	H	p	H	p
0600-0800	1.46	0.227	0.95	0.330	0.50	0.479	1.76	0.184
0800-1000	0.63	0.427	4.32	0.038	0.71	0.401	0.01	0.965
1000-1200	0.03	0.860	0.02	0.894	0.50	0.478	0.24	0.627
1200-1400	1.43	0.232	2.99	0.084	9.71	0.002	0.65	0.419
1400-1600	0.38	0.536	0.64	0.425	5.10	0.024	0.22	0.636
1600-1800	0.50	0.479	0.01	0.965	2.15	0.142	0.01	0.929

Comparative feeding activity pattern for study bands during the wet season is presented in Figure 27. For Selam band, feeding started in the early morning and increased in each hours of the day until it peaked late afternoon; while for Tikure band, it started during the late morning and increased exponentially until arriving its stable phase. For both bands feeding activity pattern was dominated starting from late morning until the band returned back to its sleeping cliffs. For both bands, feeding activity pattern decreased dramatically during the beginning of evening. Feeding activity pattern differed significantly between Selam and Tikure bands during the wet season in the early and late mornings (Table 16).

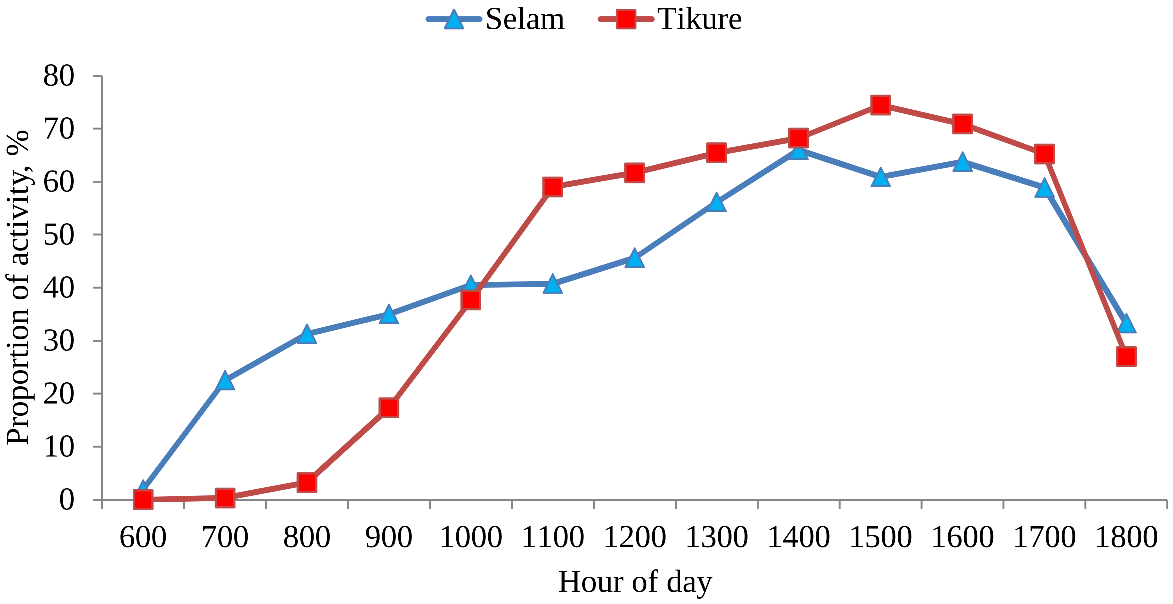

Figure 27. Distribution of feeding activity pattern between Selam and Tikure bands during the wet season.

Grooming activity pattern for Tikure band was dominated during the early and late morning and declined dramatically after that time onward during the wet season (Fig. 28). For Selam band, grooming activity pattern was also dominated during the early morning. However, it did not highly pick like Tikure band during the wet season. There was significant difference in the grooming activity pattern in the early morning (0600–0800 h) and late afternoon (1600–1800 h), however; there was no significant variation in the other daylight hours of the day (Table 16).

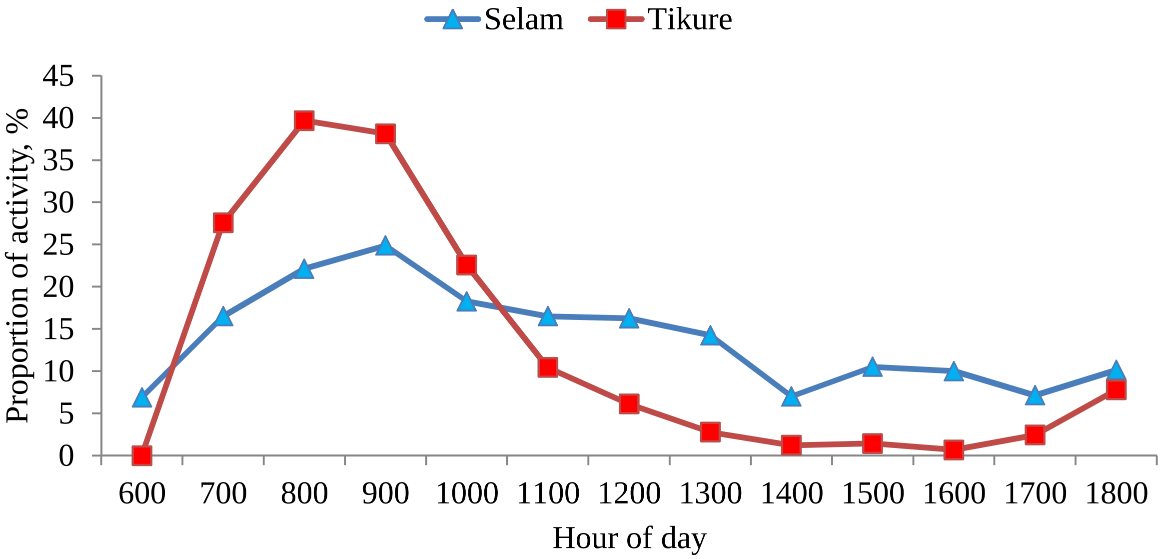

Figure 28. Distribution of grooming activity pattern between bands during the wet season.

During the wet season, the activity pattern of moving for Selam band was higher in the early morning compared to Tikure band (Fig 29). Contrary to this, the activity pattern of moving was greater during the late afternoon time hours. However, this activity showed similar manner for both Selam and Tikure bands in all the other daylight hours. There was significant difference in the moving activity pattern in different hours of the day, however; there was no significant difference in the midday and midafternoon during the wet season (Table 16).

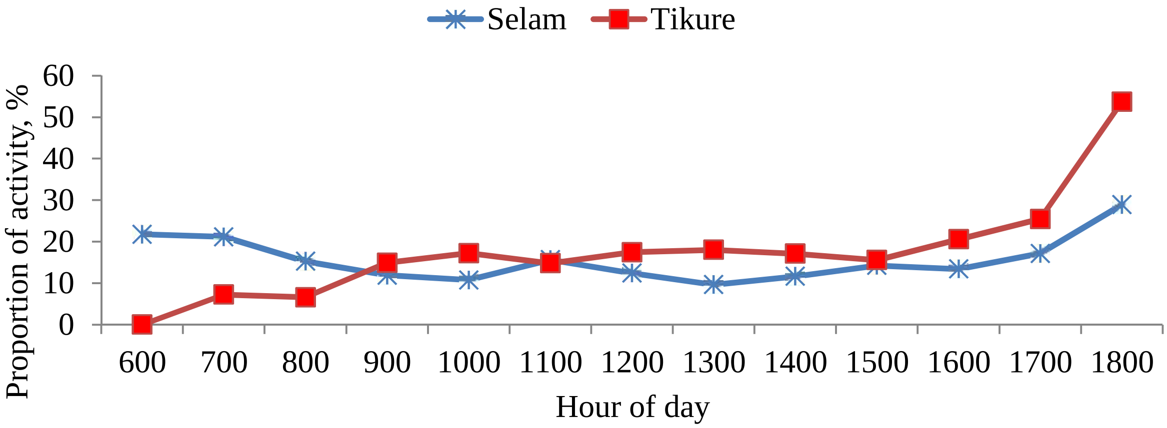

Figure 29. Distribution of moving activity pattern between bands during the wet season.

Resting activity pattern for Tikure band was dominated during the early and late morning and declined dramatically after that time onward of daylight hours during the wet season (Fig. 30). For Selam band, resting activity pattern was also dominated in the early morning. However, it was not highly picked as like as in Tikure band during the wet season. After late morning the resting pattern was more or less similar for both Selam and Tikure band during the wet season. There was a significant difference in the resting activity pattern in different hours of the day, however; there was no significant difference in the late afternoon (p = 0.060) of the wet season (Table 16).

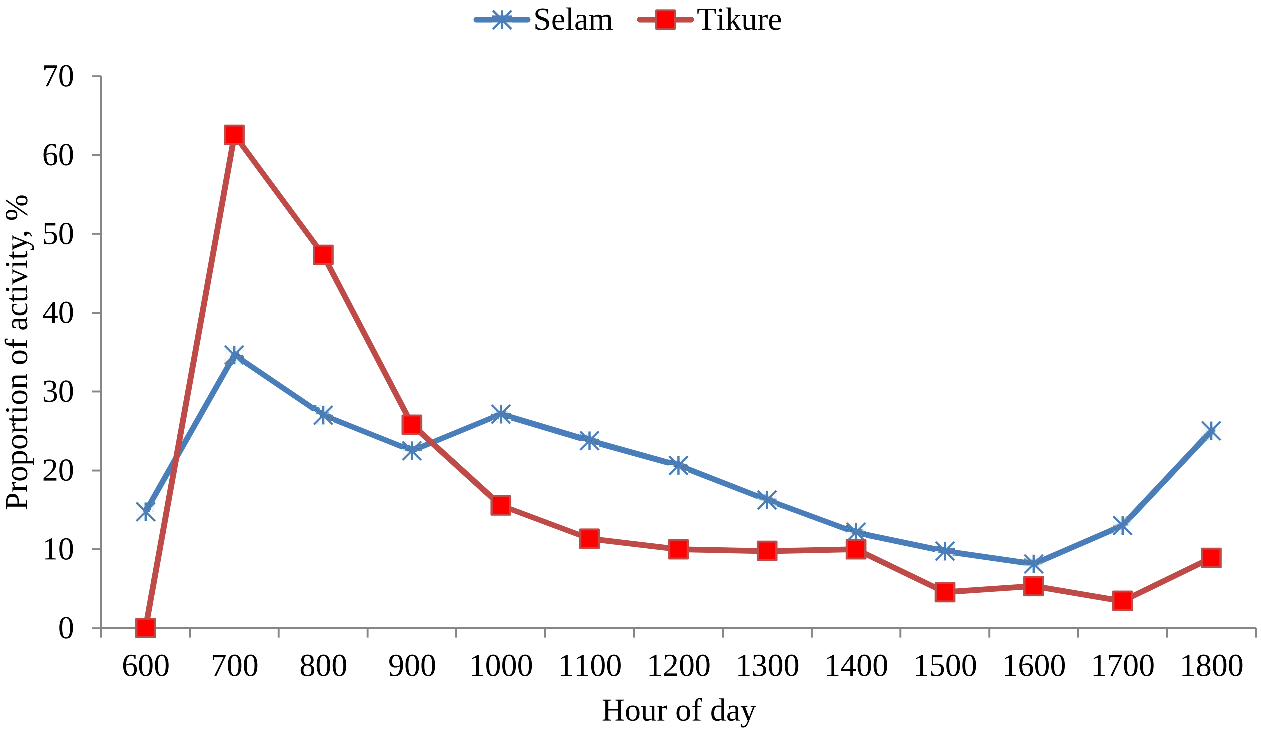

Figure 30. Distribution of resting activity pattern between Selam and Tikure bands during the wet season.

Table 16. Wet season comparison in diurnal activity pattern by Kruskal–Wallis test between Selam and Tikure bands.

Hour block	Feeding		Moving		Resting		Grooming	
	H	p	H	p	H	p	H	p
0600-0800	9.85	0.002	6.28	0.012	12.00	0.001	12.00	0.001
0800-1000	4.08	0.043	4.92	0.027	1.34	0.248	4.90	0.027
1000-1200	3.53	0.060	0.33	0.563	2.68	0.101	6.77	0.009
1200-1400	0.19	0.665	6.55	0.010	1.02	0.312	10.74	0.001
1400-1600	0.52	0.470	2.37	0.123	3.02	0.083	9.84	0.002
1600-1800	0.02	0.885	12.06	0.001	8.35	0.004	3.54	0.060

Comparative feeding activity pattern for study bands during the dry season is presented in Figure 31. For Selam band, feeding peak occurred during the early morning and declined during the late morning; while for Tikure band, it started in the late morning and increased exponentially until it reached its stable phase. For Tikure band, feeding activity pattern was more dominated than the feeding time of Selam band starting from midday until the bands returned back to their sleeping cliffs. For both bands, feeding activity pattern decreased dramatically before the evening time. Feeding activity pattern differed significantly between Selam and Tikure bands during the dry season throughout the daylight hours, except during the late afternoon (Table 17).

During the dry season, grooming activity pattern for Tikure band was dominated in the early and late morning and declined dramatically after that time onward of daylight hours (Fig. 32). However, for Selam band, the early morning grooming activity pattern had a very short duration. For Selam band, grooming increased again near the midday and became a constant activity in the afternoon time hours. However, after midday, grooming time for Tikure band reached almost at zero level. There was significant difference in the grooming activity pattern throughout the daylight hour except during the midday (10:00–12:00 h) (Table 17).

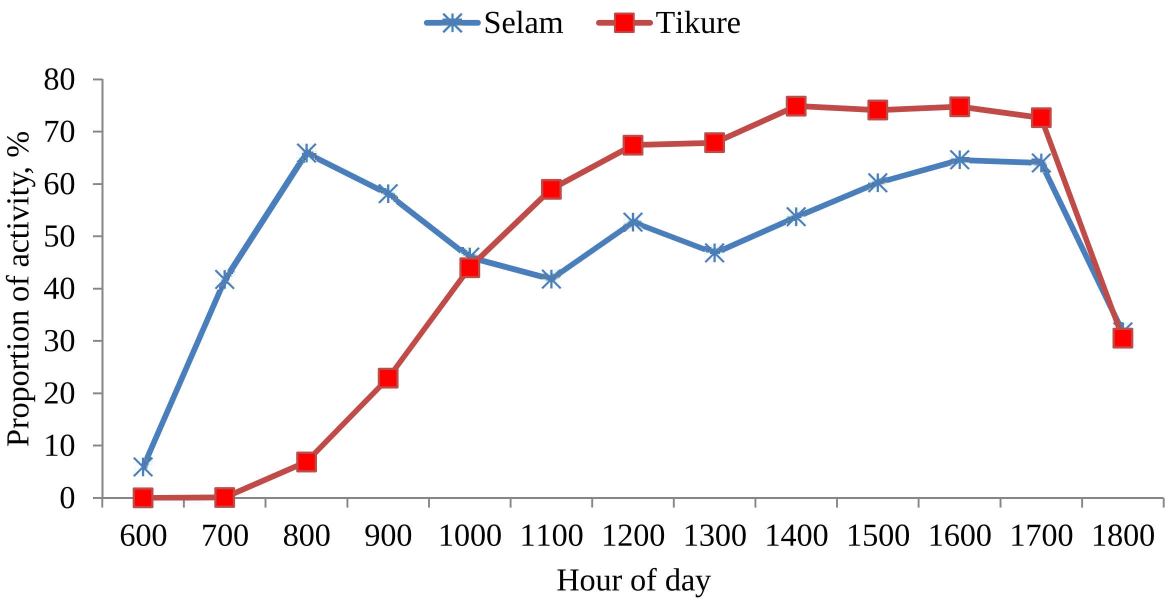

Figure 31. Distribution of feeding activity pattern between Selam and Tikure band during the dry season.

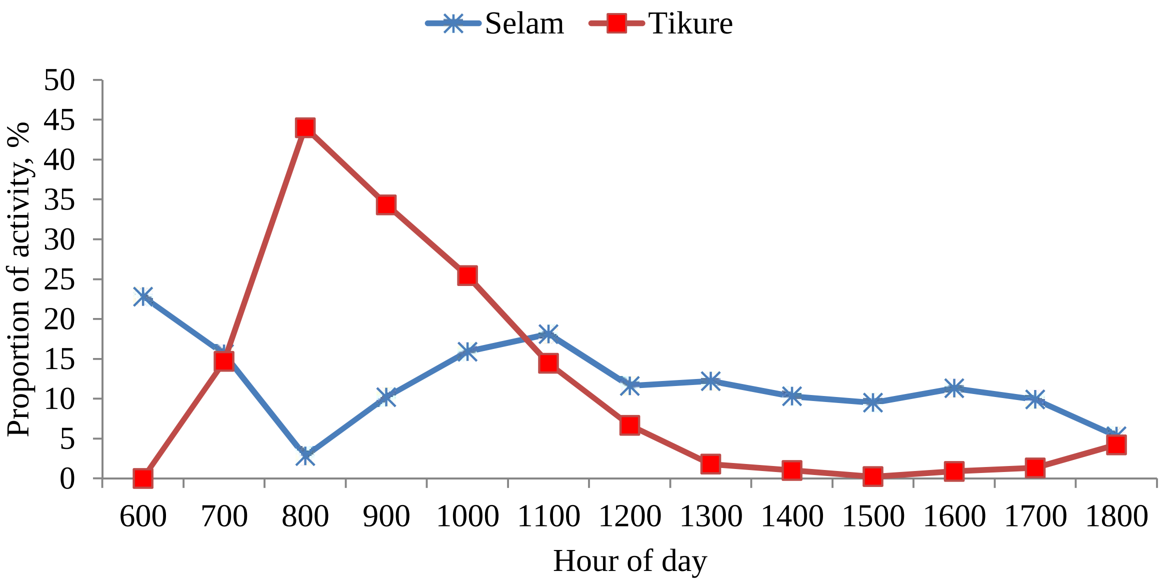

Figure 32. Distribution of grooming activity pattern between Selam and Tikure bands during the dry season.

During the dry season, the activity pattern of movement for Selam band was high during the early morning compared to Tikure band (Fig. 33). However, this activity showed similar pattern for both Selam and Tikure bands in all the other daylight hours. There was no significant difference in the moving activity pattern in different hours of the day. However, there were significant differences in the early, midafternoon and late afternoon daylight hours (Table 17).

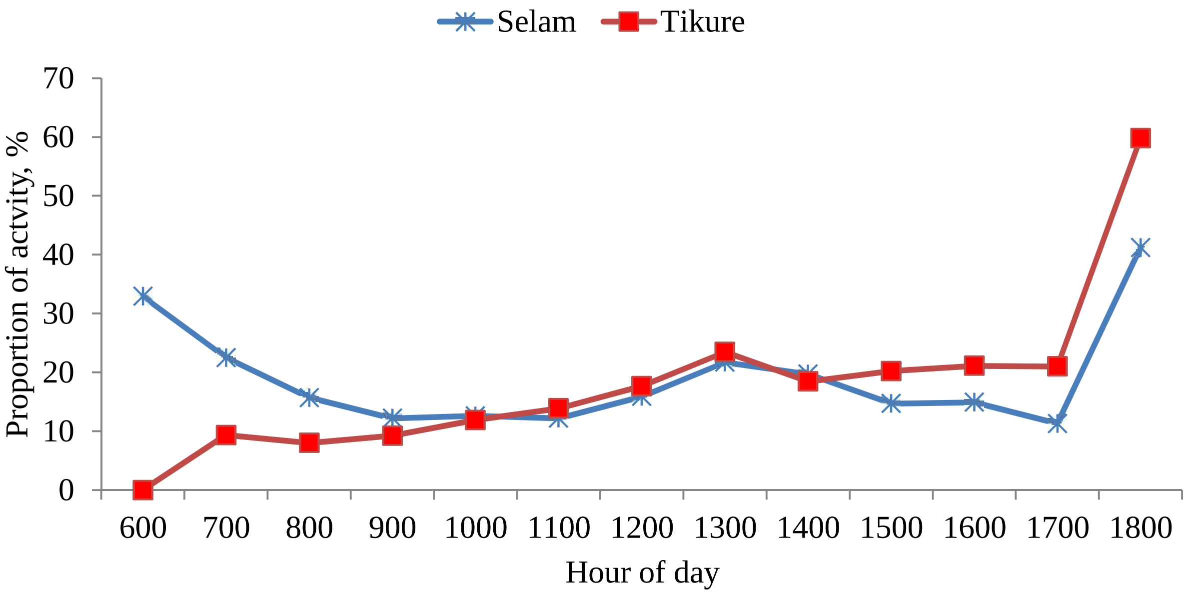

Figure 33. Distribution of movement pattern between Selam and Tikure bands during the dry season.

Resting activity pattern for Tikure band was dominated in the early and late morning and declined dramatically after that during the dry season (Fig. 34). However, for Selam band, resting activity pattern did not show any peaks, and it showed constant trend throughout the daylight hours. After late morning, the resting pattern reached zero level for Tikure band. There was significant difference in the resting activity in different hours of the day. However, there was no significant difference during the late morning (0800–1000) of the wet season (Table 17).

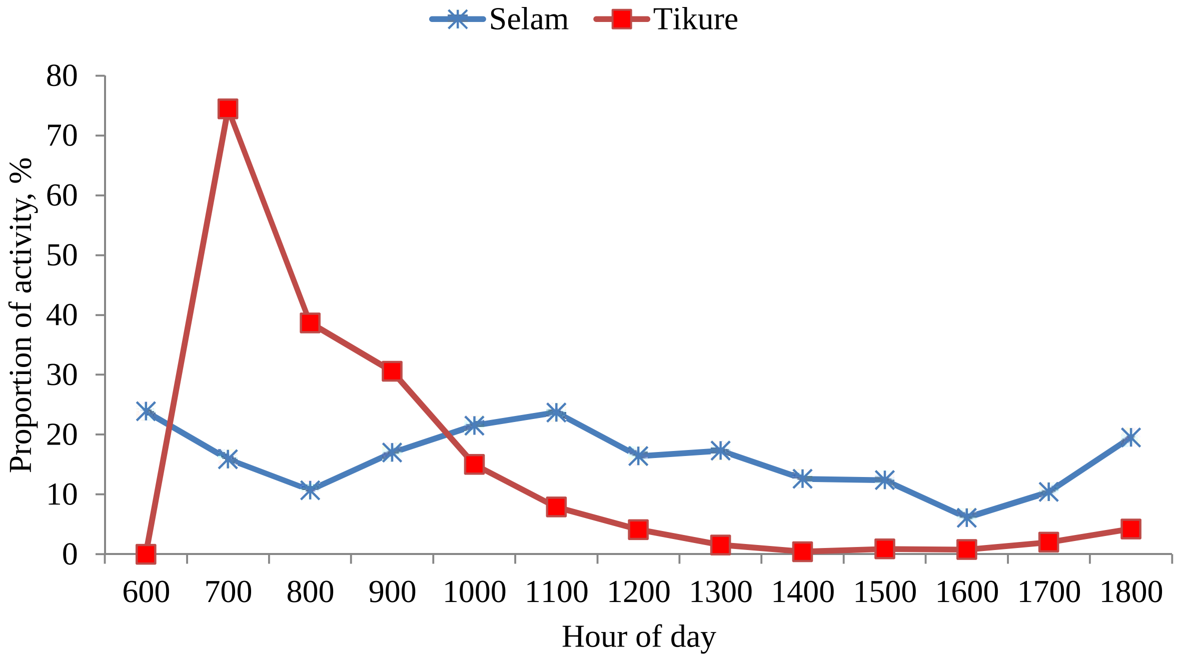

Figure 34. Distribution of resting activity pattern between Selam and Tikure bands during the dry season.

Table 17. Dry season comparison in diurnal activity pattern by Kruskal–Wallis test between Selam and Tikure bands.

Hour block	Feeding		Moving		Resting		Grooming	
	H	p	H	p	H	p	H	p
0600-0800	12.65	<0.001	12.03	0.001	12.65	<0.001	10.24	0.001
0800-1000	6.42	0.011	0.51	0.476	1.45	0.229	9.67	0.002
1000-1200	5.34	0.021	0.64	0.423	12.01	0.001	1.55	0.214
1200-1400	12.65	<0.001	0.13	0.722	12.78	<0.001	10.83	0.001
1400-1600	4.55	0.033	4.37	0.037	10.74	0.001	12.76	<0.001
1600-1800	0.88	0.350	9.43	0.002	7.93	0.005	6.22	0.013

4.3. Feeding ecology and diet

A total of 20,579 individual feeding scans were taken during the study period. Of these, 10,471 scans were recorded from Selam band and 10,108 from Tikure band. A total of 74 species of plants, 3 species of animals and 1 other (limestone) items were identified as food sources for

Selam band at Kosheme site during the study period (Table 18). Selam band included 34 species of grasses, 23 species of herbs, 7 species of shrubs, 5 species of trees and 5 species of cultivated cereal crops as food. The plant species were grouped into 19 families and 58 genera excluding one unidentified plant species. Selam band also consumed fruit of *Carissa spinarum* and *Rosa abyssinica* during phenological plot surveys but these were not observed during feeding scans. In addition, Selam band also consumed human leftovers such as masticated sugarcanes wherever they found. This was observed in the other days of the observation periods.

Tikure band consumed 36 species of plants and 4 species of animals during the observation periods (Table 19). The food of Tikure band was from 14 species of grasses, 18 species of herbs, 1 species of shrub and 3 species of cultivated cereal crops. Those plant species were grouped into 13 families and 25 genera. Geladas in BSNP also consumed the fruits of *Rubus* spp which was observed during population census survey.

For Selam band, grass species accounted for 79.57%, herbs 5.18%, trees 8.01%, shrubs 1.07%, animals 0.05%, cereal crops (cultivated) 5.59% and others 0.09%. For Tikure band, grass species accounted for 72.72%, herbs 25.02%, shrubs 0.22%, animals 1.49% and cereal crops (cultivated) 0.54%. Despite inhabiting the degraded habitat, Selam band consumed more diverse and variety of plant species; however, Tikure band had narrow niche breadth. Thus, Tikure band exhibited less dietary variation across the study months. Selam band also added more cereal crops in both amount and diversity into its food than Tikure band did by raiding the nearby farmlands. Both bands consumed selective plant parts on the basis of months and seasons.

From the total of 10,108 feeding records, the contribution of *Festuca* grasses (*Festuca abyssinica* and *Festuca macrophylla*) were only 2539 (25.12%) records even if they were the most dominant species within the home ranges of Tikure band. From the total records of of these

Festuca grasses, the corm part contributed 35.49%, blade 30.24% and seed 34.27%. The contribution of other grass species was 47.61% from the overall feeding records of the study period. Tikure band also consumed the root of *Haplosciadium abyssinicum* locally called “Shoteley” by digging the ground. The contribution of *H. abyssinicum* root was 5.30% from overall feeding records. During herb root feedings, individuals dug the ground carefully to uproot the whole part of the root, and usually cleaned the soil with their hands before consuming them.

Out of the total feeding records of Selam band, 674 feeding scores were recorded from fruits of fig trees. The contribution of fruits from *Ficus* spp was 6.44% from overall feeding scores. The band climbed those fig trees to reach those fruits. However, members of the band also fed on those dropdown fruits of the trees on the ground. *Ficus* spp occur in scattering pattern at Kosheme site, nonetheless, the band repeatedly visited these scattered tall trees everyday in the early morning during the fruiting months. Selam band travelled long distance from their sleeping site to consume these fruits. They often consumed the fruits for their early diet. However, there was no fig tree within the home range of Tikure band.

Both bands picked invertebrates from the substrate. Selam band licked the larvae of ants and termites. Individuals dislodged stones and licked those larvae, and picked termites and ants. On the other hand, Tikure band fed on caterpillars mostly from in-between *Lobelia rhynchopetalum* leaves and rarely from *Kniphofia foliosa*. They also captured and consumed flying ants from the air during the beginning of wet season when they were available during this period in the area.

Table 18. Food species included in the diet of Selam band (Habit: T=tree, S=shrub, H=herb, G=grass; Food item: B=grass blade, S=seed, P=pith, G=gum, C=corm, R=rhizome, I=invertebrate, F=flower, L=herb leaf, R=herb root, BU=bulb, FR=Fruit, SL=shrub leaf, RO=rock).

Family Species name	Vernacular name (Amharic)	Habit	Food item	Frequency (%)
Anacardaceae				
Rhus glutinosa	Embus	T	FR,P	0.58,0.29
Rhus vulgaris	Tatesa	T	FR	0.03
Anthericaceae				
Chlorophytum tuberosum	Yelam tuti	H	R	0.18
Chlorophytum spp.	Yelam tuti	H	R	0.05
Asteraceae				
Bidens pachyloma	Adey Abeba	H	F,L	0.34,0.50
Bidens ferulifolia	Adey Abeba	H	F,L	0.01,0.03
Echinops macrochaetus	Gendero	H	F	0.13
Galinsoga parviflora	Akenechera	H	L,F	0.10,0.03
Haplocarpha schimperi	Geten	H	L	0.04
Lactuca serriola	Kechekcehe	H	L	0.05
Laggera crispata	Alashume	S	SL,FR	0.02,0.04
Tagetes minuta	Yeferese zeng	H	L,F	0.07,0.01
Brassicaceae				
Erucastrum abyssinicum	Zerinit	H	L	0.23
Cactaceae				
Opuntia ficus-indica	Belese	S	SL	0.02
Chenopodiaceae				
Chenopodium ambrosioides	–	H	L	0.02
Commelinaceae				
Commelina benghalensis	Lalinch	H	L	0.19
Cypreae				
Cyperus rotundus	Engicha	G	B,C,S,R	0.94,0.30,0.04,0.32
Cyperus sesquiflorus	Engicha	G	B,C,S	0.51,0.01,0.01
Cyperus bulbosus	Yezenejoro kolo	G	B,BU	0.56,5.64
Lamiaceae				
Becium grandiflorum	Motishe	S	F	0.40
Plectranthus ornatus	Yezenjoro fese	H	L,F	0.83,0.33
Salvia tiliifolia	Yezenjoro zekakibe	H	L	0.05
Ebenaceae				
Euclea racemosa	Dedeho	S	FR	0.10
Fabaceae				

Acacia abyssinica	Girare	T	G,P,S	0.31,0.03,0.34
Medicago polymorpha	Wajima	H	L	0.30
Scorpiurus muricatus	Legelego	H	L	0.15
Trifolium docorum	Maget	H	L,F	0.26,0.03
Trifolium spp.	Maget	H	L	0.06
Cicer arietinum (cultivated)	Shembra	H	S	0.12
Lathyrus sativus (cultivated)	Goya	H	S,L	0.19,0.02
Vicia faba (cultivated)	Bakela	H	S	0.22
Geraniaceae				
Erodium moschatum	–	H	L,F	0.03,0.02
Malvaceae				
Sida schimperiana	Chiferege	S	F,SL	0.05,0.29
Hibiscus macranthus	–	S	F,SL	0.06,0.04
Moraceae				
Ficus sur	Shola	T	FR	0.46
Ficus sycomorus	Warka	T	FR	5.98
Plantaginacea				
Plantago lanceolata	Wortebe	H	L	0.14
Poaceae				
Andropogon abyssinicus	Balame	G	B,S	4.28,1.68
Andropogon distachyos	Gaja	G	B,S	0.54,0.02
Aristida purpurea	–	G	B,S	0.13,0.03
Bithriochloa insculpta	–	G	B,S,C	4.32,0.24,0.13
Bromus pectinatus	Gineche	G	B,S	0.06,0.04
Cynodon dactylon	Serido	G	B,S,R	18.48,1.30,2.83
Dactyloctenium aegyptium	–	G	B	0.02
Digitaria abyssinica	Warate	G	B,S,R	8.63,0.18,4.25
Echinochloa colona	–	G	B,S	0.22,0.07
Echinochloa spp.	Mochera	G	B,S	0.15,0.02
Eleusine floccifolia	Akirma	G	B,S,C	0.41,0.11,0.11
Eragrostis cilianensis	Yewof teff	G	B,S	0.06,0.05
Eragrostis tenuifolia	Yewof teff	G	B,S,C	2.89,0.31,0.34
Harpachne schimperi	–	G	B,S	1.06,0.13
Hyparrhenia rufa	Lema senebelit	G	B,S,C	3.35,0.05,0.24
Hyparrhenia hirta	Gomeche	G	B,C	0.15,0.03
Melinis repens	–	G	B	0.17
Oplismenus compositus	Yekok sare	G	B	0.06
Pennisetum clandestinum	Serido yemayabebe	G	B	0.17
Pennisetum mezianum	Yegedel sare	G	B,S	0.71,0.07
Pennisetum setaceum	Lisha sare	G	B,S,C	1.26,0.27,0.76
Pennisetum sphacelatum	Sebeze	G	B,C	0.21,0.02
Pennisetum villosum	Yejeb embosa	G	B,R	4.20,3.81
Polypogon interruptus	–	G	B,S	0.05,0.04

Setaria incrassata	–	G	B	0.24
Setaria pumila	Yewusha sindido	G	B,S	0.22,0.11
Snowdonia polystachya	Muja	G	B,S	0.85,0.54
Sporobolus africanus	Mura	G	B	0.02
Sporobolus piliferus	–	G	B,S	0.22,0.01
Themeda triandra	Genefel	G	B,S	0.06,0.02
Urochloa panicoides	Kilo	G	B,S	0.18,0.05
Triticum spp. (cultivated)	Sendie	G	B,S	0.32,4.50
Eragrostis tef (cultivated)	Teff	G	B,S	0.10,0.12
Polygonaceae				
Rumex nervosus	Enbocho	S	SL	0.05
Rubiaceae				
Galium spurium	Ashekete	H	L	0.33
Scrophulariaceae				
Striga gesnerioides	–	H	L,R	0.10,0.01
Unidenfiifed herb	Yewusha milase	H	L,R	0.53,0.06
Animals				
Formicidae				
Ant	Kuchache	–	I	0.35
Termite	Misit	–	I	0.07
Flying ant	Kermte agebe	–	I	0.08
Other				
-	Behika dengaye	–	RO	0.09

Table 19. Food species included in the diet of Tikure band (Habit: H=herb, S=shrub, G=grass; Food item: B=blade, L=herb leaf, R=herb root, S=stem, F=flower, FR=fruit, BU=bulb, I=invertebrate).

Family Species name	Vernacular name (Amharic)	Habit	Food item	Proportion, %
Apiaceae				
Haplosciadium abyssinicum	Shotelaye	H	L,R	0.65,5.30
Haplosciadium spp.	Shotelaye	H	L,R	0.24,0.58
Asphodelaceae				
Kniphofia foliosa	Ashengideye	H	S	0.32
Asteraceae				
Bidens pachyloma	Adey Abeba	H	F,L	0.03,0.03
Cotula cryptocephala	–	H	L,R	1.09,0.13
Haplocarpha schimperi	Geten	H	L,R	1.14,0.05
Taraxacum galeatum	–	H	L,R	0.44,0.10

Taraxacum spp.	–	H	L,F	0.54,0.02
Commelinaceae				
Cyanotis barbata	Chachet	H	L,R	0.25,0.40
Caryophyllaceae				
Uebelinia abyssinica	–	H	L,F	0.28,0.02
Cyperaceae				
Carex monostachya	Gugufitu	G	S	0.09
Carex petitiana	Fila	G	B,S,C	0.05,0.08,0.03
Carex conferta	Engecha	G	B,C	0.82,0.11
Fabaceae				
Trifolium acaule	Chemekote	H	L,F,R	9.79,0.52,0.10
Trifolium rueppellianum	Alema/maget	H	L	0.04
Trifolium spp.	Chemekote	H	L	0.17
Iridaceae				
Romulea rosea	Yeregna Kolo	H	L,BU	0.01,0.70
Lamiaceae				
Thymus schimperi	Tosign	H	L	0.43
Poaceae				
Aira caryophyllea	Laboche	G	B,S,C	4.39,0.04,0.26
Andropogon abyssinicus	Kara sare	G	B,S,R	12.72,0.06,0.33
Andropogon distachyos	Gaja	G	B	0.13
Eragrostis spp.	–	G	B,C	0.98,0.02
Festuca abyssinica	Leme	G	B,S,C	0.31,1.25,0.05
Festuca macrophylla	Ginchere	G	B,S,C	7.29,7.36,8.86
Festuca punctoria	Angedigide	G	B,S	0.44,0.05
Festuca versicolor	Angedigide	G	B,S	12.72,0.27
Pennisetum clandestinum	Serido yemayabibe	G	B	0.11
Pennisetum thunbergii	Yewesha sindo	G	B	0.51
Poa annua	Laboche	G	B,S,C	13.05,0.17,0.18
Avena abyssinica (cultivated)	Selalie	G	B	0.04
Hordeum vulgar (cultivated)	Gebese	G	B,S	0.05, 0.11
Triticum spp. (cultivated)	Sendie	G	S	0.35
Ranunculaceae				
Ranunculus oreophytus	Gudegn	H	L,R	0.13,0.01
Rosaceae				
Rosa abyssinica	Kega	S	FR	0.22
Alchemila pedata	Yemedere koso	H	L,R	1.45,0.01
Rubiaceae				
Galium asparinoides	Asheket	H	L	0.06
Animals				

Lepidoptera				
Caterpillar	Tile	–	I	1.34
Formicidae				
Ant	Gundane	–	I	0.09
Flying ant	Keremite Agibe	–	I	0.04
Termite	Misit	–	I	0.03

The top 15 most consumed plant species which accounted for about 82.22% of the overall diet for Selam band and about 93.65% for Tikure band is depicted in Tables 20 and 21, respecitively. For Selam band, out of the top 15 consumed plant species, *Cynodon dactylon* and

Table 20. Top 15 food species and percent cumulative contribution in the diet of Selam band (BL=grass blade, GS=grass seed, RH=grass rhizome, BU=bulb, CO=grass corm, SFR=tree fruit, PI=tree pith, HF=herb flower, HL=herb leaf).

