ADDIS ABABA UNIVERSITY

SCHOOL OF GRADUATE STUDY

DEPARTMENT OF ZOOLOGICAL SCIENCES

Population Status, Diets, Activity Budget and Range Use by Arsi Gelada (*Theropithecus gelada arsi*) in Eastern Arsi, Ethiopia

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Addis Ababa, Ethiopia

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By: **Amera Moges Gebeyehu**

A Thesis Submitted to the Department of Zoological Sciences, Addis Ababa University, in Fulfilment of the Requirements for the Degree of Doctor of Philosophy (Ph.D) (Ecological and Systematic Zoology)

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This is to certify that the dissertation prepared by Amera Moges Gebeyehu, entitled: "*Population Status, Diets, Activity Budget and Range Used by the Arsi Gelada (Theropithecus gelada arsi) in Eastern Arsi, Ethiopia"* and submitted in fulfillment of the requirements for the Degree of Doctor of Philosophy in Biology (Ecological and Systematic Zoology) compile with the regulation of the university and meets the accepted standard with respect to the originality and quality.

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ABSTRACT

Population Status, Diets, Activity Budget and Range Used by the Arsi Gelada (*Theropithecus gelada arsi*) in Eastern Arsi, Ethiopia

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Addis Ababa University

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Geladas (Theropithecus gelada arsi) are robust terrestrial primates endemic to Ethiopian highlands containing two known (T.g.gelada and T.g.obscurus) subspecies and the possible third subspecies, the T.g.arsi. Arsi gelada is an isolated population found in eastern Arsi, southeast of the Rift Valley. Knowledge of the population status and behavioral ecology of the species are crucial to design conservation and management plans. The aim of study was to assess the population size, distribution patterns and behavior of the gelada in eastern Arsi around Goro-Jena villages. Above ground grass biomass and phenological pattern were assessed to investigate temporal changes in food availability. Total count was used to investigate the population size of gelada. The activity budget, feeding ecology and range used by Arsi geladas were carried out using scan sampling method at 30-minute intervals from the selected focal group in a band. Ranging ecology data were analysed with a combination of ArcGIS and Home Range Tools. Home range was estimated using fixed Kernel Density Estimation and Minimum Convex Polygon. Habitat use of geladas was assessed. A mean total of 1315±11.3 individuals were recorded. Arsi geladas occurred in patchy distribution. They comprised an average unit size of 9.42±3.31and 11.43±3.95 individuals, and 26.04 and 31.19 individuals per band during the wet and dry seasons, respectively. Geladas spent the highest time in feeding (57.29%±5.04) and socializing (18.64%±3.80). Diurnal cyclic activities start early in the morning until dusk. Socializing and resting was peak early in the morning. Feeding peaked late in the morning and afternoon. The gelada diet is composed of graminoids (83.33%). Digitaria abyssinica was the most preferred species. Geladas utilized the highest (51.87%±15.87) frequency on open grazing plains and escarpment/cliffs (47.64%±16.16). The overall home range size of geladas is 134 ha using 95% KDE. Geladas traveled a mean daily path length of 1439.7 m ± 494.68. Greenness and grass biomass were significantly correlated with monthly rainfall. The overall graminoid production was estimated with a mean wet weight of 197.1±110.8 g/m^2 and dry-weight of 98.8±47.7 g/m^2. Activity budget of geladas showed significant difference across months (ANOVA, $P < 0.001$). However, there were insignificant variations among activities of feeding ($P = 0.548$), socializing ($P = 0.356$) and resting ($p = 0.708$) during the wet and dry seasons. Moving showed significant difference ($P = 0.034$) between the two seasons. Feeding time of Arsi geladas was high during both the wet and dry seasons due to lower quality and availability of diet in lower elevation and marginal habitat. Gelada fed on brown yellow grasses during dry season. Seasonal variations and warmer weather conditions contributed a lot for shifting food items and activity budgets. Arsi geladas are highly threatened due to warmer weather condition and high anthropogenic activities. Thus, conservation managers should do more to ensure the long-term survival of this unique, little is known about gelada in its narrow and human dominated landscape in Eastern Arsi. Further, researches on Arsi gelada including its nutritional requirement, gastrointestinal parasitic ecology and conflict with human are crucial to design conservation strategy.

Keywords: Activity budget, Arsi gelada, feeding behavior, graminoids, home range, population status.

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ACRONYMS

AMU	All Male Unit
EWCA	Ethiopian Wildlife Conservation Authority
GME	Geospatial Modeling Environment
GPS	Global Positioning System
HRT	Home Range Tools
KDE	Kernel Density Estimation
MCP	Minimum Convex Polygon
MYA	Million Years Ago
OMU	One Male Unit
SMNP	Simien Mountains National Park

1. INTRODUCTION

The population status (including distribution pattern and population size) and behavioral ecology of primates are highly influenced by anthropogenic activities and climate changes (Chapman *et al*., 2006; Addisu Mekonnen *et al.,* 2018). The increasing human population growth and agricultural land expansion are the major threats of nonhuman primate conservation in the tropics (Oates, 1996; Estrada *et al.*, 2012). Anthropogenic activities cause threat to terrestrial mammals, birds and other animals (Tilman *et al.*, 2017). Habitat alterations (conversion, modification, fragmentation and degradation) distress the survival of primate populations through reducing habitat quality, shrinking the range and increasing disturbances (Addisu Mekonnen *et al*., 2017; Zerihun Girma *et al.,* 2018).

Population distribution of primates is usually affected by human activities, such as agricultural land expansion, logging, human encroachment, hunting and competition with livestock (Dunbar, 1977a; Beehner *et al*., 2007; Addisu Mekonnen *et al*., 2012; Estrada *et al*., 2017). Many primates are restricted to survive in narrow geographic range and specialized niches (e.g. Bale monkey: Addisu Mekonnen *et al*., 2017) while more generalist species occupy large geographic range and can survive in diverse habitat types (e.g. Baboons: Bronikowski and Altmann, 1996). Geladas are found patchily distributed in the Ethiopian Highlands at higher elevation where high human population occurs. Previously, the populations of geladas in the Simien Mountains National Park had been declining due to agricultural land expansion and habitat conversion associated with increasing human population growth (Dunbar, 1977a; Hunter, 2001; Beehner *et al*., 2007). The Arsi gelada is an isolated population that occupies marginal habitats (Mori and Gurja Belay, 1990; Gurja Belay and Shotake, 1998; Kelil Abu *et al*., 2018). Arsi geladas occupied a lower elevation and a more disturbed habitat than the other two known subspecies of geladas. Agricultural crops are adjacent to most of gelada habitats (Dunbar, 1977a; Beehner *et al*., 2007; Mesele Yihune *et al*., 2009). Livestock grazing reduces foraging opportunity of graminivorous primates through direct competition (Dunbar, 1978; Beehner *et al*., 2007).

The behavior and ecology of nonhuman primates are influenced by the anthropogenic activities including habitat alterations and disturbances (Witch and Marshal, 2016; Kelil Abu *et al*., 2018), seasonality and climate change (Dunbar, 1992a, 1998; Hill and Dunbar, 2002). Seasonal variation may affect diet composition and feeding behavior (Iwamoto and Dunbar, 1983; Dunbar, 1998; Jarvey *et al*., 2018), time budgets of primates (Dunbar, 1977a, 1992a; Zhou *et al*., 2007) and range size (Campera *et al*., 2014; Moua, 2015). The abundance and distribution of food resources determine the ranging behavior and activity budgets (Barton *et al.,* 1992; Stevenson, 2006). Due to their diet specialization, geladas are severely affected by warmer climate and seasonal environment (Dunbar, 1998; Hill and Dunbar, 2002). Range restricted species are vulnerable to the impacts of seasonal change and habitat alterations (Chapman *et al*., 2006).

Geladas (*Theropithecus geladas*) are the only extant species of a once widespread genus of robust terrestrial grazing primates (Delson, 1993; Jablonski, 1993). At present, geladas are endemic to the alpine grasslands of the Ethiopian highlands (Dunbar, 1977a, 1998; Bergman *et al*., 2013). Arsi gelada is an endemic subspecies with restricted geographic range, currently threatened by anthropogenic impacts and seasonal climate change (Mori and Gurja Belay, 1990; Dunbar, 1992a, 1998). Little is known about its distribution and population estimate and behavioral ecology of the Arsi geladas (Kelil Abu *et al.,* 2018). Understanding the distribution pattern, population size, activity budget, ranging patterns, and feeding ecology are fundamental to design conservation management plan. Thus, the present study focuses on the distribution pattern and population size, and behavioral ecology of the Arsi geladas. The result will be an input for conservation and management of threatened Arsi gelada population.

1.1 Significance of the Study

A preliminary study on Arsi geladas was conducted for a brief period of time at limited site (Mori and Gurja Belay, 1990; Kelil Abu *et al*., 2018). The present study is conducted for long time period on Arsi gelada for over a year in eastern Arsi. Arsi geladas are highly threatened due to anthropogenic impacts and warmer weather conditions. The significant of the present study is for aware the Regional government officials and National Wildlife professionals and provide scientific data for conservationists as well as for IUCN Red List as the conservation status of Arsi gelada is unknown. The findings of the study will be imperative for decision makers and conservationists to design conservation strategies and management plans on Arsi geladas found in limited geographic ranges confined in marginal habitats.

1.2 OBJECTIVES OF THE STUDY

1.2.1 General Objective

- ✓ To investigate the population status, ecology and behavioral ecology of the probable threatened Arsi geladas in eastern Arsi, Ethiopia.

1.2.2. Specific Objectives

- ✓ To determine the distribution pattern and population size of Arsi geladas in eastern Arsi
- ✓ To assess the activity budgets of Arsi geladas at Goro-Jena
- ✓ To examine habitat use and ranging ecology of Arsi gelada at Goro-Jena
- ✓ To evaluate the feeding ecology of Arsi gelada at Goro-Jena
- ✓ To assess the effect of seasonality on the food availability and behavior of Arsi gelada

2. LITERATURE REVIEW

Primate is one of the few mammalian orders. Order primate includes human and nonhuman primates (Fleagle, 1999). Studies showed that nonhuman primates originated in the tropics and radiated into various habitat types. Nonhuman primates differ in ecology and behavior (Fleagle, 2013). Tropical ecosystems sustain much the earth's biological diversity (Laurance *et al*., 2014). However, climate change and land use intensification are potential threats to high altitude species in tropical alpine habitats (Dunbar, 1998; Grunenfelder, 2005; Desalegn Chala *et al*., 2016). Tropical ecosystems face greater pressure from agricultural land expansion and habitat conversion. Habitat alteration affects particularly birds and mammals (Tilman *et al.*, 2017). The current global declines of primate populations are primarily due to anthropogenic activities (Cowlishaw and Dunbar, 2000). The major threats to nonhuman primates come from habitat conversion and fragmentation by anthropogenic impacts (Wich and Marshal, 2016) and climate change (Brockman and Van Schaik, 2005).

The increasing human population growth and ever expanding agricultural activities impinge upon wildlife habitats (Cowlishaw and Dunbar, 2000). Agricultural land expansion causes habitat degradation and fragmentations (Gibbs *et al.*, 2010), which alter vegetation structure and composition, shrink natural habitat and decrease food quality and availability for the species (Laurance *et al*., 2014; Addisu Mekonnen *et al*., 2018). Seasonality (fluctuation of temprature and rainfall) characterizes tropical habitats (van Schaik and Brockman, 2005) which reduce food quality and availability (Wrangham and Waterman, 1981). Overall, habitat degradation and seasonality decrease population size of primates and influence their behavior and ecology (Dunbar, 1992a, 1998).

Anthropogenic pressure and seasonal change on nonhuman primates: Increasing anthropogenic impact causes a rapid change of wildlife habitats (Mortelliti *et al*., 2010). Rapid human population growth and associated land use changes alter primate habitats (Estrada *et al.*, 2012). Anthropogenic activities threat primate population size and distribution through reduced vegetation composition and cover (Arroyo-Rodríguez *et al.*, 2013; Laurance *et al*., 2014), reduce range size, increase predators and spread of diseases resulting from contact with humans and domestic livestock (Irwin *et al*., 2010; Schwitzer *et al*., 2011). Local responses to these alterations may be expressed through changes in species occupancy, demography and behavioural ecology (de Almeida-Rocha *et al*., 2017). Environmental variables (rainfall and temperature) determine ecological behavior of primates (Iwamoto and Dunbar, 1983; Hill and Dunbar, 2002). Seasonal climate changes contribute in altering vegetation production and availability that directly affect primate behavior and ecology (Dunbar, 1992a, 1998; Hill and Dunbar, 2002).

Adaptations of primates for anthropogenic impacts and seasonality: Primates exhibit ecological and behavioral flexibility in response to a changing environment and habitat alterations (Riley, 2007; Addisu Mekonnen *et al.*, 2018). Behavioral flexibility is a response to habitat changes and seasonal variations (Hemingway and Bynum, 2005). Human modifications in habitat quality cause changes in feeding behavior and dietary diversity for primates (Riley, 2007; Menard *et al*., 2014). Primates are flexible in diets and feeding behavior during periodic variation in food availability (Hemingway and Bynum, 2005; Addisu Mekonnen *et al.*, 2018) and scarcity of preferred food (Marshall *et al*., 2009; Jarvey *et al.*, 2018). Dietary responses of nonhuman primates to habitat degradation include consumptions on low-quality ("fallback foods") (Bicca-Marques, 2003; Marshall *et al*., 2009). The term "fallback foods" is a diet during periods when preferred foods are scarce (Marshall *et al*., 2009; Lambert and Rothman, 2015).

Primates may switch diets to optimize nutrient intake or because of declining of preferred foods (Wrangham *et al*., 1998; Alberts *et al*., 2005). The later case is termed as "fallback food" (Lambert and Rothman, 2015). Primates that increase their reliance on "fallback foods" increase foraging time at the expense of other activities. For example, brown howler monkeys switch to leaf diet during the periods of fruit scarcity (Chaves and Bicca-Marques, 2016). Bale monkeys *(Chlorocebus djamdjamensis*) consume herbs and graminoids in modified habitats (Addisu Mekonnen *et al*., 20018). Macaque adjusts its diet according to seasonal variations in the wild (Albert *et al*., 2013). Geladas in SMNP are graminoid specialists, yet they shift consuming underground food items during the dry season (Dunbar, 1977a; Iwamoto, 1979; Iwamoto and Dunbar, 1983; Jarvey *et al.*, 2018).

Home range size and habitat utilization of nonhuman primates are primarily dependent on the availability, distribution and quality of food resources (Barton *et al.*, 1992). Primates increase their range size and daily path length (DPL) during food scarcity (Iwamoto and Dunbar, 1983; Riley, 2008; Campera *et al*., 2014). Gelada bands/foraging group may split into units when low food availability in a degraded habitat (Iwamoto and Dunbar, 1983; Isbell, 1991; Chapman and Chapman, 2000). In addition, gelada bands may increase the home range size and day path length during scarcity and/or decline of food resources during the dry season (Iwamoto and Dunbar, 1983; Moua, 2015). In contrast, macaques decrease home range size and day path length during low fruit abundance to conserve energy (Albert *et al*., 2013).

Most primates exhibit dietary flexibility to cope with seasonal changes of resource availability in response to habitat change (Riley, 2007; Xiang *et al.*, 2007). They respond to dry season food scarcities by shifting to "fallback foods" that are abundant but low profit (Altmann, 1998; Marshall *et al*., 2009). Seasonal dietary flexibility has been described in many primate species (Menard *et al*., 2014). Many cercopithecines shift their diets when preferred (high-quality) foods become seasonally scarce/decline (Marshall *et al*., 2009). Baboons (Alberts *et al*., 2005), chimpanzees (Doran, 1997) and vervets (Kavanagh, 1978) switch to "fallback foods" during periods of low food availability. Geladas switch to underground food items when their preferred items desiccate during the dry season (Dunbar, 1977a; Iwamoto, 1979, Jarvey *et al*., 2018). Geladas may spend longer time feeding to obtain the daily required nutrient from high fiber content graminoids during the dry season (Dunbar and Bose, 1991). The "bulk feeding" and ingesting larger quantity of fibrous graminoids are adaptations to increase the intake rate and compensate for the reduced nutrient extraction from desiccated graminoids (Dunbar and Bose, 1991).