Species	Part eaten contribution, %									Contribution,%
	BL	GS	RH	CO	BU	FR	PI	HL	HF	
Cynodon dactylon	18.48	1.30	2.83	0.00	0.00	–	–	–	–	22.61
Digitaria abyssinica	8.63	0.18	4.25	0.00	0.00	–	–	–	–	13.06
Pennisetum villosum	4.20	0.00	3.81	0.00	0.00	–	–	–	–	8.01
Cyperus bulbosus	0.56	0.00	0.00	0.00	5.64	–	–	–	–	6.21
Ficus sycomorus	–	–	–	–	–	5.98	–	–	–	5.98
Andropogon abyssinicus	4.28	1.68	0.00	0.00	0.00	–	–	–	–	5.96
Bithriochloa insculpta	4.32	0.24	0.00	0.13	0.00	–	–	–	–	4.69
Hyparrhenia rufa	3.35	0.05	0.00	0.24	0.00	–	–	–	–	3.64
Eragrostis tenuifolia	2.89	0.31	0.00	0.34	0.00	–	–	–	–	3.54
Pennisetum setaceum	1.26	0.27	0.00	0.76	0.00	–	–	–	–	2.29
Cyperus rotundus	0.96	0.04	0.32	0.30	0.00	–	–	–	–	1.61
Snowdonia polystachya	0.85	0.54	0.00	0.00	0.00	–	–	–	–	1.39
Harpachne schimperi	1.06	0.13	0.00	0.00	0.00	–	–	–	–	1.19
Plectranthus ornatus	–	–	–	–	–	–	–	0.83	0.33	1.17
Rhus glutinosa	–	–	–	–	–	0.58	0.29	–	–	0.87
Total										82.22

Digitaria abyssinica accounted for 22.61% and 13.06%, respectively, whereas *Pennisetum villosum*, *Cyperus bulbosus* and *Ficus sycomorus* ranked third, fourth and fifth during the study period. For Tikure band, *Festuca macrophylla* and *Poa annua* accounted for 23.52% and 13.40%, respectively, and *Andropogon abyssinicus, Festuca versicolor* and *Trifolium acaule* were third, fourth and fifth from the top five during the study period. The top 15 plant species differed between the two bands.

Table 21. Top 15 food species included and percent cumulative contribution in the diet of Tikure band (BL: grass blade, GS: grass seed, RH: grass rhizome, CO: grass corm, HF: herb flower, HL: herb leaf, HR: herb root, BU: bulb, AN: animal).

Species	Part eaten contribution, %								Contribution,%
	BL	GS	CO	RH	HL	HF	HR	AN	
Festuca macrophylla	7.29	7.36	8.86	0.00	–	–	–	–	23.52
Poa annua	13.05	0.17	0.18	0.00	–	–	–	–	13.40
Andropogon abyssinicus	12.72	0.06	0.00	0.33	–	–	–	–	13.11
Festuca versicolor	12.72	0.27	0.00	0.00	–	–	–	–	12.99
Trifolium acaule	–	–	–	–	9.79	0.52	0.10	–	10.42
Haplosciadium abyssinicum	–	–	–	–	0.65	0.00	5.30	–	5.96
Aira caryophyllea	4.39	0.04	0.26	0.00	–	–	–	–	4.69
Festuca abyssinica	0.31	1.25	0.05	0.00	–	–	–	–	1.60
Alchemila pedata	–	–	–	–	1.45	0.00	0.01	–	1.46
Caterpillar (Inv.)	–	–	–	–	–	–	–	1.34	1.34
Cotula cryptocephala	–	–	–	–	1.09	0.00	0.13	–	1.22
Haplocarpha schimperi	–	–	–	–	1.14	0.00	0.05	–	1.19
Eragrostis spp.	0.98	0.00	0.02	0.00	–	–	–	–	1.00
Carex conferta	0.82	0.00	0.11	0.00	–	–	–	–	0.93
Haplosciadium spp.	–	–	–	–	0.24	0.00	0.58	–	0.82
Total									93.65

Sørensen's coefficient of community did not show strong similarities in the food species between the two bands. Thus, the similarities of food species of the two bands overlapped very weakly (Sørensen's index/coefficient = 0.19). That is 18.80% of the food species commonly shared by the two bands. Only 11 species were shared between Selam and Tikure bands from the overall species. All the other species were consumed exclusively by Selam (66 species) and Tikure (29 species) bands. In addition, only one species (*Andropogon abyssinicus*) was shared by the two bands from the top 15 consumed food species.

Monthly diet: Southern geladas exhibited wide variability in their diet both at temporal and spatial patterns. The percentage of time the southern geladas at Kosheme devoted to feeding on different plants and their parts varied across sampling months (Table 22). Grass blades constituted the bulk of Selam band's diet throughout the study months. The monthly proportion of consumption of grass blades ranged from 21.39% in January 2017 to 97.46% in May 2015. Selam band at Kosheme also devoted its feeding time for rhizomes 0.00–36.25 %, seeds 0.00–47.28%, corms 0.00–8.72% and bulbs 0.00–28.66% in monthly proportion of the diet consumptions. Monthly proportion of grass seeds reached maximum level in September (2016/17), rhizome in February and April and bulbs in October over the study period. Selam band also consumed considerable amount of food items from tree and bush parts, fruits ranging from 0.00–29.64%, seeds 0.00–2.96%, flowers 0.00–2.75% and piths 0.00–1.84% in the monthly proportion of consumption. Selam band consumed the ripe fruit of fig trees specially from *Ficus sycomorus* species for 7 consecutive study months. The maximum consumption of fruits from trees was in December 2016 and January 2017 and seeds in April 2016 and March 2017. From the herb parts, monthly proportion of leaves in the diet for Selam band ranged from 0.47–11.55%, flowers 0.00–11.35% and roots 0.00–1.55% during the study period. In addition, geladas at Kosheme added considerable amount of crops (0.00–41.53%) maximum in July 2015 and November 2016 and some invertebrates (0.00–3.35%) maximum in July 2016 in their monthly diet consumption. The maximum consumption of crops was at the time of sawing and harvesting months of the year. Occasionally, Selam band fed on limestones, possibly for mineral intake.

The percentage of time that Tikure band devoted to feeding on different plant parts was similar across sampling months. Grasses constituted the bulk of Tikure’s monthly diet throughout the study months (Table 23). Monthly proportion of grass blades in the diet ranged from 15.34% in January 2017 to 85.65% in June 2015. Tikure band also devoted their feeding time for different grass parts: rhizomes 0.00–5.34 %, seed 0.00–38.40% and corms 0.00–50.34% in monthly proportion of diet consumption. Seed consumption from grasses reached its maximum level in October and November 2016, and corm in April and January 2017 of the study months. Tikure also consumed considerable amount of food items from herb parts, leaves ranging from 8.62–29.57%, roots 1.27–13.29%, flowers 0.00–3.75% and bulbs 0.00–2.50% in the monthly proportion of consumptions. In addition, geladas at Keywasha added considerable amount of invertebrates 0.16–4.08% and few crops 0.00–3.28% in their monthly diet. The maximum consumption of invertebrates was recorded in April and the minimum in September 2016.

Geladas at Keywasha added small amount of fruits ranging from 0.00–2.85% from shrubs in their monthly consumption. The fruit consumption was recorded in June 2015 and May 2016 from *Rosa abyssinica*. Geladas at Keywasha did not include any tree parts in their diet during the course of the study period.

Table 22. Monthly plant part contribution for southern geladas at Kosheme from May 2015–March 2017.

Month	N	Monthly contribution, %												
		Grass					Herb			Tree/Shrub				
		BL	RH	CO	SE	BU	HL	HF	HR	SFR	TSA	CR	IN	OA
May 2015	512	97.46	0.00	0.00	0.00	0.00	2.15	0.00	0.00	0.00	0.39	0.00	0.00	0.00
Jun 2015	457	92.78	0.00	0.00	0.00	0.00	6.13	0.00	0.00	0.00	0.66	0.00	0.44	0.00
Jul 2015	420	63.81	0.00	0.00	0.00	0.00	1.43	0.00	0.00	0.00	0.00	33.81	0.95	0.00
Aug 2015	528	72.54	0.00	0.00	0.00	7.20	11.55	0.00	0.00	0.00	1.90	5.87	0.95	0.00
Sep 2015	497	33.80	0.00	0.00	47.28	4.83	10.26	2.82	0.00	0.00	0.80	0.00	0.20	0.00
Oct 2015	663	42.38	7.09	0.30	10.71	28.66	7.09	0.15	0.00	0.00	1.81	1.36	0.45	0.00
Nov 2015	496	43.95	3.23	0.20	3.63	0.00	4.44	1.21	0.00	0.60	1.00	41.53	0.20	0.00
Dec 2015	639	56.96	2.97	0.78	0.00	3.91	0.47	0.00	0.00	29.11	0.32	5.16	0.31	0.00
Jan 2016	544	49.26	19.12	0.37	0.74	5.70	3.68	0.00	0.00	17.46	3.68	0.00	0.00	0.00
Feb 2016	665	39.55	35.34	8.72	0.00	13.23	1.95	0.00	0.45	0.15	0.45	0.00	0.15	0.00
Mar 2016	671	76.15	15.65	1.94	0.00	2.98	0.75	0.00	0.30	0.60	1.34	0.00	0.30	0.00
Apr 2016	709	30.18	36.25	6.35	0.00	11.28	1.83	0.00	1.55	7.33	4.66	0.00	0.56	0.00
May 2016	691	86.25	0.00	0.00	0.00	0.72	3.62	0.00	0.14	5.07	3.62	0.00	0.29	0.29
Jul 2016	627	86.76	0.00	0.00	0.48	0.00	5.42	0.00	0.00	0.00	2.40	1.12	3.35	0.48
Sep 2016	564	39.89	0.00	0.00	38.30	0.89	6.03	11.35	0.00	0.00	2.66	0.71	0.18	0.00
Nov 2016	617	42.46	11.99	0.97	2.59	4.21	2.43	1.46	0.81	19.29	0.98	12.48	0.00	0.32
Jan 2017	533	21.39	25.52	3.75	0.00	1.88	2.44	0.00	0.38	29.64	0.76	14.26	0.00	0.00
Mar 2017	638	31.19	28.37	7.99	0.00	7.68	2.35	0.16	1.10	15.52	4.86	0.00	0.47	0.31

Key: BL=blade; RH=rhizome, SE=seed, CO=corm, BU=bulb, HR=herb root, HF=herb flower, HL=herb leave, SFR=fruit, TSA=other part of tree and shrub includes piths, leaves, seeds, flowers and gums, CR: crop (cultivated), IN: invertebrate, OA: other. N=number of records. No=number of species.

Table 23. Monthly plant part contribution for southern geladas at Keywasha from May 2015–March 2017.

Month	N	Monthly contribution, %										
		Grass				Herb				Shrub		
		BL	RH	CO	SE	HL	HF	HR	BU	SF	CR	IN
May 2015	541	62.85	0.00	0.00	0.00	27.36	0.00	7.02	0.00	0.00	0.00	2.77
Jun 2015	474	85.65	0.00	0.00	0.00	8.86	0.00	1.27	0.00	1.27	0.00	2.95
Jul 2015	487	62.83	0.00	0.21	0.00	29.57	0.00	5.95	0.00	0.00	0.00	1.44
Aug 2015	518	75.48	0.00	0.00	0.00	22.20	0.00	1.93	0.00	0.00	0.00	0.39
Sep 2015	565	52.57	0.00	0.00	23.89	18.41	0.71	3.72	0.35	0.00	0.00	0.35
Oct 2015	586	35.15	0.00	0.00	38.40	16.89	3.75	4.78	0.68	0.00	0.34	0.00
Nov 2015	572	44.76	0.00	0.00	28.50	20.28	0.35	4.90	0.70	0.00	0.17	0.35
Dec 2015	519	58.96	0.00	1.93	3.08	17.34	0.58	13.29	2.50	0.00	0.39	1.93
Jan 2016	604	58.94	0.00	9.93	2.32	19.37	0.83	4.97	1.49	0.00	1.66	0.50
Feb 2016	661	42.97	0.00	25.57	0.76	15.73	0.00	9.98	2.42	0.00	0.76	1.82
Mar 2016	626	47.44	0.00	24.28	0.16	14.38	0.16	11.18	0.32	0.00	0.00	2.08
Apr 2016	539	43.04	0.00	30.80	1.67	10.02	0.00	10.20	0.19	0.00	0.00	4.08
May 2016	561	69.16	0.00	0.00	0.00	20.32	0.36	3.39	0.00	2.85	2.50	1.43
Jul 2016	506	79.64	0.00	0.00	0.40	15.42	0.00	3.56	0.00	0.00	0.00	0.99
Sep 2016	617	55.92	0.00	0.00	26.74	11.51	1.30	2.92	1.13	0.00	0.32	0.16
Nov 2016	595	35.29	0.00	5.88	33.28	15.63	2.18	6.39	1.01	0.00	0.00	0.34
Jan 2017	580	15.34	5.34	50.34	1.90	8.62	0.00	10.86	1.21	0.00	3.28	3.10
Mar 2017	557	53.68	0.36	13.64	0.36	16.88	0.00	12.39	0.00	0.00	0.00	2.69

Key: BL=blade; RH=rhizome, SE=seed, CO=corm, HR=herb root, HF=herb flower, HL=herb leave, BU=bulb, SF=shrub fruit, CR=crop, IN=invertebrate. N=total number of feeding records. No=number of species eaten in each month.

During the 18 months when Selam band consumed heavily on grass blades, there was reduction in consumption of underground grasses, grass seeds, bulbs, fruits and herb roots. Grass blade consumption was significant and negatively correlated with monthly underground grass item (Spearman rank correlation: $r_s = -0.641$, $p = 0.004$) and herb root ($r_s = -0.618$, $p = 0.006$) consumption (Table 24). Similarly, monthly herb aboveground consumption was significant and negatively correlated with monthly fruit ($r_s = -0.489$, $p = 0.039$) consumption. However, monthly underground grass consumption was significant and positively correlated with monthly bulb ($r_s = 0.653$, $p = 0.003$), herb root ($r_s = 0.741$, $p < 0.001$) and fruit ($r_s = 0.680$, $p = 0.002$) consumption. Similarly, monthly grass seed consumption was significant and positively correlated with monthly aboveground herbs ($r_s = 0.705$, $p = 0.001$) and herb roots with monthly fruit ($r_s = 0.595$, $p = 0.009$) consumption for Selam band.

Table 24. Relationship between percent of different monthly diet item consumption for Selam band.

Food items		Grass (underground)	Grass Seeds	Bulbs	Herbs (above-ground)	Herb roots	Fruits	Crops
Blades	r_s	–0.641	–0.243	–0.618	–0.038	–0.518	–0.407	–0.083
	p	0.004	0.331	0.006	0.880	0.028	0.093	0.744
Grass (underground)	r_s		–0.204	0.653	0.466	0.741	0.680	–0.153
	p		0.417	0.003	0.051	<0.001	0.002	0.543
Grass Seeds	r_s			0.063	0.705	–0.375	–0.235	0.187
	p			0.804	0.001	0.125	0.348	0.458
Bulbs	r_s				0.003	0.438	0.247	–0.248
	p				0.990	0.069	0.324	0.320
Herbs (aboveground)	r_s					–0.431	–0.489	0.092
	p					0.074	0.039	0.718
Herb roots	r_s						0.595	–0.240
	p						0.009	0.338
Fruits	r_s							0.084
	p							0.740

During the 18 months when Tikure band fed heavily on grass blades, the band reduced its consumption of underground grasses and herb roots. Similarly, when Tikure band heavily fed on grass seeds, it reduced the consumption of grass blades and invertebrates. Within the 18 month periods, grass blade consumption was significant and negatively correlated with monthly underground grass item (Spearman rank correlation: r_s = -0.563, p = 0.015), grass seeds (r_s = -0.679, p = 0.002) and herb root (r_s = -0.498, p = 0.035) consumption (Table 25). In addition, monthly underground grass consumption was significant and negatively correlated with monthly herb aboveground (r_s = -0.469, p = 0.050). However, monthly underground grass consumption was significant and positively correlated with monthly herb root (r_s = 0.786, $p < 0.001$) and invertebrate (r_s = 0.537, p = 0.022) consumption. Similarly, monthly herb root consumption was significant and positively correlated with monthly invertebrate consumption.

Table 25. Relationship between percent of different monthly diet item consumption for Tikure band.

Food item		Grass (underground)	Grass seeds	Herbs (above-ground)	Herb roots	Invertebrates
Blades	r_s	-0.563	-0.679	0.269	-0.498	0.110
	p	0.015	0.002	0.280	0.035	0.663
Grass (underground)	r_s		0.052	-0.469	0.786	0.537
	p		0.837	0.050	<0.001	0.022
Grass seeds	r_s			-0.170	0.107	-0.577
	p			0.500	0.671	0.012
Herbs (aboveground)	r_s				-0.176	-0.398
	p				0.484	0.102
Herb roots	r_s					0.503
	p					0.033

Seasonal variation of diet: Selam band consumed more plant species during the wet season (range: 21–46) than the dry season (range: 21–33), and the difference was statistically significant ($F_{1,16}$ = 7.11, p = 0.017). Tikure band consumed more or less similar species in both the wet and dry seasons, and the difference was not statistically significant across seasons ($F_{1,16}$ = 0.14, p = 0.718). A comparison across sites revealed that Selam band consumed more number of plant species than Tikure band both during the wet and dry seasons, and the difference was statistically significant in both seasons (wet: H = 6.34, p = 1, p = 0.012; dry: $F_{1,15}$ = 6.80, p = 0.018). Overall comparison across sites also revealed that the number of species consumed by Selam band was statistically more significant than Tikure band (H = 11.00, df = 1, p = 0.001).

Diet of Selam band at Kosheme varied markedly across the two seasons (Table 26). Seed consumption from *Acacia* trees and shrub flowers from *Sida schimperiana* were recorded only during the dry season. Selam band at Kosheme consumed more grass parts during the wet season than the dry season, however; the difference was not significant between the seasons ($F_{1,16}$ = 1.91, P = 0.186). Selam band also consumed more herb parts during the wet season than the dry season, however; the difference was not significant between seasons (H = 1.78, df = 1, p = 0.183). Similarly, there was no significant difference in shrub part diet between the wet and dry seasons ($F_{1,16}$ = 1.07, p = 0.315). Crop parts accounted for 4.28% of the wet season diet and 6.49% of the dry season and the difference was not significant (H = 0.14, df = 1, p = 0.704). Tree parts accounted for 12.94% and 0.93% of the wet and dry seasons diet, respectively, and the difference was significant (H = 8.63, df = 1, p = 0.003).

Grass blades accounted for a significantly greater proportion of the diet for Selam band during the wet season than the dry season ($F_{1,16}$ = 9.23, p = 0.008). There was no contribution of rhizome and corm diet items during the wet season. Similarly, bulbs comprised 1.68% of the wet and 8.40% of the dry seasons, and the difference was significant (H = 5.04, df = 1, p = 0.025). Herb leaves contributed 5.82% of the wet season and 2.69% of the dry season for Selam band, and the difference was significant between seasons ($F_{1,16}$ = 5.44, p = 0.033). Fruits of trees and shrubs accounted for 0.81% of the wet season diet and 11.62% of the dry season.

Table 26. Seasonal dietary variation for both Selam and Tikure bands.

Food category and item	Seasonal diet items contribution, %			
	Wet season		Dry season	
	Selam	Tikure	Selam	Tikure
Grasses	84.57	74.36	76.10	71.23
Blades	72.32	63.48	43.63	44.34
Seeds	10.57	10.85	1.77	7.98
Rhizomes	0.00	0.00	19.01	0.63
Corms	0.00	0.02	3.29	18.28
Bulbs	1.68	–	8.40	–
Herbs	7.66	23.71	3.45	26.23
Leaves	5.82	18.85	2.69	15.38
Roots	0.02	3.85	0.49	9.29
Flowers	1.82	0.74	0.28	0.46
bulbs	0.00	0.27	0.00	1.10
Trees	0.93	–	12.94	–
Fruits	0.76	–	11.42	–
Pith	0.05	–	0.50	–
Seeds	0.00	–	0.58	–
Gums	0.12	–	0.44	–
Shrubs	1.61	0.45	0.70	0.00
Leaves	0.42	–	0.44	–
Flowers	1.14	–	0.06	–
Fruits	0.05	0.45	0.20	0.00
Cereal crops	4.28	0.37	6.49	0.70
Invertebrates	0.84	1.11	0.26	1.85
Others	0.12	–	0.06	–

For Tikure band, fruit consumption from shrubs namely *Rosa abyssinica* was only recorded during the wet season (Table 26). Tikure consumed proportionally higher grass parts during the wet season than the dry season but the difference was not significant ($H = 1.22$, $df = 1$ $p = 0.270$). Similarly, the band consumed relatively more herb parts during the dry season than the wet season, however; the difference was not significant ($F_{1,16} = 7.25$, $p = 0.407$). There was no significant difference in invertebrate diet between the wet and dry seasons (1.85 vs. 1.11%, $F_{1,16} = 1.57$, $p = 0.228$).

Grass blades accounted for a significantly greater proportion of the diet for Tikure band during the wet season than the dry season ($F_{1,16} = 8.48$, $p = 0.010$). Seed of grasses accounted for 10.85 % of the wet season and 7.98% of the dry season diet (Table 26). Herb leaves contributed more during the wet season than the dry season diets, however; the difference was not significant ($F_{1,16} = 1.89$, $p = 0.189$). Herb roots accounted for 3.85% of the wet season and 9.29% of the dry season diets, and the difference was significant ($F_{1,16} = 20.63$, $p < 0.001$).

For both Selam and Tikure bands, grass parts constitued the largest proportion of the diet in both seasons (Table 26). Grass parts as a whole accounted for a greater proportion of the diet for Selam band than for Tikure band during the wet seasons, and the differences were significant ($F_{1,15} = 4.93$, $p = 0.042$). Even if grass parts still accounted for a greater proportion of the diet for Selam band than for Tikure band during the dry season, the difference was not significant ($H = 0.43$, $df = 1$, $p = 0.514$). However, herbs as a whole accounted for a greater proportion of the diet for Tikure band than for Selam band during both the wet and dry seasons, and the difference was significant (wet: $F_{1,15} = 22.17$, $p < 0.001$; dry: $F_{1,17} = 242.90$, $p < 0.001$).

During the dry season, the rhizomes of *Digitaria abyssinica*, *Pennisetum villosum* and *Cyperus bulbosus* were the most important components of diet items for Selam band; while the corm of *F. macrophylla* and the root of *H. abyssinicum* were the two most contributors of the underground food items for Tikure band. Invertebrates accounted for 1.11% of the wet season diet for Tikure band and 0.84% for Selam band, and the difference was not significant ($F_{1,15}$ = 0.54, $p = 0.475$). Invertebrates accounted for 1.85% of the dry season diet for Tikure band and only 0.26% for Selam band, and difference was significant ($F_{1,17}$ = 20.01, $p < 0.001$).

There was no significant difference in the proportion of grass blade diet consumptions for Selam and Tikure bands during both the wet and dry seasons (wet: $F_{1,15}$ = 0.57, $p = 0.463$; dry: $F_{1,17}$ = 0.30, $p = 0.866$). Herb leaves were consumed significantly in greater proportion by Tikure band than Selam band during the wet ($F_{1,15}$ = 23.76, $p < 0.001$) and dry ($F_{1,17}$ = 0.57, $p < 0.001$) seasons. The proportion of grass corm was significantly higher for Tikure band than Selam band during the dry season (H = 4.86, df = 1, $p = 0.027$). Bulbs accounted for 8.40% of the dry season diet for Selam band and only 1.10% for Tikure band, and the difference was significant ($F_{1,15}$ = 8.85, $p = 0.009$). When corms and rhizomes are combined together as ‘underground diet’ for both Selam and Tikure bands during the dry season, there was no significant difference between the two bands (22.30 vs. 18.91%, $F_{1,17}$ = 0.16, $p = 0.697$). In both sites, the decrease in grass blade consumption and the consequent higher intake of underground food items was more accentuated during the dry season.

The top 10 most consumed plant species which accounted for about 73.63% of the wet season diet for the Selam band is depicted in Table 27. Out of the top 10 consumed plant species, *Cynodon dactylon* and *Digitaria abyssinica* accounted for the greatest percentage in cumulative proportions during the wet season period. In terms of grass seeds *Andropogon abyssinicus*, *Cynodon dactylon* and *Snowdonia polystachya* were ranked first, second and third, respectively in proportions.

Table 27. Top 10 food species and percent contribution in the diet of geladas at Kosheme during the wet season.

Species	Part eaten contribution, %			Cumulative contribution, %
	Blade	Grass seed	Bulb	
Cynodon dactylon	17.88	2.23	0.00	20.11
Digitaria abyssinica	13.99	0.40	0.00	14.39
Andropogon abyssinicus	7.59	3.68	0.00	11.27
Hyparrhenia rufa	5.24	0.02	0.00	5.26
Bithriochloa insculpta	4.73	0.40	0.00	5.12
Pennisetum villosum	5.05	0.00	0.00	5.05
Eragrostis tenuifolia	3.00	0.54	0.00	3.54
Snowdonia polystachya	1.96	1.30	0.00	3.26
Cyperus bulbosus	1.09	0.00	1.68	2.77
Pennisetum setaceum	1.93	0.54	0.00	2.47
Total				73.24

The top 10 most consumed plant species which accounted for about 79.65% of the dry season diet for Selam band is depicted in Table 28. Out of the top 10 consumed plant species, *Cynodon dactylon* and *Digitaria abyssinica* still accounted for the greatest percentage in cumulative proportions during the dry season. *Ficus sycomorus* was ranked fourth in providing fruit diets in cumulative proportions during the season. *Digitaria abyssinica, Pennisetum villosum* and *Cynodon dactylon* were first, second and third in terms of rhizome contribution during the dry season.

Table 28. Top 10 food species and percent contribution in the diet of geladas at Kosheme during the dry season.

Species	Part eaten contribution, %						Cumulative,%
	Blade	Grass seed	Rhizome	Corm	Bulb	Fruit	
Cynodon dactylon	18.90	0.65	4.79	0.00	0.00	–	24.34
Digitaria abyssinica	4.91	0.03	7.21	0.00	0.00	–	12.15
Pennisetum villosum	3.61	0.00	6.46	0.00	0.00	–	10.07
Ficus sycomorus	–	–	–	–	–	9.60	9.60
Cyperus bulbosus	0.19	0.00	0.00	0.00	8.40	–	8.60
Bithriochloa insculpta	4.03	0.13	0.00	0.23	0.00	–	4.39
Eragrostis tenuifolia	2.82	0.15	0.00	0.58	0.00	–	3.55
Hyparrhenia rufa	2.04	0.06	0.00	0.40	0.00	–	2.51
Andropogon abyssinicus	1.98	0.29	0.00	0.00	0.00	–	2.27
Pennisetum setaceum	0.79	0.08	0.00	1.30	0.00	–	2.17
Total							79.65

The contribution of different food items according to the rank during the wet and dry seasons is presented in Table 29. Grass blades ranked first during both the dry and wet seasons. Grass seeds, herb leaves, herb flowers and bulbs ranked from the second to the fifth excluding crops during the wet season. Rhizomes, fruits, bulbs, and corms ranked from the second to the fifth excluding crops during the dry season. There was no rank for rhizomes and corms during the wet season. However, during the dry season, Selam band completely reduced and shifted its feeding habit from aboveground food items to the underground food items.

Table 29. Food item ranks according to their contribution for Selam band during the wet and dry seasons.

Food item	Wet season contribution, %	Food item	Dry season contribution, %
Grass blade	72.32	Grass blade	43.63
Grass seed	10.57	Rhizome	19.01
Herb leaf	5.82	Fruit	11.61
Crop	4.28	Bulb	8.40
Herb flower	1.82	Crop	6.49
Bulb	1.68	Corm	3.29
Shrub flower	1.14	Herb leaf	2.69
Invertebrate	0.84	Grass seed	1.77
Fruit	0.81	Tree seed	0.58
Shrub leaf	0.42	Pith	0.50
Gum	0.12	Herb root	0.49
Other	0.12	Gum	0.44
Pith	0.05	Shrub leaf	0.44
Herb root	0.02	Herb flower	0.28
Rhizomes	0.00	Invertebrate	0.26
Corm	0.00	Shrub flower	0.06
Tree seed	0.00	Other	0.06

For Selam band, the Sørensen’s index showed strong similarities in the diet items between the wet and dry seasons. Thus, the similarities of diet items between the wet and dry seasons overlapped very strongly (Sørensen’s index = 0.90), 90.32% of the diet items is commonly shared by the two seasons. 14 diet items were shared from the overall items which were included by Selam band during the wet and the dry seasons. Three diet items were included exclusively by the band during the dry season.

The top 10 most consumed plant species which accounted for about 90.19% of the dry season diet for Tikure band is depicted in Table 30. Out of these top 10 consumed plant species, *F. macrophylla* contributed the highest food species followed by *Festuca versicolor* during the dry season. *F. versicolor*, *Poa annua* and *Andropogon abyssinicus* were the three most contributor species in terms of grass blade item during the season. *Trifolium acaule* and *H. abyssinicum* were the highest herb leave and herb root contributors respectively as diet items during the dry season.

Table 30. Top 10 food species and percent contribution in the diet of Tikure band during the dry season (BL: blade, GS: grass seed, RH: rhizome, CO: corm, HL: herb leaf, HF: herb flower, HR: herb root, AP: animal prey/invertebrate).

Species	Food item contribution, %								Cumulative, %
	BL	GS	RH	CO	HL	HF	HR	AP	
Festuca macrophylla	4.42	6.42	0.00	17.04	–	–	–	–	27.87
Festuca versicolor	14.68	0.29	0.00	0.00	–	–	–	–	14.96
Poa annua	11.19	0.10	0.00	0.34	–	–	–	–	11.63
Trifolium acaule	–	–	–	–	9.19	0.46	0.19	–	9.84
Andropogon abyssinicus	8.93	0.06	0.63	0.00	–	–	–	–	9.61
Haplosciadium abyssinicum	–	–	–	–	0.82	0.00	7.01	–	7.82
Aira caryophyllea	3.66	0.04	0.00	0.49	–	–	–	–	4.19
Caterpillar	–	–	–	–	–	–	–	1.58	1.58
Haplocarpha schimperi	–	–	–	–	1.35	0.00	0.08	–	1.43
Haplosciadium spp.	–	–	–	–	0.40	0.00	0.86	–	1.26
Total									90.19

The top 10 most consumed plant species which accounted for about 88.27% of the wet season diet for Tikure band is depicted in Table 31. Out of these top 10 consumed plant species, *Andropogon abyssinicus*, *Poa annua* and *Festuca versicolor* were the three top contributors of grass blade items during the wet season. *F. macrophylla* and *F. abyssinica* were the major contributors of seed item for Tikure band during the wet season. *T. acaule* and *H. abyssinicum* were the highest herb leave and herb root contributors respectively as diet items during the wet season.

Table 31. Top 10 food species and percent contribution in the diet of Tikure band during the wet season (BL=blade, GS=grass seed, CO=corm, HL=herb leaf, HF=herb flower, HR=herb root).

Species	Food item contribution, %						Cumulative, %
	BL	GS	CO	HL	HF	HR	
Festuca macrophylla	10.40	8.38	0.02	–	–	–	18.81
Andropogon abyssinicus	16.83	0.06	0.00	–	–	–	16.89
Poa annua	15.06	0.25	0.00	–	–	–	15.30
Trifolium acaule	–	–	–	10.44	0.60	–	11.04
Festuca versicolor	10.61	0.25	0.00	–	–	–	10.85
Aira caryophyllea	5.19	0.04	0.00	–	–	–	5.23
Haplosciadium abyssinicum	–	–	–	0.47	0.00	3.46	3.93
Festuca abyssinica	0.64	1.73	0.00	–	–	–	2.37
Alchemila pedata	–	–	–	2.20	0.00	–	2.20
Eragrostis spp.	1.65	0.00	0.00	–	–	–	1.65
Total							88.27

Different food items based upon their rank contribution during the wet and dry seasons are presented in Table 32. Grass blades ranked the first during both the dry and wet seasons. Herb leaves and grass seeds ranked from the second to the third contributor of food items during the wet season. Conversely, corms, herb leaves and herb roots ranked from the second to the fourth during the dry season. Corms were the least consumed food items during the wet season. However, during the dry season, Tikure band completely reduced the aboveground food items and shifted its feeding habit to the underground items.

Table 32. Food item ranks according to their contribution for Tikure band during the dry and wet seasons.

Food item	Wet season contribution, %	Food item	Dry season contribution, %
Blade	63.48	Blade	44.34
Herb leaf	18.85	Corm	18.28
Grass seed	10.85	Herb leaf	15.38
Herb root	3.85	Herb root	9.29
Invertebarate	1.11	Grass seed	7.98
Herb flower	0.74	Invertebarate	1.85
Fruit	0.45	Bulb	1.10
Crop	0.37	Crop	0.70
Bulb	0.27	Rhizome	0.63
Corm	0.02	Herb flower	0.46
Rhizome	0.00	Fruit	0.00

For Tikure band, Sørensen's index showed strong similarities in the diet items between the wet and dry seasons. Thus, the similarities of diet items between the wet and dry seasons overlapped very strongly (Sørensen's index = 0.92). That is 91.67% of the diet items commonly shared by the two seasons. 11 diet items were shared from the overall items which were included by the Tikure band during the wet and dry seasons. One diet item was included exclusively by the band during the wet season and, another one diet item was included exclusively during the dry season.

The Sørensen's index similarity of diet items of the two bands was 0.75 during the wet season and 0.74 during the dry season. That is 75.00% of the diet items commonly shared by the two bands during the dry season, and 74.07% in the dry season during the study period. 9 diet items were shared by Selam and Tikure bands during the wet season. 7 diet items were consumed exclusively by Selam band during the dry season. The overall Sørensen's index similarity of diet items of the two bands was 0.79 during the study period. Overall 6 (33.33%) diet items were uniquely consumed by Selam band. The 12 common items made up 100% of the diet for Tikure band.

Annual diet: This study showed that southern geladas depended more on grass parts. But, they also added considerable amount of fruits from trees and leaves from herbs. For Selam band, out of the total annual diet of plant habit categories, grass cumulatively comprised 79.57%, herb 5.18%, tree 8.01% and shrub 1.07%, and additionally, cultivated cereal crops accounted for 5.59%, invertebrates 0.50% and other 0.09%. From the grass parts, grass blades contributed 55.40%, grass rhizomes 11.21%, grass heads/seeds 5.38%, grass corms 1.94% and bulbs 5.64% of the annual diet. Herb parts comprised leaves 3.97%, flower 0.91% and roots 0.30%, and tree parts contributed fruits 7.05%, pith 0.32%, gums 0.31%, seeds 0.34% and shrub parts comprised flower 0.51%, fruits 0.13% and leaves 0.43% for Selam band from the average annual diet.

From the total 839 tree feeding records, fruits accounted for 87.96%, seeds 4.29%, pith 3.93% and gums 3.81%. At Kosheme site, trees contributed 98.14% of fruit diet for Selam band, and shrubs accounted for 1.86% of fruits. The fruit of *F. sycomrous* accounted for 84.82% from total 738 tree fruit records and 83.24% from overall 752 fruit records across the study period. In addition, from the total of 112 feeding records of shrubs, flowers accounted for 47.32%, leaves/stem/pith 40.18% and fruits 12.50%. From the total 8332 annual grass diet records, blades comprised 69.62%, rhizomes 14.09%, seed 6.76%, corm 2.44% and bulb 7.09% during the course of the study. *Digitaria abyssinica*, *Pennisetum villosum* and *Cynodon dactylon* were the three major grass species for the source of rhizomes.