Primates may diversify their diets during times of food scarcity. For specialist primates, such as chimps, during the time of food scarcity they increase the diversity of the species and plant parts (Foley, 1987; Wrangham *et al.*, 1998). In contrast, for generalists, such as baboons, food scarcity results in reduced dietary diversity during the dry season (Norton *et al.*, 1987). It is important to understand the ecological flexibility of a species, in order to implement effective management strategies for their future conservation (Harcourt, 2002).

In seasonal fluctuations and food scarcity in degraded habitats, several primate species use different strategies. First, "energy minimizing" in which animals minimize energy expenditure by extending resting or decreasing daily traveling (Albert *et al*., 2013; Campera *et al*., 2014).

Second, primates may use "energy-maximizing" in which animals maximize energy during resource scarcity by decrease resting or spend more feeding time (Albert *et al*., 2013; Campera *et al*., 2014). For example, macaques are primarily time minimizers that decrease foraging effort by incorporating high return foods, but may utilize "energy-maximization" when food availability is low (Menard an Vallet, 1997; Wrangham *et al*., 1998).

Impacts of anthropogenic disturbances and seasonality on primates: More than half of the world's primate species are currently threatened by extinction (Chapman and Peres, 2001; Estrada *et al*., 2017). The majority of African primates occupy small geographical ranges due to anthropogenic effects, and only a few are widely distributed (Eeley and Lawes, 1999; Cowlishaw and Dunbar, 2000). Anthropogenic disturbances have direct and indirect impact on primate populations via reduced availability of resources, nutritional bottleneck and exposure to predators (Irwin *et al*., 2010; Schwitzer *et al.*, 2011). At present, many extant primate populations have been threatened and inhabit small and isolated habitats in the human dominated landscape (Mittermeier *et al.*, 2005; Estrada *et al*., 2017). The decline of population size of primates is strongly correlated with habitat loss, reduction of abundance and nutritional quality (Hobbs and Hanley, 1990). The small population size of primates leads to decline in their genetic diversity (Addisu Mekonnen *et al*., 2018; Zinner *et al*., 2018) and this effect will be intensified when such populations inhabit isolated and fragmented habitats.

Activity budgets of primates may be influenced by human disturbances (Li and Rogers, 2004; Vasey, 2005) and seasonal climate change (Dunbar, 1992a, 1998). Dietary quality and distribution determine the activity budgets of primates (O'Brien and Kinnaird, 1997). Primates of large foraging groups spend more time feeding and traveling in degraded habitats to obtain the required amount of nutrients (Iwamoto and Dunbar, 1983; Isbell and Young, 1993). The small group size decreases competition, spending lower time feeding and traveling (Iwamoto and Dunbar, 1983). Geladas reduce their time resting at the expense of more time feeding and moving in degraded habitats (Dunbar, 1992a). Seasonal variations in activity budgets of primates reflect differences in food availability, which increase foraging and traveling time during periods of lower food availability (Iwamoto and Dunbar, 1983). Primates may respond to seasonal variations in resources by shifting their diets (Remis, 1997). They travel longer and consume more species when food is scarce or when food is patchy. Primates are flexible and capable of shifting activity patterns as preferred foods dwindle.

Human activities and seasonality alter the natural habitats of wild animals (Dunbar, 1977a; Hill and Dunbar, 2002). Habitat fragmentation and degradation alter vegetation structure and composition in human modified habitats (Arroyo-Rodríguez *et al.,* 2013; Addisu Mekonnen *et al*., 2018). Diet composition, vegetation structure and availability are constrained by the impact of seasonal changes (Byrne *et al*., 1993; Dunbar, 1998). The change has direct effect on primate ecology and behavior (Dunbar, 1998; Chapman *et al*., 2006).

Animals in seasonal environments either concentrate on specific food sources which are available year-round or switch their diet in relation to seasonal changes (Hill, 1997). Dietary shifts of primates may typically correspond with seasonal change or resource scarcity (Hanya, 2004; Jarvey *et al*., 2018) or during habitat modification (Kelil Abu *et al*., 2018; Addisu Mekonnen *et al*., 2018).

Changes in habitat use and ranging size of primates are often associated with anthropogenic disturbances (Schwitzer *et al*., 2011). Habitat fragmentation and seasonal climate changes determine the spatial distribution of primates (Barton *et al*., 1992; Dunbar, 1998). Primates in poor habitat quality where a scattered resources and low food availability tends to exhibit larger home range size and longer day path lengths (Kaplin, 2001; Riley, 2008; McKinney, 2011). Habitat disturbances shape range size (Schwitzer *et al*., 2007; Boyle *et al.*, 2009). Study shows home range variation in primates often explained by seasonal variation in food availability (Stevenson, 2006; Wallace, 2006).

Ecological generalist primates are known to inhabit wide geographic ranges and consume diverse food resources and are usually able to cope with changes in response to habitat disturbances and degradation by exhibiting substantial ecological and behavioral flexibility (Eppley *et al.*, 2016). Conversely, ecological specialists are adapted to narrow geographic ranges and dietary niches; and less tolerance to habitat disturbances (Kamilar and Tecot, 2016). Thus, specialist species are highly vulnerable to the adverse ecological consequences of habitat degradation (Harcourt *et al.*, 2002; Colles *et al*., 2009) and seasonal climate change (Hill, 1997; Dunbar, 1998).

Unlike the arboreal ones, terrestrial quadruped primates frequently occupy and move rapidly on the ground. Terrestrial quadruped nonhuman primates are larger Old World monkeys including baboons, geladas and patas monkey. They tend to have larger home range and longer day path length than arboreal ones. Frugivores tend to have larger home ranges than folivores (Clutton-Brock and Harvey, 1977). Primates with larger range size thought to be the most vulnerable in habitat fragmentation. Primates may either increase day range for preferred food or decrease day range by reducing energy requirements (Dunbar, 1988). Folivorous (leaf eaters) have shorter day range length and smaller home range size as leaves are abundant and evenly distributed though lowers nutrient value (Fashing *et al*., 2007). Whereas, frugivorous have larger home range size as fruits are patchily distributed (Clutton-Brock and Harvey, 1977). Frugivorous species increase day range length during fruit availability, but decrease during scarcity. Unlike folivorous and frugivorous primates, graminivorous geladas increase their range size during low food availability during uneven distribution of green graminoids during the dry season (Iwamoto and Dunbar, 1983).

2.1 Anthropogenic effect on Ethiopian primates:

Ethiopia is a country of ancient geologic history with varying landscapes, climate and ecosystems due to the wide range of altitudinal and topographical variations. Altitude ranges from 4543 m asl at the top of Mt. Ras Dejen to 116 m below sea level in the Danakil depression (Yalden, 1983). The country comprises extensive highland ecosystems. The Ethiopian highlands encompass the Eastern Afromontane Hotspot and exhibit exceptionally high level of biological diversity and endemism due to the diversity of natural ecosystems and isolated highlands (Yalden and Largen, 1992). Ethiopian highlands are homes for 36 endemic species of mammals from a total of more than 300 mammals (Afework Bekele and Yalden, 2013). For example, geladas (*Theropithecus gelada*) and Bale monkeys (*Chlorocebus djamdjamensis*) are the endemic primates that occupy Ethiopian highlands. Most of the primates occur in the remains of human induced habitats with high anthropogenic disturbances.

Currently, the endemic and other mammals of the Ethiopian highlands are facing particular risks of extinction because of intense human encroachment and habitat alteration, which lead to population fragmentation and decline in population size (Butynski *et al*., 2008; Berihun Geberemedhin and Grubb, 2008; Addisu Mekonnen *et al*., 2018). Large areas of the highland plateau top are converted into cultivation, human encroachment and overgrazing. The vegetation is overused for fuel wood, construction and timber production. As a result, wildlife resources of the country are at present largely restricted in protected areas and inaccessible areas (Hillman, 1993). Yet, large numbers of wildlife are also found outside the protected areas in different regions of the country. The wildlife both in the protected and outside the protected areas have been under serious threat from the expansion of human settlement, cultivation, overgrazing, deforestation and fragmentation. The Alpine grasslands in Ethiopia, where geladas and other endemic species depend on are not only threatened by anthropogenic habitat alteration, but will most likely also shrink as a result of global warming (Dunbar, 1998; Desalegn Chala *et al*., 2016). Thus, there is a need for ecological studies to examine species habitat relationships in the context of changing habitat conditions and increasing anthropogenic pressures on the highland plateaus. Such investigation is critical to endemic species that are confined in limited geographic range like Arsi gelada.

Ethiopia has many protected areas including national parks, wildlife reserves, biosphere reserves and community conservation areas. Protected areas cover from 15% (BIDNTF, 2010) to 16.5% (Scherl *et al.,* 2004) of the country's land mass. However, given its rich biodiversity resources, the extent of protected areas in the country is negligible and is exposed to many disturbances (BIDNTF, 2010). Wildlife habitats both in protected and unprotected areas have been under serious threat from human encroachment, cultivation, overgrazing, deforestation and fragmentation. Geladas inhabit both protected and unprotected areas of the Ethiopian highlands with characteristic vegetation (Dunbar and Dunbar, 1974; Dunbar, 1977a; Iwamoto, 1979; Mori and Gurja Belay, 1990; Fashing *et al*., 2014). Gelada habitats in Arsi are nearby human settlements (Mori *et al.,* 1999). They constantly compete with livestock grazing and local farmers (e.g. crop raiding). Increase in the local human population expands the agricultural habitat which has serious impact in shrinking and losing the natural habitats. Geladas change their feeding behavior and develop crop raiding habit which causes conflict with the local farmers (Mesele Yihune *et al*., 2009). In Indetu, the agricultural expansion and livestock grazing force geladas to retreat to marginal habitats (Kelil Abu *et al*., 2018).

2.2 Baboons and the related *Theropithecus gelada*

Recent taxonomists prefer to split primates into the suborder Strepsirrhini (wet-nosed) and suborder Haplorrhini (dry-nosed) (Anthropoids) (Disotell, 1996). Anthropoids are further divided into platyrrhines (New World monkeys) and catarrhine (Old-World monkeys) include baboons, guenons, macaques, and apes (Harcourt and Schreier, 2009). Catarrhine have wide geographic distribution and occupy diversified habitats mainly in Africa, Middle East and Asia. Old World monkeys (Cercopithecidae) are split into ecological and morphological distinct subfamilies of Cercopithecinae and Colobinae (Fleagle, 2013). Cercopithecines are dietary generalists, characterized by “cheek pouches” for storing food (Hemingway and Bynum, 2005). Baboons and *Theropithecus* are the most terrestrial cercopithecines which form stable and complex social organization (Altmann and Altmann, 1970). Colobines are “leaf eater” monkeys with specialized stomach, which include African colobines and Asian languor.

Cercopithecines are further split into Cercopithecini (guenons) and *Papionini*. *Papionini are* further split into two subtribes: *Papionina* (*Papio* and *Theropithecus)* and *Macacina* (*Macaca*) (Liedigk *et al.*, 2014). *Papionins* are mainly restricted in Africa with the exception of hamadryas baboon (*P. hamadryas*) which also occurs in the Arabian Peninsula (Liedigk *et al*., 2014). Baboons are sexually-dimorphic monkeys found throughout Africa and the closest living families of geladas (Groves, 2001). Yet, baboons are ecological generalists feeding on a variety of species and items including fruits, seeds and leaves (Whiten *et al.*, 1991; Altmann, 1998).

Cercopithecines are exclusively diurnal and the most social animals forming large groups (Mitani *et al.*, 2012). Large group size is advantageous for various ecological needs such as predation avoidance, optimal habitat use and infanticide avoidance (Dunbar and Shultz, 2010;

Swedell and Plummer, 2012). However, group living has its own constraints including within group competition for resources and mates. Several factors can determine group size in primates though competition for food and predator pressures are primary determinant factors (Dunbar, 1988).

The extant species of geladas: Gelada (*Theropithecus gelada)* is the last remaining member of the genus and one of the most successful and widespread terrestrial primates (Dunbar, 1998). It is the only graminivore cercopithecine genus once widely distributed taxon in Africa and Eurasia during the Plio-Pleistocene (Delson, 1993; Jablonski, 1993). Geladas are sexually dimorphic, males bigger and weigh about 20.5 kg while females weigh 11 kg. Adult males have larger canine and long cap which are absent in females (Ankel-Simons, 2007). Gelada is termed as a "bleeding-heart monkey", red patch of bare skin on the chest. Bright red coloration appears when a male becomes a group "leader" (Dunbar and Dunbar, 1975). The hairless patch of female skin on their chest is brighter during estrus. Females display "necklace" of red bead fluid-filled blisters surrounding the hairless patch when ready to mate (Dunbar and Dunbar, 1975). This is thought to be analogous to the swollen buttocks common to most baboons during estrus (Ankel-Simons, 2007). Female geladas become sexually mature within 5 year. Gestation period lasts about 6 months and breeding is not seasonal, usually occurring after the main wet season.

Formerly, *Theropithecus gelada* was considered to consist of two subspecies: *T. g. gelada* (Ruppell, 1835), which is distributed in the northern highlands of Ethiopia, north of Lake Tana, and *T. g. obscurus* which is distributed in the central Highlands, South of Lake Tana that includes Wollo and Shewa (Mori and Gurja Belay, 1990; Yalden and Largen, 1992; Gippoliti, 2010). Populations of the two taxa are isolated both geographically and genetically (Yalden and Largen, 1992; Gurja Belay and Shotake, 1998; Gippoliti, 2010). The third isolated population of

Theropithecus gelada was discovered along the Wabi Shebelle gorges, south of the Rift Valley, Arsi (Mori and Gurja Belay, 1990). Preliminary research of the genetic analysis suggested that the Arsi gelada population represents a new taxon (Mori and Gurja Belay, 1990; Gurja Belay and Shotake, 1998; Gurja Belay and Mori, 2006; Gippoliti, 2010). In more recent study of the phylogenetic and mtDNA analysis confirmed that the Arsi gelada population is a distinct taxon, genetically and morphologically related to the geographically distant, *T. g. gelada* ("northern" population) than the more proximate, *T. g. obscurus* ("central" population) geladas (Gurja Belay and Mori, 2006; Shotake *et al*., 2016; Zinner *et al*., 2018).

The recent ancestor of *T. geladas* split into the northwestern population (*T. g. gelada* and *T. g. obscurus*) and the "southern" population (Arsi gelada) at an estimated time *ca* 0.4057 mya. The northwestern population of geladas split into *T. g. gelada* (the "northern" population) and *T. g. obscurus* (the "central" population) in an estimated time *ca* 0.2474 mya. Thus, the Arsi geladas are proposed as a third subspecies with a scientific name *T. g. arsi* (Shotake *et al*., 2016). A more recent study showed that Arsi geladas are more closely relared to the northern gelada lineage (*T. g. gelada*) than the *T. g. obscurus* supporting the previous study that Arsi geladas are distinct from the other two known species (Zinner *et al.,* 2018). However, until the taxonomy of geladas is fully relosolved, Arsi gelada will be used throughout the text (Kelil Abu *et al*., 2018).

Social organization and structure: Geladas form multilevel social organization at hierarchical levels (Kawai *et al*., 1983; le Roux *et al*., 2011). The multilevel hierarchy comprises basic "reproductive units" (one-male units, OMUs) (2–12 females and their offspring, a dominant "leader" male, and sometimes one or more subordinate "follower" males), and all-male units (AMUs) that associate together in a "band," which shares common home range and include hundreds of geladas travel, eat and sleep together and form herds (a temporary foraging group)

(Snyder-Mackler *et al*., 2012). The social structure of geladas increases the size in subsequent hierarchies, which allows reducing competition in limited resources and defends predator risks (Swedell and Plummer, 2012). A gelada band may split up into smaller feeding groups during the resource scarcity to reduce food competition (Dunbar, 1977a; Wrangham, 1980). Geladas reunite and form bands to avoid predation risk (van Schaik, 1983). Social grooming maintains social bond in geladas (Dunbar and Sharman, 1984). Allogrooming is highly kin-biased (Akinyi *et al*., 2013). Social structure of gelada units is maintained by females (Dunbar, 1986). Females in geladas devote highest percentage of their allogrooming toward maternal kin (Silk *et al*., 1999). However, females do not usually interact with more than two or three kin females within the unit (Dunbar, 1986). Hamadryas baboon also forms multilevel hierarchy of social structure superficially similar with geladas (Kummer, 1968). Unlike hamadryas baboons, in gelada groups, females are philopatry which maintain the social unit. The aggressive behavior of "leader" males maintains the social units in hamadryas (Swedell *et al.*, 2011).

Takeover is common in gelada units either by taking the entire unit (group takeover) or peripheral females by the follower male/AMUs (Dunbar, 1984). A subordinate male may join a reproductive unit and eventually breaks off and takes some (peripheral) females with him (Dunbar, 1986). A direct combat forcefully between the new coming male and the former "leader" male is also observed. During takeover, the new leader male overthrows the former "leader" male. The new leader male maintains his relationship with OMU females by allogrooming them rather than forcing, in contrast to hamadryas baboons (Swedell *et al*., 2011). Females acknowledge the new "leader" male by presenting themselves to him (Mori and Dunbar, 1985). Soon after a takeover, a new "leader" male attempts to kill unweaned infants of the unit females to enhance fertility (Mori *et al*., 1997; Beehner and Bergman, 2008). However, geladas may also kill infants as a result of aggression during takeover (Beehner and Bergman, 2008). Following a successful takeover, the former "leader" male could remain in the unit as a "follower"/subordinate male or leave the unit and joins all-male units (AMUs). There may often be considerable fighting between former "leader" male and the new "leader" male. The former "leader" male may remain in the group and care the offspring to avoid harassment by the new leader male.

2.3 Population size and ecological behavior of Geladas

Geladas are distributed over a small geographic range compared to baboons (Jordan *et al*., 2018). The availability of food resources determines the species' geographic range and limits its population density (Cant, 1980). The population density of wild animals often depends on habitat quality and disturbance (Dunbar, 1978). Most of the gelada populations occur on plateau to close to cliffs and gorges. The highest population density of geladas occurs in the Simien Mountains National Park (Beehner *et al*., 2007). However, several populations occur in the central highlands of the country including Wollo and Shewa (Yalden and Largen, 1992; Fashing and Nguyen, 2010; Gippoliti, 2010; Zewdu Kifle *et al*., 2013; Fashing *et al.,* 2014; Kassahun Abie and Afework Bekele, 2017; Zinner *et al.,* 2018). The gelada habitats are highly disturbed due to habitat conversion into farmlands, human settlement and livestock grazing (Dunbar, 1977a; Iwamoto, 1979; Hunter, 2001). Like other two well known gelada subspecies, the distribution pattern and accurate population size of Arsi geladas are not well known in the region.

Data on population size of geladas are essential to determine whether numbers of a particular species are being maintained, in decline or in recovery and to design conservation and management plans and wildlife management policies (Beehner *et al*., 2007). Arsi geladas are found discontinuously in highly marginal habitats due to high human interference and habitat conversion. So far there was only a limited knowledge about the distribution pattern and population size of geladas. Even though the phylogeography of *Theropithecus geladas* is determined recently (Zinner *et al*., 2018), their accurate population size and distribution pattern were poorly known and lack scientific data. Knowledge about the population status and distribution pattern of the Arsi gelada was very limited. Understanding the accurate population size of geladas helps to design conservation starategy and to determine population status. A few days study on Arsi geladas at three decades ago was estimated a total of ~ 600 individuals (Mori and Gurja Belay, 1990). Further, Kelil Abu *et al*. (2018) estimated that Arsi gelada population to be not more than 1000 individuals.

Geladas are exclusively diurnal. They allocate the available time into their daily activities of feeding, traveling, resting, socializing (allogrooming, sexual, playing and aggression) and other activities (drinking, defecation, looking to the observer and vocalizing) (Iwamoto and Dunbar, 1983; Dunbar *et al.*, 2009; Fashing *et al.*, 2014). The diurnal activity pattern of primates may not be consistent, rather certain activities peak at certain time of a day. For example, white-headed langurs spend feeding peaks in the morning and afternoon, and resting peak during mid-day (Huang *et al*., 2003). However, some large-body terrestrial species, e.g., *Macaca nigra* and *Papio anubis* show less marked difference (Post, 1981; O'Brien and Kinnaird, 1997).

Primates adjust their activity budgets in response to changing ecological conditions (Zhou, *et al*., 2007) and environmental factors (temperature and rainfall) (Dunbar, 1992a, 1998). Animals acquire food in degraded habitats or during seasonal food shortage. They may be able to adjust their time budgets according to changes in resource availability and diet composition (Di Fiore and Rodman, 2001; Hill and Dunbar, 2002; Vasey, 2005). Time budgets and activity patterns are also influenced by foraging group size (band size) (Iwamoto and Dunbar, 1983; Dunbar, 1992a;

Isbell and Young, 1993), proximity to human settlements (Dunbar and Dunbar, 1974; Mori *et al*., 1997), human disturbances (Dunbar, 1977a) and competition with ungulates. The time budget of gelada is highly dependent on altitude and ambient temperature (Iwamoto and Dunbar, 1983; Hanya, 2004). Temperature affects the activity budgets of primates (Iwamoto and Dunbar, 1983; Dunbar, 1992a; Fan *et al*., 2008). Frugivores spend less time moving to conserve energy during lower fruit availability. Time spent feeding by baboons is negatively related to feeding fruits (Hill and Dunbar, 2002). Folivores decrease the time spend feeding as abundant distribution of leaves. Geladas prefer green graminoid leaves which is soft, easily digested and more nutritious (Dunbar, 1977a; Iwamoto, 1993; Fashing *et al*., 2014).

Primates can regulate their activity budgets seasonally in response to changes in food abundance, habitat quality or resource distribution (Doran, 1997; Estrada *et al*., 1999; Di Fiore and Rodman, 2001, Hanya, 2004). The impact of seasonality and change of food supply result in behavioral shifts or changes in particular activities of primates (Bronikowski and Altmann, 1996). Study showed that seasonal variations in time budgets of primates are related to seasonal changes in diet or food availability (Iwamoto and Dunbar, 1983; Zhou *et al*., 2007). Seasonal differences in activity budgets of primates are a reflection of differences in food availability and weather variation across seasons with increase time of feeding and/or traveling typically associated with periods of lower food availability (van Doorn *et al*., 2010). High mid-day temperatures during the dry season may cause an increase in time spent resting and decrease social behaviors such as play and grooming (Post, 1981).

Activity patterns reveal that the abilities of animals to optimize their nutritional and metabolic requirements against their energy expenditure, e.g., primates, selectively feed on energy-rich or high-quality foods, or traveling less when energy is limited (Bronikowski and Altmann, 1996), or traveling long to obtain better quality food (Iwamoto and Dunbar, 1983; Hunter, 2001). Activity patterns provide valuable insights into how primates organize their lives, elucidating the relative importance of each activity (Clutton-Brock, 1977). Identifying how animals divide their activities throughout the day and year offers insight into their interaction with the environment and strategies for maximizing energetic and reproductive success (Defler, 1995).

Habitat use and ranging size: Home range is defined as the area in which an animal spends its adult life in search for food and care for its offspring (Jolly, 1985). Primates occupy a wide variety of habitats (Wish and Marshall, 2016). Habitat use and home range size of primates are associated with resource availability and habitat disturbances (Dunbar, 1977a; Iwamoto and Dunbar, 1983). Studies indicate that primates may decrease day path length during food scarcities, a strategy for energy conservation in frugivorous primates (Boinski, 1987). Primates may also increase day path length (Barton *et al*., 1992), foraging time (Garber, 1993) and home range size (Clutton-Brock, 1977) during times of food scarcity. Baboons increase their home range and day path length during periods of resource scarcity (Henzi *et al*., 1992). Macaques increase their home range size when fruits are patchily distributed to obtain the required amount of nutrients (Albert *et al*., 2013).

Ranging pattern and home range size of primates are associated with temporal and spatial distribution and abundance of food resource (O'Brien and Kinnaird, 1997). The distribution and abundance of food resources are suggested to be the most important environmental determinants of primate ranging size (Isbell, 1983). Temporal variations in availability and distribution of preferred food resources shapes primate ranging patterns, and ultimately affects the size and shape of their home range (Wallace, 2006). Home range size of arboreal primate species is smaller than the terrestrial one (Milton and May, 1976). Frugivorous and omnivorous species have larger ranging size than those of folivores (leaf eaters) (Milton and May, 1976). Fruit resources are usually sparsely distributed, thus frugivores travel long distance to obtain sufficient fruits (Hladki, 1975). In contrast, leaves are more abundant and uniformly distributed, thus folivores travel small ranges. Studies show that even distribution of resources and high food availability allow animals to decrease daily path length, whereas in habitats with more scattered resources and low food availability, they increase day path length (Kaplin, 2001; Boyle *et al*., 2009). However, other studies have found that opposite trend, with longer day path length of frugivorous in the areas with high fruit availability to maximize energy (Wallace, 2006).

Habitat degradation modifies vegetation composition and structure, consequently reducing habitat quality and food availability for the species inhabiting the area (Laurance *et al*., 2014; Wilson *et al*., 2016). Seasonality changes the vegetation composition, food availability or reduces habitat quality (Gregory *et al.*, 2012). Primates in seasonal environments exhibit greater dietary variability (Hemingway and Bynum, 2005).

Ranging behavior in primates may be influenced by feeding behavior, including foraging strategies and availability of food resources (Di Fiore, 2003). Home range variations are often explained by seasonal variation in food availability (Stevenson, 2006; Wallace, 2006). Daily path length and home range size may be influenced by group size (Iwamoto and Dunbar, 1983), habitat quality (Izumiyama *et al*., 2003) and weather conditions (Clutton-Brock and Harvey, 1977; Dunbar, 1998). Habitat disturbances are expected in shaping the range size and habitat use of primates (Schwitzer *et al*., 2007; Boyle *et al.*, 2009). Ranging behavior may be altered in order to maximize or to conserve energy (Campera *et al*., 2014). Some primates increase their range during food scarcity. Others decrease their range when food is scarce (Donati *et al*., 2011). Macaques adjust ranging behavior according to seasonal variations in wild resources. Home range size and day path length of macaques decreased during low fruit abundance (Albert *et al*., 2013). Baboons decrease their daily path length during increase in vegetation availability (Barton *et al*., 1992). Wallace (2006) found that spider monkeys (*Ateles chamek*) reduce their travel distances when resources became scarce. Lemurs living in degraded habitats reduce their daily path length, probably for energy minimizing strategy (Campera *et al*., 2014).

Geladas respond for food scarcity, habitat quality and competition in different ways. Gelada groups increase their day path length during resource scarcity (Dunbar, 1977a; Iwamoto and Dunbar, 1983). The large foraging group size moves longer distances and increase home range size (Iwamoto and Dunbar, 1983). Day path length tends to increase with band size but decreases in a quality habitat (Iwamoto and Dunbar, 1983). Geladas may change locations by moving among habitats and out of their regular home range in search of more resource (Dunbar, 1977a). Seasonal variations in food availability influence ranging behavior, day path length and habitat use of primates (Clutton-Brock, 1975). Temporal variations in the availability and distribution of preferred resources are thought to shape primates' ranging patterns and ultimately affect the size and shape of their home ranges (Defler, 1996).

Feeding is the prominent behavior of graminivorous primates (Dunbar and Dunbar, 1974; Dunbar, 1977a; Iwamoto, 1979; Hunter, 2001; Fashing *et al*., 2014). *Theropithecus geladas* are the only graminivorous primates that show a higher level of dietetic specialization compared to other terrestrial primates. Geladas primarily consume graminoid (grass and sedge) leaves (Dunbar, 1977a; Iwamoto, 1979, 1993; Hunter, 2001; Fashing *et al*., 2014). They exhibit several behavioral and morphological features associated with graminivory (Dunbar and Bose, 1991; Delson, 1993; Mau *et al*., 2011). 'Bulk feeding' is adopted by gelada to gain the required level of nutrients from a lower quality diet (Dunbar and Bose, 1991; Hunter, 2001). Their elongated thumbs and reduced second finger form efficient plucking, pinching and pick selectively the sparsely distribution of green graminoid blades (Dunbar, 1977a; Iwamoto, 1979, 1993; Mau *et al.*, 2011). Their phalanges are short and robust, which allows geladas to scavenge underground storage items efficiently (Dunbar, 1977a; Iwamoto, 1979). Geladas employ a characteristic shuffling gait that allows them to move around in a sitting position while harvesting food (Dunbar, 1977a). The combination of specialized craniodental, manual grazing and shuffling of geladas facilitate to acquire nutrients from the low quality graminoids (Jablonski, 1994; Fashing *et al.*, 2014).

Green graminoids are the major diet of gelada (Dunbar, 1977a; Iwamoto and Dunbar, 1983; Iwamoto, 1979, 1993; Hunter, 2001). In Ethiopian highlands at higher elevation, the vegetation stays green due to high rainfall and low temperature (Iwamoto and Dunbar, 1983; Iwamoto, 1993). However, geladas face serious anthropogenic disturbances (Dunbar, 1977a; Beehner *et al.*, 2007). Arsi geladas occur in unusually lower elevation and warmer environmental condition. The harsh environmental condition changes diet composition and availability. The marginal habitats and anthropogenic disturbances affect the behavior and socio-ecology (unstable band and aggressive behavior) of Arsi geladas. Geladas consume alternative species and food items ("fallback food") during the decline and scarcity of preferred foods (Dunbar, 1977a; Iwamoto, 1979; Jarvey *et al.*, 2018).

Primates are flexible feeders in response to the shifting of foods (Napier and Napier, 1967). For example, frugivorous primates consume fruits whenever it is available, but they consume less digestible alternatives during deficiency. Chimpanzees are fruit specialists; however, they switch to terrestrial herbaceous vegetation during fruit scarcity (Lambert and Rothman, 2015). Primates switch diet composition following seasonal changes (Chaves and Bicca-Marques, 2016). Bale monkeys (*C. djamdjamensis*) alter their diet into forbs and graminoids during habitat degradation (Addisu Mekonnen *et al*., 2018).

Despite their predominant graminivore, gelada dietary variability is associated with seasonal decline in preferred food (Dunbar, 1977a; Iwamoto, 1979; Hunter, 2001) with the diet consisting of less proportion of green graminoid during the dry season and the highest proportion during the wet season (Dunbar, 1977a; Fashing *et al*., 2014; Jarvey *et al*., 2018). Geladas consume more than 90% of green graminoid during the wet seasons (Dunbar and Dunbar, 1974; Iwamoto, 1993). However, they switch diets as green graminoids desiccate during the dry season (Dunbar, 1977a; Iwamoto, 1979; Iwamoto and Dunbar, 1983; Fashing *et al*., 2014; Jarvey *et al*., 2018). Animals that live in seasonally changing environments either concentrate on specific food sources which are available all year round or vary their diet in relation to seasonal changes (Guo *et al*., 2007). In more seasonal environments, food shortage is likely to occur at certain times of the year (Jarvey *et al*., 2018). Geladas switch to underground food items, forb seeds, shrub leaves and tree fruits when green graminoids are desiccated during the dry season (Dunbar, 1977a; Iwamoto, 1979; Hunter, 2001; Fashing *et al*., 2014).

Anthropogenic disturbances and seasonal variation in food availability influence geladas feeding ecology. Simien Mountains National Park is heavily disturbed by agriculture and domestic livestock grazing (Dunbar, 1977a; Hunter, 2001; Iwamoto, 1979). Study shows that the distinct differences in feeding ecology of gelada in Guassa and Simien Mountains is a decreased consumption of graminoid leaves and an increased consumption of forb leaves in Guassa (Fashing *et al*., 2014). In Simien Mountains, geladas switch diet from green graminoid leaves during the wet months to a much greater reliance on underground foods during the dry season months (Dunbar, 1977a; Iwamoto, 1979; Jarvey *et al*., 2018).

2.4 Conservation *Threats of Geladas*

Due to destruction of their natural habitat as a result of rapid population growth and related human activities, there was rapid decrease of wildlife in size, species and distribution (Dunbar, 1977, Beheener *et al*., 2007). However, today due to conseravation works, geladas in Simen Mountains slightly increase their population (Dessalegn Ejigu and Afework Bekele, 2017). Currently, two National Parks including Simien Mountains National Park and Borena Saynt National Park, and community conservation areas including Menze Guassa and Mt. Abune Josef harbor geladas. In addition, geladas are known to live outside protected areas including Arsi (Mori and Gurja Belay, 1990), Bole Valley (Dunbar and Dunbar, 1974) and Debre Libanos (Crook Aldrich-Blake, 1968) and Wonchit Valley in South Wollo (Zewdu Kifle *et al*., 2013; Zinner *et al*., 2018). However, geladas that inhabit outside the protected areas are highly disturbed by the local community and may be killed by the local farmers due to their crop raiding behavior. For instance, geladas at Mt. Guna Community Conservation area in South Gondar is at high risk of extinction in the wild in the near future due to habitat encroachment and agricultural land expansion to high altitude afroalpine habitat.