Similarly, from the total of 542 annual herb diet records, leaves comprised 76.75%, flowers 17.53% and roots 5.72% during the study period. Geladas at Kosheme also raided crops.

From the total 585 crop consumption records, seedling comprised 7.52%, leftover seeds at the time of sawing 63.60%, seeds at the time of sowing 23.93% and crop heads at the time of vegetative/fruiting stages 4.90% during the study period.

For Tikure band, out of the total annual feeding records of the plant habit, grass cumulatively accounted 72.72%, herb 25.02%, shrub 0.22% and crop 0.54%, and additionally animal prey 1.49%. From the grass parts, grass blades contributed 53.53%, grass rhizomes 0.33%, grass seeds/heads 9.36% and grass corms 9.51% of the annual diet. Herb parts comprised flower 0.59%, leaves 17.05%, roots 6.68% and bulbs 0.70% from the total annual diets. Tikure band consumed greater proportion of grass parts than herb parts, and the different was highly significant (72.72 vs. 25.02%, $F_{1,34} = 517.97$, $p < 0.001$).

From the total of 7351 annual grass diet records of Tikure band, blades comprised 73.61%, corms 13.07%, seeds 12.87% and rhizomes 0.45% during the study. *F. macrophylla* contributed grass seeds/heads 10.12% and corm 12.19% from the annual recorded grass species. However, the blades of *F. macrophylla* only contributed 10.03% from the annual grass species even if it was the most dominant grass species within the home range of Tikure band. Form the total of 2529 annual herb diet records, leave/stem comprised 68.13%, root 26.69%, flowers 2.37% and bulbs 2.81% during the study period. The leaves of *T. acaule* contributed 39.15% and the roots of *H. abyssinicum* accounted for 21.04% of the total herb species records. From the total of 151 invertebrate records, caterpillars from the leaves of *Lobelia rhynchopetalum* contributed 89.40% of the total animal prey records within the study period. *Rosa abyssinica* was the only shrub for sources of fruits for Tikure band.

The annual diet item contribution for Selam band at Kosheme and for Tikure band at Keywasha is presented in Table 33. For both bands, grass parts made up the largest proportion of the diet in their annual menu. Grass parts as a whole accounted for a greater proportion of diet for Selam band than Tikure band in the annual feeding records. However; the difference was not

Table 33. Comparison of mean annual contribution of each dietary item to the total diet with standard deviation for Selam and Tikure bands (SD=standard deviation).

Food item	Annual food item contribution, %			
	Selam	SD	Tikure	SD
Grasses	79.57	14.78	72.72	6.28
Blades	55.40	23.93	53.53	17.37
Seeds	5.38	13.81	9.36	13.84
Rhizomes	11.21	13.13	0.33	1.26
Corms	1.94	2.92	9.51	14.51
Bulbs	5.64	7.09	–	–
Herbs	5.18	4.51	25.02	6.31
Leaves	3.97	3.13	17.05	5.69
Roots	0.30	0.45	6.68	3.78
Flowers	0.91	0.95	0.59	0.99
Bulbs	0.00	0.00	0.70	0.82
Trees	8.01	10.91	–	–
Fruits	7.05	10.46	–	–
Piths	0.32	0.57	–	–
Seeds	0.34	0.86	–	–
Gums	0.31	0.30	–	–
Shrubs	1.07	1.08	0.22	0.72
Leaves	0.43	0.38	–	–
flowers	0.51	0.83	–	–
Fruits	0.13	0.34	0.22	0.72
Crops	5.59	12.22	0.54	0.96
Invertebrates	0.50	0.77	1.49	1.22
Others	0.09	0.15	–	–

significant ($H = 3.37$, $df = 1$, $p = 0.066$). Herb parts accounted for a greater proportion of the diet for Tikure band than for Selam band in the annual feeding records, and the difference was highly significant ($F_{1,34} = 101.35$, $p < 0.001$). Similarly, invertebrate prey accounted for a greater proportion of the diet for Tikure band than for Selam band in the annual feeding records, and the difference was significant ($H = 8.31$, $df = 1$, $p = 0.004$).

For both bands, grass blades made up the largest proportion of the annual diet (Fig. 35). The annual diet of grass blades accounted for a greater proportion for Selam than Tikure bands, but the difference was not significant ($F_{1,34} = 0.05$, $p = 0.830$). Underground grasses cumulatively accounted for 13.15% for Selam band and 9.84% for Tikure band, however; the difference was not significant ($H = 0.29$, $df = 1$, $p = 0.593$). Grass seeds accounted for greater proportion for Tikure band than for Selam band of the annual diet, however; the difference was not significant ($H = 2.27$, $df = 1$, $p = 0.132$). Similarly, aboveground herbs cumulatively accounted for 17.64% for Tikure band and 4.88% for Selam band, and the difference was significant ($F_{1,34} = 57.53$, $p < 0.001$).

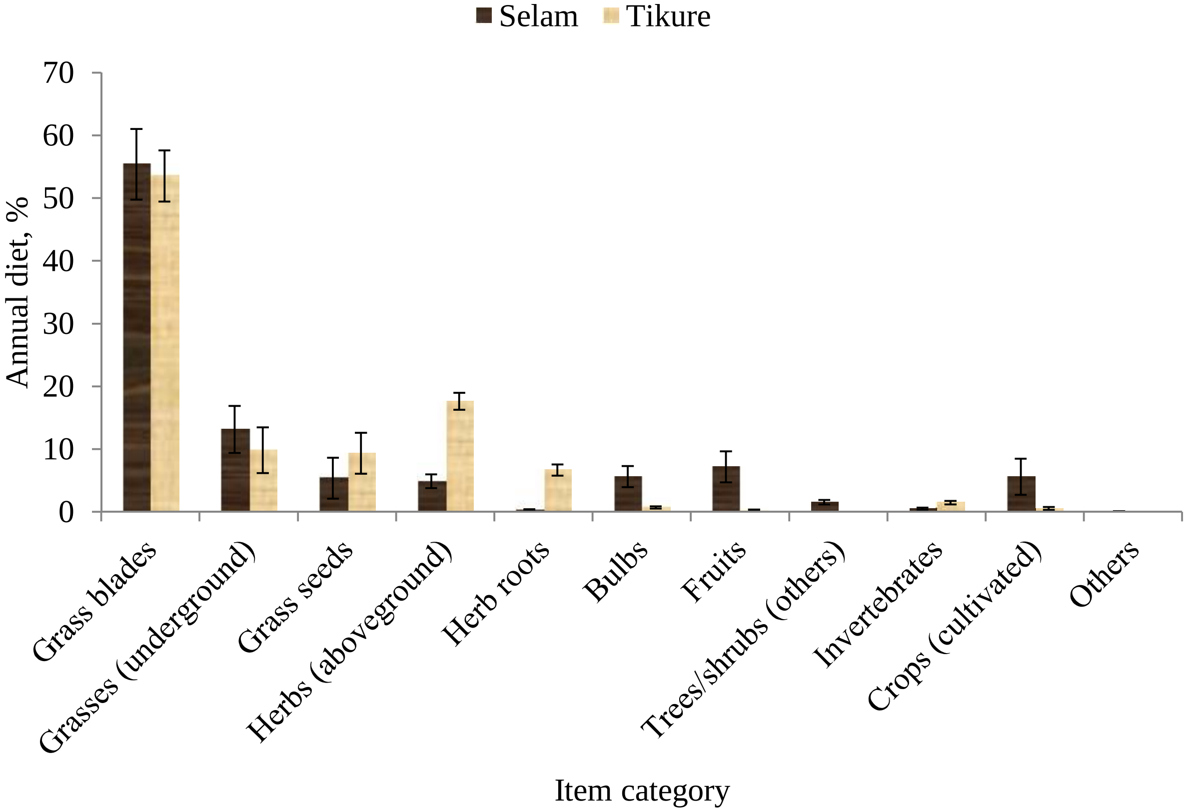

Figure 35. Comparative percentage accounted by different items in the annual diet between Selam and Tikure bands; values represent the mean ± SE. Grass underground includes grass corms and rhizomes; herb aboveground represents leaves and flowers of herbs. Tree/shrub (other) represents pith, leaves, seeds and flowers of trees and shrubs.

Correlations between the phenology of grasses/herbs and type of diet consumption: There were distinct wet and dry seasons at Kosheme and Keywasha sites. These in turn affect the yearly uniform distribution of grass and herb phenology of the study sites. The availability of green grasses in both habitats was related with rainfall. In both habitats, the availability of strictly green plots differed significantly from a uniform distribution (Shapiro–Wilk test, Kosheme: $Z = 0.66$, $p < 0.001$; Keywasha: $Z = 0.74$, $p < 0.001$) during the study period. Similarly, the availability of light green plots differed significantly from a uniform distribution (Shapiro–Wilk test, Kosheme: $Z = 0.75$, $p < 0.001$; Keywasha: $Z = 0.83$, $p = 0.004$).

The phenology of grasses and herbs varied between the two habitat types. At Keywasha the phenology of grass and herbs were stayed in strictly green and light green level for more months compared than at Kosheme site. From October onwards the percentage of greenness at strictly green level of grasses and herbs dramatically and more rapidly declined until the next wet season at Kosheme compared to Keywasha. Greenness availability in strictly green level of grasses and herbs was significantly greater at Keywasha than at Kosheme (H = 4.41, df = 1, p = 0.036). However, the availability of light greenness was not significantly different between the habitat of Selam and Tikure bands (H = 0.60, df = 1, p = 0.806).

The availability of strictly green grasses and herbs reached highest point during the wet months (Fig. 36). It reached highest peak in June, July and August. The monthly availability of strictly green grasses had a strong positive relationship with the consumption with grass blade items at Kosheme.

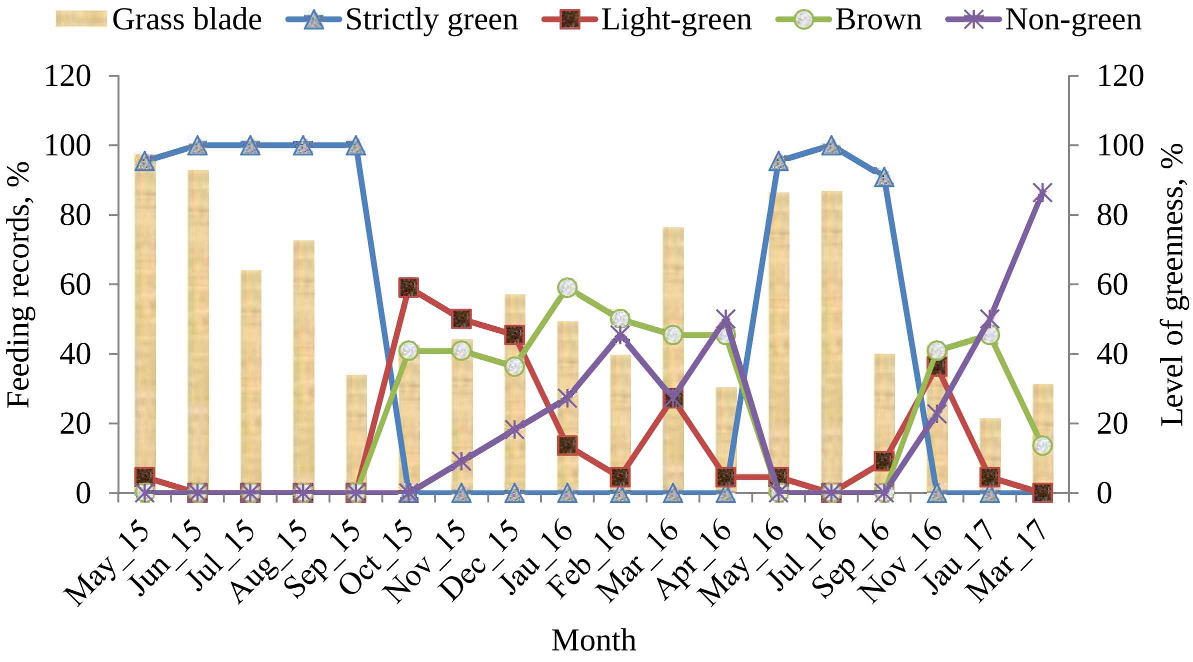

Figure 36. Relationship between monthly level of greenness and percentage of monthly grass blade consumption at Kosheme.

When the availability of strictly green grasses and herbs was reduced during the dry months, geladas at Kosheme changed their feeding habitat into underground grass items (Fig. 37). The availability of strictly green grasses had a negative relationship with the consumption of underground grass items. When green plots were changed into brown and non-green levels, Selam band shifted its feeding habit to the underground diet items.

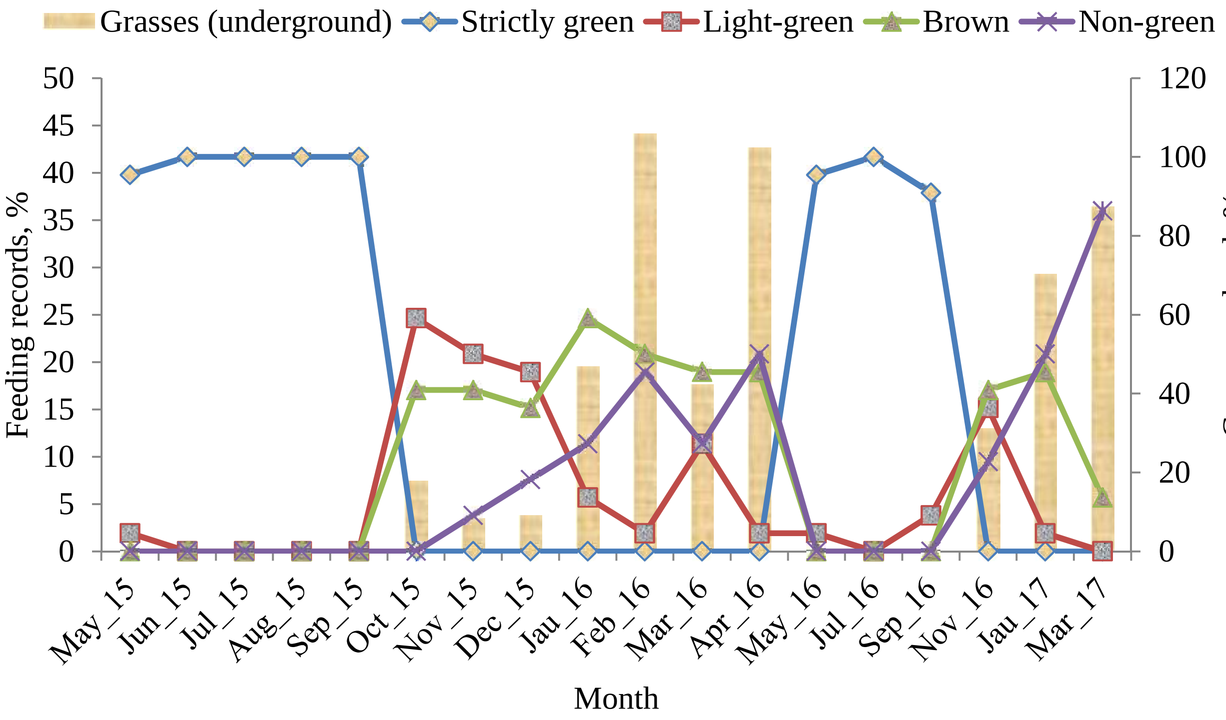

Figure 37. Relationship between monthly level of greenness and percentage of monthly underground grass consumption at Kosheme.

The availability of strictly green grasses and herbs reached highest point during the wet months (Fig. 38). The availability of strictly green grasses and herbs had a strong relationship with the consumption of aboveground herb items. As the level of greenness level increases, the consumption of herb leaves and flowers by the Selam band also increases.

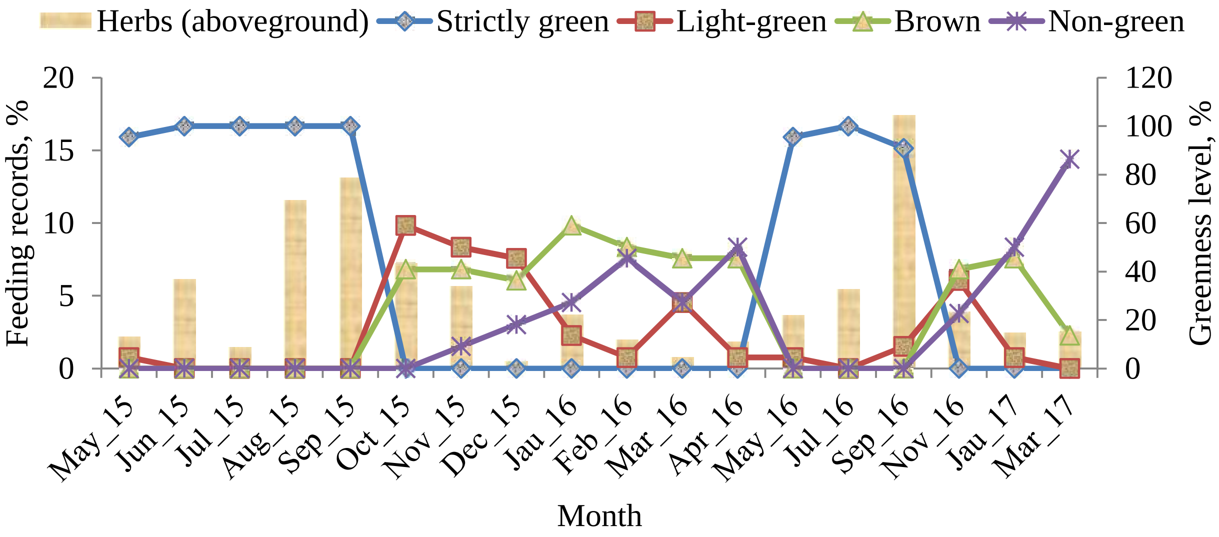

Figure 38. Relationship between monthly level of greenness and percentage of monthly herb (aboveground) consumption at Kosheme.

The availability of strictly green grasses and herbs had a strong negative relationship with the consumption of fruit. As the level of greenness level decreases, the consumption of fruits by Selam band increases (Fig. 39). Thus, the consumption of fruits was very important at this time.

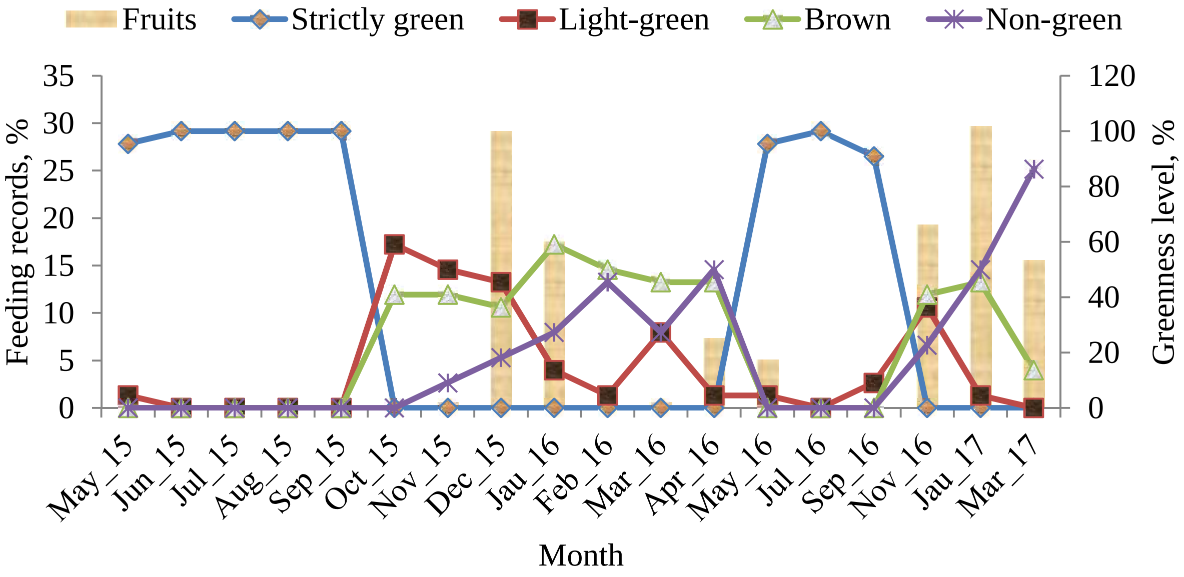

Figure 39. Relationship between monthly level of greenness and percentage of monthly fruit consumption at Kosheme.

The availability of strictly green grasses and herbs had a negative relationship with the consumption of bulb items. As the level of greenness level decreases, the consumption of bulbs by Selam band increases (Fig. 40). Most of the bulb consumption by the band occurred when plots changed into light-green and brown levels.

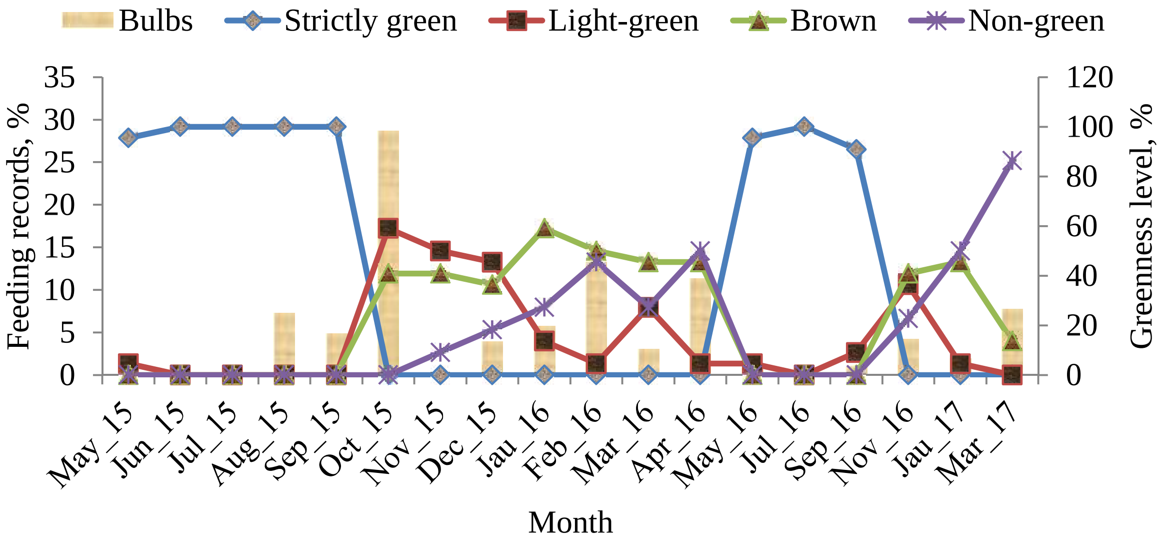

Figure 40. Relationship between monthly level of greenness and percentage of monthly bulb consumption at Kosheme.

Rainfall patterns strongly influenced the greenness level of grasses and herbs at Kosheme. The greenness of grasses/herbs depends on the presence and absence of rain in the area. The monthly phenology of greenness level of grasses and herbs in turn has effect on the diet items consumed by Selam band at Kosheme (Table 34). The availability of strictly green grasses was significant and positively correlated with the monthly percentage consumption of grass blades (*r* = 0.610, p = 0.007) and herbs aboveground items (*r* = 0.491, p = 0.039). The availability was significant and negatively correlated with the monthly percentage consumption of underground grass items (*r* = -0.700, p = 0.001), herb roots (*r* = -0.499, p = 0.035) and fruits (*r* = -0.555, p = 0.017). Similarly, monthly percentage consumption of grass blades was significant and negatively correlated with high percentage availability of brown (*r* = -0.527, p = 0.025) and non-green plots (*r* = -0.581, p = 0.011). However, monthly percentage consumption of underground grass items was significant and positively correlated with higher percentage availability of brown (*r* = 0.644, p = 0.004) and non-green plots (*r* = 0.904, p < 0.001). Monthly percentage consumption of fruits was also significant and positively correlated with higher percentage availability of brown (*r* = 0.472, p = 0.048) and non-green plots (*r* = 0.523, p = 0.026).

Table 34. Relationship between phenology of grasses and percent of monthly (N = 18) diet consumption of different gelada food items for Selam band.

Food item		Level of greenness			
		Strictly green	Light green	Brown	Non-green
Grass blade	*r*	0.610	-0.193	-0.527	-0.581
	p	0.007	0.443	0.025	0.011
Grass (underground)	*r*	-0.700	-0.123	0.644	0.904
	p	0.001	0.627	0.004	<0.001
Grass seed	*r*	0.320	-0.054	-0.310	-0.311
	p	0.196	0.830	0.211	0.209
bulb	*r*	-0.447	0.399	0.418	0.194
	p	0.063	0.101	0.085	0.441
Herb (aboveground)	*r*	0.491	-0.115	-0.462	-0.464
	p	0.039	0.649	0.054	0.052
herb root	*r*	-0.499	-0.133	0.351	0.780
	p	0.035	0.599	0.154	<0.001
Fruit	*r*	-0.555	0.192	0.472	0.523
	p	0.017	0.446	0.048	0.026
Invertebrate	*r*	0.383	-0.247	-0.377	-0.224
	p	0.116	0.323	0.123	0.371

Rainfall patterns also strongly impacted on the availability of green grasses and herbs at Keywasha. The phenology of grass and herb levels in turn impacted the diet item selection of Tikure band (Fig. 41). As the greenness of the area increased, grass blade consumption by band also increased during the study months.

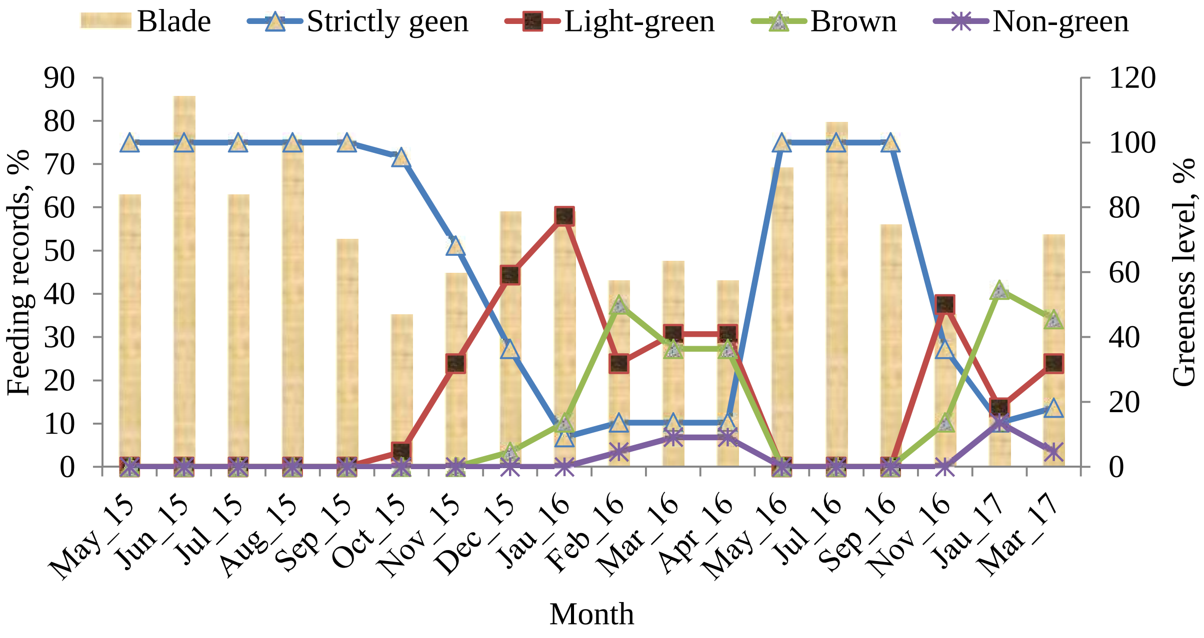

Figure 41. Relationship between monthly level of greenness and percentage of monthly grass blade consumption by Tikure band.

The availability of strictly green grasses and herbs had a strong negative relationship with the consumption of underground grass items. As the level of greenness level decreases (changed into brown or non-green levels), the consumption of underground grass items increases (Fig. 42).

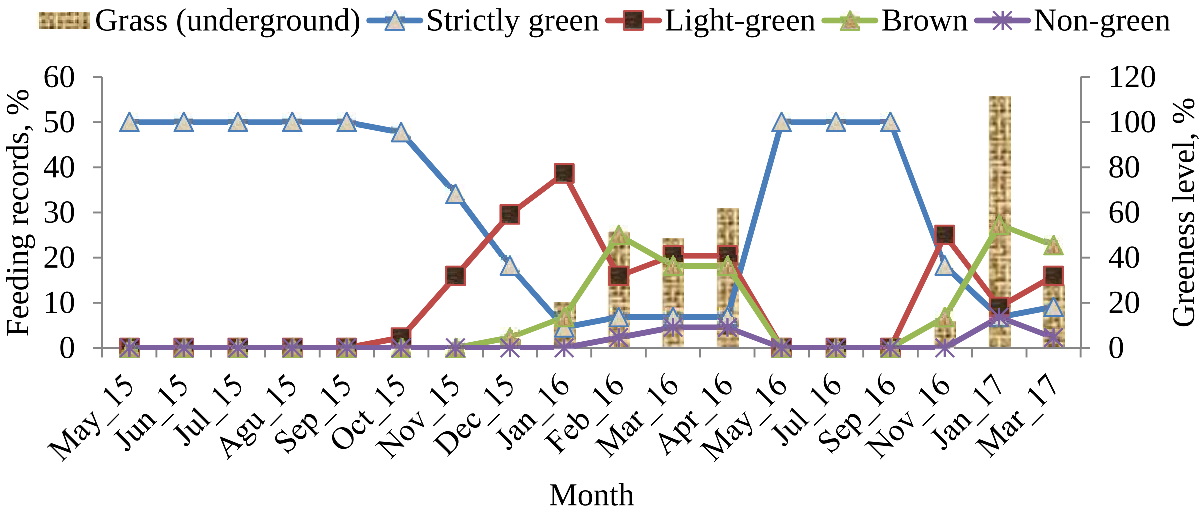

Figure 42. Relationship between monthly level of greenness and percentage of monthly underground grass consumption by Tikure band.

The availability of strictly green grasses and herbs had a positive relationship with the consumption of herb aboveground items. As the level of greenness level decreases, the consumption of aboveground herb items by Tikure band also decreases (Fig. 43). Similarly, as the level of greenness level increases, the consumption of aboveground herb items by Tikure band also increases.

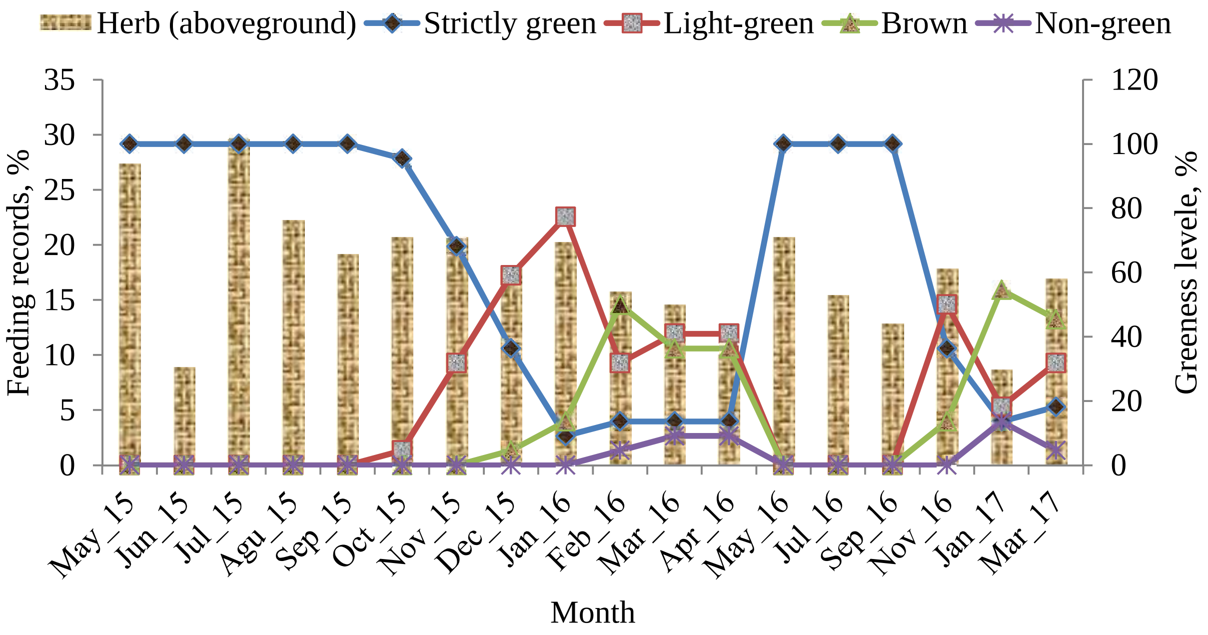

Figure 43. Relationship between monthly level of greenness and percentage of monthly aboveground herb item consumption by Tikure band.

The availability of strictly green grasses and herbs had a negative relationship with the consumption of herb roots. As the level of greenness level decreases, the consumption of herb root by Tikure band increases (Fig. 44). Thus, the consumption of herb roots was very important when the green plots change into light-green, brown and non-green levels. Thus, they were an important diet during the dry season.

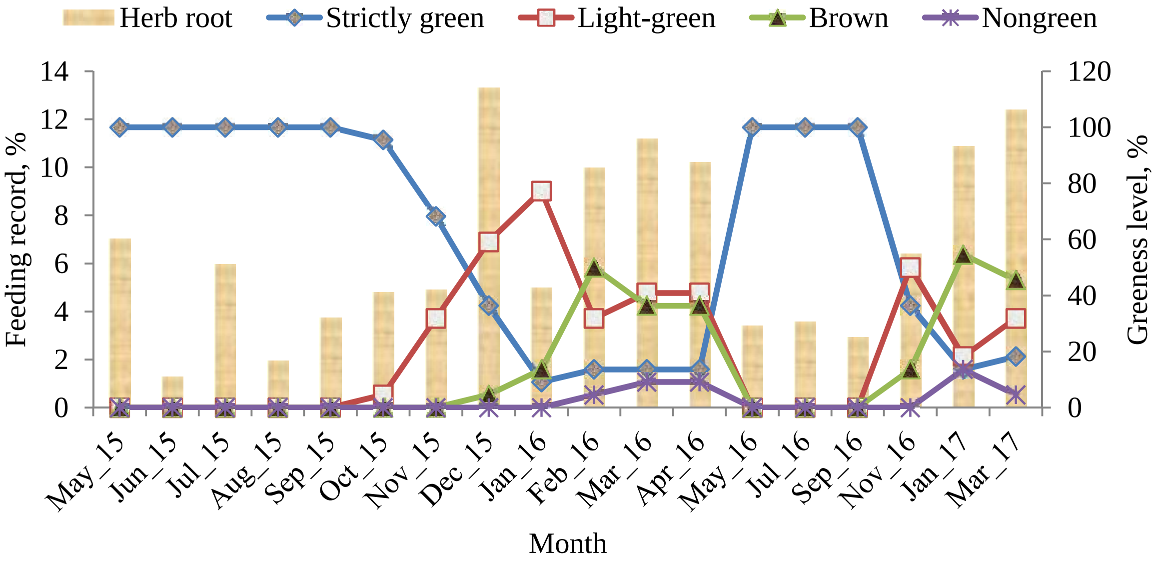

Figure 44. Relationship between monthly level of greenness and percentage of monthly herb root consumption by Tikure band.

The availability of strictly green grasses and herbs had a negative relationship with the consumption of invertebrates. As the level of greenness level decreases, the consumption of invertebrates by Tikure band increases (Fig. 45).

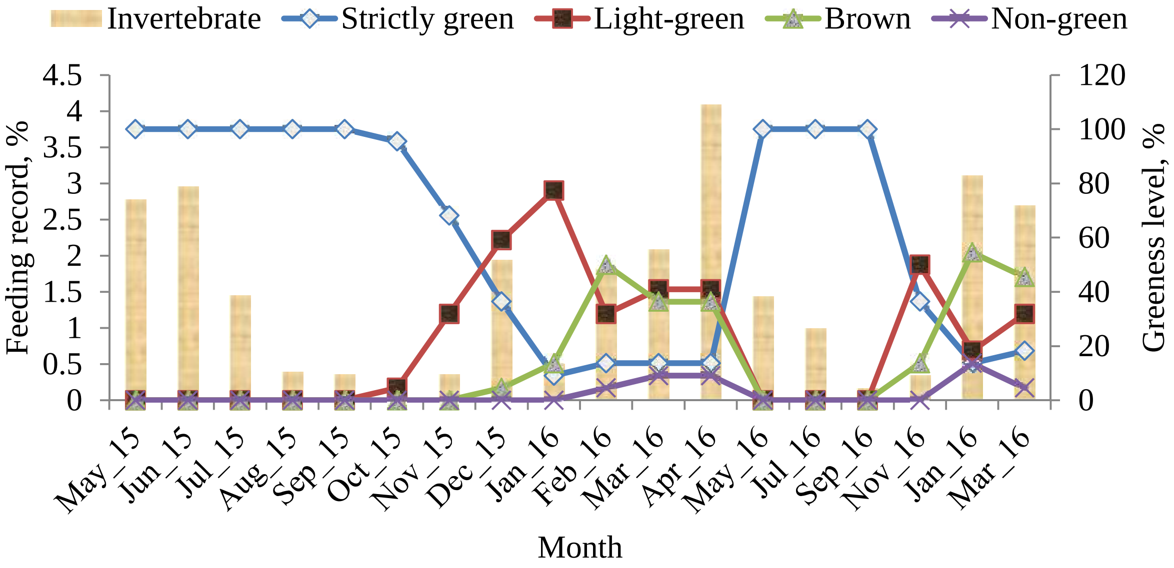

Figure 45. Relationship between monthly level of greenness plots and the percentage of monthly invertebrate consumption by Tikure band.

The monthly pattern of greenness level of grasses and herbs strongly affect the type of diet item consumption by Tikure band (Table 35). The high percentage availability of strictly green plots was significant and positively correlated with the monthly percentage consumption of grass blades ($r = 0.577$, $p = 0.012$). There was significant and negatively correlated with the monthly percentage consumption of underground grass items ($r = -0.745$, $p < 0.001$), herb roots ($r = -0.783$, $p < 0.001$) and bulbs ($r = -0.510$, $p = 0.031$). Similarly, monthly percentage consumption of grass blades was significant and negatively correlated with higher percentage availability of brown ($r = -0.599$, $p = 0.009$) and non-green plots ($r = -0.609$, $p = 0.007$). However, monthly percentage consumption of underground grass items was significant and positively correlated with higher percentage availability of brown ($r = 0.903$, $p < 0.001$) and non-green plots ($r = 0.960$, $p < 0.001$).

Table 35. Relationship between phenology of grass/herb levels and the percentage of monthly (N = 18) consumption of different food items for Tikure band.

Food item		Level of greenness			
		Strictly green	Light-green	Brown	Non-green
Grass blades	*r*	0.577	-0.354	-0.599	-0.609
	p	0.012	0.150	0.009	0.007
Underground grass	*r*	-0.745	0.322	0.903	0.960
	p	<0.001	0.193	<0.001	<0.001
Grass seed	*r*	0.219	-0.037	-0.327	-0.323
	p	0.383	0.885	0.185	0.190
Herb aboveground	*r*	0.411	-0.162	-0.507	-0.580
	p	0.090	0.521	0.032	0.012
Herb root	*r*	-0.783	0.568	0.744	0.647
	p	<0.001	0.014	<0.001	0.004
Bulb	*r*	-0.510	0.586	0.290	0.084
	p	0.031	0.011	0.244	0.741
Fruit	*r*	0.314	-0.292	-0.235	-0.182
	p	0.204	0.239	0.347	0.469
Invertebrate	*r*	-0.403	0.088	0.568	0.647
	p	0.097	0.729	0.014	0.004

Monthly percentage consumption of aboveground herb items was significant and negatively correlated with higher percentage availability of brown (r = -0.507, p = 0.032) and non-green plots (r = -0.580, p < 0.012). Monthly percentage consumption of herb roots was significant and positively correlated with higher percentage availability of light-green (r = 0.568, p = 0.014), brown (r = 0.744, p < 0.001) and non-green plots (r = 0.647, p = 0.004). Similarly, monthly percentage consumption of invertebrates was significant and positively correlated with higher percentage availability of brown (r = 0.568, p = 0.014) and non-green plots (r = 0.647, p = 0.004).

Dietary diversity of food species and diet items: Selam band at Kosheme consumed a maximum of 46 species in August (2015), July (2016) and September (2016) and a minimum of 21 species in May (2015) and February (2016) with a mean of 30.89 (SD = 8.69) species (Table 36). Tikure band at Keywasha consumed a maximum of 27 food species in May (2016) and a minimum of 18 species in March (2017) with a mean of 22.67 (SD = 2.50) species during the study period. For Tikure band, there were few variations in the consumption of plant species among the sampling months. Selam band consumed more diversified food species than Tikure band, and the difference was significant between the two bands in the number of species (Kruskal–Wallis H test: H = 11.00, df = 1, p = 0.001).

The dietary diversity (H') and evenness (J) for Selam and Tikure bands is also depicted in Table 36. For Selam band, the dietary diversity was highest in August 2015 (H' = 3.07) and September 2016 (H' = 2.90) whereas it was lowest in November 2015 (H' = 1.89) and March 2016 (H' = 2.07). For Tikure band, the food plant diversity was highest in July 2015 (H' = 2.60) and May 2016 (H' = 2.51) and lowest in January 2017 (H' = 1.99) and October 2015 (H' = 2.08). The plant species consumed by Selam band was highly diverse and showed more monthly variation than the dietary diversity of Tikure band over the study period. The annual dietary diversity (H') for Selam band was 2.45 and for Tikure band 2.26. There was significant difference in annual dietary diversity between Selam and Tikure bands ($F_{1,34}$ = 4.95, P = 0.033) during the study period.

Table 36. Shannon–Wiener diversity index (H') and evenness index (J) of food species consumed by Selam and Tikure bands.

Month	Selam band			Tikure band		
	Number of species	H'	*J*	Number of species	H'	*J*
May 2015	21	2.11	0.69	22	2.39	0.77
Jun 2015	30	2.45	0.72	19	2.16	0.73
Jul 2015	24	2.31	0.73	22	2.60	0.84
Aug 2015	46	3.07	0.80	24	2.30	0.72
Sep 2015	35	2.67	0.75	23	2.24	0.71
Oct 2015	33	2.41	0.69	21	2.08	0.69
Nov 215	23	1.89	0.60	25	2.34	0.73
Dec 2015	25	2.17	0.67	23	2.46	0.79
Jan 2016	28	2.28	0.68	26	2.24	0.69
Feb 2016	21	2.14	0.70	20	2.21	0.74
Mar 2016	22	2.07	0.67	20	2.23	0.75
Apr 2016	27	2.52	0.76	24	2.08	0.65
May 2016	41	2.55	0.69	27	2.51	0.76
Jul 2016	46	2.85	0.74	22	2.20	0.71
Sep 2016	46	2.90	0.76	26	2.27	0.70
Nov 2016	33	2.56	0.73	24	2.20	0.69
Jan 2017	26	2.41	0.74	22	1.99	0.64
Mar 2017	29	2.71	0.81	18	2.26	0.78
Mean	30.89	2.45	0.72	22.67	2.26	0.72

For Selam band, the dietary evenness (*J*) was highest in March 2017 (*J* = 0.81) and August 2015 (J = 0.80) whereas it was lowest in November 2015 (*J* = 0.60). For Tikure band, the food species evenness was recorded highest in July 2015 (*J* = 0.84) and lowest in January 2017 (*J* = 0.64). However, the cumulative annual dietary evenness for Selam band was equal to the annual dietary evenness of Tikure band (*J* = 0.72), and the difference was not significant ($F_{1,34}$ = 0.28, p = 0.599).

The food dietary diversity (H') and evenness (*J*) for Selam and Tikure bands during the wet and dry seasons differed from each other. For Selam band, the dietary diversity was higher during the wet season (H' = 2.61) than during the dry season (H' = 2.32), and the difference was significant ($F_{1,15}$ = 4.87, p = 0.042). For Tikure band, the dietary diversity was also higher during the wet season (H' = 2.31) than during the dry season (H' = 2.22), but contrary to Selam band, the difference was not significant ($F_{1,16}$ = 1.31, p = 0.269). During the wet season, the dietary diversity for Selam band was significantly greater than Tikure band ($F_{1,15}$ = 6.35, p = 0.024). Similarly, during the dry season, the dietary diversity for Selam band was greater than Tikure band, but the difference was not significant (H = 0.67, df = 1, p = 0.414).

For Selam band, the dietary evenness was higher during the wet season (*J* = 0.74) than during the dry season (J = 0.71), but the difference was not significant ($F_{1,15}$ = 1.61, p = 0.222). Similarly, for Tikure band, the dietary evenness was also higher during the wet season (*J* = 0.74) than during the dry season (*J* = 0.72), and the difference was not significant ($F_{1,16}$ = 0.63, p = 0.438). During the wet season, the dietary evenness for Selam band was equal to Tikure band, and the difference was not significant ($F_{1,15}$ = 0.01, p = 0.937). During the dry season, the dietary evenness for Selam band was greater than Tikure band, but the difference was not significant ($F_{1,15}$ = 0.25, p = 0.625).

The diet item diversity (H') and evenness (*J*) for Selam and Tikure bands are presented in Table 37. For Selam band, the diet item diversity was highest in March 2016 (H' = 1.84) and 2017 (H' = 1.81) whereas the lowest was in May 2015 (H' = 0.13) and in June 2015 (H' = 0.30). On the other hand, for Tikure band, the diet item diversity was highest in January (2017, H' =

1.59) and in November (2016, H' = 1.52) and lowest in June 2015 (H' = 0.56) and August 2015 (H' = 0.64). The diet items consumed by Selam band were highly diverse and showed more monthly variation compared to the diet items diversity of Tikure band, and the cumulative annual difference was significant between the two bands (mean: 9.22 ± 3.02 SD vs. 6.94 ± 1.66 SD; $F_{1,15} = 7.86$, $p = 0.008$). The mean annual diet item diversity (H') for Selam band was 1.20. The dietary diversity (H') for Tikure band was 1.16 over the entire study period. Although the annual diet item diversity for Selam band was higher than Tikure band, the difference was not significant between the bands (H = 0.40, df, = 1, p = 0.527).

Table 37. Shannon–Wiener diversity index (H’) and evenness index (J) of food items consumed by Selam and Tikure bands.

Month	Selam			Tikure		
	Number of food items	H'	J	Number food items	H'	J
May 2015	3	0.13	0.12	7	0.93	0.67
Jun 2015	4	0.30	0.21	9	0.56	0.35
Jul 2015	4	0.76	0.55	8	0.89	0.56
Aug 2015	8	0.97	0.47	8	0.64	0.46
Sep 2015	8	1.26	0.60	5	1.19	0.61
Oct 2015	12	1.53	0.62	7	1.36	0.70
Nov 2015	11	1.26	0.52	7	1.27	0.61
Dec 2015	10	1.17	0.51	8	1.29	0.59
Jan 2016	10	1.47	0.64	8	1.29	0.59
Feb 2016	9	1.36	0.62	9	1.47	0.71
Mar 2016	10	1.84	0.37	9	1.34	0.64
Apr 2016	12	1.70	0.68	8	1.40	0.72
May 2016	9	0.62	0.28	7	0.97	0.50
Jul 2016	10	0.61	0.27	7	0.66	0.41
Sep 2016	9	1.35	0.61	4	1.17	0.56
Nov 2016	13	1.73	0.67	5	1.52	0.73
Jan 2017	10	1.67	0.72	5	1.59	0.72
Mar 2017	14	1.81	0.68	4	1.30	0.67
Mean	9.22	1.20	0.51	6.94	1.16	0.60

For Selam band, the diet item evenness (*J*) was highest in January 2017 (*J* = 0.72) and lowest in May 2015 (*J* = 0.12). For Tikure band, the diet item evenness was highest in November 2016 (*J* = 0.73) and lowest in June 2015 (*J* = 0.35). However, the cumulative annual diet item evenness for Tikure band (*J* = 0.60) was greater than the annual diet item evenness of Selam band (*J* = 0.51), and the difference was not significant (H = 1.99, df = 1, p = 0.159).

Diet item diversity (H') and evenness (*J*) for Selam and Tikure bands during the wet and dry seasons differed from each other. For Selam band, the diet item diversity was higher during the dry season (H' = 1.55) than during the wet season (H' = 0.75), and the difference was significant ($F_{1,16} = 25.76$, $p < 0.001$). Similarly, for Tikure band, the diet item diversity was also higher during the dry season (H' = 1.39) than during the wet season (H' = 0.93) with significant differences (H = 9.84, df = 1, p = 0.002). During the wet season, the diet item diversity of Tikure band was higher than Selam band, but the difference was insignificant ($F_{1,15} = 1.08$, p = 0.314). During the dry season, the diet item diversity for Selam band was greater than Tikure band, but the difference was not still significant (H = 2.54, df = 1, p = 0.111).

For Selam band, the number of diet item consumed per month changed over the study period. Number of diet item consumption was significantly negatively correlated with the monthly consumption of grass blades (Spearman rank correlation coefficient: $r_s = -0.519$, p = 0.027). Consumption of number of diet items was significant and positively correlated with the monthly consumption of underground grasses ($r_s = 0.669$, p = 0.002), herb roots ($r_s = 0.537$, p = 0.022) and fruits ($r_s = 0.611$, p = 0.007). In addition, there was also positive correlation between the consumption of bulbs and number of food items, but the relationship was not significant ($r_s = 0.464$, p = 0.052). However, there was no significant relationship between the number of diet items consumption and grass seed (r_s = 0.220, p = 0.380), herb (r_s = -0.092, p = 0.716) and crop consumption (r_s = 0.160, p = 0.526).

For Tikure band, the number of diet item consumed per month also changed over the study period. However, the number of diet item consumption was not significantly correlated with the monthly consumption of grass blades (r_s = 0.250, p = 0.317), underground grasses (r_s = 0.190, p = 0.450), grass seeds (r_s = -0.429, p = 0.076), herb above items (r_s = 0.005, p = 0.983), herb roots (r_s = 0.043, p = 0.864) and invertebrates (r_s = 0.353, p = 0.151) over the study period.

4.4. Comparative daily path length and home range size

A total of 4140 GPS points (2070 from each band) were recorded from Selam and Tikure bands in 180 days follow up period. Southern gelada exhibited wide daily fluctuation in daily travel length. Thus, the daily travel distance varied widely between days for both Selam and Tikure bands. Selam band at Kosheme spent daily path length ranging from 757.18–4381.79 m, SD = 766.53. Similarly, the daily path length for Tikure band ranged from 791.49–4650.32 m, SD = 796.69 during the observation days. There was no significant difference in the daily travel length within the 180 days of the sampling period between Selam and Tikure bands (ANOVA, $F_{1,178}$ = 0.41, p = 0.525).

Mean monthly daily path length varied among months for both Selam and Tikure bands. For Selam band, mean monthly path length ranged from 1392.31 to 3701.53 m, SD = 629.15 (Table 38). The longest mean monthly path length used by Selam band was recorded in March 2017, whereas the shortest path length was recorded in September 2016. Similarly, for Tikure band, the mean monthly path length ranged from 2000.48 to 3178.01 m, SD = 320.57. The longest mean monthly path length used by Tikure band was recorded in April 2016, while the shortest path length was recorded in January 2016. There was no significant difference in the mean daily path length within the 18 months between Selam and Tikure bands (H = 0.32, df = 1, p = 0.569).

Table 38. Mean monthly day length (the first values represent for Selam band and the second for Tikure band) and monthly home range estimated by the minimum convex polygon (MCP) and kernel density estimation (KDE) for Selam and Tikure bands from May 2015–March 2017.

Month	Mean monthly day length (m)	Monthly home range size estimator (ha)							
		Selam band				Tikure band			
		95% KDE	100% MCP	95% MCP	90% MCP	95% KDE	100% MCP	95% MCP	90% MCP
May 2015	2126,2597	26.99	28.48	23.95	20.80	100.60	91.70	74.88	52.99
Jun 2015	1946,2243	79.27	77.31	76.08	73.16	194.15	81.37	73.37	69.71
Jul 2015	2353,2355	75.03	77.50	63.16	57.00	106.60	61.12	60.63	53.75
Aug 2015	1764,2297	17.92	16.70	14.01	11.82	93.39	67.19	58.41	54.25
Sep 2015	2128,2697	56.13	44.66	36.67	35.10	90.64	62.59	52.69	43.69
Oct 2015	1825,2358	32.58	29.14	17.02	14.97	71.52	59.28	51.72	37.68
Nov 2015	2363,2525	55.84	73.39	54.54	31.10	89.77	80.90	71.31	54.87
Dec 2015	2950,2180	57.84	54.17	47.00	44.98	41.91	41.04	32.36	24.65
Jan 2016	2761,2000	195.49	149.16	130.81	118.03	199.54	117.28	80.19	78.80
Feb 2016	2876,2784	60.33	50.96	41.35	40.68	294.66	145.13	138.96	136.19
Mar 2016	2873,2966	44.36	37.30	35.18	29.11	171.16	115.71	82.19	63.77
Apr 2016	2838,3178	110.42	97.37	93.06	79.13	159.28	86.49	84.15	77.12
May 2016	2270,2432	255.38	164.21	159.37	153.52	202.54	207.77	172.48	167.33
Jul 2016	1560,2355	33.73	25.75	22.63	19.39	170.88	148.22	90.76	90.10
Sep 2016	1392,2785	16.98	18.99	17.11	15.04	79.01	71.97	50.95	37.04
Nov 2016	2738,2270	39.14	38.15	33.01	31.14	104.97	112.11	57.97	38.69
Jan 2017	3419,2328	211.27	194.86	171.28	156.44	213.77	160.24	124.17	119.84
Mar 2017	3701,2965	120.78	112.19	85.69	81.77	159.84	104.47	91.03	89.76

The home range size of both bands varied between the methods used for analysis. Monthly range size varied among months for both Selam and Tikure bands (Table 38). For Selam band monthly range size varied from 16.70 ha in August (2015) to 194.86 ha in January (2017) using 100% MCP method. For Tikure band monthly range size varied from 41.04 ha in December (2015) to 207.77 ha in May (2016) using 100% MCP. Similarly, for Selam band monthly range size varied from 16.98 ha in September (2016) to 255.38 ha in May (2016) using 95% KDE method.

The seasonal daily path length and home range size for Selam and Tikure bands are presented in Table 39 and Figures 46, 47, 48 and 49. Both Selam and Tikure bands travelled longer daily path length during the dry season than the wet season. For Selam band, there was a significant difference in daily path length between the wet and dry seasons ($F_{1,88} = 45.00$, $p < 0.001$) of the observation days. However, the daily path length for Tikure band was not significant difference between the wet and dry seasons ($F_{1,88} = 0.60$, $p = 0.441$). There was significant difference in daily path length during the wet season comparing between Selam and Tikure bands ($H = 7.40$, $df =1$ $p = 0.007$). However, there was no significant difference in mean daily path length during the dry season between the two bands ($F_{1,88} = 3.43$, $p = 0.067$).

The mean seasonal home range size for Selam band was larger during the dry season than the wet season, but the difference was not significant between seasons (56.70 vs. 83.67 ha: ANOVA, $F_{1,16} = 1.17$, $p = 0.296$) using 100% MCP method. Similarly, using 100% MCP method, the mean home range size of Tikure band did not differ significantly between the wet and dry seasons (94.58 vs. 107.04 ha: $F_{1,16} = 0.37$, $p = 0.553$). Seasonal home range size varied between bands. There was no significant difference for home range size determination comparing between Selam and Tikure bands during both the dry and wet seasons (wet: 56.70 vs. 94.58%, $F_{1,15} = 2.41$, $p = 0.142$; dry: 83.67 vs. 107.04%, $F_{1,17} = 1.19$, $p = 0.290$) using 100% MCP methods. In addition, using 95% KDE method, there was no significant difference for home range size determination between Selam and Tikure bands during the dry season (wet: 70.18 vs. 123.26%, $F_{1,15} = 2.78$, $p = 0.116$; dry: 92.81 vs. 159.43%, $F_{1,17} = 4.32$, $p = 0.053$).

Table 39. Seasonal daily path length, home range and core area for Selam and Tikure bands.

Band	Group size	Daily path length (m)	Season	Seasonal home range estimator (ha)				Core area (ha)	
				95% KDE	100% MCP	95% MCP	90% MCP	50% KDE	50% MCP
Selam	31-42	1942.65±584	Wet	116.73	205.52	101.07	88.92	29.89	13.38
		2834.92±659	Dry	156.59	272.84	225.07	214.42	55.14	88.71
Tikure	75-147	2447.52±891	Wet	309.81	370.52	342.33	219.57	67.76	20.56
		2577.75±693	Dry	208.48	213.02	180.25	157.01	44.30	23.22

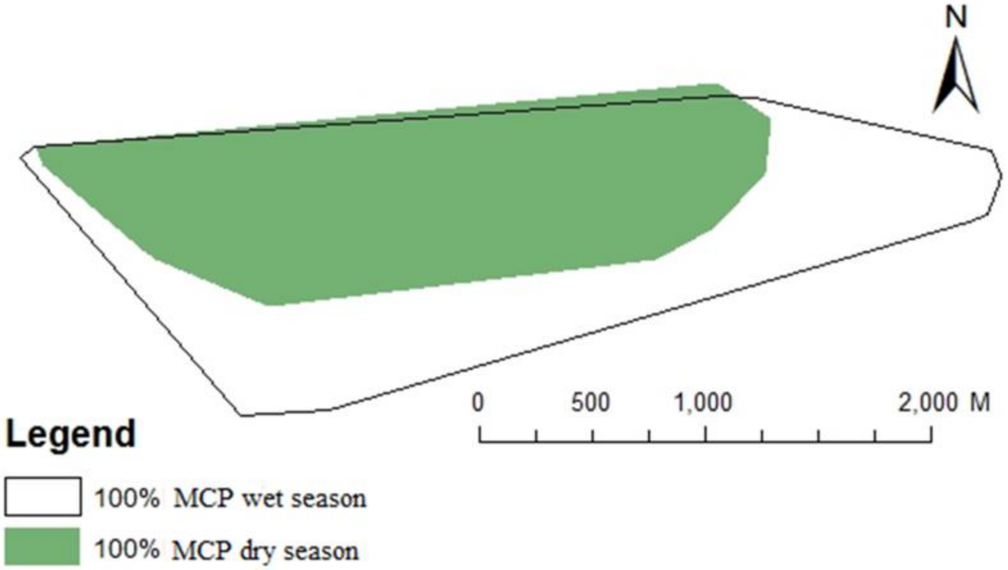

Figure 46. Seasonal home range size utilized by Tikure band using MCP method.

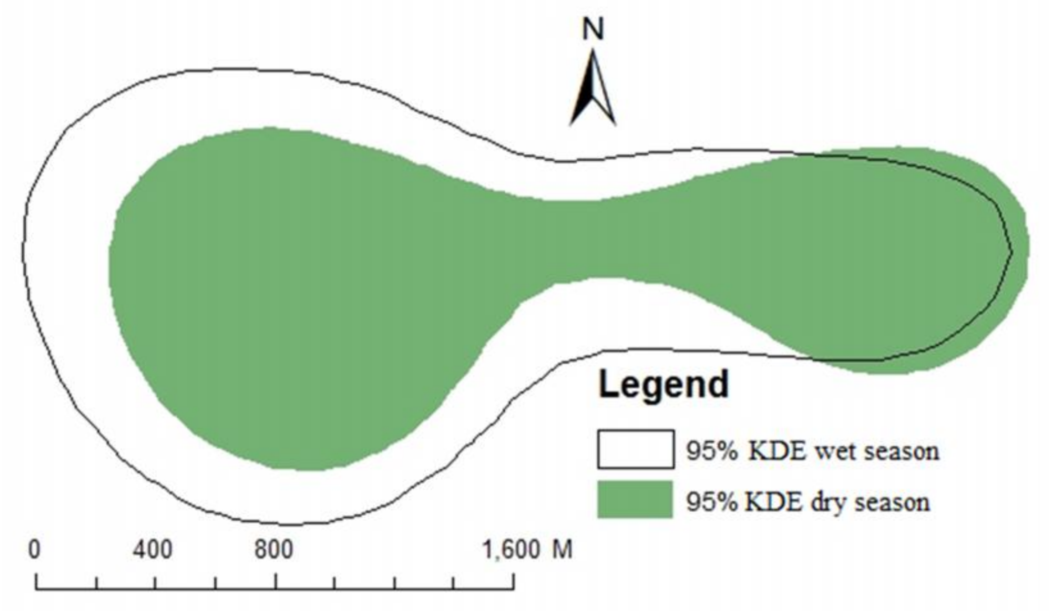

Figure 47. Seasonal home range size utilized by Tikure band using KDE menthod.

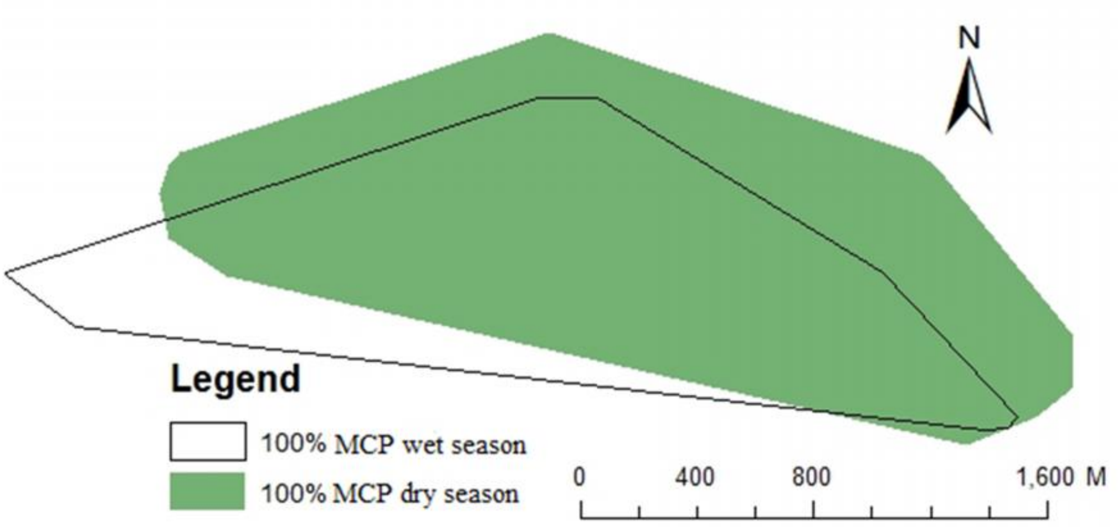

Figure 48. Seasonal home range size utilized by Selam band using MCP method.

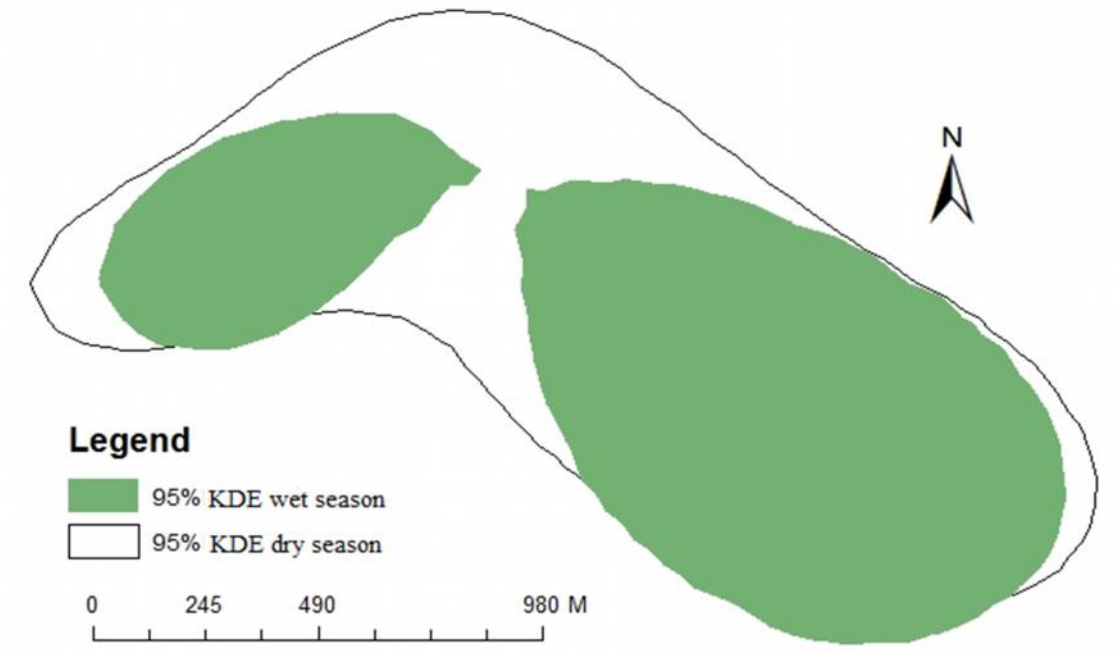

Figure 49. Seasonal home range size utilized by Selam band using KDE method.

The annual home range size and core area occupied by both Selam and Tikure bands is presented in Table 40 and Figure 50, 51, 52 and 53. The mean annual day path length for Selam band was 2438.35 m while it was 2512.64 m for Tikure band. Using the 100% MCP method, the annual home range size occupied by Selam band was 328.13 ha and 382.06 ha by Tikure band. Similarly, using the 95% KDE method, the annual home range size occupied by Selam band was 150.80 ha and 265.41 ha by Tikure band. The mean annual home range size utilized by Tikure band was higher than Selam band, but the difference was not significant between bands (71.68 vs. 100.81 ha: $F_{1,34} = 3.30$, $p = 0.078$) using 100% MCP method. However, using 95% KDE method, the mean annual home range size differed significantly between Selam and Tikure bands (82.75 vs. 141.35 ha: $F_{1,34} = 6.77$, $p = 0.014$).

Table 40. Annual home range and core area estimated by minimum convex polygon and kernel density methods occupied by Selam and Tikure bands.

Band	Group size	Habitat type	Annual home range estimator (ha)				Core area (ha)	
			95% KDE	100% MCP	95% MCP	90% MCP	50% KDE	50% MCP
Selam	31-42	Afromontane	150.80	328.13	213.68	167.14	37.92	33.61
Tikure	75-147	Afroalpine	265.41	382.06	260.97	239.04	51.56	27.80

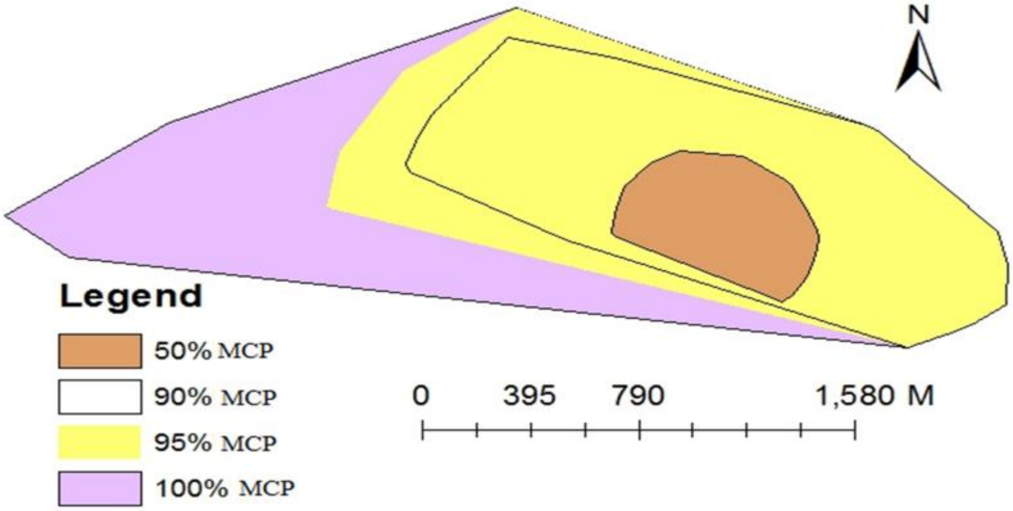

Figure 50. Annual home range size and core area occupied by Selam band using MCP.

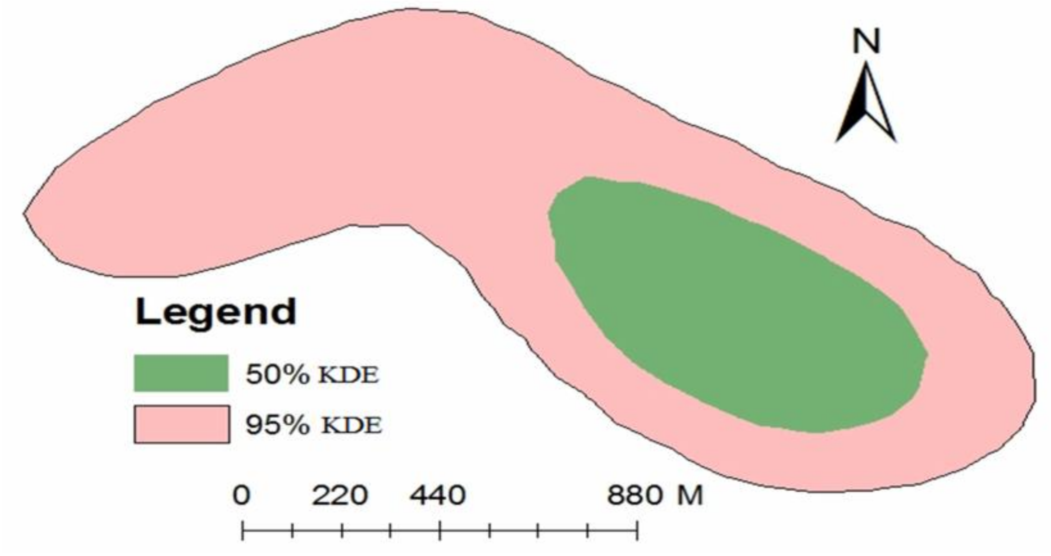

Figure 51. Annual home range size and core area utilized by Selam band using KDE method.

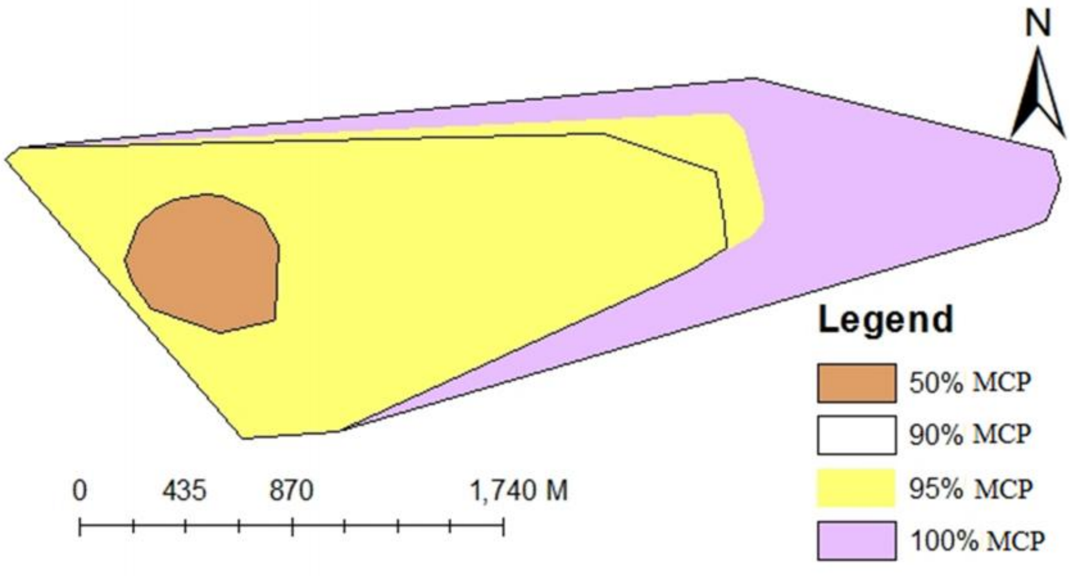

Figure 52. Annual home range size and core area utilized by Tikure band using MCP method.