Arsi gelada is a little known and an isolated population of geladas certainly classified as an endangered status as third subspecies (Shotake *et al*., 2016; Kelil Abu *et al*., 2018). Arsi gelada is identified as genetically distinct from other gelada subspecies and believed to represent a new taxon of geladas (Shotake *et al*., 2016; Zinner *et al*., 2018). Arsi geladas are among the world's least known primates that occupy a densely human populated and disturbed region (Kelil Abu *et al*., 2018). Geladas are ecologically specialized and have a restricted geographical distribution at high elevations where such human density is high. Consequently, geladas have always been at high risk of extinction. Anthropogenic activities including habitat fragmentation and agricultutral land expansion as well as global warming force the distribution of geladas in small and narrow geographic range restricting in disjunct cliffy habitats in Eastern Arsi.

Currently, habitat fragmentation and destruction are the primary threats facing primates in Ethiopia (Beheener *et al*., 2007; Gippoliti, 2010; Addisu Mekonnen *et al.,* 2017). In Arsi, the dense human population growth and the need for more land for the local farmers cause the conversion of gelada habitats into farmland and human settlements. Study showed that human activity causes habitat degradation and alters behavioral ecology of primates (Addisu Mekonnen *et al.,* 2017, Addisu Mekonnen *et al.,* 2018; Trosvik *et al*., 2018). Climate change and drought had a severe impact on geladas in lower elevation as they predominantly depend on gramineae (Dunbar, 1998). Studies indicate that gelada population has been markedly reduced nationally by severe droughts and anthropogenic factors (Beehner *et al*., 2007; IUCN, 2017). The warmer weather condition and low rainfall increase seasonal variation in resource availability and result in degradations of habitats. Habitat destruction leads to a reduction of preferred food resources for geladas. Geladas raid mainly wheat, teff, and maize which are the staple food for the locals. They are also compute with domestic livestock for grasses in the current study area. In the present study, geladas are being killed by local people at different localities (Amera Moges pers. obs.).

Knowledge on population size, activity budget, ranging ecology and diet composition for a species is crucial for understanding its behavioral ecology and habitat requirements (Singleton and van Schaik, 2001) and vulnerability to extinction. Only little is known about the distribution pattern, population size, activity budget, ranging behavior and feeding ecology of Arsi geladas.

3. MATERIALS AND METHODS

Nikon binoculars were used for observing the study individuals and food items from far. Garmin GPSMap 62s were used to record focal group locations. Taylor ® digital waterproof thermometer and Oregon wireless rain gauge and indoor/outdoor thermometer were used to measure the daily tempratures and the amount of rainfall in the study area during the study periods.

3.1 Descriptions of the Study Area

Location

The study area is located in Oromia Regional State, Eastern Arsi, about 250 km southeast of Addis Ababa. The study area extends from 7^{o} 30.072’ N to 7^{o} 44.992’ N latitude and 39^{o} 48.726’ E to 40^{o} 11.956’ E longitude with altitude ranges from 1800 - 2400 m asl (Fig. 1). The study was conducted in four neighboring administration districts found adjacent to two big rivers. Intensive agricultural activities are conducted in the areas due to high human population growth.

Topography

The landscape of the study are includes escurpments/steep cliffs, plains and deep gorges covered by broadleaf trees along seasonal rivers in the deep gorges. The escarpments and gorges have scenic beauty and attractive. The escarpments of the study area are dissected by the two big rivers: Robe River and Wabi River. Robe River originates from the Arsi highlands, while Wabi River emerges from the western highlands of Bale Mountains and Arsi areas crossing the gorges about 1000 m deep (Mori and Gurja Belay, 1990). Small intermittent rivers from different directions join Robe River, which flow deep in gorge beginning from Robe River fall.

The distribution pattern and population size of Arsi geladas were conducted in four neighboring administration districts located on the opposite sides along the Robe River and Wabi-Shebelle River. The behavior and ecology of Arsi gelada were conducted at Goro – Jena. It is about 30 km North of Indetu. Goro - Jena is unprotected area with high human population growth which forms horizontally W- shap valley, and steep cliffs at the end of small tributaries (Iwamoto *et al*., 1996; Mori *et al*., 1999). A perpendicular wall 100 – 200 m depth is observed below the upper cliff edge (Iwamoto *et al*., 1996). The lower part of the cliff wall descends with a relatively gentle slope where animals and humans could rarely traverse. The study area is not legally protected but contains different wildlife and variable habitats including escarpment/cliffs, bushlands, open grasslands, and cultivated lands close to human settlement.

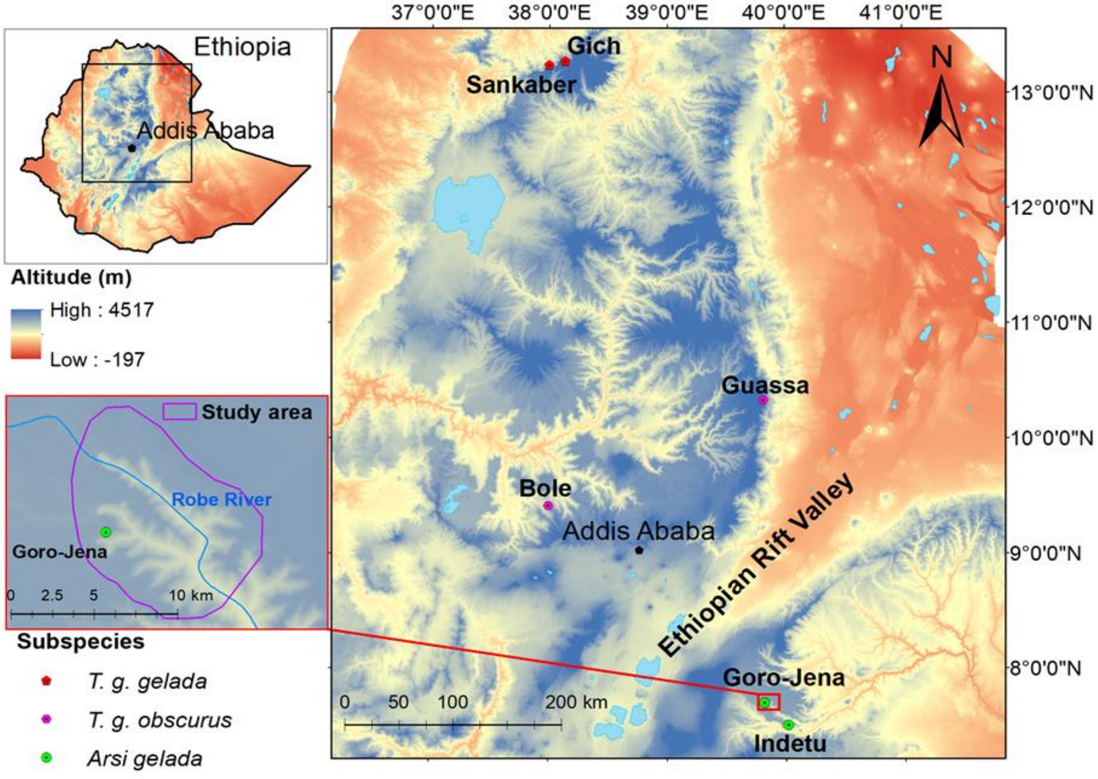

Figure 1. Map of the present study area and the location of other *Theropithecus gelada* sites across the Ethiopian highlands.

Soil

The study area comprised different soil types including sand soil in the escarpments which is highly eroded. The escarpments are unareble land which is not important for cultivation. However, the plains are rich in loam soil which is fertile and suitable for crop growing.

Climate

The study area has very warm climate characterized by seasonal unimodal rainfall with long dry season with a short rain between March and April. The lower elevation results in longer and more intense periods of drought and higher temperature (Kelil Abu *et al*., 2018) than gelada study sites north of the Rift Valley (Hunter, 2001; Fashing *et al*., 2014). The main rain season extends from June to October which receives maximum rainfall in August, and the dry season extends from November to May. Temperature data indicate that the area shows a great variation in annual minimum and maximum temperature. Unpredicted weather condition is frequent in the area which results in high scarce of water during the long dry season.

Fauna and Flora

Arsi highlands are part of the eastern Afromontane Biodiversity Hotspot which contains numerous fauna and flora though under immense human pressure (Mittermeier *et al*., 2005). The dominant flora in the study area provide diets of Arsi geladas include *Pennisetum squarnulaturn, Hyparrhenia rufa, Themeda triandra, Cymbopogon vallidus, Hyparrhenia anthistirioides, Andropogon abyssinicus, Cymbopogon caesius,* and *Hyparrhenia pigerana* were graminoid species in the escarpment/cliffs. *Digitaria abyssinica, Eleusine floccifolia, Cynodon dactylon, Pennisetum villosurn, Pennisetum thunbergii, Eragrostis tenuifolia,* and *Chloris pycnothrix* have grown at open plateau top. Forbs include *Commelina erecta, Falkia oblonga, Chlorophytum comosumand* and *Scorpiurus muricatus* were commonly occurred at plateau top. *Rhus glutinosa* and *Opuntia ficus-indica* were small trees and bushes, respectively, distributed sparsely in the area.

Besides the study area harbors large mammals include bush duiker *(Sylvicapra grimmia*), golden jacal (*Canis aureus*), rabbit, spotted hyaena (*Crocuta crocuta*), leopard (*Panthera pardus*). Primates include geladas (*Theropithecus gelada*), anubis baboons (*Papio anubis*), hamadryas baboons (*Papio hamadryas*), grivet monkeys (*Chlorocebus aethiops*) and black and white colobus monkey (*Colobus Guereza*) are common in the area. A variety of birds including several endemic species have also been found in the area.

Local people use selective cutting of trees in the escarpments for firewood and home-building material. The local farmers clip and collect tall grasses at cliffs frequently for their cattle foraging. However, open grassland is heavily grazed by domestic animals. Local people converted the open grassland where previously occupied by geladas into crop fields and human settlements (Iwamoto *et al*., 1996; Mori *et al*., 1999). Cultivated crops in the area include wheat, teff, maize, linseed and bean. To date, a narrow belt of open grazing land is diminishing from 10 to 200 m from the cliff edge where geladas mainly graze competing with domestic animals. The study area include fragmented forest, shrub/bushland and scattered broad leaf trees at deep gorges and scattered trees mixed with tall grasses on the escarpment/cliffs and open grassland at the plateau top nearby villages and cultivated land. Based on the vegetation composition, the study area was categorized mainly into open grassland, escarpment/cliffs and cultivated land (Table 1).

Table 1. Descripton of major habitat types at Goro-Jena study site

Habitat types	**Descriptions**
Open grassland	Occurs at a plateau top is covered by short graminoids and forbs during the wet season and scattered eucalyptus trees under story grasses. It surrounds escarpment/cliffs with a range of 10 - 200 m from cliff edge. It is exhaustively utilized for livestock grazing.
Escarpment/cliffs	This comprises steep cliff walls and gentle slope. Cliffs comprise scattered trees and bushes/shrubs interspersed by dominant tall grasses. It includes patchy forest gorge at the bottom of the cliff covered by big broad leaf trees and seasonal rivers at the deep bottom. Patchy forest gorge at the bottom of cliffs is dominated by bush and woody shrubs along the seasonal rivers.
Human settlement	Habitat type dominated by humans with villages adjacent to grasslands and cultivated land. Villages are built nearby cliffs at some localities.
Cultivated land	Habitat type that includes agricultural fields and fallow land. Intense human activities are practiced.

The study species and group:

Arsi gelada is an isolated and a rare population of gelada which is certainly threatened and found in limited range south of the Rift Valley, east Arsi. However, Arsi gelada is wrongly classified with *T.g.obscurus*, the “central gelada population” according to IUCN Red List catagory and they are considered their conservation status in least concerned. Time budget, ranging behavior and feeding ecology of Arsi geladas were studied from the selected focal group of one male unit (OMU)/group from a gelada band at Goro-Jena villages. Arsi gelada bands have looser associations among social units (Mori *et al*., 1999). Since the gelada band containing several OMUs are unstable, stay together only for a short time, with an average of two and half hour in a day. Group instability and repeated splitting (fission-fusion) of units in Arsi gelada may result from the anthropogenic impacts, habitat degradation and seasonality associated with a decline/scarcity of resource availability (Dunbar, 1998). Thus, a specific group/OMU of geladas was selected for the study of their behavior and ecology. The study band occupied a W-shaped valley with steep cliff faces descending to the east.

All studied individuals in OMU were easily identified based on physical appearance, body size, canine size of males, distinctive body marking (individual identity, if possible), coat color or facial features were used to distinguish individuals in focal group. Individuals was categorized into four age-sex classes: adult males, adult females, subadult males, subadult females, juveniles (female and male), and infants based on morphological feature and body size (Dunbar and Dunbar, 1975; Kawai *et al.*, 1983). The study group/OMU comprised 15 individuals at the beginning of the study which include 1 leader male, 5 adult females, 1 follower male, 1 subadult male, 1 subadult female, 2 juveniles and 4 infants during the beginning of the study.

3.2 Data Collection and Analysis

The reconnaissance study was conducted to categorize habitat types and identify the focal group before the main data collection. The study group was habituated for two months (February – March, 2014) on dialy basis before starting data collection for human observations. Behavioral and ecological data, population size and distribution pattern of Arsi geladas were collected for 16 consecutive months from April 2014 to July 2015 covering the wet and the dry seasons.

Climate/weather data were recorded on daily basis from the campsite from May 2014 to October 2015. Rainfall and daily temperature (^{o}C) data were measured using an Oregon wireless rain gauge and indoor/outdoor thermometer placed at the research campsite in the study area with elevation at 2400 m asl. The campsite is found in the study area. The maximum (30.04 ^{o}C) and minimum (8.07^{o}C) daily temperature data were also recorded during April 2015 and December 2014, respectively. Two field assistants were trained to record the weather data before the beginning of data collection. The monthly and overall rainfall was calculated for the period May 2014 - July 2015. The daily rainfall values (in mm) were analysed to produce monthly and overall rainfall. In addition, the daily maximum and minimum temperatures (^{o}C) were used to produce the mean monthly minimum and maximum temperature.

The study area receives unimodal rainfall distribution with a long rainy season with the highest rainfall in August and September, and a longer dry season that change vegetation composition and abundance in the study area during the two seasons. However, there is short rain from March to April in the area. A mean total of 561.9 mm ±112.39 and 161.55 ± 23.1 mm rainfall was recorded during the wet and dry seasons, respectively in the campsite. Wet season was considered those months with mean rainfall over 71 mm. These include seven months from June - October. Rainfall usually begins in June every year with peak in July and August. Dry season was considered when the monthly rainfall is less than 71 mm (Fig. 2). These included nine months from November to May.

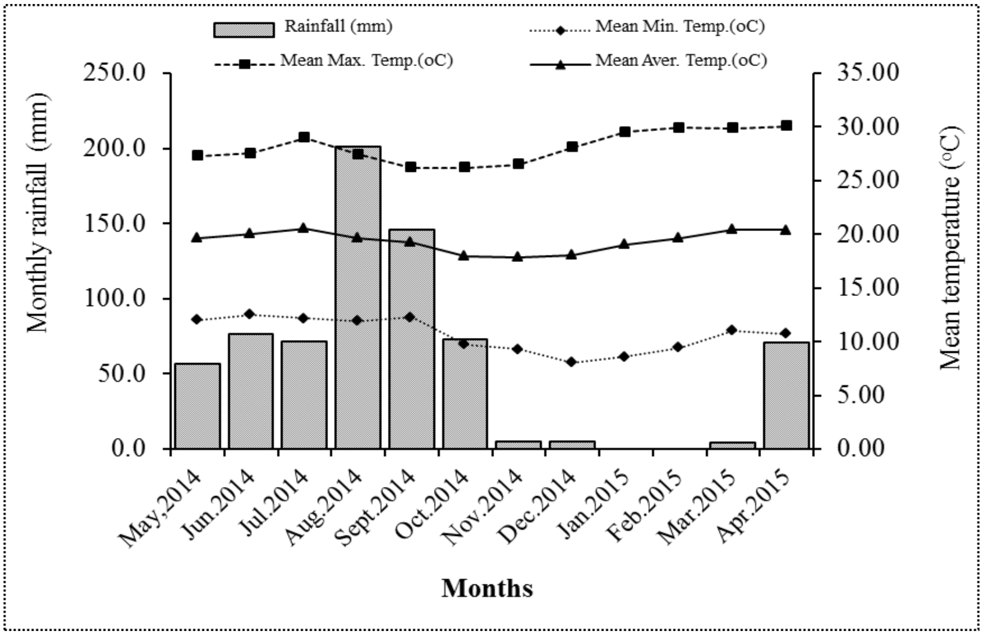

Figure 2. Mean maximum and minimum temperature and rainfall at Goro-Jena (May 2014 - July 2015).