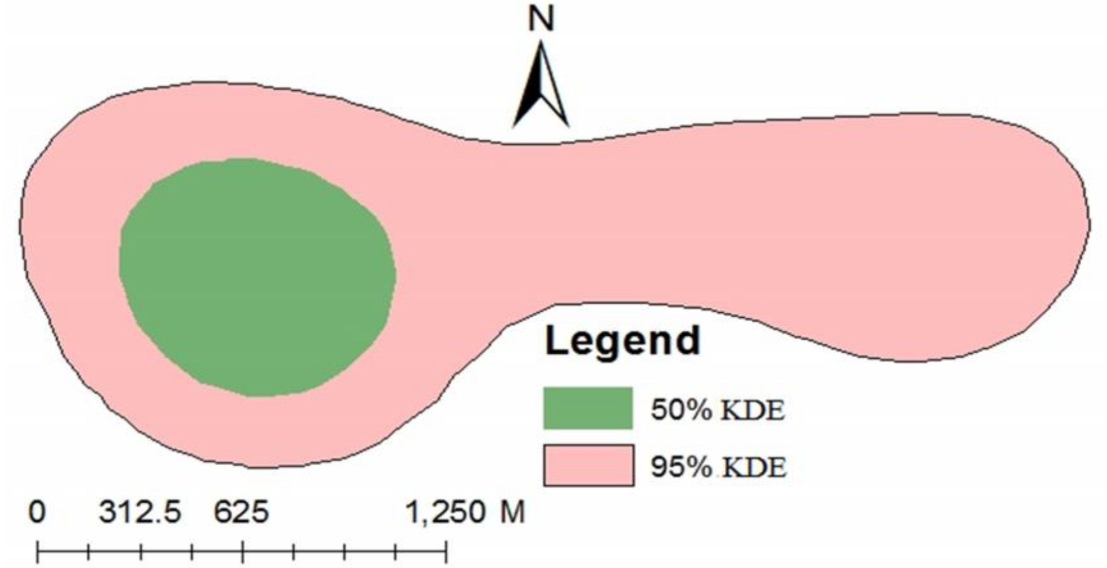

Figure 53. Annual home range size and core area utilized by Tikure band using KDE method.

The mean monthly day path length was affected by the type of diet consumptions. For Selam band, monthly mean daily path length was significant and negatively correlated with monthly proportion of grass blade (*r* = -0.476, p = 0.046) and herb aboveground (*r* = -0.686, p = 0.002) consumptions. However, monthly mean daily path length was significant and positively correlated with monthly proportion of underground grass (r = 0.744, p < 0.001), fruit (r = 0.692, p = 0.001) consumptions. There was no significant correlation between monthly mean daily path length and the proportion of crop (r = 0.060, p = 0.812) and bulb (r = 0.043, p = 0.864) consumptions. For Tikure band, there was no significant correlation between monthly mean daily path length and the proportion of grass blade (r = -0.235, p = 0.349), grass underground (r = 0.317, p = 0.199), grass seed (r = -0.051, p = 0.839), herb aboveground (r = -0.266, p = 0.286), herb root (r = 0.389, p = 0.110) and invertebrate (r = 0.402, p = 0.098) consumptions.

4.5. Habitat use of southern geladas

The study bands used different type of microhabitats which are available in their respective home ranges. For Selam band, a total of 4227 behavioural records on the microhabitat use were collected during 90 days and 1056.75 hours during the study period. Selam band at Kosheme used grazing plateau from 17.00–56.91%, bush plateau 2.62–31.65%, escarpment 0.00–27.00%, cliff 8.44–77.73%, gorge bush 0.00–32.49% and farmland 0.00–32.62% of the available microhabitats during the study months (Table 41). Selam band primarily used grazing plateau and bush plateau during the study months. Selam band showed a higher preference of open grazing plateau over the other microhabitats. The band used farmlands extensively in July (sowing month), November, December and January when local farmers harvest and collect cereal crops.

There was a significant difference in the habitat use among the 18 months of the sampling period (bush plateau: $\chi2$ = 162.31, df = 17, p < 0.001; cliff: $\chi2$ = 312.74, df = 17; escarpment: $\chi2$ = 235.88, df = 16; grazing plateau: $\chi2$ = 363.51, df = 17; farmland: $\chi2$ = 275.50, df = 14; gorge bush: $\chi2$ = 331.90, df = 15) for Selam band.

Table 41. Monthly microhabitat use by Selam band at Kosheme from May 2015–March 2017.

Month	Records	Microhabitat, %					
		Grazing plateau	Bush plateau	Cliff	Escarpment	Gorge bush	Farmland
May 2015	231	74.03	6.06	15.15	0.00	1.30	3.46
Jun 2015	226	51.33	17.26	17.70	2.65	3.98	7.08
Jul 2015	230	18.70	8.70	38.26	0.87	14.35	19.13
Aug 2015	231	71.86	9.96	9.09	6.49	0.00	2.60
Sep 2015	229	52.40	2.62	10.92	26.20	7.86	0.00
Oct 2015	233	69.53	13.30	9.87	4.72	2.58	0.00
Nov 2015	232	21.12	20.26	8.19	14.66	2.16	33.62
Dec 2015	237	36.71	5.49	0.42	11.39	32.49	13.50
Jan 2016	237	37.55	12.24	1.69	16.46	5.91	26.16
Feb 2016	240	65.00	11.67	2.50	7.50	1.25	12.08
Mar 2016	238	77.73	6.30	7.98	2.94	0.84	4.20
Apr 2016	243	57.61	9.47	7.00	6.17	12.76	7.00
May 2016	244	50.82	24.59	2.05	8.20	7.79	6.56
Jul 2016	232	66.38	18.97	10.78	1.72	0.00	2.16
Sept 2016	237	8.44	31.65	11.39	27.00	21.52	0.00
Nov 2016	234	32.91	14.53	9.83	12.82	22.65	7.26
Jan 2017	233	26.18	12.88	1.29	9.01	26.61	24.03
Mar 2017	240	47.92	18.33	3.75	4.17	22.92	2.92

For Tikure band, a total of 4150 behavioural scans of microhabitat use were collected across the 90 days and 1038.75 hours during the study periods. Tikure band at Keywasha used long grassland plateau (LGP) from 15.56–60.70%, grazing open plateau (GOP) 18.97–51.52%, escarpment 0.00–29.74%, cliff 2.22–20.52%, *Erica* dominated forest (EDF) 0.00–54.22% and farmland 0.00–2.16% across the study period (Table 42). The highest proportion use of EDF was in June 2015 (54.22%), beginning of the main rain month. The band used the afroalpine long grassland plateau, grazing grassland and cliff microhabitat types almost in similar manner across the study months. There was a significant difference in each microhabitat use among the 18 months of the sampling period (LGP: $\chi2 = 185.46$, df = 17, $p < 0.001$; cliff: $\chi2 = 97.72$, df = 17;

GOP: $\chi2 = 107.19$, df = 17; EDF: $\chi2 = 436.77$, df = 12; escarpment: $\chi2 = 242.05$, df = 9) for Tikure band.

Table 42. Monthly microhabitat use by Tikure band at Keywasha from May 2015–March 2017.

Month	Records	Microhabitat, %					
		LGP	GOP	EDF	Escarpment	Cliff	Farmland
May 2015	230	55.65	32.61	8.26	0.00	3.48	0.00
Jun 2015	225	15.56	28.00	54.22	0.00	2.22	0.00
July 2015	229	46.72	32.75	0.00	0.00	20.52	0.00
Agu 2015	231	53.25	25.11	3.03	2.16	16.45	0.00
Sep 2015	229	60.70	33.19	0.00	0.00	6.11	0.00
Oct 2015	227	59.47	32.60	0.00	0.00	7.93	0.00
Nov 2015	230	51.74	29.13	4.78	1.30	13.04	0.00
Dec 2015	230	50.87	33.04	0.00	0.00	16.09	0.00
Jan 2016	232	21.55	18.97	17.24	29.74	11.64	0.86
Feb 2016	236	38.56	31.36	16.53	4.66	8.90	0.00
Mar 2016	232	50.00	34.05	3.45	0.86	10.78	0.86
Apr 2016	235	53.19	20.43	5.96	8.94	11.49	0.00
May 2016	236	39.83	40.25	3.81	6.78	8.05	1.27
Jul 2016	236	28.81	50.00	2.12	0.85	18.22	0.00
Sep 2016	229	44.98	47.60	0.00	0.00	7.42	0.00
Nov 2016	225	28.44	45.33	6.22	2.22	17.78	0.00
Jan 2017	232	21.98	46.55	13.79	7.33	8.19	2.16
Mar 2017	231	30.30	51.52	10.82	0.00	7.36	0.00

Seasonal variation in habitat use: Southern geladas utilized escarpment, grazing plateau and bush plateau in almost similar proportion both during the wet and dry seasons. During both the wet and dry seasons, Selam band primarily used grazing plateau followed by bush plateau. Thus, there was no significant difference between the dry and wet seasons on the use of escarpment (8.96 vs. 9.19%, H = 0.94, df = 1, p = 0.328), grazing plateau (47.36 vs. 49.14%, $F_{1,16} = 0.04$, p

= 0.846) and bush plateau (12.42 vs. 15.11%, H = 0.07, df = 1, p = 0.790). Selam band showed a high preference for the gorge bush during the dry season than the wet season. However, there was no significant difference between the dry and wet seasons on the habitat use of gorge bush (13.02 vs. 7.15%, $F_{1,16}$ = 1.46, P = 0.245). There was no significant difference between the dry and wet seasons on the habitat use of farmland (13.01 vs. 5.11%, $F_{1,16}$ = 3.25, p = 0.090). Selam band used cliff more time during the wet season than the dry season, and the difference was significant (5.24 vs. 14.30%, $F_{1,16}$ = 7.55, p = 0.014).

During the wet and dry seasons, Tikure band primarily used LGP followed by GOP and cliff. There was no significant difference between the dry and wet seasons on the microhabitat use (LGP: 38.55 vs. 44.98%, $F_{1,16}$ = 0.95, p = 0.345; GOP: 34.42 vs. 35.86%, $F_{1,16}$ = 0.08, p = 0.786; EDF: 8.79 vs. 7.82%, H = 3.35, df = 1, p = 0.067; cliff: 11.67 vs. 10.09%, H = 1.03, df = 1, p = 0.310). However, there was significant difference between the wet and dry seasons on the use of escarpment (6.14 vs. 1.11%, H = 4.32, df = 1, p = 0.038).

Farmland represented the only unnatural habitat as it constitutes cultivated cereal crops as part of the geladas ranging area at Kosheme site. Access to food source was highly seasonal and restricted to the cultivation time. However, the use of farmland habitat types was rarely used by southern geladas at Keywasha site. It was the outer limits of the geladas ranging area in this site.

Annual microhabitat use: Southern geladas spent most of their time in open grazing land. Thus, geladas are open grazing land seekers for performing their daily behavioural activities. Selam band primarily used grazing plateau followed by bush plateau from the overall frequency sample records of the microhabitat types (Fig. 54). Both of these microhabitats were found above the sleeping cliff site of Selam band. Thus, the predominant occurrence of Selam band was above their sleeping sites that comprised 61.74% from the overall records excluding the farmlands.

Only 10.43% of the time used was gorge bush microhabitat. Thus, the band selected grazing plateau and avoided gorge bush.

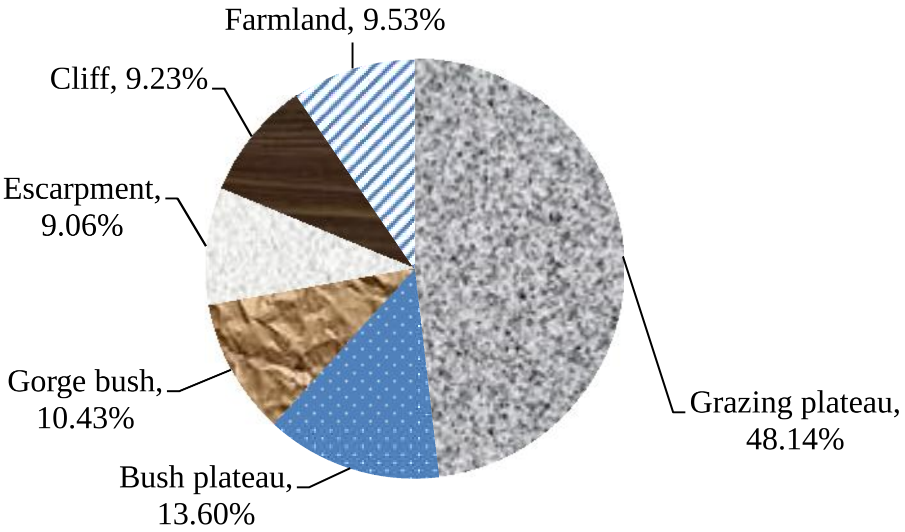

Figure 54. Annual habitat use of Selam band during the study period.

For Selam band, there was significant difference among the annual microhabitat use (Kruskal–Wallis H test, H = 40.14, df = 5, p < 0.001). Using the pairwise comparison test, a significant difference was observed as grazing plateau compared to cliff, escarpment, farmland, gorge bush (p < 0.001) and bush plateau (p = 0.001) microhabitats. However, there was no significant difference between the use of farmland compared to cliff (p = 0.829), bush plateau (p = 0.081), escarpment (p = 0.867) and gorge bush (p = 0.890). There was also no significant difference between the use of gorge bush compared to escarpment (p = 0.977), cliff (p = 0.938) and bush plateau (p = 0.109). Similarly, there was also no significant difference between the use of escarpment compared to cliff (p = 0.962) and bush plateau (p = 0.115) and cliff with bush plateau (p = 0.127).

Tikure band primarily used long grassland plateau followed by grazing grassland plateau from the overall frequency sample records of the microhabitat types (Fig. 55). Tikure band did not use the central part of the long and dense *Festuca* dominated grassland type of microhabitat.

Rather the band preferred the periphery part of this microhabitat. The band sought the grazing open plateau even if the availability of food was low as the result of livestock grazing. Thus, the band selected grazing in open plateau and avoided forest and *Festuca* dominated microhabitats.

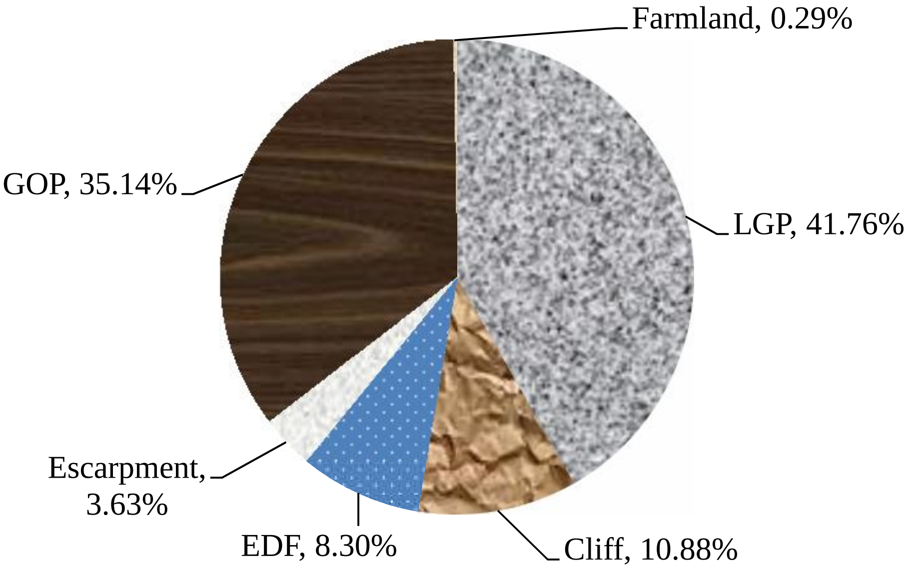

Figure 55. Annual microhabitat use of Tikure band.

For Tikure band, there was a significant difference among the overall frequency of microhabitat use (H = 63.67, df = 4, $p < 0.001$) during the course of the study period. Using pairwise comparisons, a significant difference was observed in long grassland plateau compared to cliff, *Erica* dominated forest and escarpment ($p < 0.001$) microhabitats. There was also significant difference when cliff was compared to grazing open plateau ($p = 0.001$), *Erica* dominated forest and grazing open plateau ($p < 0.001$), and escarpment to grazing open plateau ($p < 0.001$) and cliff to escarpment ($p = 0.017$). However, there was no significant difference between the frequency use of long grassland plateau and grazing open plateau ($p = 0.544$) and escarpment with *Erica* dominated forest ($p = 0.241$). Similarly, there was no significant difference when *Erica* dominated forest was compared to cliff ($p = 0.244$).

4.6. Questionnaire survey

A total of 356 individuals participated for questionnaire survey in the study area. All the respondents were directly connected and exposed to crop raiding of their farmland by southern geladas. All of the participants were from Amhara ethnic group since the study area is the resident of Amhara community. The majority of respondents 89.33% (*n* = 318) were males, while 10.67% (*n* = 38) were females. There was a significant difference between the number of male and female respondents (Chi-square goodness of fits: $\chi 2 = 220.23$, df = 1, $p < 0.001$). However, there was no significant difference in the proportion of genders interviewed between the BSNP and the unprotected village sites (Chi-square test of independence: $\chi 2 = 0.044$, df = 1, $p = 0.833$). Age of the respondents ranged from 18 to 90 years, with a mean of 48.88 and standard deviation of 16.05 years old. The ages of respondents in the unprotected site ranged from 20 to 85, with the mean of 50.97 and standard deviation of 15.18 years old; whereas the ages of respondents from the BSNP ranged from 18 to 90, with the mean of 47.07 and standard deviation of 16.60. The family sizes of the respondents ranged from 1 to 12 with a mean of 5.73 ± 2.35. From the total respondents, 53.65 % (*n* = 191) were from the BSNP while 46.35% (*n* = 165) were from the unprotected site, far from the BSNP.

The respondents involved in the questionnaire survey were the followers of Orthodox Christians (54.78%, *n* = 195) and Muslims (42.22% *n* = 161). There was no significant difference between the total number of Orthodox and Muslim respondents (Chi-square goodness of fits: $\chi 2 = 3.25$, df = 1, $p = 0.072$). From the total respondents, who lived near the BSNP, 89.01% (*n* = 170) were predominantly Orthodox Christians and 10.99% (*n* = 21) were Muslims; while 15.15% (*n* = 25) were Orthodox and 84.85% (*n* = 140) were predominantly Muslim followers who lived in the unprotected site. There was a significant difference between the sites of local settlements on their religion (Chi-square test of independence: $\chi 2 = 194.92$, df = 1, $p < 0.001$).

Regarding the education, 68.54% ($n = 244$) had no formal education, whereas 20.79% ($n = 74$) and 6.18% ($n = 22$) had primary and secondary educational status, respectively. The other 4.49% ($n = 16$) of the respondents had nonformal religious education. There was a significant difference among respondents (Chi-square goodness of fits: $\chi 2 = 382.79$, df = 3, $p < 0.001$) on their educational level. Respondents from the unprotected site generally were more educated than those respondents who were found near the BSNP. There was a significant difference among respondents on their settlement sites in their educational level (Chi-square test of independence: $\chi 2 = 29.92$, df = 3, $p < 0.001$).

Almost all of the respondents lived on subsistence farming. Out of the respondents, 77.53% ($n = 276$) had their own land while 22.47% ($n = 80$) did not have their own land (Table 43). Respondents who were found at the periphery of the Park grow barley, wheat, bean, teff, maize, potato, whereas respondents who lived in the unprotected site grow teff, wheat, bean, maize, pea, chickpea, sorghum, grasspea, and lentil. Those respondents from the unprotected site harvested more diversified type of cereal crops than those living near the Park. Those respondents who had no farmland harvest crops by renting lands from other local farmers. In addition to the cultivation of cereal crops, some farmers from the unprotected site also grew commercial crops like sugar cane, chat, onion, coffee and others in and near their compounds.

Most of the respondents 96.07% ($n = 342$) had livestock. The overall mean livestock of the respondents was 7.64 ± 6.25 maximum 43. Those respondents who lived near the periphery of the Park had greater number of livestock than those who lived in the unprotected site. Thus, respondents who lived near the BSNP had a mean of 10.31 ± 6.79 with the maximum number of

43 whereas those respondents who lived in the unprotected site had a mean of 4.54 ± 3.61 with the maximum number of 20 livestock. The livestock of respondents included cattle, sheep and goats. Pack animal and poultry were also kept. Those respondents who lived near the BSNP complain that after the development of the Park their livestock have been declined dramatically from year to year as the result of lack of grazing pasture. Most respondents 69.11% (*n* = 132) near the BSNP told that their livestock decline by half after the development of the Park. While others 25.65% (*n* = 49) and 5.24% (*n* = 10) of the respondents stated that their livestock stable and increased, respectively.

Table 43. Summary of socioeconomic and demographic profile of the respondents in the study sites.

Characteristics	Sites, n (%)	
	Unprotected	Protected
Sex		
Male	148 (89.7)	170 (89.0)
Female	17 (10.3)	21 (11.0)
Age		
18-35	32 (19.4)	55 (28.8)
36-50	50 (30.3)	59 (30.9)
>50	83 (50.3)	77 (46.7)
Education		
Uneducated	96 (58.2)	148 (77.5)
Primary	49 (29.7)	25 (13.1)
Secondary	17 (10.3)	5 (2.6)
Religion education	3 (1.8)	13 (6.8)
Religion		
Orthodox	25 (15.2)	170 (89.0)
Muslim	140 (84.8)	21 (11.0)
Land tenure		
Yes	143 (86.7)	133 (69.6)
No	22 (13.3)	58 (30.4)
Source of livelihood		
Crop and livestock	155 (93.9)	187 (97.9)
Crop production	10 (6.1)	3 (1.6)
Other source of income		

Yes	29 (23.6)	72 (37.7)
No	126 (76.4)	119 (62.3)
Harvest yearly food		
Yes	112 (67.9)	101 (52.9)
No	53 (32.1)	90 (47.1)
Livestock size		
≤10	155 (93.9)	117 (61.3)
>10	10 (6.1)	74 (38.7)
Family size		
≤5	85 (51.5)	89 (46.6)
>5	80 (48.5)	102 (53.4)

Among the respondents, 68.82% (*n* = 245) had no additional income other than livestock rearing and crop production and the other 31.18 % (*n* = 111) had other income through harvesting honey and practicing small business. 76.36% (*n* = 126) of the respondents from the unprotected site and 62.30% (*n* = 119) from the BSNP did not have any additional income other than subsistence farming activities. However 37.70% (*n* = 72) of the respondents from the Park get additional indirect income through harvesting honey. Among the total respondents of both sites, 59.83% (*n* = 213) harvested enough cereal crop products for their yearly consumption whereas 40.17% (*n* = 143) of the respondents did not produce a yearly round cereal crop to cover for their family. There was a significant difference between respondents on their production of enough cereal crop for their yearly consumption ($\chi 2 = 13.76$, df = 1, $p < 0.001$).

Trend of crop raiding by southern geladas was pronounced in the study area (Table 44). The majority of participants (54.21%, *n* = 193) across both study sites stated that the trend of crop damage increased in recent years as the result of minimizing harassments by the local people and increasing gelada population. Some (25.28%, *n* = 90) of the respondents across both study sites informed that the trend of crop damage is similar from year to year in their villages. Others (30.30%) from the unprotected site responded that the trend of crop damage decreased in recent years a result of declining number of geladas. There was a significant interaction between settlements of villages on the trend of crop damage by geladas ($\chi2 = 18.13$, df = 2, $p < 0.001$).

Table 44. Trend of crop damage by southern geladas in the study sites.

Settlement	*n*	Trend of crop damage, %		
		Decrease	Increase	Similar
Park	191	12.04	59.69	28.27
Unprotected	165	30.30	47.88	21.82
Total and mean	356	20.51	54.21	25.28

Southern geladas raided almost all type of crops that the local farmers cultivated on their farmlands such as barley, wheat, teff, sorghum, bean, pea, maize, grasspea, chickpea and lentil. The frequency of crop raiding by the southern geladas was high in the study area. Among the respondents, 55.76% from the unprotected site and 51.83% from the Park villages stated that southern geladas visited their crop almost every day. These respondents had farmlands very close to the sleeping sites of geladas. Among the respondents, 31.94% from the Park and 35.76% from the unprotected site raided their crops by geladas occasionally. These respondents strongly protected their farmlands from being raided by geladas. Only 16.23% of the respondents from the Park and 8.48% from the unprotected sites reported that southern geladas never raided their cereal crops. There was no significant relationship between settlement of sites on the rate of crop raiding occurrence of southern geladas ($\chi2 = 4.84$, df = 2, $p = 0.089$).

Geladas raided a wide range of crops that are cultivated in the study area. Respondents indicated that geladas raided different type cereal crops at different developmental stages from sowing up to cropping. Geladas raided barley, bean, pea and wheat starting from sowing to harvesting stages. Respondents reported that the intensity of crop raiding by geladas reached highest point during their fruiting and drying stages. Geladas preferred to consume teff at the seeding and vegetative stages over the other types of cereal crops. In addition, geladas preferred to raid monocots than dicots crops like beans during the seedling and vegetative stages.

Nearly all of the respondents from all villages of both study sites had experienced crop raiding, grazing competition with livestock and digging pasture lands by the southern geladas. Respondents across both study sites (92.13%) reported geladas as notorious cereal crop raiders. Southern geladas also competed with livestock for pasture lands and damaged the grazing pasture by digging the ground in order to collect subterranean diet items in both study sites. In addition, villagers reported that southern geladas snatch their cereal crops from heaps of the threshing fields and grains (grains that were put on the ground for drying) from their compounds (Table 45). Among the respondents, 93.33% from the unprotected site and 91.10% from the Park surrounding villages had experienced crop raiding problems. In addition, 84.24% from the unprotected site and 84.29% from the Park surrounding villages faced problems by geladas as the result of sharing livestock grazing pasture and digging the ground. Some highlander respondents (16.23%) from the Park site also complained that southern geladas damage kraals locally called ‘Dereba’. These farmers constructed kraals in the pasture field near the buffer zone of the Park for protecting their livestock from storm during the wet season. Southern geladas especially yearlings and juveniles climbed these kraals to play on it or find some insects. At that time, they dismantle the thatching covers. The forms of human-gelada conflicts did not differ significantly between the two study sites: crop raiding ($p = 0.435$), competition with livestock for pasture ($p = 0.990$) and stealing grains from the compound ($p = 0.066$).

Table 45. Forms of conflict between geladas and the local farmers.

Variables	Response of villagers, %				$\chi 2$	df	p value
	BSNP		Unprotected				
	Yes	No	Yes	No			
Forms of conflcits							
Crop raiding	91.09	8.91	93.33	6.67	0.61	1	0.435
Pasture grazing and digging	84.29	15.71	84.24	15.76	0.01	1	0.990
Theft from the compound	53.40	46.60	43.63	56.36	3.38	1	0.066
Kraal damage	16.23	83.77	0.00	0.00			

In addition to crop damage, pasture grazing and snatching from the compound, geladas contribute to hidden costs to the local farmers. Most of the respondents from both sites had labour bottleneck and travel restriction opportunity costs as the result of guarding their cereal crops throughout the daylight hours (Table 46). They kept their farmlands by shifting the family members or helping each other throughout the day starting from sowing till threshing the harvested crops. Guarding hindered family members from doing other activities. Guarding hindered students from going to schools, mothers and fathers from doing housework and farming activities intensively and other social activities like marketing, meeting and mourning. Respondents replied that they moved up and down, throwing stones, bouldering and slinging throughout the daylights to chase geladas far away from their farmlands. The hidden effect of human-gelada conflicts did not differ significantly between the two sites: sleeping ($\chi 2$ = 4.73, df = 2, p = 0.094), labour ($\chi 2$ = 0.46, df = 2, p = 0.795), travel ($\chi 2$ = 2.53, df = 2, p = 0.767), schooling ($\chi 2$ = 0.68, df = 2, p = 0.714) and energy costs ($\chi 2$ = 2.42, df = 2, p = 0.298).

Table 46. Hidden effects of the southern geladas on the local farmers.

Variables	Responses, %					
	BSNP			Unprotected		
	High	Low	No effect	High	Low	No effect
Hidden/opportunity effect						
Less sleep	43.98	34.03	21.99	55.15	29.09	15.76
Labour bottleneck	74.87	14.14	10.99	72.73	13.94	13.33
Travel restriction	73.30	13.09	13.61	71.52	15.75	12.73
Disruption students from schooling	35.08	26.18	38.74	32.73	24.24	43.03
Loss of energy during chasing	47.64	32.98	19.38	53.33	25.46	21.21
Accident	5.24	10.47	84.29	15.15	17.58	67.27

Respondents in the study area used varieties of deterrent method to protect their cereal crops from being damaged by southern geladas. The most commonly utilized method used by most farmers against geladas was direct watching with chasing by standing in front of their farmlands throughout the cropping seasons. Guarding by chasing was the most effective and frequent method considered and used by most local farmers. Respondents from both sites also used shouting, stoning, bouldering, sticking, slinging and dogs to chase geladas far away from the nearby farmlands. But they claimed that these methods are not effective. When the farmers chased geladas and return back, they follow them immediately. Some of these methods cause some accident and risk of death due to falling from the cliff. Some respondents also used horn to scare geladas, and considered as good method to create fear among them. Additionally, respondents erected scarecrow wrapping with clothes just in front of or inside their farmlands, but temporary.

Variable responses are given by respondents about the trends in geladas (Table 47). 84.82% of the respondents around the Park believed that the population of gelada is increasing in recent years. Their reason for the increasing of gelada is due to conservation activities in the area. 63.63% of the respondents from the unprotected site believed that the population of geladas increased in their villages. There was significant difference among respondents on the view of trends on population of geladas in their villages ($\chi 2 = 36.16$, df = 3, p = 0.001).

Table 47. Trend of gelada populations in and around the BSNP.

Respondents settlement	*n*	Respondents view on trends of gelada populations, %			
		Increasing	Decreasing	Stable	Not sure
Park	191	84.82	3.14	1.57	10.47
Unprotected	165	63.63	19.39	9.71	7.27
Total and mean	156	75.00	10.66	5.34	9.00

Conflict between the local farmers and the southern gelada is intense across both study sites. Respondents from both sites stated that southern geladas are among the notorious crop raiders in the study area. As the result of this, 93.94% (*n* = 155) of the respondents from the unprotected site and 90.58% (*n* = 173) from the BSNP considered southern geladas as crop pests. Among the total respondents, 92.13% (*n* = 328) across both study sites considered southern geladas as crop pest in their village. No significant difference was observed between respondents of the Park and unprotected sites on their view of crop pest status ($\chi 2 = 1.38$, df = 1, p = 0.240). Chi-square association model also showed that consideration of geladas as crop pests did not differ significantly in all the other four independent variables between sexes, ages, religions and education (Table 48).

Among the respondents from the Park, 54.45% (*n* = 104) and 79.39% (*n* = 131) from the unprotected site had no knowledge on the endemicity of the geladas. Respondents from the Park site had more knowledge on the endemicity of geladas than those respondents from the unprotected site. There was significant difference among the respondents between the two conservation status sites on their knowledge on the endemism of geladas in Ethiopia ($\chi2 = 24.55$, df = 1, $p < 0.001$).

Table 48. Respondents view of geladas as pests based on the sites of villages and demographic variables.

Variables	Gelada as pest, %		Chi-square association model		
	Yes	No	$\chi2$	df	p value
Villages					
BSNP	90.58	9.42	1.38	1	0.240
Unprotected	93.94	6.06			
Gender					
Male	92.76	7.24	1.64	1	0.220
Female	86.84	13.16			
Age					
18-35	93.10	6.90	1.08	2	0.584
36-50	89.91	10.09			
>50	93.13	6.87			
Religion					
Orthodox	90.26	9.74	2.10	1	0.147
Muslim	94.41	5.59			
Education					
Uneducated	92.92	7.38	3.49	3	0.321
Primary	93.24	6.76			
Secondary	81.82	18.18			
Religion education	93.75	6.25			

The majority (65.73%) of respondents from both study sites supported the need for gelada conservation of in the area (Table 49). Those, respondents who supported the conservation of geladas elaborated that the conservation of geladas is ethical and they viewed geladas as aesthetics. Those respondents who opposed the necessary of gelada conservation elaborated and claimed that geladas had no any value other than creating a lot of problems like raiding crop and wasting unnecessary time and energy for guarding them.

Respondents from the Park boundaries had more interest on the need of gelada conservation than those respondents from the unprotected site ($p < 0.001$; Table 49). Males significantly supported gelada conservation more than females (p = 0.002). In addition, young respondents were more interested on the need of gelada conservation than adult and old age respondents, and the difference was significant among age categories (p = 0.011).

Table 49. Respondent view towards the need of gelada conservation in the study sites.

Demographic variables	Need of gelada conservation, %			Chi-square association model		
	Yes	No	Neutral	$\chi2$	df	p value
Villages						
BSNP	75.92	20.42	3.66	19.94	2	<0.001
Unprotected	53.94	41.82	4.24			
Gender						
Male	67.92	29.25	2.83	12.56	2	0.002
Female	47.37	39.47	13.16			
Age						
18-35	78.16	19.54	2.30			
36-50	69.72	26.61	3.67	13.15	4	0.011
>50	56.25	38.75	5.00			
Education						
Uneducated	65.98	29.92	4.10			
Primary	64.86	31.08	4.06	0.77	6	0.993
Secondary	63.64	31.82	4.55			
Religion education	68.75	31.25	0.00			

The full logit model containing all predictors was statistically significant ($\chi2$ = 33.33, df = 4, p < 0.001) indicating that the model was worthwhile, and able to distinguish between respondents who had yes or no answer on the need of gelada conservation. The Wald chi-square test criterion demonstrated that age, settlement site, gender and religion made significant influences on the conservation of geladas (Table 50). Educational level was not significant predictor to the model on the conservation of geladas. Nagelkerke's R^2 was 0.130, and correctly predicted percentage was 71.3%. The strongest predictor on the need of conservation of geladas was settlement site, recording odd ratio of 2.66.

Table 50. Binary Logit model regarding local farmer's on the need of gelada conservation (outcome variable: conservation need (1 = yes, 0 = no).

Predictor variables	Estimate	Std error	Wald chi-square	df	p value	Odd ratio
Settlement (1 = Park)	0.978	0.251	15.13	1	<0.001	2.66
Age	-0.025	0.008	9.86	1	0.002	0.98
Gender (1 = male)	0.829	0.397	4.37	1	0.037	2.29
Educational level (1 = Educated)	-0.087	0.275	0.10	1	0.751	0.92
Constant	0.849	0.550	2.38	1	0.123	2.34

Among the respondents, 51.69% across both study sites had positive attitude while 42.41% had negative attitude towards geladas (Table 51). Many respondents (61.78%) surrounding the Park, had positive attitude while 53.33% in the unprotected villages had negative attitude toward geladas. The attitude of respondents towards geladas differed significantly ($\chi 2 = 17.075$, df = 2, $p < 0.001$) between respondents of study sites. Males had significantly more positive attitude towards geladas than females ($p < 0.001$). Younger respondents had more positive attitude than adult and old age respondents, but the difference was not significant ($p = 0.057$).

Table 51. Attitude of local farmers based on different variables toward southern geladas.

Settlement and Demographic variables	Attitude of respondents, %			Chi-square association model		
	Positive	Negative	Neutral	$\chi 2$	df	p value
Villages						
BSNP	61.78	32.98	5.24	17.08	2	<0.001
Unprotected	40.00	53.33	6.67			
Gender						
Male	54.72	41.51	3.77	28.69	2	<0.001
Female	26.32	50.00	23.68			
Age						
18-35	62.07	34.48	3.45	9.18	4	0.057

36-50	55.05	40.37	4.78			
>50	43.75	48.13	8.12			
Education						
Uneducated	48.77	44.67	6.56			
Primary	52.70	40.54	6.76	8.15	6	0.227
Secondary	72.27	22.73	0.00			
Religion education	56.25	43.75	0.00			

The full model containing all predictors was statistically significant ($\chi2 = 32.23$, df = 4, $p < 0.001$) indicating that the model was worthwhile, and able to distinguish between respondents who had negative and positive attitudes towards geladas. The Wald chi-square test criterion demonstrated that age, settlement site and gender made significant influences on the attitude of geladas (Table 52). Religion and educational level were not significant predictors to the model on the attitude of geladas. Nagelkerke's R^2 was 0.123, and correctly predicted percentage was 64.5%. The strongest predictor on the attitude of geladas was settlement site, recording as odd ratio of 2.68.

Table 52. Binary Logit model regarding attitude of local farmers towards geladas (outcome variable: attitude (1 = positive, 0 = negative).

Predictor variables	Estimate	Std error	Wald chi-square	df	p value	Odd ratio
Settlement (1 = Park)	0.985	0.241	16.76	1	<0.001	2.68
Age	-0.016	0.007	4.61	1	0.032	0.98
Gender (1 = male)	1.005	0.429	5.48	1	0.019	2.73
Educational level (1 = Educated)	0.434	0.263	2.72	1	0.099	1.54
Constant	-0.601	0.564	1.14	1	0.287	0.55

Local farmers from the unprotected site stated many reasons for the cause of crop raiding (Table 53). Many of the interviewees from the unprotected site mentioned that habitat contraction (56.97%) and degradation (58.18%) were the causes for frequent raiding of cereal crops by geladas. However, respondents from the Park site reported that habitat contraction, habitat degradation and lack of natural food were insignificant contributors for the reason of crop raiding by geladas. Many respondents (79.39%) from the unprotected site claimed that proximity of farmlands as the main cause of crop raiding by geladas.

Table 53. Perceptions of interviewees on reason of crop raiding by geladas (Ind = indifferent).