For comparative purpose, ten year (April 2006 – March 2016) climate data were collected from five different stations in the study area each ranges 10 – 30 km from the campsite of the present study site. Data were obtained from National Meteorological Agency. The rainfall and temperature data from all stations merge and take the average. The ten year weather data displayed lower mean monthly temperature and higher mean monthly rainfall (Fig 3).

The mean total rainfall was recorded the highest (958 mm±79.86) of ten year rainfall data compared to the current rainfall (723.45 mm±60.29) in the campsite with the highest rainfall recorded from July to September in both case. In the ten year data, the mean total rainfall (611mm) was recorded in wet season and (346.5 mm) during the dry season with a mean monthly rainfall of 79.86 mm. Mann-Whitney U test indicated that insignificant difference (Z= -1.271, P = 0.020) between the present and the ten year rainfall. Mean maximum (22.2^{o}C) and minimum (5.7^{o}C) temperature was recorded in February and December, respectively (Fig. 3). T-test indicated that a significant difference (t- 3.748, df = 22, P = 0.001) between mean maximum and minimum temperature of the present and the ten year temperature in the area.

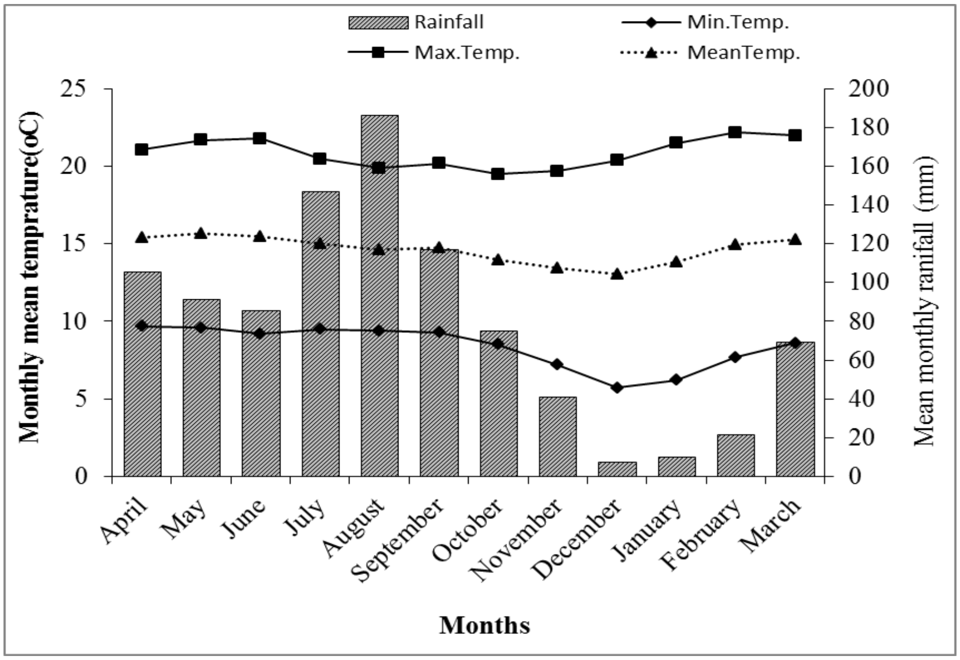

Figure 3. Mean maximum and minimum temperature and mean monthly rainfall in the entire study area (April 2006 - March 2016).

The above figure 2 and figure 3 indicate the trend of climate and the current weather conditions in the study area. Figure 2 shows the weather data in the camp site where the behavior and ecology of the focal groups was conducted during the entire study period. Whereas figure 3 shows ten year climate data collected from five weather stations in the entire study area.

3.2.1 Vegetation composition and food availability

Habitat quality and food availability is quantified by measuring productivity and availability of vegetation. Food availability of Arsi gelada was investigated using measure of above-ground grass biomass, phenological assessment and vegetation cover. Temporal changes in availability of potential food resources of Arsi gelada were assessed on plant phenology in the home range of the study group. Monthly phenological records on the selected food trees and grass plots were carried out. The phenological data collection was conducted beginning from May 2014 – July 2015. The tree/bush phenology was conducted on five selected food plant species along 5 transects (each 250 -500 m long).

Trees with breast height (DBH) ≥10 cm and bushes of $7 \leq n \leq 10$ individuals per species which produce fruits and leaves within or near the vegetation transects in the home range of the study group were identified and marked (Addisu Mekonnen *et al*., 2017). Phenological data were collected for five tree species consumed by the study species including *Carissa spinarum*, *Rhus glutinosa*, *Ficus vasta*, *Ficus thonningii* and *Opuntia ficus-indica*. After visual inspection, individual plant was estimated for a relative abundance score for each of its potential food items (young/mature leaves, flowers/fruits) (Riley, 2007; Addisu Mekonnen *et al.*, 2017). Each month, all ripe and unripe fruits, flowers, and young/mature leaves of trees of tagged stems were recorded. The relative abundance score ranged from 0 (item absent from plant) to 4 (plant fully laden with item) at intervals of 1. The percentage of young/mature leaves, fruits/flowers in a given tree crown was recorded as score from 0 – 4 in an interval of 1: none of the crown = 0, 1 – 25 % = 1, 26 – 50 % = 2, 51 – 75 % = 3, 76 – 100 % = 4 (Sun *et al*., 1996; Riley, 2007). The proportion of monitored trees bearing each of the phenophases every month was calculated (Yeager, 1989; Yiming, 2006). The temporal variations of monthly and seasonal changes in availability of potential food resources were calculated.

Grass phenology was assessed on 22 1 x 1 m permanent grass quadrats arranged on the open grazing plain and on the escarpment/cliffs in the home range of the study group. Quadrats were photographed at monthly intervals and monitored visually in all months for percentage cover of food and non-food plants and degree of desiccation (Hunter, 2001). Food plants were determined at the begning of the study. Green graminoid availability was measured in percentage of monthly occurrence (or absence) and determined the greenness of the graminoid leaves. The grass plots were selected at random and each was given a tag. The value of greenness of each graminoid plot was given in the range of 0 - 4 with an interval of 1: 0 = no graminoid in plot, 1 (1-25 %) = dry graminoid plot, 2 (26 - 50%) = brown graminoid plot, 3 (51-75%) = mixed green graminoid plot and 4 (76 - 100%) green graminoid plot.

To determine the above ground grass biomass of diets of Arsi gelada, six temporary grass plots were clipped per month within the home range of the study animal at the escarpment/cliffs where tall graminoids frequent. As homogeneous patches of the vegetation, small number of plots, 6 (0.5 x 0.5 m) in size were selected in monthly basis, and a total of 72, 0.5 x 0.5 m square plots per year were clipped and harvested to measure above ground grass biomass (Boutton *et al.*, 1988; Sala and Austin, 2000; Hunter, 2001; Fashing *et al*., 2014). Monthly clipped of above ground vegetation from the six plots starting from July 2014 – July 2015 were harvested. Each plot had to be replaced with a nearby plot of similar size and composition on monthly basis. During monthly harvesting of the above ground grass biomass from each plot, the harvested was assigned the following categories:1) green graminoid leaves (emergent or mature) and 2) brown/dry graminoid leaves (senescent or dead). The harvest was weighed after clipping and dried in a tent in the campsite. All samples were oven dried at 80°C and weighed in Phyco-physiology Lab, Department of Botany, Addis Ababa University. The wet and dry mass harvested graminoids were compared on monthly and seasons basis.

Grass biomass was recorded: (i) to measure the availability of green graminoid biomass per plot for each month, (ii) to measure dry weight of monthly graminoid production and water moisture in each plot, (iii) to compare the wet weight (green weight) and dry weight of graminoids per plot during different months and determine green graminoid availability. These measures offer insights of the percentage of available graminoid leaves that are edible (i.e., green) for geladas during a given month. The measures of monthly food availability were later correlated with measures of the rainfall to obtain a simple index enabling to track changes in food availability over time.

Vegetation availability and ground cover of the diets of Arsi gelada were also investigated according to Fashing *et al*. (2014). A total of 205, 1 x 1 m temporary plots along randomly selected eight non-overlapping transect lines of different lengths placed randomly at the escarpment/cliffs and at open grazing plains in the home range were established. The temporary plots were each spaced 10 m apart along each transect (Dunbar, 1977a). GPS location of plant taxa and percentage ground cover accounted for by each plant taxon in each plot were recorded (Mueller-Dombois and Ellenberg, 1974; Fashing *et al.*, 2014). In each plot, the proportions of ground cover of graminoids and forbs were estimated. Lists of plant species visually identified during encounter were compiled. All plants in the plots were identified to species level. Within each plot, the scores for the percentage ground cover accounted for by each plant taxon present were assigned during the assessment.

The mean monthly phenological scores of young leaves, mature leaves, fruits and flowers were calculated for each individual plant species. The percentage of greenness and brown grass blades were determined from the grass phenological assessment. The monthly percentage of grass biomass was measured from the sum of average weight graminoids clipped from each plot. Seasonal mean weight of graminoids was determined from the mean of monthly percentage of biomass. From the assessment of vegetation plot of ground cover, vegetation abundance was examined in two ways (Mueller-Dombois and Ellenberg, 1974; Fashing *et al.*, 2014) to determine percentage of total plots where each taxon exists and percentage contribution of each taxon to the total ground cover within each of the plots. Ground cover score for each plant taxon derived from the percentage ground cover assigned to the taxon during the vegetation assessments. The measure of the value of ground cover was categorized according to Fashing *et al*. (2014). Categories of scores were assigned as “very low” (accounting for <1% of total coverage), “low” (1–9% coverage), “some” (10–50% coverage), and “high” (>50% coverage).

Correlation analysis between rainfall and feeding records (food items) of Arsi gelada, and rainfall and above ground grass biomass were examined for food abundance. The correlation between greenness of graminoids with rainfall of previous month/months was tested.

3.2.2. Distribution pattern and population size

The distribution pattern and population size of Arsi gelada were conducted from April 2014 – July 2015 in four districts. Informal interviews were used to the local people who are familiar and reside in the vicinity of the escarpment/cliffs by showing them photographs of geladas, hamadryas baboon, anubis baboon and other primates (Iwanaga and Ferrari, 2002; Addisu Mekonnen *et al*., 2012). In addition, local people were also asked whether the geladas at each site engage in crop raiding and hunting by humans (Addisu Mekonnen *et al*., 2012). Surveys were conducted late in the morning when geladas ascend the cliff top or in the afternoon when geladas were most likely to be active and visible before descending to the sleeping site (Beehner *et al*., 2007).

During the distribution survey, when geladas were sighted, GPS locations, altitude, group size, age-sex classes, instance of crop raiding and polyspecific association of primate species in 50 m range and habitat types of group spotted and habitat disturbance status were recorded. Habitat type was recorded as cliff, forest/bush, open grazing land, cultivated fields and human settlements (Addisu Mekonnen *et al*., 2012). Population structures of geladas were determined based on body size and morphology. Age-sex categories of individuals were identified as geladas are terrestrial and easily visible. Age-sex categories were recorded as adult male, adult female, subadult, juvenile and infant (Dunbar and Dunbar, 1975; Mori *et al*., 1999) (Table 2).

Table 2. Age-sex categories of Arsi geladas

Age-sex classes	Age-sex ranges
Adult females	≥ 6 years old
Adult males	≥ 9 years old
Subadult	4-8 years-old
Subadult female	4-5 years old
Juvenile	1-3 years old
Infant	< 1 year old

Adult males were defined as males with manes and size about twice that of the adult females. Adult males may be leader male or follower male. Adult follower male is the one who had been a leader male and then been overtaken by new leader males. Subadult males were males similar in size to adult females and with initial development of manes. Adult and subadult females were identified based on the body size (Mori *et al*., 1999). All other individuals were considered as juveniles (male and female) and infants based on the body size (Beehner *et al*., 2007). Due to their smaller body size juvenile and infant identification of sex was difficult from distance. However, binoculars were used for observing them and to identify male and female juveniles from distance.

Population size and distribution patterns were conducted using total count method, which is effective and manage for species inhabiting small area and open terrestrial habitats (Beehner *et al*., 2007; Kumara *et al*., 2014). Grid method was adopted to determine distribution patterns and population size of a most probable threatened Arsi geladas. Two trained field assistants together with the researcher were moving parallel with each other forward in continuous grids to avoid double counting. Habitat types, vegetations, group size, age-sex groups and individual geladas were recorded on each grid cell (Kumara *et al*., 2014). Based on the habitat use of Arsi geladas in a range of 10 - 200 m on open plains from cliff edge (Gurja Belay and Mori, 1990; Iwamoto *et al*., 1996; Mori *et al*., 1999), open plains close to cliff edges and cliff face were surveyed for the presense of geladas. The entire gelada potential sites were divided into a total of 62 square grids to estimate the distribution patterns and population size of geladas in eastern Arsi. Each grid was set at 4 (2 x 2 km) square block/grid cell (Kumara *et al*., 2014). Grids cover the escarpment/cliff face, open grazing plains and cultivated fields adjacent to the cliffs in all gelada potential habitats. Habitat use of geladas to each grid was recorded. The trial length was ≥ 2 km per grid cell depending on the terrain and feasibility of the animal. Two replicate walks were made across each grid cell following permanent routes or animal paths at diagonal to each grid/block. The survey was conducted by the researcher with the help of a trained field assistant and a local-resident who are familiar in the areas. A uniform sampling effort of 1-2 km/h was spent along the diagonal of each grid cell.

A total of more than 248 km length walk was traveled in a total of two replicas during the survey. Geladas were censuse once per sampling season and presence/absence data from each location and sampling occasion (Bailey *et al.,* 2004). The routes walked were tracked using a hand-held GPS Map62s, mapped on a map using ArcGIS 10.4.0 software. All visible gelada individuals and group sizes were recorded. For each sighting, the team spent 15–20 min and data were collected on group location, group size and age/sex composition of individuals from four districts. Thus, mean group size and age/sex composition and group location were determined.

GPS locations of gelada sites recorded during the survey were incorporated into geographic information system (ArcMap10.4.0) to display the distribution map for Arsi gelada. Age-sex ratio of gelada groups was assessed. Adult sex-ratio (total number of adult males to females) and age-ratio (total number of adults to immature) of geladas were calculated in different census sites and in the total population (Ohsawa and Dunbar, 1984; Mori *et al.*, 1999). Group compositions of geladas were assessed from each site and localities where the survey was conducted. Abundance was calculated in mean group encounter rate for each grid cell from the encounters during the two replicate censuses. The mean values of geladas were determined from each grid cell to calculate group encounter per km. Density was calculated by dividing the group size of geladas per grid area, and the population size in each census site to the total area of grid cells where counting was conducted. The total population size of Arsi geladas was divided by the total area covered during the census.

3.2.3 Activity pattern and time budgets

Activity data were collected from the randomly selected study group for 10 days in each month from April 2014 - July 2015 covering both the wet and dry seasons. During each scan, the activity data were recorded for the first up to 5 visible individuals for up to 5 min duration at 30 min interval (Altmann, 1974) from dawn to dusk (0700 – 1830 h). Care was taken to avoid sampling the same individual more than once in a given group scan, but the same individuals could be sampled in successive scans. Activity recorded for each individual was the first activity that lasted for ≥ 3 seconds once it became into view. The group was scanned each time from left to right to avoid possible biases towards eye-catching activities such as aggression, allogrooming and mating (Fashing, 2001). During each scan sampling, individuals were recorded as performing one of the following activity categories: feeding (when the group was plucking grass blade, digging underground food items, shuffling when plucking, manipulating, masticating or swallowing food items); resting (when geladas were motionless, whether standing, lying, sleeping, or sitting); moving (when a gelada was on any mobile activity, whether walking, climbing, running or jumping that resulted in a change in spatial position without feeding); socializing (when geladas interacted between two or more individuals and performed activities including playing, allogrooming, copulation and aggression), and "other activities" (when geladas performed activities such as defecation, drinking, vocalizations, looking to observer and suckling) (Iwamoto and Dunbar, 1983; Iwamoto, 1993; Zhou *et al.*, 2007; Addisu Mekonnen *et al.*, 2010). The analyses are based on a total of 18, 217 behavioral records collected during 3633 group scans recorded in 160 days of 16 months of observation as full-day follow up from 10:00 - 12:00 hrs per day.

During each scan, time, date, habitat type and age-sex class of an individual were recorded. The scanned individual was recorded and assigned to one of the following classes: adult male, adult female, subadult male, juvenile male and juvenile female and infant. The scanned individual was recorded as terrestrial if it occupies the ground or arboreal when the individuals climb trees/bushes. Wet season data were collected from June 2014 - October 2014 and June - July 2015 whereas dry season data were collected from April – May 2014 and November 2014 - May 2015.

Unique body marks (individual identity, if possible) and body sizes were used to distinguish individuals in focal group.

Hourly time budgets were calculated by averaging scan budgets in an hour to avoid potential biases. The average percentage of time allocated to each main activity was calculated in hourly classes from 0700 to 1830 h to express the diurnal activity patterns. Behavioral records of Arsi geladas for each activity category were divided by the total number of activity records to calculate the proportions of time engaged in different activities. Behavioral records of the focal group were used to calculate the activity budgets for each day and averaged within each month to construct monthly activity budgets for the study group. The grand mean proportions of the monthly budgets provided the overall wet and dry season activity budgets as well as the overall activity budgets for the entire study period (Di Fiore, 2003; Zhou, *et al.*, 2007; Addisu Mekonnen *et al*., 2010; Fashing *et al*., 2014). Social activity such as allogrooming, playing, aggression and sexual activities of the study group was merged for the analysis as their proportion is < 1%. Minor activities such as drinking, defecation, looking to the observer, vocalization, and suckling as "other activities" were also merged, because the "other activities" accounted small proportion, < 1%. Seasonal variation in activity time, feeding behavior and movement pattern of geladas were evaluated in relation to weather data, diet composition, vegetation cover and food availability in the study area.

3.2.4. Feeding Ecology of Arsi gelada

During scan sampling, if the gelada was observed feeding, the species and food item consumed were reorded. Commonly known food plants were identified in the field using background knowledge of the researcher and using plant guide. The food items of geladas were recorded as tall graminoid leaves (≥10 cm), short graminoid leaves (<10 cm), graminoid seed, graminoid crowns/rhizomes, forb leaves, forb roots, forb tubers, forb flowers, unidentified graminoid, unidentified forbs, invertebrates or others (Dunbar, 1977a; Iwamoto, 1979; Iwamoto and Dunbar, 1983; Iwamoto,1993; Fashing *et al*., 2014). "Graminods" comprise grasses and sedge. "Graminoid corms" were the base from which leaves grow and sometimes consume in association with the rhizomes. "Rhizomes" were the creeping root stalks and "corms" of the swollen storage organs of graminoid. “Forbs” consisted of a wide variety of non-graminoid herbs (Fashing *et al.*, 2014). The unidentified species were collected for later identification in the National Herbarium, Addis Ababa University.

The frequency of each food item and species consumed by the Arsi geladas during the study was categorized following Fashing *et al*. (2014). The diets were categorized as “often” (regular part of annual diet), “sometimes” (regular part of diet seasonally or consumed at low to moderate levels throughout the year), “rare” (more than 5 feeding incidents per year though not a common food item), and “very rare” (less than 5 feeding incidents per year).

Diet compositions were evaluated by calculating the proportion of different food items and species consumed by geladas. The daily food items and type of species consumed by the focal group was summed up within each month to construct monthly proportion of food items and the species consumed. The monthly proportion of each food item and species consumed were calculated as the total number of monthly individual scans for each food item and the species divided by the total number of monthly scan records for all food items and species, respectively. Grand means of the monthly proportion of food items and species consumed were used to calculate the wet and dry seasons as well as the overall diet consumed during the entire study period.

To assess the dietary diversity, Shannon-Wiener diversity index, *H*’ for each month of the study was calculated (Krebs, 1999). High value of *H*’ (in richest biological community, *H*’ peak about 5.0) indicates greater level of diversity.

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

Where, H' is Shannon-Wiener diversity index, S = is total species, Pi = Percentage of that species out of the total, i = individual species, ln = natural logarism.

Dietary evenness on a monthly basis was calculated using the evenness index, J (Krebs, 1999).

$$J = H/\ln(S),$$

Where, J is the evenness of those species. Values for J can range from 0.0 to 1.0, with 1 indicating that an equal number of feeding record existed for each species in the diet (Krebs, 1999).

Food availability and the actual feeding of gelada in different months and seasons were compared in the study habitat using the phenological assessment, measure of above ground biomass, vegetation cover and dietary data. Rough “selection ratios” for above ground food items including a) tall graminoids, b) short graminoids, and c) forb parts were determined by dividing percentage contribution to the annual diet contribution to vegetation cover for each of the three food item groups (Fashing *et al.,* 2014).

Diet selection of Arsi geladas was determined by dividing the total consumption of a food species by the total number of records of all species consumed by the geladas during the entiyer study perod.

3.2.5 Ranging Behavior and Habitat use of Arsi geladas

During the time of each activity scan sample, the geographic center of the focal group and elevation were recorded using hand held Garmin GPSMap 62s Global Positioning System (GPS) units at 30 minute intervals for full-day follow up (Fashing, 2001; Addisu Mekonnen *et al*., 2017). GPS locations of the study group were recorded even when the geladas were at stationary (at rest) for prolonged time. Complete day follow was used for the analyses of day range length and home range pattern of Arsi geladas. GPS location records were used to assess the group's home range size and day path lengths. A total of 3633 GPS location points were recorded in 160 observation days in16 months for the focal group during the entire study period.

A combination of ArcGIS10.4.0 (ESRI, 2011) and Home Range Tools (HRT) version 2.0 (Rodgers *et al*., 2015) and R (R Development Core Team, 2015) were used to generate home range size and day path lengths of the focal group following Addisu Mekonnen *et al*. (2017). Home range use of geladas at Goro-Jena was estimated using all GPS locations recorded using Home Range Tools (HRT) in ArcGIS10.4.0. Home-range was estimated using the MCP (Mohr, 1947) and 95% fixed Kernel Density Estimate and 50% KDE core area (Worton, 1989; Addisu Mekonnen *et al*., 20017). Fixed Kernel Density Estimation (KDE) was used to measure utilization distribution (UD) within the home range by providing a probability density function (Silverman, 1986) that corresponds to an animal's utilization distribution (Worton, 1989; Seaman and Powell, 1996). Algorithms determine both the distance between the Kernel and an evaluation point in the environment, and the contribution of the Kernel to the overall density estimate at a location. Of the numerous bandwidth methods available, *An ad hoc* bandwidth estimator was used, which minimizes over-smoothing of the reference bandwidth (h_{ref}), that performs better for clumped GPS locations (Kie *et al*., 2010). In the current study, home range was defined as *ad hoc* fixed KDE with 95% isopleths (contour lines) and "core area" with 50% isopleths. "Core area" is defined as the small area in the home range where the focal group utilized more frequently (Samuel *et al.*, 1985). Further, Minimum Convex Polygon (MCP) (Harris *et al*., 1990) method was also used for the purpose of comparison from earlier studies. MCP (90%, 95%, and 100% MCPs) was calculated using fixed mean points (Rodgers *et al*., 2015; Addisu Mekonnen *et al*., 2017).

Daily path lengths for the focal group was determined based on the shortest linear distance between consecutive GPS location records from full-day follows. To estimate daily path lengths, the consecutive GPS locations of the study group were converted to point shapefile and measured in ArcGIS10.4 following Addisu Mekonnen *et al.* (2017).

The influence of patch area effects was assessed in the home range of geladas. A shape index (perimeter-to-area ratio) of 95% KDE was calculated by dividing its perimeter (m) by the square root of home range size (m^2) multiplied by π. Shape index values usually vary from 1 (more circular) to >5 (more elongated and irregular) (Forman and Godron, 1986). A shape index value indicates the patch area exposed to the edge (Helzer and Jelinski, 1999). Home-range use (ha), daily path length (km) and seasonal range (ha) of the study group were summarized.

Habitat use: During each scan sampling at 30-minute intervals GPS locations and corresponding habitat type were recorded. Habitat use of geladas was determined using both encounter rate of the group scan samples at each habitat types and the spatial analyses using ArcGIS 10.4.0. Data on habitat use were recorded as the habitat type in which most members of the study group were observed during each scan sample of activity records (Vié *et al*., 2001; Dereje Tesfaye *et al*., 2013). Habitat types in the home range were divided into three categories: open grassland, escarpment/cliff and cultivated land based on vegetation cover and land feature. Open grassland is a grazing land covered by short graminoids and forbs exploited by livestock. The cliff is rich in tall grasses, scattered trees and shrubs/bushes. Patchy forest gorge is located at the bottom of cliff bed along the seasonal rivers covered by fragmented forest and broad leaved trees. Cultivated lands are open areas with intensive crop cultivation of cereals by the local farmers. Encounter rates of group scan sample records and 95% KDE were calculated for comparative purpose of habitat use frequency of geladas.

Habitat use patterns of the focal group were analyzed by calculating proportion of group scans that the group spent in each habitat (Wallace, 2006). The percentage of habitat use frequency of the focal group was determined by dividing the total scan records of the focal group at each habitat types by the total scan sample records of the group in all habitats during the entire study. Habitat selection ratios were calculated from the 95% KDE home range of the study group by dividing the frequency of observed use (% of scans in each habitat type) by the frequency of expected use (% of home range area accounted for by each habitat type) (Manly *et al*., 2002; Addisu Mekonnen *et al*, 2017). To obtain the frequency of expected use, the habitat types within each home range were classified using high-resolution Google Earth images of the study area in ArcGIS 10.4.0 (Kelley, 2013) and the ground truth with the GPS and habitat type data collected during group follow up. A habitat selection ratio close to 1 indicates no selectivity for that habitat, < 1 indicates a habitat is avoided and > 1 indicates the habitat is selected.

Statistical Analysis:

All statistical tests were analyzed using SPSS version 20 (IBM, North Castle, NY, USA) was used to run the analysis. Data were tested for normality using the Shapiro -Wilk test and homogeneity of variances using the Levene test (P > 0.05). Independent t-test and ANOVA were used for parametric test. Monthly and seasonal green level of graminoids and grass biomass were tested using non-parametric test, Kruskal Wallis H and Mann-Whitney U tests, respectively. Group size and age-sex composition of Arsi geladas were compared using Kruskal-Wallis H test. Mean group size of geladas was compared during the two census periods using Mann-Whitney U test. Mann-Whitney U test was used to examine the age-sex composition of gelada at each census site between the wet and dry season surveys. Mann-Whitney U test and Kruskal-Wallis H test were used to test differences in activity budgets of geladas between seasons and across months, respectively. Spearman correlation was used to test the relationship between monthly rainfall in 60 and 30 previous days of rainy months and percentage of feeding records by the study group (Hunter, 2001; Fashing *et al*., 2014). Linear Correlation was used to test the association between activity budget and monthly food availability (Marsh, 1981). The mean monthly day path length of the focal group was compared across months using Kruskal-Wallis H-test, and seasonal home range size of the study group was compared using Mann-Whitney U test. Habitat use frequency of the focal group was tested using Kruskal-Wallis H-test, Mann-Whitney U test and t-test. Spearman Correlation was used to test the association between the day range length and weather condition (rainfall and temperature). Percentage composition of species and food items consumed by the study group were compared between seasons using Mann-Whitney U test and across months using Kruskal Wallis test.

4. RESULTS

4.1 Vegetation composition

All the edible plant species identified in Goro-Jena study habitats were listed as in the following forms: graminoids (42.19%), forbs (20.31%), trees (14.06%), bushes/shrubs (15.63 %), cereals (6.25%) and liana (1.56%) in each plant category (Appendex 1). However, not all edible plants were consumed by the geladas. The plant compositions of all edible plants in the home range affected the percentage of food plants consumed.

Green graminoid production across months had a mean weight of 197.4 g/m^2 ±110.8 (range 62.4 – 433 g/m^2, n = 100) with the minimum in May 2015 and maximum in October 2014. Monthly dry weight of green grass had a mean weight of 98.8 g/m^2 ±47.71 g/m^2 (range 44.6 – 172.5 g/m^2) with the lowest in May 2015 and maximum in December 2014. The monthly water moisture of green graminoid had a mean weight of 98.6 g/m^2 ±83.94 (range 7.8 - 275 g/m^2) with the lowest in May 2015 and maximum in October 2015. Net production increased as the accumulation and growth until the end of the wet season in precipitation. The mean monthly percentage weight of water moisture was 43.69% ±20.2 (range 20.77 - 71.84 %) from the green graminoid with the highest in August and the lowest in March 2015. The mean percentage dry weight of graminoids has 56.32% ±20.2 (range 28.16 - 79.23%), the lowest in August 2014 and the highest in March 2015 (Table 3). The moisture lost and dry matter remained highest in March. Mann-Whitney *U* test, ($P < 0.05$) showed a significant difference between green grass weight (wet weight) and dry weight of the above ground forage. Pearson Correlation test showed the wet weight of grass biomass was positively correlated between dry weight ($r_p = 0.71$, $P = 0.01$) and water moisture ($r_p = 0.92$, $P < 0.001$) in monthly measurement of grass biomass.

Table 3. Net production of graminoid from the cliff habitat of gelada home range at Goro-Jena (n =100 grass plots).

Months	Graminoid (w.w. g/m^2)	Graminoid (d.w.g/m^2)	Moisture (g/m^2)	% Moisture (g/m^2)	% Dry weight (g/m^2)
Jul. 2014	227.50	66.30	161.3	70.90	29.14
Aug.2014	209.50	59.00	150.5	71.84	28.16
Set. 2014	252.30	81.70	170.5	67.58	32.38
Oct.2014	433.00	157.2	275.8	63.70	36.30
Nov.2014	318.70	154.2	164.5	51.62	48.38
Dec.2014	262.50	172.5	90.00	34.29	65.71
Jan. 2015	165.30	128.3	37.00	22.38	77.62
Feb. 2015	175.30	137.5	37.80	21.56	78.44
Mar.2015	104.00	82.40	21.60	20.77	79.23
Apr.2015	88.40	57.30	31.20	35.29	64.82
May.2015	62.40	44.60	7.80	28.53	71.47
Jun. 2015	70.10	45.00	25.10	35.81	64.19
Mean	197.4±110.81	98.8±47.71	97.8±84.86	43.7±20.2	56.3±20.2

The above ground green graminoid biomass was highest during the wet season (238 g/m^2) compared to the dry season (168.09 g/m^2). The dry weight of grass biomass was highest (110.97 g/m^2) during the dry season compared to the wet season (81.84 g/m^2). The measure of water moisture of the above ground forage of geladas was highest (156.64 g/m^2) during the wet season compared to the dry season (57.13 g/m^2) (Table 4). The mean percentage of water moisture was the highest (61.97%) during the wet season, and lowest (30.63%) during the dry season. The mean percentage dry weight was the highest (69.38%) during the dry season, and lowest (38.03%) during the wet season (Table 4). Pearson Correlation analysis indicated a strong significant correlation between wet weight and dry weight of grass ($r_p = 0.947$, $p = 0.015$) during the wet season and ($r_p = 0.912$, $P < 0.05$) during the dry season.