Variable	Respondents, %						$\chi2$	df	p value
	BSNP			Unprotected					
	Yes	No	Ind	Yes	No	Ind			
Cause of crop raiding									
Habitat contraction	12.04	86.91	1.05	56.97	38.79	4.24	89.68	2	<0.001
Habitat degradation	3.66	96.34	0.00	58.18	39.39	2.43	136.60	2	<0.001
Lack of natural food	2.62	97.38	0.00	49.09	49.09	1.81	110.14	2	<0.001
Proximate of farmland	46.07	53.40	0.53	79.39	20.00	0.61	42.04	2	<0.001
Attraction by crop	96.34	2.62	1.04	94.55	4.85	0.60	1.44	2	0.487

Farmers from the Park site differed significantly from those of unprotected site in their opinion regarding causes of crop raiding by geladas. 95.51% of all respondents from both study sites reported that attraction by the nutritional contents of crops as the main reason for the cause of crop raiding. Opinions regarding the cause of crop raiding by attraction of crops did not differ significantly between the two conservation status sites (P = 0.487).

Most of the respondents (92.70%) from both study sites suggested that guarding method was the best way for protecting cereal crops from being raided by geladas (Table 54). Most of the respondents wanted to guard their cereal crops alone and still other guarded their cereal crops by shifting system. Job opportunity, followed by compensation and government action were also suggested as the mitigation measures by most respondents in both study sites. Most respondents (76.12%) suggested that job opportunity should be taken into account for the young people to stop any further agricultural expansion and degradation within the habitat of geladas. Still many respondents (72.19%) suggested that they should be compensated for any crop loss even if they had doubt for earning compensation.

Table 54. Mitigation measures proposed by the researcher to the respondents (Ind = indifferent).

Variable	Respondents, %						χ2	df	p value
	BSNP			Unprotected					
	Yes	No	Ind	Yes	No	Ind			
Mitigation proposal									
Guarding	89.01	10.47	0.52	96.97	3.03	0.00	8.45	2	0.015
Seasonal displacement	15.71	83.77	0.52	31.52	68.48	0.00	13.17	2	0.001
Government action	68.06	18.32	13.62	67.88	24.85	7.27	5.10	2	0.078
Change farming practice	11.52	87.96	0.52	7.88	90.30	1.82	2.57	2	0.277
Job opportunity	78.01	16.75	5.24	73.94	21.82	4.24	1.56	2	0.457
Compensation for loss	70.16	24.61	5.23	74.55	22.42	3.03	1.44	2	0.488

Few respondents from both sites explained that if compensation is provided for crop loss, it would bring a lot of complications and conflict between wildlife managers and farmers. There was no significant difference among the respondents between the two sites on job opportunity ($p = 0.457$), compensation ($p = 0.488$) and government action ($p = 0.078$) as ways of mitigation.

Respondents from the unprotected site suggested that southern geladas face a lot of threats in the study sites. Many respondents across the two study sites claimed that leopard predation was the major threat for geladas. Most of the respondents from the Park site stated that habitat degradation, agricultural expansion, hunting and dog predation did not affect the population of geladas (Table 55). Many respondents from the unprotected site stated that habitat degradation (50.91%) and drought (66.66%) were considered as the major threat for geladas. The differences in respondent towards threats on geladas between the two sites on agricultural expansion, habitat degradation, hunting, drought and dog predation variables were significant ($p < 0.001$).

Table 55. Respondents view on the threat of geladas in the study sites.

Variable	Respondents view, %								$\chi2$	df	p value
	BSNP				Unprotected						
	High	Less	No effect	Not sure	High	Less	No effect	Not sure			
Threats											
Agricultural ex.	0.00	6.28	91.10	2.62	33.33	32.12	33.33	1.21	142.8	3	<0.001
Habitat degra.	0.00	16.03	81.15	2.62	50.91	26.67	21.82	0.60	162.0	3	<0.001
Hunting	1.57	8.90	86.91	2.62	28.48	33.95	36.97	0.60	109.4	3	<0.001
Predation	52.88	24.61	13.61	8.90	52.73	29.70	9.70	7.88	2.11	3	0.550
Dog predation	1.57	14.14	80.10	4.19	13.33	30.30	55.76	0.61	40.26	3	<0.001
Drought	14.14	37.17	43.98	4.71	66.66	31.52	1.21	0.61	136.6	3	<0.001
Disease	34.03	37.70	21.47	6.80	32.12	50.30	13.93	3.64	7.79	3	0.051

Most (73.82%) of the respondents from the BSNP and 93.33% from the unprotected site did not report the incidents of crop raiding. Others had experienced on reporting crop raiding incidents either to the local chairmen or scouts or local officials or agricultural workers or other sources. Mostly of the respondents did not know to whom to report, and others assumed that no one would act even if the problem was reported to the local officials. There was no significant difference among the respondents between the two study sites on their reporting experiences (Chi-square test of independence: $\chi2 = 23.74$, df = 1, $p < 0.001$) of crop raiding by geladas.

5. DISCUSSION

In this study, a lot of variables like population parameter, activity budget and pattern, feeding ecology, ranging ecology, habitat use and human-gelada conflict were measured and their results were expressed in different sections. Each of these findings of the parameters is discussed step by step as follows:

Gelada is an enigmatic primate that not only brings tourism to the area as the result of its endemicity but it is also an Ethiopian treasure. Monitoring this species is an important component to any wildlife conservation and management plan for the BSNP and surrounding landscapes. As agricultural activities and grazing pressure by livestock intensify in the habitat of geladas, overlap leads to high degree of conflict with the local farmers. These affect the population growth and size of geladas in their ranges of the Ethiopia landscapes.

The mean group size and density of the southern geladas was smaller in the unprotected than Park sites. This may possibly because of habitat fragmentation and degradation that could not allow for the formation of larger groups. When habitats become fragmented, the availability of resources may not support larger group size, and the population density becomes lower. Likewise, Onderdonk and Chapman (2000) suggested that the smaller group size of *C. guereza* in fragments may be due to limitation of resources. Geladas may occupy the available habitats by forming smaller group sizes at different distances in order to reduce competition over food resources. Thus, the group size in geladas might be determined by the availability of ample grassland habitats. Food availability may also influence gelada's density. Forming smaller group size might be an adaptation that helps geladas to survive in human modified and degraded landscapes. Smaller group size is an adaptation of primates like howler monkeys to exist in small isolated habitats (Ostro *et al*., 1999). On the other hand, geladas existing in unproductive areas may be under dietary stress especially during the dry seasons. Similarly, Estrada *et al*. (1999)

reported that primates existing in small forest fragments live under dietary stress that may result in high mortality of individuals.

When the group size increases, animals should travel longer distance to look for sufficient food resources. However, in the human dominated landscapes, longer distance movement by geladas may be restricted as the result of intense agricultural activities and human disturbances. This may lead geladas to form smaller group size and use patchily distributed food resources in the unprotected areas. Tsuji and Takatsuku (2009) pointed out that primates adjust their intensity of use for foraging area and their daily movements according to food availability. Other studies in the Simien Mountains National Park revealed that variations of the band size across populations of geladas are due to internal changes (Ohsawa and Dunbar, 1984). On the other hand, when enough and broader grassland habitats are available, geladas may form larger group size in the protected site. Larger group size may help to scan predators, since predators like leopards attack them more in the protected areas.

The range of band size of BNSP population was somehow similar to the population of Sankaber and Gich, Simien Mountains National Park (Ohsawa, 1979; Ohsawa and Dunbar, 1984). Similarly, the range of band size of the unprotected site of this study was similar to Bole and Wonchit Valley populations (Dunbar, 1984a, Zewdu Kifle *et al*., 2013) (Appendix 3). Thus, protected areas support larger group size than the unprotected fragmented areas as the result of large unbroken grassland. Larger AMU observed in BSNP compared to other sites (Appendix 4).

Large group size also may be related with altitude. As the altitude increases the size of the band also increases. Thus, temperature may be one of the factors for the formation of larger group size for geladas. Afroalpine ecosystem may be the ideal place for the formation of larger group sizes. As the result of this scenario, geladas may be exposed and suffered from the current global warming. Dunbar (1998) also pointed out that climate change is one of the risk factors for the extinction of geladas. As BSNP is one of the protected afroalpine ecosystems with the gelada range, it is important to conserve the area in order to maximize the potential chance of survival of the species. Gich, Sankaber and BSNP are found at higher attitudes compared to the Bole Valley, Arsi and the unprotected site of the present study. Thus, for geladas, higher altitude may favour larger group formation compared to the lower habitats. In addition, the Ethiopian afroalpine ecosystem is not favorable for farming. Thus, geladas experience broad land mosaic habitats to forming larger group sizes.

Although, the mean number of adult females did not show any significant differences between sites, the proportion of more females per males outweighed in the protected site than the unprotected site. The higher proportion of females per male in the BSNP might be as a result of longer stay in their natal harems. As the band size increases, takeover by bachelor males decline as a result of cooperative fighting and chasing among adult males that might favour more adult females for each adult males.

In this study, the sex ratio between adult males and adult females was 1:4.81 in the unprotected site whereas, it is 1:5.09 in the BSNP. The sex ratios of both of the current study sites were high compared to other study areas like Arsi (Mori *et al*., 1999) and Gich (Dunbar, 1984a; Ohsawa and Dunbar, 1984). It was also high compared to the Guassa population (Eshetu Moges and Balakrishnan, 2015) (Appendix 3). The high adult male to adult female ratio in this study might be the combination of adult females with subadult females. In addition, low migration of females may favour for the presence of more females within the group. In Arsi population, the harem leader faces a challenge leading to invasion of bachelor males into a unit more easily. This leads lowering the sex ratio of adult male to females (Mori *et al*., 1999).

It is difficult to discuss the trend of geladas (i.e., whether the number is increasing, decreasing or remains stable) using a short duration census in the study sites. However, the result of the present census shows that the population of geladas in the study sites is in a better shape even if the area is used for agricultural, livestock rearing and human settlement purposes. The presence of many infants and yearlings in both the unprotected and BSNP populations suggest that most groups may have an adequate reproductive potential. Geladas may have developed survival strategies to tolerate those threats throughout their ranges.

Understanding how primates adjust their time budgets and activity patterns in response to habitat alteration and seasonality in contrasting habitat types is fundamental for conservation work. Previous studies on time budget of geladas have been of short duration and most are carried out in afroalpine ecosystems (Dunbar and Dunbar, 1975; Kawai and Iwamoto, 1979; Hunter, 2001). The present study took place in both afroalpine and afromontane ecosystems to broaden the behavioural ecology of geladas in depth.

A comparable analysis between Selam and Tikure bands on the overall activities budget (feeding, moving, resting, grooming and socializing) did not reveal any significant difference, even if the two bands live in differnt habitat types that vary in altitude, size and level of degradation. Similarly, Onderdonk and Chapman (2000) found that the activity budgets of black and white colobus monkeys living in forest fragments and those living in Kibale National Park did not show any significant difference. Thus, the overall activity budget of geladas might not be affected by the habitat type, level of degradation and other factors.

Daily, monthly, seasonal and annual time budgets of the two bands of the southern geladas showed feeding as the predominant activity. Dunbar (1992) suggests that the availability of food and its energy content are critical determinants of daily activity budgets. This study indicated that geladas devote almost half time in feeding over other activities. The type of food that animals fed may determine the time allocated in feeding and other activities. Dunbar and Bose (1991) revealed that the reason for the high proportion of time allocated in feeding activity may be due to gelada's dietary specialization on grass.

It was assumed that geladas invest more time feeding as altitude increases, as the result of the increased metabolic energy requirements from the lower ambient temperatures (Iwamoto and Dunbar, 1983). The current study showed that the time budget for feeding was not significantly differed between Selam and Tikure bands at Kosheme (2400 m asl) and Keywasha (3400 m asl) sites, respectively. The afroalpine habitat of Tikure band promoted more time in feeding due to lower food quality and higher metabolic investment. In the degraded lower altitude, geladas might invest more time in feeding in order to fulfill their daily energy requirements from the available resources. As the quality of a certain habitat declines, the feeding time of geladas in that area increases to compensate the energy requirements (Iwamoto and Dunbar, 1983; Hunter, 2001). Similar studies on geladas were conducted at Bole, Debra Libanos and Sankaber, and the result showed that there is no significant difference among the three sites in their feeding time (Crook and Aldrich-Blake, 1968). Therefore, habitat type and level of habitat alteration do not have impact on the feeding time of geladas. Similarly, Boyle and Smith (2010) noted that there is no relationship between fragment size and time devoted to feeding in Saki monkeys. Silva and Ferrari (2009) also reported that *Chiropotes satanas* spends a similar time feeding in continuous forest and in fragments.

It is generally assumed that a diet based on grass requires a bulk feeding strategy, which in turn will impose on the animal's time budget requiring extra time for feeding (Hunter, 2001). The alimentary canal of geladas is poor to digest the cellulose of grasses. Gelada defecate undigested food materials may be due to poor digestive system. The digestive system of gelada extracts nutrients from grasses inefficiently (Dunbar and Bose, 1991). As the result of their poor digestive system and their feeding habit, geladas might devote more time feeding at the expense of the other behavioural activities.

In the current study sites, geladas spent less time feeding compared to Sankaber (Hunter, 2001), Gich (Kawai and Iwamoto, 1979; Cherkos Woldegeorgis and Afework Bekele, 2015) sites (Appendix 5). But it is relatively higher than Bole and Sankaber studied by Iwamoto and Dunbar (1983). However, all of these studies, except Cherkos Woldegeorgis and Afework Bekele (2015) were undertaken within short period of time to reflect the true annual feeding budget of geladas. The difference in sampling time and duration might be the reason for having variable findings by different researchers even at single study site.

In the current study sites, both bands spent more time moving compared to Sankaber (Hunter, 2001) and Gich (Kawai and Iwamoto, 1979; Iwamoto and Dunbar, 1983) sites (Appendix 5). But this was relatively less compared to Bole (Dunbar and Dunbar, 1975), Sankaber (Iwamoto and Dunbar, 1983) and Guassa (Eshetu Moges and Balakrishnan, 2015) geladas, but comparable to Bole gelada populations (Iwamoto and Dunbar, 1983). The current study negated the findings of Kawai and Iwamoto (1979) on moving time budget. As the area became fragmented, geladas should move from one patch to the other in order to get the available resources of those patches in turn increasing moving time. In addition, geladas did not use the same area continuously for foraging purposes. Geladas shift their foraging areas almost on daily basis. These all may have increased the movement time of geladas in the current study sites. The position of sleeping sites and the distance between them may also determine the moving time of geladas at Keywasha.

Similarly, the cumulative time spent for resting for both Selam (17.43%) and Tikure (16.82%) bands were almost similar during the study period. The time budget of resting was only 2% and 5.2% at Gich (Kawai and Iwamoto, 1979; Iwamoto and Dunbar, 1983), 26.3% at Bole (Dunbar and Dunbar, 1983), 10.7% at Gich (Cherkos Woldegeorgis and Afework Bekele, 2015) and 7.31% at Guassa (Eshetu Moges and Balakrishnan, 2015). The current finding is completely incompatible with these studies. The duration of data collection might have contributed for different results by different researchers. In addition, resource availability, degree of human interference and level of temperature may vary the resting time of geladas at different study sites. The nutritional stress associated with resource scarcity of the area might have resulted in less resting time (Dunbar and Bose, 1991).

The weather condition, the types of food they consume and human interference might affect the monthly, seasonal and annual time budget of geladas at both Kosheme and Keywasha sites. The result indicates significant monthly variation in the activity budgets of the studied bands. For example, at Keywasha in heavy storm days, Tikure band prefers resting by huddling together near *Lobelia rhynchopetalum* or on cliffs other than doing other behavioural activities. In addition, the lower ambient temperature at Keywasha gives geladas more resting time in the morning to warm their bodies. Similarly, in extremely hot sunny days, Selam band retreat to the shade of *Acacia* trees and initiate resting and grooming by reducing their feeding and moving activities. During crop raiding days, Selam band prefer resting until crop guardians move out rather than feeding on the wild plants. These behavioural activities may give more time for resting in both Selam and Tikure bands in their respective habitats.

The activity time budget of Selam and Tikure bands was not uniform during the wet and dry seasons. Environmental variables like rain, climatic conditions and availability of food may cause seasonal differences in activity time budget in primates (Iwamoto and Dunbar, 1983; Hunter, 2001; Shah, 2003; Grüter and Zinner, 2004). Similarly, availability of food, weather condition of the day, human interference and crop raiding behaviour may affect the seasonal variation of time budget of southern geladas at the present study sites. Felton *et al*. (2009) and Chaves and Stoner (2011) found that time spent feeding by spider monkeys is higher during the rainy season to store surplus energy than during the dry season to conserve energy. In the current study, the pattern of feeding habitat did not cause any significant difference on feeding time between the wet and dry seasons for Tikure band, but it differed significantly for Selam band. Even for Selam band, the difference was minor (p = 0.049). Gelada at both sites spend only slightly high amount of time feeding during the dry season in order to compensate the daily energy requirement from those respective drier habitats. The current finding changed the idea of feeding ecology of geladas on seasonal basis. For Selam band, there was changing of feeding habit on the fruits of *Ficus* spp. and picking the seeds of cereal crops that may be a good source of nutrient. These food items reduce the expected peak of feeding time during the dry season. Feeding fruits and seeds provides sugar and protein, which are among the more nutritious food sources (Barton *et al*., 1992). Similarly, Tikure band lives in afroalpine ecosystem with prolonged wet season, which helps the animal to get relatively sufficient green food items above the ground, thus feeding time did not vary on season. In addition, geladas dedicated for feeding herb roots that might provide enough source of nutrition during the dry season. Hunter (2001) revealed that underground food items are unlikely to have lower nutritional quality and they do not take much time to process them. Other researchers (Dunbar, 1977a; Iwamoto, 1979) assumed that dry season represents a period of nutritional stress to geladas. The present study revealed that the types of inhabited habitats and the degree of dryness and longevity of the dry season may determine the nutritional stress of geladas.

Geladas that live in highland and protected areas use their time budget in resting and grooming without significant differences at both seasons. However; time budget engaged in resting and grooming significantly varied in degraded and lowland site during both seasons. Hunter (2001) reported that both resting and grooming time were reduced significantly during the dry season. This finding is similar with Selam band at Kosheme but even if grooming and resting time budget decreased during the dry season, they were insignificant at Keywasha site. During the dry season, geladas spent more time in feeding thereby reducing the activities spent for resting and grooming. Most of the extra time in feeding comes from resting (Iwamoto and Dunbar, 1983; Hunter, 2001). Similarly, since Selam band spent less time invested in movement during the wet season, the band had more time available for resting and grooming. As the environment becomes very harsh in terms of availability of food during the dry season, gelada spent more time feeding by reducing other activities like grooming and resting in order to compensate the daily energy requirements. Masi *et al*. (2009) pointed out that forest primates spent more time resting during the dry season than the wet season to reduce energy expenditure through travelling.

Hunter (2001) reported that geladas at Sankaber spent more time moving during the wet season than the dry season. However, in the current study, Selam band spent less time budget for movement during the wet season than the dry season, even if the result was insignificant. This may be due to the restriction of Selam band from movement as the result of intense farming activities near the vicinity of their sleeping cliffs. However during the dry season after post-harvesting time, geladas at Kosheme move whatever they like without much restriction by the farming activities of the local farmers, and then the time budget engaged in moving become higher during the dry season than the wet season. Contrasting this, the impact of agricultural activity on the movement of Tikure band was minimal and had no effect for wandering within their home range during both the dry and wet seasons, thus time spent invested in moving was almost in equal proportions. Water availability might be the other factor for increasing the time spent invested in moving for Selam band during the dry season. However, this trend is different for Tikure band as the result of water availability in every distance within their home range almost throughout the year.

Geladas at Kosheme and Keywasha sites spent comparable time budget invested in feeding during both the wet and dry seasons. Similarly, grooming, resting and socializing time budgets did not show significant variation between Selam and Tikure bands during both seasons. Thus, habitat types, level of habitat degradation, altitude and group size might not have any influence on those behavioural categories between the bands on seasonal basis. However, Selam band at Kosheme spent significantly less time budget invested in moving during the wet season than Tikure band, but not during the dry season. The restriction of Selam band by the extensive agriculture activities during the wet season may hinder moving, resulting in significant difference comparing with Tikure band.

There was extreme variation in the annual activity patterns in different behavioural categories between Selam and Tikure bands. One of the interesting adjustments of the activity patterns was the reversal of the annual activity pattern in feeding, grooming, resting and moving between Selam and Tikure bands. The study bands showed significantly varied activity patterns in their daylight hours. Even if Selam and Tikure bands adapted completely different strategies of daily activity rhythms for feeding, resting, grooming and moving time, the annual cumulative of these activity budgets were almost exactly in equal proportions without significant differences.

For Tikure band, the activity pattern of resting and grooming occurred in almost exclusively in the morning sessions. In the morning, members of Tikure band sat on the bare rocks or short grasses for resting and grooming activities, as well as lay on the bare rocks for sunbathing. For Tikure band, climatic conditions may play a role primarily in the late onset of feeding activity and early and late morning grooming and resting activity patterns. In addition, since, Tikure band lives in protected area where the human interference on their daily activity patterns is minimal, thus their daily activity pattern might show a '*relaxing type of behavioural activity*'.

Selam band started feeding early morning, and this activity reached its peak point before midday. The band spent short time grooming and resting of its early morning hours, and occurred almost in a constant level without any clear peak throughout the day. Likewise, some terrestrial species, like *Papio anubis* and *P. cynocephalus*, show less marked activity pattern peaks in their diurnal activity patterns (Dunbar and Dunbar, 1974; O'Brien and Kinnaird. 1997). Thus, the activity pattern of Selam band may represent an adaptation and flexibility of geladas in human-dominated and modified landscapes.

Variation in activity time patterns between Selam and Tikure bands may also represent an adaptation to temperature differences at Kosheme and Keywasha sites. Some studies have shown that primates increase their resting time in response to high temperature by staying in the forest (Campos and Fedigan, 2009). Similarly, Selam band stayed under the *Acacia* trees to get shade of cooler environment at the time of higher temperature during the midday and early afternoon of the sunny days. Other primates increase energy intake from the sun at low temperature for thermoregulation (Agetsuma, 2000). Likewise, geladas at Keywasha bask on the ground for long sunbathing in the morning. This may increase more resting time in the morning than the other parts of the daylight hours for Tikure band. For Selam band, seasonal variations in activity patterns might relate with variation in food availability and type, temperature and human disturbances of the study site.

Previous studies on the feeding ecology of geladas have been of short duration (lasting a few weeks or few months) and mostly carried out in afroalpine ecosystems (Dunbar, 1977a; Iwamoto, 1979; Iwamoto and Dunbar, 1983; Hunter, 2001) and some in lowland areas (Dunbar and Dunbar, 1974; Iwamoto and Dunbar, 1983, Zewdu Kifle *et al*., 2013). Fashing *et al.* (2014) studied the feeding ecology of geladas at Guassa for a longer duration; but still this study occurred in the afroalpine ecosytem. The present study encompassed both the afroalpine and afromontane habitats. Diet composition in southern geladas is primarily linked with the habitat type where they lived i.e, southern gelada that live in different habitat types consume different types and varieties of plant species. Thus, the type of habitats and resource availabilities determine the feeding ecology of geladas.

The diets of primates are often less diverse in disturbed habitats than in intact habitats (Riley, 2008; Tesfaye *et al*., 2013). Fashing *et al*. (2014) at Guassa also claimed that gelada that live in a relatively intact ecosystem consumed a much more varied diet than geladas at more human dominated sites. However, in the contrary of Riley (2008), Tesfaye *et al*. (2013) and Fashing *et al*. (2014), this study revealed that geladas living in relative lowland and human dominated and degraded habitats consumed much more varieties of food species and diet items than geladas at higher altitude of relatively intact habitats. Fashing *et al*. (2014) at Guassa identified 56 plant species as the potential food sources for geladas. This finding is somehow higher than Tikure band at Keywasha and lower compared to Selam band at Kosheme, which is a human dominated and degraded habitat. The present study revealed that relatively lower altitudes promote the growth of diverse vegetation. Thus, the study pointed out that lowland and degraded habitats get opportunity and promote geladas to consume more diversified plant species and diet items rather than geladas living in afroalpine ecosystems like Keywasha, Guassa and Gich.

Geladas have long been regarded as exclusively graminivores (Dunbar and Dunbar, 1974; Dunbar, 1977a; Iwamoto and Dunbar, 1983; Iwamoto, 1993; Hunter, 2001). These finding showed that grasses accounted over 90% of the diet. Recently, Cherkos Woldegeorgis and Afework Bekele (2015) at Gich also noted that geladas use mostly grasses. But the present study contradicted those findings, and it revealed that geladas consumed more and considerable amount of fruits and herbs in their annual diets in addition to grasses within their respective habitat. The current study prefers geladas as ‘facultative graminivore’ rather than obligate graminivore in their feeding ecology.

The feeding ecology of gelada greatly changed on monthly and seasonal basis. The result showed that the diet of geladas varied among months in both bands. The diet of both bands was highly inclined on fresh green grass blades during the wet season compared to the dry season. This might be due to their easy availability and high nutritional content during the wet season compared to the dry season. At the beginning of the wet season, grasses can quickly recover from dryness and grow rapidly leading to more grass blades consumption by geladas.

Selam band did not include underground grass items in their wet season menu, and almost negligible amount of these items included by Tikure band. However, these food items were consumed in extremely higher proportion during the dry season, when the green grass blade scarcity reached at minimum level. Geladas that live in lowland and degraded habitats consumed underground diet items in greater proportion than did the highlander geladas. The grass species that were excavated from the underground were not also similar. However, the consumption of these underground diet items of grasses was in insignificant proportion between the two bands. Exploitation of underground food items represents an adaptation that allowed all the Theropithecenes to tap into grassland food sources (i.e. subterranean storage parts) that is unavailable to the gelada's main competitors, namely ungulates (Jolly, 1972).

This study revealed that underground food items were extensively used by both bands in certain months of the dry season by declining the consumption of grass blades. Iwamoto and Dunbar (1983) at Sankaber likewise noted that the consumption of subterranean food items increased during the dry season. Hunter (2001) pointed out that, as the green grasses dry out, geladas shift their foraging profile to digging for more subterranean food sources. The present finding also goes in line with Fashing *et al*. (2014) that geladas significantly increased the consumption of underground food items at Guassa during the lengthy dry season. This study suggests that the scarcity of green grass blades might be the reason for the shifting the consumption of higher underground food items during the dry season.

Subterranean plant parts like tubers provide an alternative source of energy in the form of carbohydrates (Byrne *et al*., 1993). Struhsaker (1967) pointed out that, rhizomes and roots represent a highly nutritious dry season food source for vervet monkeys (*Cercopithecus aethiops*) in the savanna environment. Likewise, addition of underground food items like bulbs, rhizomes and herb roots by geladas for their diet menu may be good sources of carbohydrates, proteins and other nutrients during the dry season.

Both bands consumed underground food items by digging the ground or uprooting them. Digging the ground or uprooting grasses and herbs may need high amount of energy and require more strength to extract, but it might be the only option to survive during the dry season. These food items may be more nutritious and help geladas to survive in severe environment of the dry season even if they need more energy and strength to exploit them. The gain might be more than the expense. In addition, geladas consumed different species of herb roots and underground grass items in differnt areas. For example, the roots of *Cotula cryptocephala* provided the bulk of the plant components in Simien population during the dry season (Dunbar, 1977a). The root of *thyme* spp. also exploited more intensively from the underground by geladas at Sankaber (Hunter, 2001) during the dry season. Whereas the root of *Haplosciadium abyssinicum* was the main herb root consumed by geladas at Keywasha. This shows that geladas exploit different plant species of food items from the ground that are available within their habitats.

Herb roots accounted minimal for Selam band but more for Tikure band during the dry season. This might be due to high availability and greenness of these herb roots in afroalpine ecosystem during the dry season. Gelada at Sankaber also consumed higher amount of herb roots during the dry season (Hunter, 2001). The higher feeding of bulbs and herb roots during the dry season might be due to their easily finding from non-muddy dry land in their respective habitats. On the other hand, high consumption of bulbs and herb roots by Selam and Tikure bands during the dry season contradicted with the work of Dunbar (1977b) and Hunter (2001), but goes in line with the Fashing *et al*. (2014). Hunter (2001) found that geladas fed more bulb/corm during the wet season than the dry season, but he did not explain the reason. Similar to this study, Fashing *et al*. (2014) explained that geladas significantly increased their consumption of forb root food items at Guassa when green graminoid changed to brown colour.

During the dry season, the contribution of fruits from trees and shrubs was high. This finding negated those short based studies that geladas have long been regarded as obligate graminivores (Dunbar and Dunbar, 1974; Dunbar, 1977a; Iwamoto and Dunbar, 1983; Iwamoto, 1993). Hunter (2001) at Sankaber pointed out that geladas consumed 5.5% of fruits from shrub (*Rosa abyssinica*) during the end of dry season. But, Tikure band consumed the fruits of this shrub during the wet season (May through June, which is the beginning of the wet season). It was the single most important food item in the gelada's diet at a height above ground level vegetation at Sankaber. Similarly, *R. abyssinica* was the only source of fruit for Tikure diet above the height of ground level even if its contribution was much less. The low contribution of *R. abyssinica* for Tikure band might be due to the less availability of this shrub within their home range. The high consumption of fruits by geladas at Sankaber (Hunter, 2001) compared to Tikure at Keywasha might be the easily availability of the shrub within the main core area of the band.

For Selam band, the higher source of fruits was from fig trees. Fruits from fig trees might be an important food diet that provides relief for the nutritional bottleneck during the dry season. The fruit of *Ficus* species contains excess amount of sugar (Byrne *et al*., 1993). *Ficus* species are known to be keystone species that help sustain frugivores (Byrne *et al*., 1993). The availability of *Ficus* species in the habitat of Selam band offers stable calories during the dry season. All trees of *F. sycomorus* did not develop fruits in a single month; instead they produced fruits continuously along the dry season months. Thus, *F. sycomorus* might be a reliable nutrient source for Selam band during dry season months, when food scarcity is common in human-modified and lowland habitats. Thus, *F. sycomorus* may serve as a keystone food sources for southern geladas living in human-impacted habitats where the species often thrive. In turn, the band may disperse the seeds of fig trees over long distances, away from the mother tree as seeds of fig species are not easily digested within the elementary canal of geladas (Personal observation, this study).

The underground annual diet of grasses for Selam and Tikure bands was high compared to other studies at Guassa, Gich and Sankaber. Fashing *et al*. (2014) at Guassa pointed out that the underground items from graminoid for gelada accounted less in the total annual diet (Appendix 6). For Selam band, the annual diet components of herb accounted less than Tikure band. This might be due to the relative high availability of green herbs throughout the year as the result of moisture of afroalpine habitat compared to habitat of warmer inhabiting geladas. Geladas that live in afroalpine ecosystem consumed more herbs in their annual diet in order to compensate for the lower diversity of grass species. Similarly, geladas at Guassa (an afroalpine ecosystem like Keywasha of the BSNP) consumed more of forb parts (Fashing *et al*., 2014). Hunter (2001) also found that herbs accounted more for gelada diet at Sankaber. In similar study site with Hunter (2001), the contribution of herbs was extremely low (Dunbar, 1977a; Iwamoto and Dunbar, 1983) but comparable with Selam band at Kosheme.

Grass seeds were another important diet item for southern geladas both at Kosheme and Keywasha sites. During seed producing months, both bands increase their feeding effort to add more seeds even if grass blades were still green. This may be due to the high nutritional values of seeds compared to grass blades. Similarly, gelada at Sankaber added considerable amount of grass seeds (Dunbar, 1977a). However, geladas at Guassa consumed minimal amount in their annual diet even if the habitat is intacted and contained long grasses (Fashing *et al*., 2014). Grass seed is not stated as part of gelada’s diet at Sankaber and Gich (Iwamoto and Dunbar, 1983; Cherkos Woldegeorgis and Afework Bekele, 2015). Therefore, this study provides information to scholars on how much grass seeds are very important to the gelada’s annual diet at Kosheme and Keywasha sites.

The annual diet of fruits from trees and shrubs for Selam band accounted higher amount compared to Tikure band, and other study areas like at Bole (Dunbar and Dunbar, 1974) and at Sankaber (Hunter, 2001). Gelada at Gich (Iwamoto, 1979; Cherkos Woldegeorgis and Afework Bekele, 2015) and Guassa (Fashing *et al*., 2014) did not include any fruit items in their annual menu. The diet of Arsi population of gelada consisted of considerable amount of fruits (Iwamoto *et al*., 1996, Kelil Abu *et al*., 2017). Thus, the availability of fruit from trees and shrubs in a certain habitat might determine the amount of fruit consumption by geladas. Thus, geladas are not strictly graminovores, but they utilize tree and bush parts where they are available, and are therefore friguivores in some habitat types contrary to Iwamato and Dunbar (1983).

Invertebrates accounted for 1.49% of the annual diet for Tikure band, and as much as 4.08% of the monthly diet. This is somehow similar to gelada diet at Guassa that accounted for 2.8% of the annual diet (Fashing *et al*., 2014). But invertebrates accounted for only 0.5% of the annual diet for Selam band, and as much as 3.35% of the monthly diet. These values at Kosheme still higher as compared to other sites like at Sankaber (Dunbar, 1977a; Iwamoto, 1993; Hunter, 2001) (Appendix 6). Geladas at Keywasha frequently inspected the leaves of *Lobelia rhynchopetalum* to find and eat caterpillars. In turn, geladas at Kosheme dislodged stones to find and feed ants and termites from the ground. Invertebrates might be the source of protein and fats for geladas.

No gelada was ever observed to eat any part of *Erica arborea*, *Hypericum revolutum* and *L. rhynchopetalum* even if they are common within the home range of Tikure band. However, the aforementioned plant species were consumed by geladas at Guassa (Fashing *et al*., 2014) and the last two at Gich (Cherkos Woldegeorgis and Afework Bekele, 2015). *L. rhynchopetalum* is the top 3 pant species as a diet of gelada at Gich (Cherkos Woldegeorgis and Afework Bekele, 2015). In similar manner, *F. sycomorus* was available within the home range of geladas at Bole (Dunbar and Dunbar, 1974). However, the study did not note on the consumption of fruits from fig trees. This may be due to the small portion of a year and data of the study period at Bole missed the information. Further, intensive study is essential.

Selam band also added seeds, piths and gums from trees. But, Tikure did not include any tree parts during the study period. Thus, geladas that live in lower altitude and degraded habitats added more plant part than did geladas living in afroalpine ecosystem, which is low in species diversity. These diet items were not reported in other study sites except at Wonchit Valley (Zewdu Kifle *et al*., 2013).

Most of the cereal crops feeding occurred just at the time of sowing and harvesting period when the local farmers are reluctant at this time. Geladas live in unprotected, degraded and human-dominated environment raided crop in greater proportion than geladas that live in protected and afroalpine ecosystems. There is no report, except Eshetu Moges (2015), from other studies for the contribution of cereal crop on the feeding ecology of geladas. Extreme constriction of a certain habitat may promote geladas to consume more cereal crop in degraded environment. These cereal crops are more nutritious and help geladas to adapt and survive in the severely modified environment even if crop raiding has a greater risk up to death by local farmers. As the result of their crop raiding behaviour, local farmers frequently harassed geladas especially during crop harvesting months. Crop raiding behaviour of geladas is also reported in other study sites (Mesele Yihune *et al*., 2008; Zewdu Kifle *et al*., 2013).

Festuca grasses (*F. macrophylla* and *F. abyssinica*) are the most dominant grass species at Keywasha. But, contrary to the studies of Fashing *et al*. (2014), Eshetu Moges (2015) and Cherkos Woldegeorgis and Afework Bekele (2015), this *Festuca* spp. was not as such selected at its green blade stages by Tikure band. Cherkos Woldegeorgis and Afework Bekele (2015) put this grass as the top first selected grass species (74.3%) at Gich and Eshetu Moges (2015) also put this grass as the top selected species (68.6%) at Guassa. The current study showed that blades of *F. macrophylla* and *F. abyssinica* were inferiorly selected by geladas at Keywasha relative to their abundance. Rather, geladas consumed their seeds during fruiting time and corms during the harsh dry season.

There was higher dietary diversity for Selam band than for Tikure band. Lower dietary diversity observed for Tikure band may reflect lower diversity of food species in the afroalpine ecosystem. In contrast, Selam band, whose habitat provides greater foraging options resulting in high dietary diversity, might be favoured by afromontane ecosystem. Thus, the number of food species consumed may vary on the type of habitats where they occupy. In addition, the low food species similarity between the study bands results from the flexibility of geladas to exploit a wide range of plant species across a set of altitudinal changes in floristic composition. A similar reason was proposed to explain the similarity in the diet of *Ateles geoffroyi* across its range (Gonzalez-Zamora *et al*., 2009). This dietary flexibility in southern geladas might represent one of the factors that boost their ability to survive in various forms of grassland fragments.

Studying the home range of animals in a certain area is important to recognize the relationship between ecological variables of ranging behaviour (Di Fiore, 2003). In addition, studying the home range sizes and daily path lengths of primates are crucial for understanding their behavioural ecology and for conservation works and habitat managements. Travel length of southern geladas varied daily, monthly and seasonally. There was daily path length variation between bands of southern geladas living in different habitat types. Thus, the level of human disturbances and level of habitat losses and degradations may affect the daily path length of geladas. On the other hand, the home range size of geladas is negatively correlated with the habitat quality of the areas (Iwamoto and Dunbar, 1983). The size of home range sizes increase in lower quality habitats (Dunbar, 1987). In addition, the patchiness of grassland habitats and fruiting trees like figs, crop raiding behaviours and the size of bands might affect the daily travel distance and home range size of southern geladas.

Variable travel distance was observed by Kawai and Iwamoto (1979), Iwamoto and Dunbar (1983), (Hunter, 2001) and (Dunbar and Dunbar, 1975) from different study sites. However, southern geladas at the current study area travelled longer distance as compared to the other study sites. Similarly, the home range of geladas at Sankaber was 2.9 km^2 (Dunbar and Dunbar, 1975), 1.0 km^2 at Gich (Iwamoto, 1979) and 9.3 km^2 (Hunter, 2001). In this study, the home range size of Selam band was 3.28 km^2, and for Tikure it was 3.82 km^2 using 100% MCP method. Variation in methods used for analysis affect the accuracy of home range determination in geladas living in different sites.

The home range size of geladas varied within seasons. During the wet season, southern gelada in unprotected areas did not get access to move freely from patches of grasslands as the result of intensive agricultural activities near their sleeping sites. Their movement might be restricted within the available of small patches of habitats. However, during the dry season, travel restriction by farmers from patches to patches may cease due to the end of the harvesting season. Thus, geladas moved freely increasing the home range size during the dry season in search of available food and water resources. Fruits from figs and searching for leftover cereal crops from farmlands might be factors for increasing day path length and home range size during dry seasons. Contrary to this, geladas in the protected areas use their habitats without significant variation upon seasons as the result of less movement restriction by human activities like agricultural activities. Differential use of home range by geladas during the wet and dry seasons has also been reported at Sankaber (Dunbar, 1977a; Hunter, 2001). Variation in home range size during the dry and wet seasons was also observed in other species of primates like chacma baboons (*Papio ursinus*) (Gwenzi *et al*., 2007).

The location of sleeping sites is another factor for increasing the home range size by geladas. A number of studies have also demonstrated the importance of water sources and the distribution of sleeping sites affecting the length of daily travel and home range sizes (Barton *et al*., 1992). Southern geladas respond to habitat alteration through increase in daily path length and home range size in order to cover more area to obtain sufficient food resources. Irwin (2008) and Boyle *et al*. (2009) pointed out that monkeys that live in a fragmented area use smaller home range size and travel greater daily distances in comparison to those living in a continuous forest.

Ostro *et al*. (1999) pointed out that group size influencing ranging ecology and daily path length of primates. Day travel length in geladas is closely related to its group size, with larger groups moving longer distances (Kawai and Iwamoto, 1979; Iwamoto and Dunbar, 1983). Home ranges are also related to group size, with larger groups possessing larger home range sizes (Iwamoto and Dunbar, 1983). However, in this study, variation in group size did not influence typical difference (insignificant) in daily path length and range size on southern geladas. Thus, despite its smaller size of Selam band, it travelled insignificant daily path length to Tikure band in order to obtain the available resources on a daily basis. Resource availability of the area and intragroup competition over food are critical factors affecting variation in ranging ecology of geladas, both within and across bands (Grüter and Zinner, 2004). In addition, variation in habitat types where geladas live might affect differences in home range size and daily path length.

Studying the use of different habitat types by primates is one of the central investigations of behavioural ecology. The most important factor affecting the use of habitats by primates is the spatial and temporal distribution of food (Dunbar and Dunbar, 1988). The predominant long *Festuca* spp. grasses grow in dense clumps preventing the growth of other grass species in afroalpine ecosystem. This may reluctant geladas to use the interior part of the Park intensively. In addition, predator risk might hinder Tikure band to use the greater proportion of the forest and the long grassland area of the microhabitats. Hunter (200l) revealed that the distribution of food sources and predation risk are likely to be important factors in shaping the habitat use of geladas.

Each of the two study bands showed selections for particular microhabitat types. Southern geladas preferred open grazing grassland plateaux to gorge bushes, forest patches and long *Festuca* dominated grasslands in their respective habitats. Typically, southern geladas use open grazing plateau as foraging site and cliffs as sleeping and/or resting site. The inferior use of gorge bush and forest areas may be related with predator avoidances. In addition, lower grass diversity in the gorge bushes and long *Festuca* dominated areas may be the factors for limited utilization of those microhabitat types by geladas.

Further, Selam band used farmland in greater proportion compared to Tikure band. Thus, geladas that live in constricted areas use farmland habitats more intensively. Habitat alternation may lead geladas to use farmlands to raiding cereal crops and picking those leftovers items. In contrast, when the broad mosaic grassland habitats are available, geladas stay more time in it leading to use farmland rarely. The distance of sleeping sites may be the factor for use of farmlands in different proportions. As the sleeping sites found near agricultural areas, the habitat use of farmlands increase in greater proportions.

Southern geladas provide one of the best examples of commensalism with humans. They live very closely near the farmlands and villages with local farmers in love-hate type of relationships. This relationship invokes niche overlap between the two competitors over habitat use in a larger scale and results in intense human-gelada conflicts. Many primates are known to raid crops (Naughton-Treves, 1998; Siex and Struhsaker, 1999; Hill, 2000; Warren *et al*., 2007). This study showed that human-gelada conflict is a day to day interaction within the range of gelada's habitat especially at the time of crop producing months. The size and location of the farm relative to the habitats of primates and the type of primate in the area are important factors for the level of human-primate conflict (Naughton-Treves, 1998; Saj *et al*., 2001; Linkie *et al*., 2007; Warren *et al*., 2007).

Among different primate taxa that are engaged in crop-raiding, terrestrial frugivores and omnivores like baboons and macaques are the primary culprits, topping the list (Cowlishaw and Dunbar, 2000; Linkie *et al*., 2007). The result of the questionnaire from the respondents showed that there is intense conflict between the local farmers and geladas in Ethiopian highlands due to crop damage. This might relate with the feeding ecology of geladas. Most of the respondents considered geladas as 'crop pest' in their residents. Similarly, many other primates are considered as the dominant crop raiders in African and Asian reserves (Balakrishnan and Ndhlovu, 1992; Naughton-Treves *et al*., 1998; Warren, 2008; Marchal and Hill, 2009). The notorious crop raiding behaviour of geladas might be the closeness of farming activities in their sleeping cliffs and foraging areas. Naughton-Treves (1998), Saj *et al*. (2001), Linkie *et al*. (2007) and Warren *et al*. (2007) also noted that the location of the farm relative to the habitats of primates is an important factor for the level of human-primate conflict.

Almost half of the respondents from both study sites had negative attitude towards geladas. This negative attitude is the result of crop raiding behaviour of geladas that cause economic and opportunity costs. Similarly, Hill (2002), Mesele Yihune *et al*. (2008) and Campbell-Smith *et al*. (2010) reported that, farmers who had experienced crop damage by primates tend to develop negative attitude towards them. Naughton-Treves (1998) also noted that human-wildlife conflict can create intense hostility between poor farmers from rural areas and wild animals that destroy their crops and threaten their livelihoods. The economic losses related to crop raiding by geladas may affect food security for those farmers who live as subsistence farmers. Similarly, Hoffman and O'Riain (2010) and Kaplan *et al.* (2011) reported that primates cause economic losses related to crop raiding. Where agriculture is central to sustaining rural livelihoods, crop-raiding may be perceived as a basic factor affecting peoples' livelihood (Hill and Wallace, 2012).

The attitude of local farmers towards geladas differed significantly between the two sites. Local farmers who lived near the Park boundary had developed more positive attitude towards geladas than those farmers who lived in the unprotected site. Similarly, Khatun *et al*. (2012) pointed out that farmers from high conservation status areas had more positive attitude towards langurs. This might be due to better conservation awareness of respondents near the Park than those respondents from the unprotected site. Respondents from the Park might develop tolerance even if intense crop damage occurs in the area. Similarly, in spite of high predation on sheep by the Ethiopian Wolf more than half of the local people at Abune Yosef had positive attitude towards this predator (Girma Eshete *et al*., 2014). The availability of sufficient natural food items in the wide habitats help geladas to spend most of their time there, thus reducing crop losses and decreasing negative attitudes by local farmers. Similarly, Khatun *et al*. (2012) noted that sufficient food trees in the habitat of langurs helped to spend most of their time there. The present study suggested that perceptions and attitudes of local farmers on geladas may depend on the level of damaging and awareness of the individuals.

Similarly to the earlier study on different large mammals that cause conflict with humans (Bandara and Tisdell, 2003; Selebatso *et al*., 2008; Wang *et al*., 2006), the present study found that age as a strong predictor of local farmer's attitudes toward the conservation of geladas. In addition, in contrast to finding on Ethiopian wolf (Girma Eshete *et al*., 2013) and similar to finding on orangutan (Campbell-Smith *et al*., 2010), this study found that gender as strong predictor of the local farmer's attitudes toward geladas. However, similar to Girma Eshete *et al*. (2013) on Ethiopian wolf and Campbell-Smith *et al*. (2010) on orangutan, this study did not find educational status to be strong predictors of local farmer's attitude. This study also found that settlement site as strong predictor of the local farmer's attitudes toward gelada conservation.

Respondents from the unprotected site believed that the reason behind crop raiding behaviours of geladas is land constriction. When natural food resources are limited, easily digestible human food items provide an alternative source of nutrition for primates, intensifying the conflict (Horrocks and Baulu, 1994). During crop harvesting seasons, geladas preferred to consume cereal crops more enthusiastically than grasses. This may be due to the nutritional quality (protein and carbohydrate) of cereal crops and easily digestibility compared to grasses. Earlier studies have also demonstrated that a close association with humans, pattern of crop cultivation, distance of farm from the forest boundary and temporal scarcity of edible foods are responsible for crop damage by wild animals (Naughton-Treves, 1998; Hill, 1998; 2000; Saj *et al*., 2001). As human populations increase, they use more agricultural land and then baboons compete for space with human as a consequence of habitat alteration (Laurance, *et al.*, 2002). Similarly, as reported by Hill and Wallace (2012), field crops provide a reliable and readily-accessible source of food for primates to compensate habitat loss.

Guarding cereal crops from raiding by southern geladas is costly in terms of energy and time. It hinders like travelling, meeting, marketing, household chores, mourning and schooling. It requires the availability of the guards near their farmlands throughout the daylight hours.

Children may be absent in many occasions from the schools, and they may also record poor result in performances. Hill (2000) and Linkie *et al.* (2007) pointed out that, children miss schools to guard their family fields from crop pest species. Mothers may be tired as the result of workload of protecting cereal crop from primate raiding during day time, and doing housework during the night time. Fathers may also devote their working time and energy for protecting their cereal crop from raiding rather than doing other chores. Similarly, Tchamba (1996) and Hill (2000) reported that, guarding fields from wildlife pest incur costs to household members.

The economic losses and opportunity costs undermine the conservation interest of southern geladas by the local farmers. Similarly, Gillingham and Lee (2003) pointed out that conservation perception declines if wild animals show negative impacts to livelihood of local farmers. This may be also due to lack of awareness about wildlife species regarding their ecological value and low income generation from tourism sector by the local people in the study area.

Anthropogenic factors like deforestation and extensive use of wildlife habitats for agricultural activities and settlement affect the survival of primates (Cowlishaw and Dunbar, 2000). Any habitat modification that alters population density and food availability has great impact on primates (Siex, 2003). Habitat degradation, agricultural expansion, drought and hunting cause stress and instability in the population of geladas, and in the long run these may reduce the population size and growth rate. Infectious disease can cause devastating mortality in primates (Leendertz *et al*., 2004). Respondents reported that many geladas affected by parasitic infection. During the study period, many individuals from Tikure band developed parasitic infection on different parts of their body (Personal observation, this study).

6. CONCLUSION AND RECOMMENDATIONS

6.1. Conclusion

Long-term studies are necessary to reflect the population structure and ecological behaviour of a primate in a better way. The small group size populations and low density of the southern geladas observed in the unprotected site may be the optimal size in which foraging efficiency is maximized for the habitat as a survival strategy. Similarly, larger group sizes in afroapline habitat types might be due to the higher preference of geladas at the highlands or the presence of broad mosaic grasslands with low habitat disturbances at the afroalpine ecosystems.

Data on behavioural ecology from the contrasting sites are useful in understanding the behavioural adaptations of primate to different sets of ecological conditions. This dissertation contributes to our understanding of the ecological and behavioural flexibility of primates in human-modified environments, as well as conservation implication of such flexibility. The results of this study indicate that southern geladas can respond to anthropogenic habitat alteration by being flexible in their diet, by incorporating more alternative food items such as cereal crops, fruits, bulbs, roots, rhizomes, corms and seeds. They exploit more resources available in human-altered landscapes. Geladas are able to adjust their group sizes depending upon the habitat alteration. Plasticity in activity budgets and patterns, diets and ranging ecology during seasons are key factors for the survival strategies of geladas in human-modified environments. Intensive use of a particular habitat and the use of sharp cliff as sleeping sites and hiddenness from harassments by local farmers are other key adaptive abilities of survive in degraded habitats.

The high diversity in consumption of different food species is an adaptation to survive in highly human-dominated landscapes. Figs are recognized as major fruit resources for geladas living in the lowland areas, and the fruiting patterns of figs result in a reliable food source for geladas during elongated dry season and general food scarcity. Anthropogenic habitat alteration can dramatically affect the quality, availability and distribution of food resources and the addition of anthropogenic food sources into the diets with both positive and negative effects on the survival of gelada. In addition, the study concludes that geladas are opportunistic in the diet choices rather than obligate graminivores.

Southern geladas in the current study sites showed dramatic variation in their activity time patterns throughout the daylight hours. Each band in their respective habitats develops different patterns in time budget, since it may be adaptive strategies of survival. Thus, the activity pattern of geladas can be determined by the ecosystem of the areas, altitude, temperature, habitat alternations and human disturbances.

In general, based on the findings, it can conclude that southern geladas are of much greater ecological and behavioural flexible than any other primates that live in open highly human dominated landscapes. They developed a certain degree of dietary plasticity and habitat adaptability for living on the devastated environment where other primate species cannot cope up. They developed a better way of survival strategies to live in Ethiopian highland landscapes by sharing the available resources with livestock. Geladas respond to habitat alteration through increase daily path length and home range size in order to cover more area to obtain quality food resources like fruits from figs and cereal crops from farmlands. This flexibility may allow them to persist in areas subject to human influences.

The findings suggest that human-gelada conflict has serious implications for both the local conflict-affected farmers and geladas. Both the local farmers and geladas suffered in the conflicts. Local farmer loss their crops and guarding took energy and time. In turn southern geladas harassed by local farmers. Habitat degradation, agricultural expansion and drought are the main threats of geladas in the unprotected site while disease and predation in the BSNP.

Conservation of geladas in the unprotected sites requires attention. The need of larger home range areas for geladas should be considered in conservation and management strategies. Leaving mosaic grassland habitats and creating awareness among the local residents in the human-dominated landscapes within the habitat of geladas may alleviate some of the pressures like diminished suitable habitat and food resources. Most gelada populations live outside the protected area. Even those geladas that live inside the Park often utilize buffer zone. Therefore, effort should be paid to the conservation value of landscapes outside the protected areas of the human-modified habitats for the long-term survival of geladas and other primates.

6.2. Recommendations

Based on the findings of the study, the following recommendations are forwarded to the stakeholders to ensure the sustainable and long-term conservation of the southern geladas and their habitats:

☞ A single census during a single year cannot track the trajectory of a population. Future counts should be carried out in subsequent years to determine the population trend for southern geladas in and around BSNP.

☞ Analyze the chemical composition of food items consumed by the habituated bands.

☞ Test the impact of predator risk on the habitat selection of the southern geladas in BSNP.

☞ Only small number of geladas live within the protected areas of Ethiopia, thus attention should be paid to the conservation value of land outside the protected areas, in human-modified habitats.

☞ Even if reducing crop raiding by geladas seems to be complicated; collaborating or shifting types of active guarding system and leaving cliff proximate field lands for gelada’s foraging areas should be practiced.

- A community-based conservation education and outreach programme especially in the unprotected areas is essential to improve the awareness of local farmers and to develop positive attitude toward the conservation of geladas.
- Fig trees should be conserved since their fruits are reliable food sources for geladas.
- Foraging area should be left for geladas by creating alternative job opportunity for the young.
- Local farmers affected by human-wildlife conflict should play a leading role in developing conservation policies that explore ways to reduce the conflict. The needs and aspirations of local farmers must be taken into account when designing optimal gelada conservation protocols. Ignoring the plight of these farmers may lessen their future support for gelada conservation.
- Further wildlife reserve areas or habitat protection and resource preservation should be developed to conserve more geladas through increased enforcement and local community participation. Finally, the establishment of additional reserve is fundamental for the sustainable development of geladas.
- The promotion of tourism activities should be undertaken broadly in BSNP to develop positive attitudes and change the perceptions of the local farmers towards geladas and biodiversity conservation of the area.
- Local people would benefit from new jobs and might be encouraged to participate in income-generating programmes that might improve their socioeconomic conditions.
- *Festuca* grasses should be cut every two years to initiate the growth of fresh grasses for geladas and other wild animals, and in turn benefiting the local farmers by using the grasses for different purposes. But studies should be done prior to this act.

7. REFERENCES

Afework Bekele and Corti, M. (1997). Forest blocks and altitude as indicators of *Praomys albipes* (Mammalia: Rodentia) distribution in Ethiopia. *Trop. Zool*. **10**: 287–293.

Afework Bekele and Yalden, D. W. (2013). *The Mammals of Ethiopia and Eritrea*. Addis Ababa University Press, Addis Ababa.

Agetsuma, N. (2000). Influence of temperature on energy intake and food selection by macaques. *Int. J. Primatol*. **21**: 103–111.

Aich, H., Moos-Heilen, R. and Zimmermann, E. (1990). Vocalizations of adult gelada baboons (*Theropithecus gelada*): acoustic structure and behavioural context. *Folia Primatol*. **55**: 109–132.

Altmann, J. (1974). Observational study of behaviour: sampling method. *Behaviour* **49**: 227–267.

Altmann, J., Schoeller, D., Altmann, S. A., Muruthi, P. and Sapolsky, R. M. (1993). Body size and fatness of free living baboons reflect food availability and activity levels. *Am. J. Primatol*. **30**: 149–161.

Bahiru Zewdie (1998). Forests and forest management in Wollo in historical perspective. *J. Ethio. Stud.* **31**: 45–78.

Balakrishnan, M. and Ndhlovu, D. (1992). Wildlife utilization and local people: a case study in Upper Lupande Game Management Area, Zambia. *Environ. Conserv*. **19**: 135–144.

Bandara, R. and Tisdell, C. (2003). Comparison of rural and urban attitudes to the conservation of Asian elephants in Sri Lanka: empirical evidence. *Biol. Conserv*. **110**: 327–342.

Barton, R. A., Byrne, R. W. and Whiten, A. (1996). Ecology, feeding competition and social structure in baboons. *Behav. Ecol. Sociobiol*. **38**: 321–329.

Barton, R. A., Whiten, A., Strum, S. C., Byrne, R. W. and Simpson, A. J. (1992). Habitat use and resource availability in baboons. *Anim. Behav*. **43**: 831–844.

Beehner, J. C. and Bergman, T. J. (2008). Infant mortality following male takeovers in wild geladas. *Am. J. Primatol*. **70**: 1152–1159.

Beehner, J. C., Berhanu Gebre, B., Bergman, T. J. and McCann, C. (2008). Population estimate for geladas (*Theropithecus gelada*) living in and around the Simien Mountains National Park, Ethiopia. *Ethio. J. Sci*. **30**: 149–154.

Bergman, T. J and Beehner, J. C. (2013). *Theropithecus gelada*, gelada (gelada baboon). **In**: *Mammals of Africa. Volume II*: *primates,* Butynski, T. M., Kingdon, J. and Kalina, J. (eds.). Bloomsbury Publishing, London.

Bergman, T. J., Ho, L. and Beehner, J. C. (2009). Chest color and social status in male geladas (*Theropithecus gelada*). *Int. J. Primatol*. **30**: 791–806.

Bininda-Emonds, O. R. P., Cardillo, M., Jones, K. E., MacPhee, R. D. E., Beck, R. M. D., Grenyer, R., Price, S. A., Vos, R. A., Gittleman, J. L. and Purvis, A. (2007). The delayed rise of present-day mammals. *Nature* **446**: 507–512.

Bishop, N., Hrdy, S. B., Teas, J. and Moore, J. (1981). Measuring human influence in habitats of Asian monkey. *Int. J. Primatol*. **2**: 153–167.

Bloch, J. I., Silcox, M. T., Boyer, D. M. and Sargis, E. J. (2007). New Paleocene skeletons and the relationship of plesiadapiforms to crown-clade primates. *Proc. Nat. Acad. Sci.* **104**: 1159–1164.

Boyle, S. A. and Smith, A. T. (2010). Behavioral modifications in northern bearded saki monkeys (*Chiropotes satanas chiropotes*) in forest fragments of central Amazonia. *Primates* **51**: 43–51.

Boyle, S. A., Lourenco, W. C., da Silva, L. R. and Smith, A. T. (2009). Home range estimates vary with sample size and methods. *Folia primatol.* **80**: 33–42.

Byrne, R. W., Whiten, A., Henzi, S. P. and Mcculloch, F. M. (1993). Nutritional constraints on mountain baboons (*papio ursinus*): Implications for baboon socioecology. *Behav. Ecol. Sociobiol.* **33**: 233–246.

Campbell-smith, G., Simanjorang, H. V. P., Leader-Williams, N. and Linkie, M. (2010). Local attitudes and perceptions toward crop-raiding by orangutans (*Pongo abelii*) and other nonhuman primates in Northern Sumatra, Indonesia. *Am. J. Primatol*. **71**: 1–11.

Campos, F. A. and Fedigan, L. M. (2009). Behavioral adaptations to heat stress and water scarcity in white-faced capuchins (*Cebus capucinus*) in Santa Rosa National Park, Costa Rica. *Am. J. Phy. Anthropol.* **138**: 101–111

Chapman, C. A. and Peres, C. A. (2001). Primate conservation in the new millennium: The role of scientists. *Evol. Anthropol.* **10**: 16–33.

Chaves, O. M. and Stoner, K. E. (2011). Seasonal differences in activity patterns of Geoffroyi´s spider monkeys (*Ateles geoffroyi*) Living in continuous and fragmented forests in Southern Mexico. *Int. J. Primatol*. **32**: 960–973.

Cherkos Woldegeorgis and Afework Bekele (2015). Diet and feeding behaviour of geladas (*Theropithecus gelada*) at the Gich area of the Simien Mountains National Park, Ethiopia. *Glob. J. Biol. Agri. Heal. Sci*. **4**: 178–184.

Cowlishaw, G. and Dunbar, R. I. M. (2000). *Primate Conservation Biology*. University of Chicago Press, London and Chicago.

Crook, J. H. (1966). Gelada baboon herd structure and movement: a comparative report. *Symp. Zool. Soc. Lond*. **18**: 237–258.

Crook, J. H. and Aldrich-Blake, P. (1968). Ecological and behavioural contrast between sympatric ground dwelling primates in Ethiopia. *Folia Primatol.* **8**: 192–227.

Delson, E., Eck, G., Leakey, M. and Jablonski, N. (1993). A partial catalogue of fossil remains of *Theropithecus*. **In**: *Theropithecus*: *The Rise and Fall of a Primate Genus*, Jablonski, N. G. (eds.). Cambridge University Press, Cambridge.

Di Fiore, A. (2003). Ranging behaviour and foraging ecology of low land woolly monkey (*Lagothrix lagotricha poeppigii*) in Yasuni National Park, Ecuador. *Int. J. Primatol*. **22**: 449–480.

Di Fiore, A. (2004). Diet and feeding ecology of woolly monkeys in a western Amazonian rainforest. *Int. J. Primatol.* **25**: 767–801.

Dunbar, R. I. M. (1976). Australopithecine diet based on a baboon analogy. *J. Hum. Evol*. **5**: 161–167.

Dunbar, R. I. M. (1977a). *Feeding Ecology of Gelada Baboons*. Academic Press, London.

Dunbar, R. I. M. (1977b). *The Gelada Baboon*: *Status and Conservation*. Academic Press, New York.

Dunbar, R. I. M. (1979). Structure of gelada baboon reproductive units. I. stability of social relationships. *Behaviour* **69**: 72–87.

Dunbar, R. I. M. (1980a). Demographic and life history variables of a population of gelada baboons (*Theropithecus gelada*). *J. Anim. Ecol.* **49**: 485–506.

Dunbar, R. I. M. (1980b). Determinants and evolutionary consequences of dominance among female gelada baboons. *Behav. Ecol. Sociobiol*. **7**: 253–265.

Dunbar, R. I. M. (1983a). Structure of gelada baboon reproductive units. II. Social relationships between reproductive females. *Anim. Behav*. **31**: 556–564.

Dunbar, R. I. M. (1983b). Theropithecines and hominids: contrasting solutions to the same ecological problem. *J. Hum. Evol*. **12**: 647–658.

Dunbar, R. I. M. (1984a). Infant-use by male gelada in agonistic contexts: agonistic buffering, progeny protection or soliciting support? *Primates* **25**: 28–35.

Dunbar, R. I. M. (1984b). *Reproductive Decisions: An Economic Analysis of Gelada Baboon Social Strategies*. Princeton University, Princeton.

Dunbar, R. I. M. (1986). *The Social Ecology of Gelada Baboons*. Princeton University, Princeton.

Dunbar, R. I. M. (1987). Habitat quality, population dynamics, and group composition in colobus monkeys (*Colobus guereza*). *Int. J. Primatol*. **8**: 299–329.

Dunbar, R. I. M. (1992). A model of the gelada socio-ecological system. *Primates* **33**: 69–83.

Dunbar, R. I. M. (1993a). *Conservation Status of the Gelada*. Cambridge University Press, Cambridge.

Dunbar, R. I. M. (1993b). *Social Organization of the Gelada*. Cambridge University Press, Cambridge.

Dunbar, R. I. M. (1998). Impact of global warming on the distribution and survival of the gelada baboon: a modeling approach. *Glob. Chan. Biol*. **4**: 293–304.

Dunbar, R. I. M. and Bose, U. (1991). Adaptation to grass-eating in gelada baboons. *Primates* **32**: 1–7.

Dunbar, R. I. M. and Dunbar, E. P. (1974). Ecological relations and niche separation between sympatric terrestrial primates in Ethiopia. *Folia Primatol*. **21**: 36–60.

Dunbar, R. I. M. and Dunbar, E. P. (1975). Social dynamics of gelada baboons. *Contrib. Primatol*. **6**: 1–157.

Dunbar, R. I. M. and Dunber, E. P. (1988). Maternal time budgets of gelada baboons. *Anim. Behav*. **36**: 970–980.

Dunbar, R. I. M., Hannah-Stewart, L. and Dunbar, E. P. (2002). Forage quality and the costs of lactation for female gelada baboons. *Anim. Behav*. **64**: 801–805.

Eck, G. (1993). *Theropithecus darti* from the Hadar Formation, Ethiopia. **In**: *Theropithecus*. *The Rise and Fall of a Primate Genus*, Jablonski, N. G. (eds.). Cambridge University Press, Cambridge.

Eshetu Moges (2015). Population Structure, Behavioural Ecology and Habitat Vulnerability of Gelada (*Theropithecus gelada)* Protected Area, Central Ethiopia, Ph.D. thesis, Addis Ababa University, Addis Ababa.

Eshetu Moges and Balakrishnan, M. (2015). Demographic structures of gelada (*Theropithecus gelada*) in Guassa Community Protected Area, Ethiopia. *Glob. J. Sci*. **15**: 19–24.

Estrada, A. (2013). Socioeconomic contexts of primate conservation: population, poverty, global economic demands, and sustainable land use. *Am. J. Primatol.* **75**: 30–45.

Estrada, A., Juan, S., Ortı´z-Martı´nez, T. and Coates-Estrada, R. (1999). Feeding and general activity patterns of a howler monkey (*Alouatta palliata*) troop living in a forest fragment at Los Tuxtlas, Mexico. *Am. J. Primatol.* **48**: 167–183.

Estrada, A., Raboy, B. E. and Oliveira, L. C. (2012). Agroecosystems and primate conservation in the tropics: a review. *Am. J. Primatol.* **74***:* 696–711.

EWCA (Ethiopian Wildlife Conservation Authority) 2012. Wildlife Utilization, 2012 annual report (Unpublished), Addis Ababa.

Fashing, P. J. (2001). Activity and ranging patterns of guerezas in the Kakamega Forest: intergroup variation and implications for intragroup feeding competition. *Int. J. Primatol*. **22**: 549–577.

Fashing, P. J. and Cords, M. (2000). Diurnal primate densities and biomass in the Kakamega Forest: An evaluation of census methods and a comparison with other forests. *Am. J. Primatol.* **50**: 139–152.

Fashing, P. J., Mulindahabi, F., Gakima, J., Masozera, M., Mununura, I., Plumptre, A. J. and Nguyen, N. (2007). Activity and ranging patterns of *Colobus angolensis ruwenzorii* in Nyungwe Forest, Rwanda: possible costs of large group size. *Int. J. Primatol.* **28**: 529–550.

Fashing, P. J., Nguyen, N. and Fashing, N. J. (2010). Behavior of gelada and other endemic wildlife during a desert locust outbreak at Guassa, Ethiopia: Ecological and conservation implications. *Primates* **51**: 193–197.

Fashing, P. J., Nguyen, N., Venkataraman, V. V. and Kerby, J. T. (2014). Gelada feeding ecology in an intact ecosystem at Guassa, Ethiopia: Variability over time and implications for Theropith and Hominin dietary evolution. *Am. J. Phy. Anthropol*. **155**: 1–16.

Fedigan, L. M. and Jack, K. (2001). Neotropical primates in a regenerating Costa Rican dry forest: A comparison of howler and capuchin population patterns. *Int. J. Primatol.* **22**: 689–713.

Felton, A. M., Felton, A., Wood, J. F., Foley, W. J., Raubenheimer, D., Wallis, I. R. (2009). Nutritional ecology of Ateles chamek in lowland Bolivia: How macronutrient balancing influences food choices. *Int. J. Primatol*. **30**: 675–696.

Fleagle, J. G. (2013). *Primate Evolution and Adaptation*. 3rd edn. Elsevier Inc. San Diego.

Fleagle, J. G. and Gilbert, C. C. (2006). Biogeography and the primate fossil record: the role of tectonics, climate, and chance. **In**: *Primate Biogeography*, Lehman, S. and Fleagle, J. G. (eds.). Springer, New York.

Friis, I., Sebsebe Demissew and Beugel, P. (2011). *Atlas of the Potential Vegetation of Ethiopia*. Addis Ababa University Press, Shama Books.

Frost, S. R., Jablonski, N. G. and Haile-Selassie, Y. (2014), Early Pliocene Cercopithecidae from Waranso-Mille (Central Afar, Ethiopia) and the origins of the *Theropithecus oswaldi* lineage. *Hum. Evol*. **76**: 39–53.

Gillingham, S. and Lee, P. C. (2003). People and protected areas: a study of local perceptions of wildlife crop-damage conflict in an area bordering the Selous Game Reserve, Tanzania. *Oryx* **37:** 316–325.

Gippoliti, S. (2010). Theropithecus gelada distribution and variations related to taxonomy: history, challenges and implications for conservation. *Primates* **51**: 291–297.

Girma Eshete, Girmay Tesfay, Bauer, H. Zelealem Tefera Ashenafi, Iongh, H. and Marino, J. (2015). Community resource uses and Ethiopian Wolf conservation in Mount Abune Yosef. *Enviro. Manag*. **55**: 1–13.

Golubtsov, A. S. and Darkov, A. A. (2008). A review of fish diversity in the main drainage system of Ethiopia. **In**: *Ecological and Faunistic studies in Ethiopia*, Pavlov, D. S. and Dgebuadge, Y. (eds.). Kick Science Press, Moscow.

Gonzȧlez-Zamora, A., Arroyo-Rodrἰguez, V., Chaves, O. M., Sȧnchez-Lȯpez, S., Stoner, K. E. and Riba-Hernȧndez, P. (2009). Diet of spider monkeys (*Ateles geoffroyi*) in Mesoamerica: current knowledge and future directions. *Am. J. Primatol*. **71**: 8–20.

Goodman, M., Porter, C. A., Czelusniak, J., Page, S. L., Schneider, H., Shoshani, J., Gunnell, G. and Groves, C. P. (1998). Toward a phylogenetic classification of primates based on DNA evidence complemented by fossil evidence. *Molec. Phylog. Evol.* **9**: 585–598.

Grubb, P. (2006). English common names for subspecies and species of African primates. *Prim. Conserv.* **20:** 65–73.

Grüter, C. C. and Zinner, D. (2004). Nested societies. Convergent adaptations of baboons and snub-nosed monkeys? *Prim. Rep*. **70**: 1–98.

Gurja Belay and Mori, A. (2006). Intraspecific phylogeographic mitochondrial DNA (D-loop) variation of Gelada baboon, *Theropithecus gelada*, in Ethiopia. *Bio. Syst. Ecol*. **34**: 554–561.

Gustison, M. L., le Roux, A. and Bergman, T. J. (2012). Derived vocalizations of geladas (*Theropithecus gelada*) and the evolution of vocal complexity in primates. Philosophical Transactions of the Royal Society B-Biological Sciences. **367**: 1847–1859.

Gwenzi, D., Katsvanga, C. A. T., Ngorima, G. T., Mupangwa, J. F. and Valintine, S. (2007). Baboon (*Papio ursinus*) ranging patterns and troop size relative to bark stripping in the Chimanimani Pine Plantations of Zimbabwe. *Acta. Zool. Sinica*. **53**: 777–782.

Heesy, C. P., Stevens, N. J. and Samonds, K. E. (2006). Biogeographic origins of primate higher taxa. **In**: *Primate Biogeography: Progress and Prospects*, Lehman, S. M. and Fleagle, J. G. (eds.). Springer, New York.

Hill, C. M. (1997). Crop raiding by wild vertebrates: the farmer’s perspective in an agricultural community in western Uganda. *Int. J. Pest. Manage*. **43**: 77–84.

Hill, C. M. (1998). Conflicting attitudes towards elephants around the Budongo Forest Reserve, Uganda. *Environ. Conserv.* **25**: 244–250.

Hill, C. M. (2000). Conflict of interest between people and baboons: crop raiding in Uganda. *Int. J. Primatol.* **21**: 299–315.

Hill, C. M. (2002). Primate conservation and local communities-ethical issues and debates. *Am. Anthropol*. **104**: 1184–1194.

Hill, C. M. and Wallace, G. E. (2012). Crop protection and conflict mitigation: reducing the costs of living alongside non-human primates. *Biodivers. Conserv.* **21**: 2569–2587.

Hill, W. (1970). *Primates: Comparative Anatomy and Taxonomy: Cynopithecinae. Papio, Mandrillus, Theropithecus.* Edinburgh University Press, Edinburgh.

Hillman, J. C. (1993). *Ethiopia*: *Compendium of Wildlife Conservation Information*. *Vol. I. Wildlife Conservation in Ethiopia*. Ethiopian Wildlife Conservation Organization, Addis Ababa.

Hoffman, T. S., and O’Riain, M. J. (2010). The spatial ecology of chacma baboons (*Papio ursinus*) in a human-modified environment. *Int. J. Primatol*. **32**: 308–328.

Horrocks, J. A. and Baulu, J. (1994). Food competition between vervets (*Cercopithecus aethiops sabaeus*) and farmers in Barbados: implications for management. *Rev. Ecol. Terre. Vie*. **49**: 281–294.

Hunter, C. (2001). Ecological Determinants of Gelada Ranging Pattern (*Theropithecus gelada*). Ph.D. Thesis, Liverpool University, Liverpool.

Hurni, H. (1988). Degradation and conservation of soil resources in Ethiopian highlands. *Mountain Research and Development* **8**: 123–130.

Hussien Adal (2014). Plant Diversity and Ethnobotany of Borena Sayint National Park, northern Ethiopia. Ph.D. Thesis, Addis Ababa University, Ethiopia.