Table 4. Seasonal difference of above-ground biomass in home range of geladas (n = 100 plots)

Seasons	Green wt. (g/m^2)	Dry wt. (g/m^2)	Moisture	% Moisture	%(dry wt.g/m^2)
Wet	238.48	81.84	156.64	61.97	38.03
Dry	168.09	110.97	57.13	30.63	69.38

Green weight g/m^2 *= above grond green grass weight, Dry weight* g/m^2 *= above ground dry grass weight*

Graminoids accounted for higher ground cover than forbs in the study habitat. Four plant species were found in the highest percentage in grass plots (*Hyparrhenia rufa*: 42%, *Pennisetum thunbergii:* 31.2%, *Andropogon chrysostachyus:* 26.8% and *Themeda triandra*: 26.8%). They also comprised the highest percentage ground cover (*Hyparrhenia rufa*: 12.98%, *Andropogon chrysostachyus:* 11.41%, *Hyparrhenia sp*.: 10.69%, *Pennisetum thunbergii*: 7.8%, and *Themeda triandra*: 7.4%). However, there were some plant species that occupied large percentage (≥ 15%) of plots but a very small percentage (≤ 4%) ground cover, including some forb taxa that provided food for Arsi gelada (e.g. *Falkia oblonga:* 3.34%, *Dyschoriste radicans:* 2.56% and unidentified forb: 3.53%). Some graminoid species were also found at high percentage of plots but lower percentage (e.g. *Themeda triandra:* 7.4%, *Eleusine floccifolia:* 6.54% and *Pennisetum sp.:* 5.27%) of ground cover. Bare land (rock and soil) also accounted for 28.8% of the plots (Table 5). Overall, short graminoid accounted 40 % of ground cover in the vegetation assessment plots, which is equivalent to the tall graminoid that accounted for 39.8% ground cover. Forbs of gelada food represented 9.3% of the ground cover. Bare soil and rock represented about 3.9 % and 3.2% of the ground cover, respectively. Shrub comprised 2.9 % of the ground cover. Sedge accounted for very small (1.5%) cover of the sample plot (Table 5).

Table 5. Percentage of ground cover accounted by different plant species surveyed (0.5 m x 0.5 m; n = 205 plots).

Local name SW	Family	Species	Total Plots	Total cover	% Cover	Mean cover	% plots (n=205)
Mata	Poaceae	*Hyparrhenia rufa*	86	26.6	12.98	0.31	42.0
Godir merga	Poaceae	*Andropogon chrysostachyus*	55	23.4	11.41	0.44	26.8
Jeldo merga	Poaceae	*Festuca sp.*	43	21.91	10.69	0.51	21.0
Sendedo	Poaceae	*Pennisetum thunbergii*	64	16	7.80	0.25	31.2
Gersa merga	Poaceae	*Themeda triandra*	55	15.18	7.40	0.28	26.8
Acrma merga	Poaceae	*Eleusine floccifolia*	26	13.4	6.54	0.52	12.7
Soft kecha	Poaceae	*Pennisetum squarnulaturn*	29	10.8	5.27	0.38	14.1
Tall kecha	Poaceae	*Pennisetum sp.*	17	8.05	3.93	0.52	8.3
Bare rock	-	Bare rock	18	8	3.90	0.46	8.8
Bare soil	-	Bare soil	59	6.5	3.17	0.13	28.8
Unidentified forb	-	Unidentified	53	7.24	3.53	0.14	25.9
Herb1	Convolvulaceae	*Falkia oblonga*	42	6.85	3.34	0.16	20.5
Batula merga	Poaceae	*Digitaria abyssinica*	25	6.9	3.37	0.28	12.2
Shrub	Fabaceae	*Rhynchosia albissima*	16	5.95	2.90	0.37	7.8
Senbelet balemi	Poaceae	*Bothriochloa insculpta*	22	5.45	2.66	0.25	10.7
Herb10	Acanthaceae	*Dyschoriste radicans*	32	5.25	2.56	0.16	15.6
Unknown merga	Poaceae	Unidentified	15	4.48	2.19	0.28	7.3
Yewof sar	Poaceae	*Melinis repens*	25	3.06	1.49	0.15	12.2

Cypress	Sedge	*Cypress spp.*	22	3.15	1.54	0.14	10.7
Chincha merga	Poaceae	*Hyparrhenia anthistirioides*	11	2.7	1.32	0.25	5.4
Large mata	Poaceae	*Hyparrhenia spp.*	9	2.5	1.22	0.28	4.4
Samigrass	Poaceae	*Bothriochloa insculpta*	10	1.27	0.62	0.13	4.9
Ketisa	Poaceae	*Cynodon dactylon*	4	0.9	0.44	0.23	2.0
Chekorsa	Poaceae	*Pennisetum villosurn*	1	0.3	0.15	0.3	0.5
Tefsar	Poaceae	*Eragrostis tenuifolia*	2	0.3	0.15	0.15	1.0
Horse tail grass	Poaceae	*Aristida adoensis*	3	0.25	0.12	0.08	1.5
Thread herb root	Iridaceae	*Moraea stricta Baker*	1	0.2	0.10	0.2	0.5
Asendabo	Poaceae	*Phalaris paradoxa*	1	0.1	0.05	0.1	0.5
Ketisa like	Poaceae	Unidentified	1	0.1	0.05	0.1	0.5
Murie sar	Poaceae	*Sporobolous natalensis*	1	0.05	0.02	0.05	0.5
Black seed grass	Poaceae	*Eragrostis botryodes*	1	0.05	0.02	0.05	0.5

In grass phenological assessment, the largest number (81.93%) and (78.05%) of green grass (GG) plots were observed during September and October, respectively. The highest numbers of plots (63.38%) and (62.26%) were covered by mixed green grass (MGG) during August and December, respectively. The highest percentage of brown grass plot (BGP) (66.67%) was recorded from May to June 2015, followed by February (62.5%). Dry grass plot (DGP) was recorded from March to April 2015 with a peak (76%) in March. There were no brown and dry grasses during September and October. Green grass accounted for 19.74%, MGG = 27.72%, BG = 34.59% and DG = 17.94% during the entire study period (Table 6).

Table 6. Grass phenological assessment in the home range of gelada at Goro-Jena (**GGP** = green grass plot, **MGG** = mixed green grass plot, **BG** = brown grass plot, **DG** = dry grass plot).

Months	**GG (%)**	**MGG (%)**	**BG (%)**	**DG (%)**
Jun.14	19.05	14.29	47.62	19.05
Jul.14	-	0.40	48.89	11.11
Aug.14	33.80	63.38	2.82	-
Sep.14	81.93	18.07	-	-
Oct.14	78.05	21.95	-	-
Nov.14	36.92	50.77	9.23	3.08
Dec.14	-	62.26	33.96	3.77
Jan.15	-	36.59	43.90	19.51
Feb.15	-	-	62.50	37.50
Mar.15	-	-	24.00	76.00
Apr.15	-	-	58.06	41.94
May.15	-	15.38	66.67	17.95
Jun.15	-	15.38	66.67	17.95
Jul. 15	26.67	0.50	0.2	3.33
%	19.74	27.72	34.59	17.94

The mean percentage of green grass cover across all plots correlates most strongly with the rainfall patterns. The greenness of grasses was significantly positively correlated with the monthly rainfall of the preceding month/months ($r_p = 0.768$, $P < 0.05$). Rainfall was weakly positively correlated with mixed green grass ($r_p = 0.463$, $P = 0.096$), but negative with brown grass (BG) ($r_p = – 0.556$, $P < 0.05$) and dry grass ($r_p = – 0.868$, $P < 0.05$). There was a significant correlation between the green cover and monthly rainfall of the preceding month (Fig. 4). The levels of green grass cover on open plateau top appeared more quickly than the grass cover at cliff face during a rainfall, but desiccated sooner than grasses in the cliff face.

The phenophase pattern of graminoid indicates that the level of greenness of grass plots (GG) increased during September - October with a peak in September. However, there were no plots with green grass from December 2014 – June 2015 and July 2014. The MGG was peak in August. There was no MGG observed from February – April. The brown grass was peak from May - June 2015 followed by February 2015. There was no brown and dry graminoids during the wet season (September – October). The number of dry grass plot increased from January-April 2015 with a peak in March 2015. The green and brown phenophase pattern was highly associated with rainfall (Fig. 4). The green graminoid availability of geladas was high from August to November with the highest in September and October during the present study period.

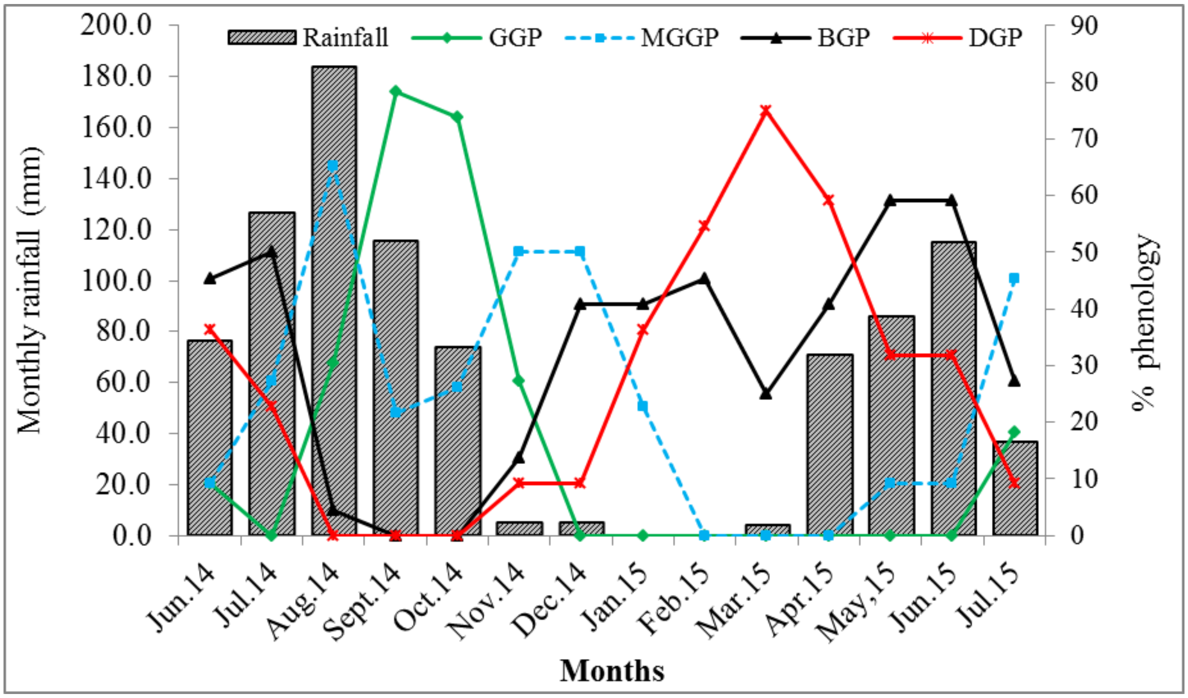

Figure 4. Relationship between rainfall and level of greenness and phenology pattern in gelada home range (**GG** = green grass, **MGG** = mixed green grass, **BG** = brown grass, **DG** = dry grass).

The average green grass plot (GG) was the highest (29.98%) followed by MGG (29.14%). Dry grass plot (DG) was the lowest which accounted for 14.29% during the wet season. Dry season comprised the highest percentage of DG (39.29%) followed by BGP (37.99%). The average percentage of BG and DG was equivalent during the dry season which comprised 38% and 39.3%, respectively (Fig. 5). Mann-Whitney U test, showed that there was no significant differences of greeness of grass during the wet and dry seasons (P = 0.773).

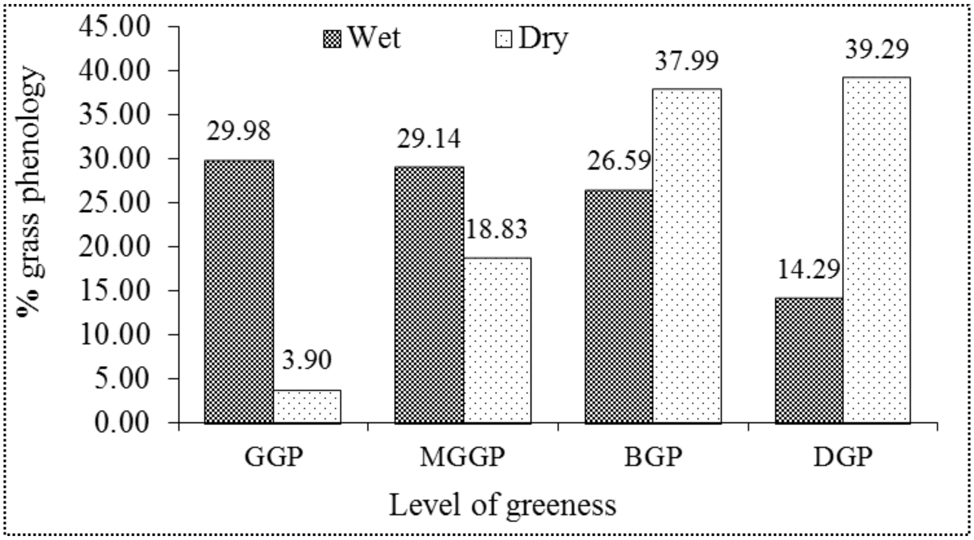

Figure 5. Percentage of grass phenology during the wet and dry seasons (**GG** = green grass plot, **MGG** = mixed green grass plot, **BG** = brown grass plot, **DG** = dry grass plot).

Overall, at least five tree species (*Rhus glutinosa* 10 trees, *Carissa spinarum* 10 trees, *Ficus vasta* 6 trees, *Opuntia ficus-indica* 10 shrubs/bushes and *Ficus thonningii* 1 tree) were food sources for Arsi geladas in addition to their dominant food items (graminoids). Flower and fruit production showed a sequential pattern (Fig. 6). Arsi geladas consumed fruits at different time of a year. Percentage of fruit was higher during the drier months (November to March) in a mean of 13.48%±6.13 and maximum productions from November to January with a peak (24.3%) in December (Table 7). *Rhus glutinosa* increases their fruit production from November to February 2015 with a mean of 18.9%±23.89 and a peak (60.00 %) in December. Agamsa fruit production increased from August to February 2015 with a mean of 12.79%±15.34 and maximum production (40%) in November. The phenological assessment of *Ficus vasta* showed a mean 8.58%±11.69 fruit production with the highest during late dry season to early wet season. *Opuntia ficus-indica* succulent leave production was observed in all seasons with fruit production during late dry season, similar to *Ficus vasta*. In all vegetation assessments, mature leaves had the highest production (62.66 % ± 4.15) than young leaves (23.86 % ± 3.77) during the entire study. Fruit production accounted for 13.48% ± 6.13 (Table 8).

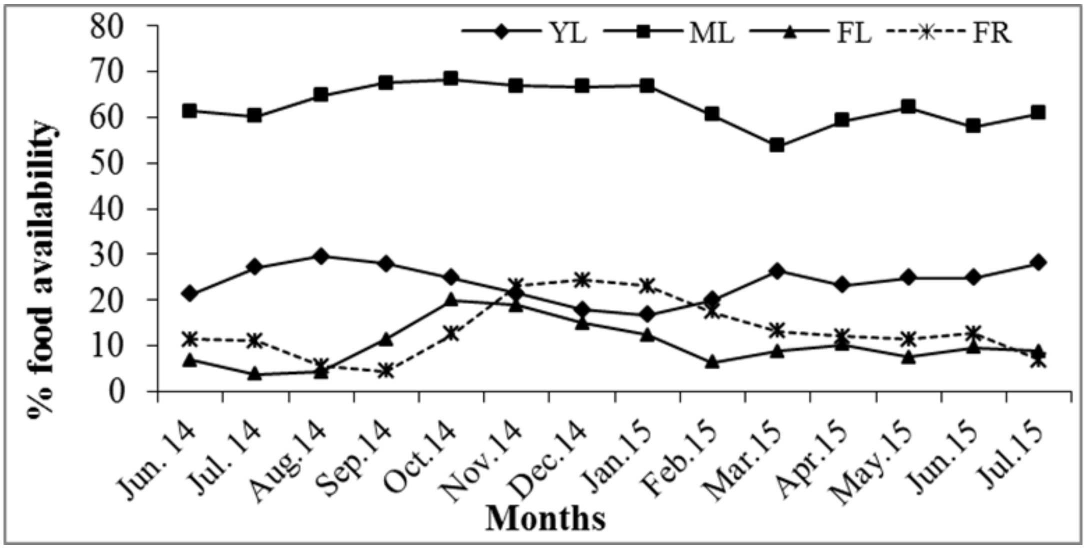

Figure 6. Differences in monthly food availability of Arsi gelada in their home range at Goro-Jena (YL = young leaf, ML = mature leaf, FL = flower, FR = fruit).