Irwin, M. T. (2008). Diademed sifaka (*Propithecus diadema*) ranging and habitat use in continuous and fragmented forest: Higher density but lower viability in fragments? *Biotropica* **40**: 231–240.

Isabirye-Basuta, G. M. and Lwanga, J. S. (2008). Primate populations and their Interactions with changing habitats. *Int. J. Primatol***. 29**: 35–48.

IUCN (International Union for Conservation of Nature and Natural Resources) (2010). *IUCN Red List Data of Threatened Animals.* IUCN, Gland.

Iwamoto, T. (1979). Feeding ecology. *Contrib. Primatol*. **16**: 279–330.

Iwamoto, T. (1993). The ecology of *Theropithecus gelada*. **In**: *Theropithecus*: *The Rise and Fall of a Primate Genus,* Jablonski, N. G. (eds.). Cambridge University Press, Cambridge.

Iwamoto, T. and Dunbar, R. I. M. (1983). Thermoregulation, habitat quality and the behavioural ecology of gelada baboons. *J. Anim. Ecol*. **52**: 357–366.

Iwamoto, T., Mori, A., Kawai, M. and Afework Bekele (1996). Anti-predator behavior of gelada baboons. *Primates* **37**: 389–397.

Jablonski, N. (1993). Evolution of the masticatory apparatus in Theropithecus. **In**: *Theropithecus: The Rise and Fall of a Primate Genus*, Jablonski, N. G. (eds.). Cambridge University Press, New York.

Jha, S. and Bawa, K. (2006). Population growth, human development, and deforestation in biodiversity hotspots. *Conserv. Biol*. **20**: 906–912.

Johnson, D. D. P., Kays, R., Blackwell, P. G. and Macdonald, D. W. (2002). Does the resource dispersion hypothesis explain group living? *Ecol. Evol*. **17**: 563–570.

Johnson, E. T., Snyder-Mackler, N., Beehner, J. C. and Bergman, T. J. (2013). Kinship and dominance rank influence the strength of social bonds in female geladas (*Theropithecus gelada*). *Int. J. Primatol*. **35**: 288–304.

Jolly, C, J. (1972). The classification and natural history of theropithecus baboons of the African Plio-pleistocene. *Bull. Brit. Mus. Nat. Hist*. **22**: 1–123.

Jolly, C. J. (2001). A proper study for mankind: Analogies from the Papionin monkeys and their implications for human evolution. *Phys. Anthropol*. **44**: 177–204.

Jolly, C. J., Wolley-Baker, T., Beyene, S., Disotell, T. R and Phillips-Conroy, J. E. (1997). Intergeneric hybrid baboons. *Int. J. Primatol*. **18**: 597–627.

Kaplan, B. S., O'Riain, M. J., van Eeden, R. and King, A. J. (2011). A low-cost manipulation of food resources reduces spatial overlap between baboons (*Papio ursinus*) and humans in conflict. *Int. J. Primatol.* **32:** 1397–1412.

Kappeler, P. M. and van Schaik, C. P. (2002). Evolution of primate social systems. *Int. J. Primatol*. **23**: 707–740.

Kawai, M. (1979a). Ecological and sociological studies of gelada baboons. *Primates* **7**: 1–16.

Kawai, M. (1979b). Auditory communication and social relations. *Contrib*. *Primatol.* **16**: 219–241.

Kawai, M. and Iwamoto, T. (1979). Nomadism and activities. *Contrib. Primatol.* **16**: 251–278.

Kawai, M., Dunbar, R., Ohsawa, H. and Mori, U. (1983). Social organization of gelada baboons: social units and definitions. *Primates* **24**: 13–24.

Kelil Abu, Addisu Mekonnen, Afework Bekele, Fashing, P. J. (2017). Diet and activity patterns of Arsi geladas in low-elevation disturbed habitat south of the Rift Valley at Indetu, Ethiopia. *Primates* 00: 1–9. https://doi.org/10.1007/s10329-017-0640-9.

Khatun, U. H., Ahsan, Md. F. and Røskaf, E. (2012). Attitudes of the local community towards the conservation of the common langur (*Semnopithecus entellus*) in Keshabpur, Bangladesh. *Int. Biodiv. Conserv*. **4**: 385–399.

Kingdon, J. (1971). *East Africa Mammals: I. An Atlas of Evolution in Africa*. Academic Press, New York.

Kingdon, J. (2004). *The Kingdon Pocket Guide to African Mammals*. Princeton University Press, Princeton.

Krebs, C. S. (1999). *Ecological Methodology.* 2nd edn. Bnjamin Cummings, Menlo Park. USA.

Largen, M. J. and Spawls, S. (2010). *The Amphibians and reptiles of Ethiopia and Eritrea. Frankfurt contribution to Natural History*. Frankfurt, Chimaira.

Last, J. (1982). *Endemic Mammals of Ethiopia*. Ethiopian Tourism Commission, Addis Ababa.

Laurance, W. F., Lovejoy, T. E., Vasconcelos, H. L., Bruna, E. M., Didham, R. K., Stouffer, P. C., Gascon, C., Bierregaard, R. O., Laurance, S. G. and Sampaio, E. (2002). Ecosystem decay of Amazonian forest fragments: A 22-year investigation. *Conserv. Biol.* **16:** 605–618.

Le Roux, A., Beehner, J. C. and Bergman, T. J. (2011). Female philopatry and dominance patterns in wild geladas. *Am. J. Primatol*. **73**: 422–430.

Leendertz, F. H., Ellerbrok, H., Boesch, C., Couacy-Hymann, E., Matz-Rensing, K., Hakenbeck, R. and Bergmann, C. (2004). Anthrax kills wild chimpanzees in a tropical rainforest. *Nature* **430**: 451–451.

Linkie, M., Dinata, Y., Nofrianto, A. and Leader-Williams, N. (2007). Patterns and perceptions of wildlife crop raiding in and around Kerinci Seblat National Park, Sumatra. *Ani. Conserv.* **10:** 127–135.

Madden, F. (2004). Creating coexistence between humans and wildlife: Global perspectives on local efforts to address human–wildlife conflict. *Hum. Dimen. Wildl.* **9**: 247–257.

Marchal, V. and Hill, C. (2009). Primate crop raiding: a study of local perception in four villages in North Sumetra, Indonesia. *Prim. Conserv*. **14**: 116–119.

Martin, R. D. (2000). Origins, diversity and relationships of lemurs. *Int. J. Primatol.* **21**:1021–1049.

Masi, S., Cipolletta, C. and Robbins, M. M. (2009). Western lowland gorillas (*Gorilla gorilla gorilla*) change their activity patterns in response to frugivory. *Am. J. Primatol*. **71**: 91–100.

McCann, C. (1995). Social Factors Affecting Reproductive Success in Female Gelada Baboons (*Theropithecus gelada*). Ph.D. Thesis, New York University, New York.

McKenna, M. C. and Bell, S. K. (1997). *Classification of mammals above the species level*. Columbia University Press, New York.

Mekonnen, A., Fashing, P. J., Bekele, A., Hernandez-Aguilar, R. A., Rueness, E. K., Nguyen, N. and Stenseth, N. C. (2017). Impacts of habitat loss and fragmentation on the activity budget, ranging ecology and habitat use of Bale monkeys (*Chlorocebus djamdjamensis*) in the southern Ethiopian Highlands. **79**: 1–13. https://DOI 10.1002/ajp.22644.

Melaku Tefera (2011). Wildlife in Ethiopia. Endemic large mammals. *Wor. J. Zool*. **2**: 108–116.

Mesele Yihune, Afework Bekele and Zelealem Tefere (2008). Human-gelada baboon conflict in and around Simien Mountains National Park, Ethiopia. *Afr. J. Ecol*. **35**: 596–606.

Meseret Chane and Solomon Yirga (2014). Distribution and diversity of small mammals in Borena-Sayint National park, South Wollo, Ethiopia. Implications for habitat specialization. *Int. Biodiv. Conserv*. **5**: 415–421.

Miller, E. R., Gunnell, G. F. and Martin, R. D. (2005). Deep time and the search for anthyropoid origins. *Phys. Anthropol*. **48**: 60–95.

Mittermeier, R. A. N., Ratsimbazafy, A. B., Rylands, L., Williamson, J. F., Oates, D., Mbora, J. U., Ganzhorn, E., RodríguezLuna, E., Palacios, E. W., Heymann, M. C. M., Kierulff, L., Yongcheng, J., Supriatna, C., Roos, S. Walker and J. M. Aguiar. (2007). Primates in peril: the world's 25 most endangered primates, 2006–2008. *Prim. Conserv*. **22**: 1–40.

Mori, A. and Gurja Belay (1990). The distribution of baboon species and a new population of gelada baboons along the Wabi-Shebeli River, Ethiopia. *Primates* **31**: 495–508.

Mori, A., Iwamoto, T. and Afework Bekele (1997). A case of infanticide in a recently found gelada population in Arsi, Ethiopia. *Primates* **38**: 79–88.

Mori, A., Iwamoto, T., Mori, U. and Afework Bekele (1999). Sociological and demographic characteristics of a recently found Arsi gelada population in Ethiopia. *Primates* **40**: 365–381.

Mori, U. (1979a). Development of sociability and social status. *Contrib. Primatol*. **16**: 125–154.

Mori, U. (1979b). Reproductive behaviour. *Contrib. Primatol.* **16**: 183–197.

Mori, U. and Dunbar, R. I. M. (1985). Changes in the reproductive condition of female gelada baboons following the takeover of one-male unit. *Z. Tierpsychol.* **67**: 215–224.

National Research Council (1981). *Techniques for the Study of Primate Population Ecology*. National Research Council (ed.), National Academy Press, Washington, DC.

Naughton-Treves, L. (1998). Predicting patterns of crop damage by wildlife around Kibale National Park, Uganda. *Conserv. Biol.* **12:** 156-168.

Naughton-Treves, L., Treves, A., Chapman, C. and Wrangham, R. (1998). Temporal patterns of crop-raiding by primates: linking food availability in croplands and adjacent forest. *J. Appl. Ecol*. **35**: 596–606.

Newmark, W. D., Manyanza, D. N., Gamassa, G. M. and Sariko, H. I. (1994). The conflict between wildlife and local people living adjacent to protected areas in Tanzania: human density as a predictor. *Conserv. Biol.* **8:** 249–255.

Oates, J. F. (1996). Habitat alteration, hunting, and the conservation of folivorous primates in African forests. *Austr. J. Ecol.* **21**: 1–9.

O'Brien, T. G. and Kinnaird, M. F. (1997). Behavior, diet, and movements of the Sulawesi crested black macaque (*Macaca nigra*). *Int. J. Primatol.* **18**: 321–351.

Ogra, M. and Badola, R. (2008). Compensating human–wildlife conflict in protected area communities: Ground-level perspectives from Uttarakhand, India. *Hum. Ecol.* **36**: 717–729.

Ohsawa, H. (1979). The local gelada population and environment of the Gich area. *Contrib. Primatol*. **16**: 4–45.

Ohsawa, H. and Dunbar, R, I, M. (1984). Variations in the demographic structure and dynamics of gelada baboon populations. *Behav. Ecol. Sociobiol*. **15**: 231–240.

Onderdonk, D. A. and Chapman, C. A. (2000). Coping with forest fragmentation: the primates of Kibale. National Park, Uganda. *Int. J. Primatol.* **21**: 587–611.

Osborn, F. and Parker, G. (2003). Toward an intergrated approach for reducing the conflict between elephants and people: a review of current research. Oryx **37**: 80–84.

Ostro, L. E. T., Silver, S. C., Koontz, F. W., Young, T. P. and Horwich, R. H. (1999). Ranging behavior of translocated and established groups of black howler monkeys (*Alouatta pigra*) in Belize, Central America. *Biol. Conserv*. **87**: 181–190.

Page, S. L. and Goodman, M. (2001). Catarrhine phylogeny: noncoding DNA evidence for a diphyletic origin of the mangabeys and for a human-chimpanzee clade. *Mol. Phylog. Evol*. **18**: 14–25.

Page, S. L., Chiu, C. and Goodman, M. (1999). Molecular phylogeny of Old World monkeys (Cercopithecidae) as inferred from γ-globin DNA sequences. *Mol. Phylog. Evol.* **13**: 348–359.

Pappano, D. J. (2013). The reproductive trajectories of bachelor geladas. Ph.D. Dissertation, University of Michigan, USA.

Peres, C. A. (1999). General guidelines for standardizing line transect surveys of tropical forest primates. *Neotropical Primates* **7**: 11–16.

Plumptre, A. J. and Cox, D. (2006). Counting primates for conservation: primate surveys in Uganda. *Primates* **47**: 65–73.

Riley, E. P. (2007). Flexibility in diet and activity patterns of *Macaca tonkeana* in response to anthropogenic habitat alternation. *Int. J. Primatol*. **28**: 107–133.

Riley, E. P. (2008). Ranging patterns and habitat use of Sulawesi Tonkean macaques (*Macaca tonkeana*) in a human-modified habitat. *Am. J. Primatol*. **70**: 670–679.

Rook, L., Martinez-Navarro, B. and Howell, F. C. (2004). Occurrence of Theropithecus sp in the late Villa Franchian of southern Italy and implication for Early Pleistocene "out of Africa" dispersals. *J. Hum. Evol*. **47**: 267–277.

Roos, C., Zinner, D., Kubatko, L., Schwarz, C., Yang, M., Meyer, D., Nash, S., Wing, J., Batzer, M. and Brameier, M. (2011). Nuclear versus mitochondrial DNA: evidence for hybridization in colobine monkeys. *Evolut. Biol*. **11**: 77.

Rylands, A. B., Williamson, E. A., Hoffmann, M. and Mittermeier, R. A. (2008). Primate surveys and conservation assessments. *Oryx* **42**: 313–314.

Saj, L. T., Sicotte, P. and Paterson, J. D. (2001). The conflict between vervet monkeys and farmers at the forest edge in Entebbe, Uganda. *Afr. J. Ecol*. **39**: 195–199.

Schneider-Crease, I. A., Jarvey, J. C., Bergman T. J. and Snyder-Mackler, N. (2013). Molecular identification of *Taenia serialis* coenurosis in a wild Ethiopian gelada (*Theropithecus gelada*). *Veter. Parasitol*. **198***:* 240– 243.

Seaman, D. E. and Powell, R. A. (1996). An evaluation of the accuracy of kernel density estimators for home range analysis. *Ecology* **77**: 2075–2085.

Selebatso, M., Moe, S. R. and Swenson, J. E. (2008). Do farmers support cheetah *Acinonyx jubatus* conservation in Botswana despite livestock depredation? *Oryx* **42**: 430–436.

Shah, N. F. (2003). Foraging Strategies in the two Sympatric Mangabey Species (*Cercocebus agilis* and *Lophocebus albigena*). Ph.D. Thesis, Stony Brook University, Stony Brook.

Shotake, T., Saijuntha, W., Agatsuma, T. and Kawamoto, Y. (2016). Genetic diversity within and among gelada (*Theropithecus gelada*) populations based on mitochondrial DNA analysis. *Anthropological Science* 1-11. DOI: 10.1537/ase.160717

Siege, N. and Castellan, J. (1988). *Nonparametric Statistics for the Behavioral Sciences*. McGraw-Hill, Sidney.

Siex, K. and Struhsaker, T. (1999). Colobus monkeys and coconuts: a study of perceived human-wildlife conflicts. *Appl. Ecol*. **36**: 1009-1020.

Siex, K. S. (2003). Effect of Population Compression on the Demography and Behaviour of the Zanzibar Colobus monkey *(Procolobus kirkii).* Ph.D. thesis, Duke University.

Silcox, M. T., Boyer, D. M., Bloch, J. I. and Sargis, E. J. (2007). Revisiting the adaptive origins of primates (again). *J. Hum. Evol.* **53**: 321–324.

Silva, S. S. and Ferrari, S. F. (2009). Behavior patterns of southern bearded sakis (*Chiropotes satanas*) in the fragmented landscape of eastern Brazilian Amazonia. *Am. J. Primatol*. **71**: 1–7.

Snyder-Mackler, N., Beehner, J. C. and Bergman, T. J. (2012). Defining higher levels in the multilevel societies of geladas (*Theropithecus gelada*). *Int. J. Primatol*. **33**: 1054–1068.

Sokal, R. R. and Rohlf, F. J. (1981). *Biometry*. W. H. Freeman and Co., San Francisco.

Southwick, C. and Blood, B. (1979). Conservation and management of wild primate populations. *BioScience* **29**: 233–237.

Strier, K. B. (2003). Primate behavioral ecology: From ethnography to ethology and back. *Am. Anthropol.* **105**: 16–27.

Struhsaker, T. T. (1967). Ecology of vervet monkeys (*Cercopithecus aethiops)* in the Masai-Amboseli Game reserve, Kenya. *Ecology* **48**: 891–904.

Struhsaker, T. T. (2008). Demographic variability in monkeys: implications for theory and conservation. *Int. J. Primatol*. **29**:19–34.

Struhsaker, T. T. and Siex, K. S. (1998). The Zanzibar red colobus: conservation status of an endangered island endemic. *Prim. Conserv*. **18**:51–58.

Sutherland, W. J. (2006). *Ecological Census Technique*. *A Handbook*. 3rd edn. Cambridge University Press, Cambridge.

Tchamba, M. N. (1996). History and present status of the human/elephant conflict in the Waza-Logone region, Cameroon, West Africa. *Biol. Conserv.* **75:** 35–41.

Tesfaye, D., Fashing, P. J., Bekele A., Mokennen A. and Atickem, A. (2013). Ecological flexibility in Boutourlini's blue monkey (*Cercopithecus mitis boutorlinii*). *Int. J. Primtol.* **34**: 615–640.

Tsuji, Y. and Takatsuku, S. (2009). Effects of yearly change in net feeding on autumn home-range use by Macaca fuscata on Kinkazan Island, Northern Japan. *Int. J. Primatol.* **30**: 169–181.

Varman, K. S. and Sukumar, R. (1995). The line transect method for estimating densities of large mammals in a tropical deciduous forest: An evaluation of models and field experiments. J. *Biosci*. **20**: 273–287.

Vasey (2005). Activity budgets and activity rhythms in Red Ruffed Lemurs (*Varecia rubra*) on the Masoala Peninsula, Madagascar: seasonality and reproductive energetics, *Am. J. Primatol*. **66**: 23-44.

Ventura, R., Majolo, B., Schino, G. and Hardie, S. (2005). Differential effects of ambient temperature and humidity on allogrooming, self-grooming, and scratching in wild Japanese macaques. *Am. J. Phys. Anthropol.* **126**: 453–457.

Wallace, R. B. (2006). Seasonal variations in black-faced black spider monkey (*Ateles chamek*) habitat use and ranging behavior in a Southern Amazonian Tropical Forest. *Am. J. Primatol*. **68**: 313–332.

Wang. S. W., Lassoie, J. P. and Curtis, P. D. (2006). Farmer attitudes towards conservation in Jigme Singye Wangchuck National Park, Bhutan. *Envir. Conserv*. **33**: 148–156.

Warren, Y. (2008). Crop-raiding Baboons (*Papio anubis*) and Defensive Farmers: A West African Perspective. *Wes. Afri. Appl. Ecol.* **14:** 1–11.

Warren, Y., Buba, B. and Ross, C. (2007). Patterns of crop-raiding by wild and domestic animals near Gashaka Gumti National Park, Nigeria. *Int. J. Pest. Manag*. **53**: 207−216.

Wildman, D. E., Bergman, T. J., al-Aghbari, A., Sterner, K. N., Newman, T. K., Phillips-Conroy, J. E., Jolly, C. J. and Disotell, T. R. (2004). Mitochondrial evidence for the origin of hamadryas baboons. *Molecul. Phylogen. Evol.* **32**: 287–296.

Wilson, D. E. and Reeder, D. M. (2005). *Mammal Species of the World: A Taxonomic and Geographic Reference.* 3rd edn. The Johns Hopkins University Press, Baltimore.

Yalden, D. (1983). The extent of high ground in Ethiopia compared to the rest of Africa. SINET: *Ethiop. J. Sci*. **6**: 35–39.

Yalden, D. W. and Largen, M. J. (1992). The endemic maminals of Ethiopia. *Mamm. Rev*. **22**: 115–150.

Yalden, D. W., Largen, M. J., Kock. D. and Hillman, J. C. (1996). Catalogue of the mammals of Ethiopia and Eritrea. 7. Revised checklist, zoogeography and conservation. *Trop. Zool*. **9**: 73–164.

Young, J. (2012). *Ethiopian Protected Areas: A“Snapshot”.* Word Press, Addis Ababa.

Zar, J. H. (1999). *Biostatistical analysis*. 4th edn. Prentice Hall, Upper Saddle River, N. J.

Zewdu Kifle, Gurja Belay and Afework Bekele (2013). Population size, group composition and beheivoural ecology of geladas (*Thercopithicus geleda*) and human-gelada conflict in Wonchit Valley, Ethiopia. *Pak. J. Biol. Sci.* **16***:* 1248–1259.

8. APPENDICES

Appendix 1. Plant species at Kosheme site.

Vernacular Name (Amharic)	Scientific Name	Family Name	Habit
Nech Girar	*Acacia abyssinica*	Fabaceae	Tree
Keye Girar	*Acacia negrii*	Fabaceae	Tree
Shekori	*Acanthus sennii*	Acanthaceae	Shrub
Mirez	*Acokanthera schimperi*	Apocynaceae	Shrub
Koke sare	*Acritochaete volkensii*	Poaceae	Herb
Sesbania	*Aeschynomene abyssinica*	Fabaceae	Shrub
Joroasfa	*Adiantum raddianum*	Adiantaceae	Fern
Sesiy	*Albizia schimperiana*	Fabaceae	Tree
Wonde eret	*Aloe percrassa*	Aloaceae	Herb
Sete eret	*Aloe pulcherrima*	Aloaceae	Herb
Motishe	*Becium grandiflorum*	Lamiaceae	Shrub
Azamer	*Bersama abyssinica*	Melianthaceae	Tree
Adey abeba	*Bidens spp.*	Asteraceae	Herb
Aballo	*Brucea antidysenterica*	Simaroubaceae	Tree
Anfar	*Buddleja polystachya*	Loganiaceae	Shrub
Digita	*Calpurnia aurea*	Fabaceae	Shrub
Agam	*Carissa spinarum*	Apocynaceae	Shrub
Yebeg lat/Legilego	*Chlorophytum tetraphyllum*	Anthericaceae	Herb
Lalinch	*Commelina benghalensis*	Commelinaceae	Herb
Bisana	*Croton macrostachyus*	Euphorbiaceae	Tree
Yemdre enboye	*Cucumis ficifolius*	Cucurbitaceae	Herb
Ameraro	*Discopodium penninervium*	Solanaceae	Shrub
Kitikita	*Dodonea angustifolia*	Sapindaceae	Shrub
Koshime	*Dovyalis abyssinica*	Flacourtiaceae	Shurb
Gendero	*Echinops macrochaetus*	Asteraceae	Herb
Sembo	*Ekebergia capensis*	Meliaceae	Tee
Zirint	*Erucastrum abyssinicum*	Brassicaceae	Herb

Neche Bahirzaf	*Eucalyptus globulus*	Myrtaceae	Tree
Dedho	*Euclea racemosa*	Ebenaceae	Shrub
Kulukole	*Euphorbia abyssinica*	Euphorbiaceae	Tree
Kulukole	*Euphorbia ampliphylla*	Euphorbiaceae	Tree
Kinicheb	*Euphorbia tirucalli*	Euphorbiaceae	Shrub
Shola	*Ficus sur*	Moraceae	Tree
Warka	*Ficus sycomorus*	Moraceae	Tree
Yejib mirkuze	*Gladiolus longispathaceus*	Iridaceae	Herb
Getm	*Haplocarpha schimperi*	Asteraceae	Herb
Senbelet	*Hyparrhenia spp.*	Poaceae	Herb
Ameja	*Hypericum revolutum*	Hypericaceae	Shrub
Tenebelel	*Jasminum grandiflorum*	Oleaceae	Herb
Sesel	*Justicia schimperiana*	Acanthaceae	Shrub
Alashuma	*Laggera tomentosa*	Asteraceae	Shrub
Kessie	*Lippia adoensis*	Verbenaceae	Shrub
Kombel	*Maytenus arbutifolia*	Celastraceae	Shrub
Atat	*Maytenus gracilipes*	Celastraceae	Shrub
Shenit	*Myrica salicifolia*	Myricaceae	Shrub
Damakessie	*Ocimum lamiifolium*	Lamiaceae	Shrub
Woira	*Olea europaea*	Oleaceae	Tree
Tife	*Olinia rochetiana*	Oliniaceae	Tree
Beles	*Opuntia ficus-indica*	Cactaceae	Shrub
Keret	*Osyris quadripartita*	Santalaceae	Shrub
Tunjit	*Otostegia integrifolia*	Lamiaceae	Shrub
Derg	*Phaulopsis imbricate*	Acanthaceae	Herb
Endod	*Phytolacca dodecandra*	Phytolaccaceae	Shrub
Yezenjoro fese	*Plectranthus ornatus*	Lamiaceae	Herb
Seged	*Psydrax schimperiana*	Rubiaceae	Shrub
Chocho	*Premna schimperi*	Verbacaceae	Tree
Kentafa	*Pterolobium stellatum*	Fabaceae	Shrub
Embus	*Rhus glutinosa*	Anacardaceae	Tree

Chakema	*Rhus natalensis*	Anacardaceae	Tree
Tilem	*Rhus retinorrhoea*	Anacardaceae	Tree
Tetasa	*Rhus vulgaris*	Anacardaceae	Tree
Kega	*Rosa abyssinica*	Rosaceae	Shrub
Tulit	*Rumex nepalensis*	Polygonaceae	Herb
Enembuacho	*Rumex nervosus*	Polygonaceae	Shrub
Yahiya Joro	*Salvia schimperi*	Lamiaceae	Herb
Chifirge	*Sida schimperiana*	Malvaceae	Shrub
Awot	*Solanum nigrum/spp.*	Solanaceae	Herb
Maget	*Trifolium spp.*	Fabaceae	Herb
Ketetina	*Verbascum sinaiticum*	Scrophulariaceae	Herb
Grawa	*Vernonia amygdalina*	Asteraceae	Tree

Appendix 2. List of some mammals at Kosheme site.

Species name	Common name	Local name
Theropithecus gelada	Gelada	Tikure/Zenejoro
Papio anubis	Olive baboon	Neche/Zenejoro
Chlorocebus aethiops	Grivet monkey	Tota
Panthera pardus	Leopard	Neber
Canis aureus	African wolf	Kebero
Crocuta crocuta	Spotted hyaena	Jibe
Hystrix cristata	Crested porcupine	Jarite
Sylvicapra grimmia	Common duiker	Medako
Oreotragus oreotragus	Klipspringer	Ses
Felis serval	Serval cat	Daliga anibse
Procavia capensis	Cape hyrax	Shekoko
Genetta abyssinica	Ethiopian genet	Afene
Genetta genetta	Common genet	Shelemetemate
Herpestes sanguineus	Slender mongoose	-
Lepus spp.	Hare	Tinchel

Appendix 3. Demography for gelada across the study sites in Ethiopia.

Study site	Band size	M:F	OMUs/ band	Reference
Sankaber	131.5 (30-262)	1:2.75	10.7	Dunbar,1984a; Ohsawa and Dunbar, 1984
Sankaber	171 (79-262)	1:3.7	16	Dunbar and Dunbar, 1975
Gich	107.2 (27-170)	1:2.35	9.7	Dunbar,1984a; Ohsawa and Dunbar, 1984
Bole	60.3 (48-78)	1:4.21	3.3	Dunbar,1984a
Arsi	54	1:1.87		Mori *et al.*, 1999
Gich	(16-170)		(2-18)	Ohsawa, 1979
Wonchit	58.03 (25-220)	1:6.61	(2-14)	Zewdu Kifle *et al.*, 2013
Guassa		1:3.11		Eshetu Moges and Balakrishnan, 2015
BSNP	81.56 (33-274)	1:5.09		This study
Kosheme	40.07 (17-71)	1:4.81		This study

Appendix 4. All-male unit (AMU) size in different sites of Ethiopia.

Study site	AMU size	Reference
Sankaber and Bole	7.8 (3-13)	Dunbar and Dunbar, 1975
Gich	(13-15)	Ohsawa, 1979
Wonchit	6.32 (3-12)	Zewdu *et al.*, 2013
BSNP	11.40 (4-19)	This study
Kosheme	6.67 (5-8)	This study

Appendix 5. Comparison of gelada time budget across the study sites of Ethiopia.

Study site	Altitude (M)	Months	Time in each activity, %						Reference
			Feeding	Moving	Resting	Grooming	Socilazing	Other	
Kosheme	2440	18	49.54	16.19	17.43	12.94	3.02	0.88	This study
Keywasha	3430	18	48.67	17.70	16.82	13.12	3.03	0.66	This study
Gich	3390	–	62.3	14.7	5.2		(16.0)	–	Iwamoto and Dunbar, 1983
Gich	3390	–	80.0	9.0	2.0		(8.0)	–	Kawail and Iwamoto, 1979
Sankaber	3330	–	45.2	20.4	13.8		(20.5)	–	Iwamoto and Dunbar, 1983
Bole	2300	–	35.7	17.4	26.3		(18.5)	–	Iwamoto and Dunbar, 1983
Arsi	2060	9	41.7	20.3	19.0		(19.0)	0.0	Kelil Abu *et al*., 2017
Wonchit	2570	4	65.2	16.5	4.5		(13.8)	–	Zewdu *et al*., 2013
Gich	3900	12	56.6	14.1	10.7		(17.5)	1.1	Cherkos and Afework, 2015
Guassa	3450	–	41.48	21.21	7.31	14.56	8.26	7.17	Eshetu and Balakrishnan, 2015

Appendix 6. Comparison of gelada diet across the study sites.

Site	Elev.	Month	Diet item, %											
			Grass blade	Grass (undergr.)	Grass seed	Herb (abovegr.)	Herb (undergr.)	Bulb	Fruit	Tree/ shrub	Inv.	Crop	Other	Reference
Guassa	3450	15	50.6	4.0	2.2	29.1	7.5	–	–	–	2.8	–	3.8	Fashing *et al.*, 2014
Sankaber	3300	6	55.2	7.55	1.8	6.2	20.5	–	3.3	–	0.1	–	1.1	Hunter, 2001
Sankaber	3300	5	45.0	24.5	23.2	2.5	1.4	–	1.0	–	0.1	–	2.3	Dunbar, 1977a
Gich	3900	3	68.8	8.0	5.1	15.7	2.5	–	0	–	–	–	–	Iwamoto, 1979
Bole	2300	6	91.4	0.5	5.0	0.6	0.00	–	2.0	–	–	–	0.5	Dunbar & D, 1974
Gich	3900	12	74.3	7.6	0.6	5.2	3.9	6.7	–	–	–	–	1.4	Cherkos & A, 2015
Kosheme	2440	18	55.40	13.15	5.38	4.88	0.30	5.64	7.18	1.89	0.50	5.59	0.09	This study
Keywasha	3430	18	53.53	9.84	9.36	17.64	6.68	0.70	0.22	0.00	1.49	0.54	–	This study

Appendix 7. Questionnaire

Questionnaire: This is the questionnaire which will be used to assess human-gelada conflict and other anthropogenic factors that affect their conservation in and around Borena Saynit National Park. This information is highly confidential.

Thank you in advance!

1. Study site:______________ Zone ____________ Woreda ___________Kebele____________ Village __________Date _______________Time: start of interview ________ End _________
2. Respondents category (**farmer, farmers and local offical, student**); Age of respondent:________ Sex: M___ F ___ Number of family members ___a. Male______b. Female _____ How many of your children attending school ? elementary ________secondary__________tertiary ______
3. Religion: Muslim _____,Orthodox _____, Protestant _____, Others________________
4. Ethnicity _______________
5. Educational status: A. None B. Primary C. Secondary C. Higher education D. Religion
6. For how long have you been living in this village? a. < 10 years b. 10 - 20 years c. 21 - 40 years d. >40 years
7. Do u have your own land tenture A. Yes . C. No if no why?______________________________________
8. What is the source of your livelihood? A. crop Cultivation b. livestock rearing c. small bussiness d. forest plantation e. honey production F. Others (specify) ____
9. How far is your farmland (in km) from the sleeping site of geladas?
   a. <100 m b. 100 – 500 m c. 0.5 – 1 km d. > 1km
10. Could you enumerate the total number of domestic animals owned per household/per respondent?
    a. Cattle_____ b. Sheep_____ c. Goat _____d. Equine ____ e. Poultry_____ f. Others (if any) ______________________
11. Do you have any other means of income other than subsistence farming/agriculure and livestock rearing? a. Yes b. No; if yes, please state your means of incomes ____
    If your answer is no, why____
12. Do you harvest enough crop every year/feed yourself? a. Yes b. No
13. Types of crops do you grow starting from the most 1. ______________2. ______________3.______________4. _____________5. _______________6. ____________7. _____________________
14. Name the most destructive crop-raiding wildlife species to your farmland in decreasing order
    a.________________b.________________c.________________d.________________e. _________________________
15. Do southern geladas show nuisance problems/pests? A. Yes B. No; If yes, what type of problem? (✓)

	Problems (rank the four bests problems)	Yes	No
1.	Crop damage		
2.	Theft of items/foods from your compound		
3.	Grazing land competition		
4.	Bites, scratches or threats on people		
5.	Property damage like "house"		
6.	Others, please specify		

16. Is it important/necessary to conserve geladas and offer more protection? A. yes b. No c. i don't know; if yes, why? ____
17. If there is crop damage by southern geladas, please list these particular crop types____
18. How is the trend of crop damage by geladas in your village? a. increase b. decrease c. similar; if increase why?____;if__
    ____

19. How is the frequency of crop raiding on your farm by geladas? A. never B. occasionally C. frequently D. very frequently
20. How much is the severity of crop raiding caused by geladas? A. severe B. medium D. Insignificant.
21. Is crop raiding by geladas create impacts on your livelihood? A. yes b. No; if yes how?
____
22. How many quintals of your crop did southern geladas damage during the last harvesting season?
____
23. In which stage of crops do geladas visit your farmlands (✓)?

Stage (✓)/Intensify stage/raiding peak	Barely	wheat	Teff	Bean/pea	Potato	Chickpen	others
1.Sowing							
2. Seedling							
3. Vegetative/flowering							
4. Fruiting							
5. Harvesting							

24. Have you reported any crop-raiding by the southern geladas before? A. Yes B. No. If yes, to whom did you report? ______________________and what was their response? ______________________________if no, why___________________________________
25. What is your attitude/perception toward southern geladas? A. Positive (like) B. Negative (dislike) C. Neutral. What factors do you like or dilike geladas?____
26. Do you know southern geladas are endemic to Ethiopia? A. Yes B.No
27. What do you think the trend of southern gelada populations in your area? A. increasing b. decreasing c. stable d. Not sure; why? ____
28. What are the perceived causes of crop-raiding/human-gelada conflict? (check ✓)

Causes of crop raiding (rank most important causes)	Agree	Disagree	Indifferent
1. Contraction of their natural habitat through agriculure expansion			
2. Degradation of their habitat due to livestock grazing			
3. Lack of natural foods			
4. Attracted by nutritional contents of crops and vegetables			
5. Proximate of farmlands near their habitat/intense agriculture			
6. If any other			

29. What are your protection methods to reduce/prevent crop raiding by southern geladas? What about their effectiveness?
____
____
____
30. What is your potential opinion to mitigate human-geladas conflict in your area? (check ✓)

Mitigation measures (rank the 4 best mitigation measures)	Agree	Disagree	Indifferent (neither)
1. Guarding			
2. Chasing them away from the villages during harvesting seasons			
3. Government action			
4. Changing farming practices/harvest non-attractive crops			
5. Create job opportunities			
6. Compensation for the losses			
7. Others, please specify			

31. What measures should be taken by government to mitigate human-gelada conflicts____

32. What are the threats of southern geladas in your areas? (check ✓)

Threats	Very high	High	Less	No effect
1. Agricultural expansion toward their preferred habitats				
2. Habitat degradation				
3. Human-gelada conflict due to crop raiding				
4. Predation by carnivores				
5. Predation by domestic dog				
6. Climate change/drought				
7. Disease				
8. Other, please specify				

33. What are opportunity costs of human-gelada conflict

Opportunity costs	High	Low	No effect	Rank
1. Less sleep				
2. Labour bottlenecks				
3.Travel restriction				
4.Termination of chidren from education/diruption schooling				
5. Loss of energy during chasing/shouting/throwing				
6. Risk of death falling into the cliff/phyiscal injure				
7. Others if any				

34. Do you have any other comments or suggestions you will like to make?____