Table 7. Food availability of trees and bush in gelada habitats in Goro-Jena (YL = young leaf, ML = mature leaf, FL = flower, FR = fruit).

Months	YL	ML	FL	FR
Jun. 2014	21.3	61.3	6.8	11.3
Jul. 2014	27.1	60.2	3.8	11.0
Aug.2014	29.6	64.8	4.3	5.6
Sep.2014	27.9	67.5	11.3	4.4
Oct.2014	24.8	68.3	20.0	12.5
Nov.2014	21.5	66.9	18.9	23.1
Dec.2014	17.9	66.8	15.0	24.3
Jan.2015	16.8	66.9	12.4	23.1
Feb.2015	20.0	60.6	6.3	17.4
Mar.2015	26.3	53.8	8.8	13.1
Apr.2015	23.2	59.2	10.2	12.1
May.2015	24.8	62.1	7.5	11.3
Jun.2015	24.8	58.0	9.6	12.7
Jul.2015	28.1	60.8	8.8	6.8
Mean	23.86	62.66	10.26	13.48

The leaf and fruit consumptions of Arsi geladas was increased when increasing their availability. Though tree and shrub leaf availability was highest during the wet season, the consumption of the food items by the geladas was increased during the dry season. Fruit consumption of Arsi geladas was highest from December to March with a peak in December when the availability was higher (Fig.7). However, leaf consumption was very less with slight increase during mid-dry season. Linear Correlation test (YL, Pearson, r_p = -**0.** 931, P<0.001), and (Fruit, $r_{P =}$ - 0.708, P < 0.001) showed that a negative relationship between leaf availablity and consumption.

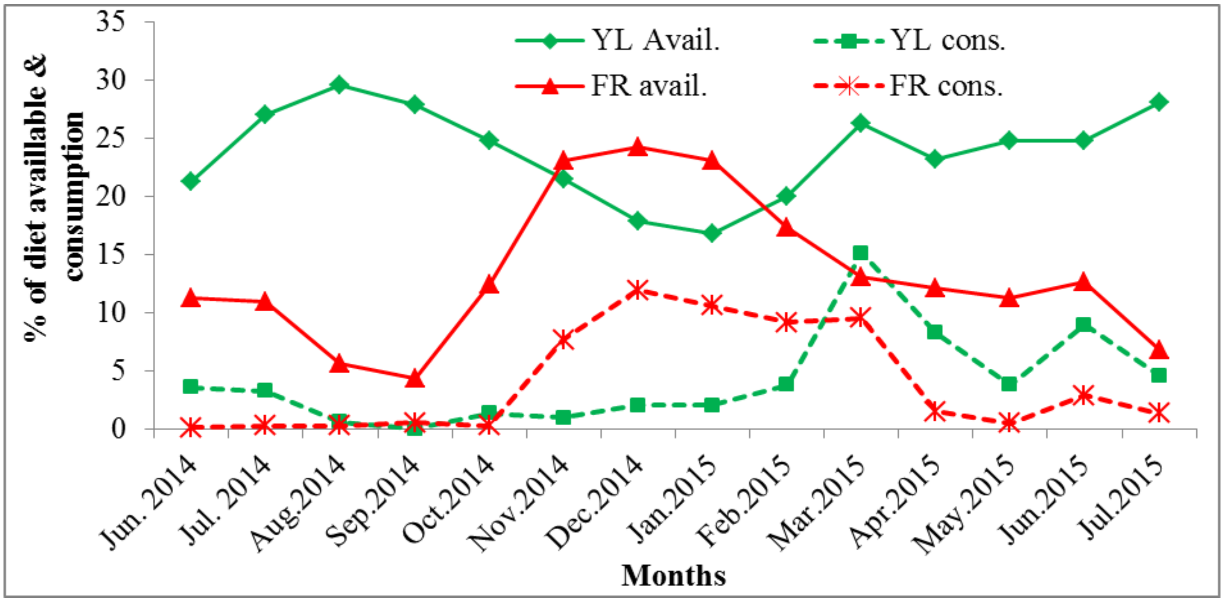

Figure 7. Tree leaf and fruit availabilities and consumption of geladas in Goro-Jena

4.2 Distribution pattern and population size

Arsi geladas were observed at three of the four District survey. Local people reported the existence of Arsi gelada at localities where their presence was not confirmed before. On average, 82 groups with a mean of 1315 ±11.3 indiviual geladas were recorded from different sites in the three neighboring Districts: Arsi Robe, Amigna and Bele. However, no geladas were observed in Seru District. Arsi geladas inhabited mainly cliffs and open plain at elevation range from 1800 - 2430 m asl.

Arsi geladas were distributed in different localities in eastern Arsi. Geladas were observed patchily distributed with more concentration along Robe River and Wabi Shebelle River gorges and cliffs (Fig. 8). They occupied different localities adjacent to the two river cliffs and gorges including Indetu (includes Sibe, Kako, Weltey and Kelisadenbel), Atucha, Goro-Jena and Ademitu in Arsi Robe District; Temamma, Soti and Gujo in Amigna and Kirbign and Arole in Bele District. The highest distribution was observed in Arsi Robe district compared to others. Geladas have limited distribution in Bele District (Fig. 8). Most of the gelada sites are human dominated landscapes.

In the present study, the distribution of Arsi gelada is concentrated at three ranges (subpopulations): the first subpopulation was concentrated at Indetu and the surrounding localities along with Wabi-Shebelli and Robe River cliffs. The second subpopulation (the largest density) was found at Ademitu, Amigna, Goro-Jena and Atucha areas, northwest of the Indetu population along both sides of the Robe River cliff. The third subpopulation (the smallest size) was found at Kirbign and Arole in Bele, north of Indetu in the opposite side of Robe River cliff (Fig. 8). It is believed that the three subpopulations are most probably isolated each other due to physical barriers including human settlements, intensive cultivation, big gorges and cliffs.

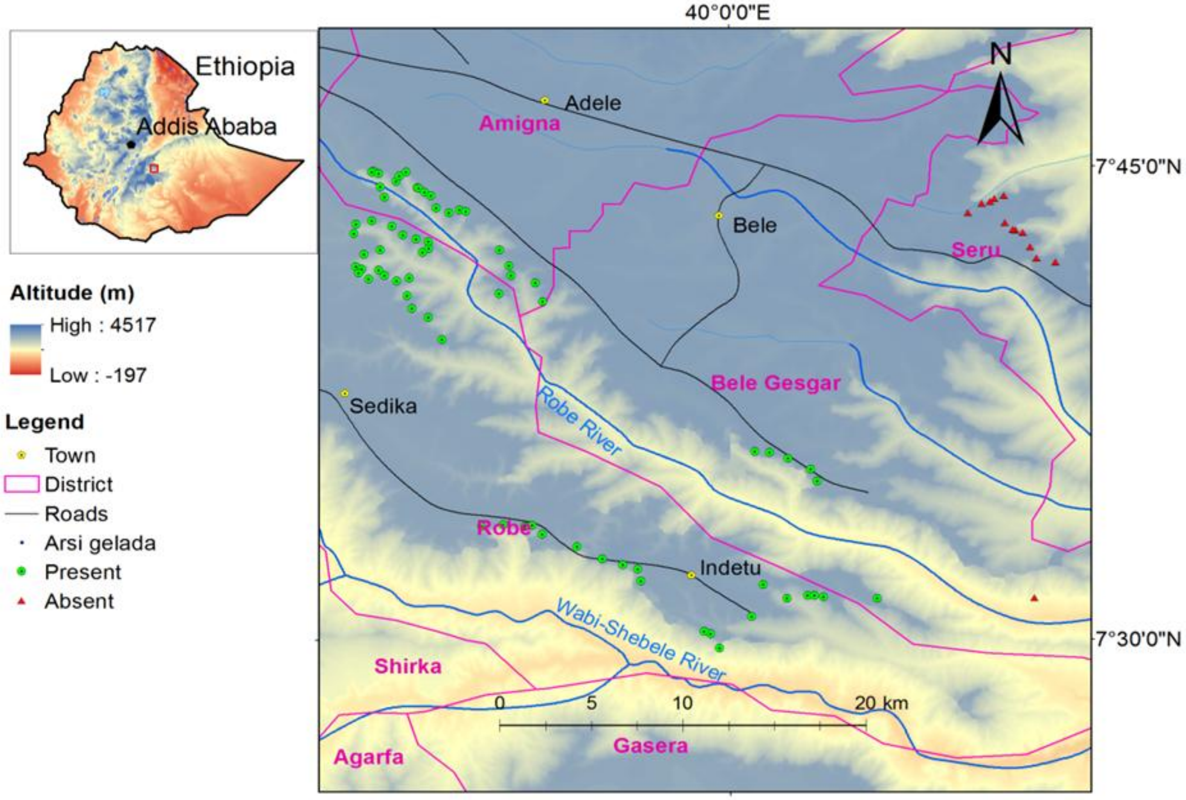

Figure 8**.** Map of the current distribution of Arsi geladas in historic and new gelada sites in three districts in eastern Arsi, Ethiopia.

In the present study, geladas were counted in eleven localities from three Districts including both in historic areas: Indetu, Goro-Jena, Ademitu and Temamma localities and new geladas sites in Gujo, Soti, Atucha localities and Kirbign and Arole in Bele districts (Table 8).

The highest mean population size 912 (69.56%) of geladas was recorded from Arsi Robe district in different localities: Indetu 379 (41.56%), Ademitu 217 (23.79%), Goro-Jena 195 (21.38%) and Atucha 122 (13.38%). The second highest mean number 280 (21.29%) of geladas were recorded from Amigna district in different localities namely Temamma 95 (33.93%), Soti 128 (45.71%) and Gujo 57 (20.36%) areas. The lowest mean population size 123 (9.35%) of geladas was recorded in Bele district from two localities namely Kirbign 91 (73.98%) and Arole 32 (26.02%) (Table 8).

Table 8. Distribution and age-sex composition of Arsi gelada during the two censuses (I and II) (ADM = adult male, ADF = adult female, SAD = subadult, Juv = juveniles, Inf. = infant).

Districts	Census Sites	Census section	Groups	ADM	ADF	SAD	JUV.	INF.	Total
Robe	Indetu	I	28	61	167	18	68	59	373
		II	21	56	151	46	61	70	384
		Mean	24.5	58.5	159	32	64.5	64.5	379
	Atucha	I	8	18	39	3	18	24	102
		II	8	10	64	5	32	31	142
		Mean	8	14	51.5	4	25	27.5	122
	Goro-Jena	I	10	22	94	9	43	25	193
		II	6	17	82	15	33	49	196
		Mean	8	19.5	88	12	38	37	195
	Ademitu	I	18	33	97	7	44	48	229
		II	11	19	88	13	38	47	205
		Mean	14.5	26	92.5	10	41	47.5	217
	Mean total		55	118	391	58	168.5	176.5	912
Amigna	Temamma	I	9	13	49		24	28	114
		II	5	6	36	1	10	23	76
		Mean	7	9.5	42.5	1	17	25.5	95
	Soti	I	10	14	65	5	20	29	133
		II	8	14	59	7	17	26	123
		Mean	9	14	62	6	18.5	27.5	128
	Gujo	I	4	5	29	3	10	10	57
		II	4	5	29	3	10	10	57
		Mean	4	5	29	3	10	10	57
	Mean total		20	28.5	133.5	10	45.5	63	280
Bele	Kirbign	I	5	8	34	2	20	23	87
		II	5	13	39	4	17	22	95
		Mean	5	10.5	36.5	3	18.5	22.5	91
	Arole	I	2	3	12	6	6	8	35
		II	2	4	15	3	3	4	29
		Mean	2	3.5	13.5	4.5	4.5	6	32
	Mean total		7	14	50	7.5	23	28.5	123
	Grand total		82	160.5	574.5	75.5	238	267	1315

The largest distance was traversed (36 km) in Indetu from a total of 124 km traveled in the entire survey area, and the shortest was in Arole (4 km) during the census. The largest census area (72 km^2) was covered at Indetu and the lowest in Arole (8 km^2). The highest gelada groups (25 groups) were recorded in Indetu and the lowest in Arole, Bele (2 groups). No gelada was observed in Seru district (Table 9).

Table 9. Gelada census using grid cells at ten different sites during the study period.

Census Sites	Grids (2 x 2 km)	Total Census	Distance walked (km)	Total groups	Area surveyed (km^2)
Indetu	18	2	36	25	72
Atucha	7	2	14	8	28
Goro-Jena	4	2	8	8	16
Ademitu	7	2	14	14.5	28
Temamma	3	2	6	7	12
Soti	4	2	8	9	16
Gujo	4	2	8	4	16
Kirbign	5	2	10	5	20
Arole	2	2	4	2	8
Seru	8	2	16	0	32
Total	62	-	124	82.5	248

Poupation size of geladas in the different age-sex groups and across the census sites during different time periods are listed in Tables 10 and 11. A total of 1323 individuals of geladas were counted from all ten sites during the dry season census. The highest number 897 (67.8 %) of geladas was recorded in Arsi Robe District. Indetu comprised the highest number 373 (28.19 %) of geladas. The lowest number 35 (2.65 %) of geladas was record in Arole from a total number 122 (9.22%) of gelada population recorded in Bele district. No geladas were observed in Seru during this census period (Table 10). Adult females was the highest number, 586 (44.29%) of the population. Immature was accounted for 507 (38.32%) of the total population during the first census.

Table 10. Count and age-sex composition of geladas in ten sites during the dry season census (ADM = adult male, ADF = adult female, SAD = subadult, Juv. = juveniles, Inf. = infant, Immat. = immature).

Census Sites	Groups	Total group size	ADM	ADF	SAD	JUV.	INF.	Immat.	Percent (%)
Indetu	28	373	60	167	19	68	59	127	28.2
Atucha	8	102	18	39	3	18	24	42	7.7
Goro-Jena	10	193	22	94	9	43	25	68	14.6
Ademitu	18	229	33	97	7	44	48	92	17.3
Temamma	7	114	13	49	-	24	28	52	8.6
Soti	9	133	14	65	5	20	29	49	10.1
Gujo	4	57	5	29	3	10	10	20	4.3
Kirbign	5	87	8	34	2	20	23	43	6.6
Arole	2	35	3	12	6	6	8	14	2.7
Seru	0	-	-	-	-	-	-	-	-
Total	91	1323	176	586	54	253	254	507	100.0

A total of 1307 geladas were recorded from all sites during the wet season census. The highest number 927 (70.01 %) of geladas was recorded in Arsi Robe District. Indetu comprised the highest number 384 (29.4%) of geladas. The lowest number 29 (2.2%) was recorded in Arole from Bele District (Tables 11). The highest number 563 (43.01) was comprised of adult females, and immature was ranked second 503 (38.49%) of the total population during the second census (Table 11).

Table 11. Group size and age-sex composition of geladas in different sites during the wet season **(**ADM = adult male, ADF = adult female, SAD = subadult, Juv = juveniles, Inf. = infant, Immat = immature).

Census Sites	Groups	Total group size	ADM	ADF	SAD	JUV.	INF.	Immat.	Percent (%)
Indetu	21	384	56	151	46	61	70	131	29.4
Atucha	9	142	10	64	5	32	31	63	10.9
Goro-Jena	6	196	17	82	15	33	49	82	15.0
Ademitu	11	205	19	88	13	38	47	85	15.7
Temamma	5	76	6	36	1	10	23	33	5.8
Soti	8	123	14	59	7	17	26	43	9.4
Gujo	4	57	5	29	3	10	10	20	4.4
Kirbign	5	95	13	39	4	17	22	39	7.3
Arole	2	29	4	15	3	3	4	7	2.2
Seru	0	-	-	-	-	-	-	-	-
Total	71	1307	144	563	97	221	282	503	100.0

On average, 1315 ±11.3 geladas were counted from all census sites in three neighboring Districts in eastern Arsi. During each census, fluctuations of geladas were recorded in each counting grid. From the distribution patterns of Arsi geladas, on average, adult females comprised the largest number 574.5 (43.67%), followed by immature 505 (38.4%). However, subadult males comprised the lowest 75.5 (5.74%) population (Table 12). Mann –Whitney U test shows no significant difference in age groups of geladas during the two census (U = 12, Z = - 0.104, P = 0.917).

Table 12. Mean group size and age-sex composition of geladas during the wet and dry seasons (ADM = adult male, ADF = adult female, SAD = sub-adult, Juv = juveniles, Inf. = infant, Immat = immature).

Surveys	Groups	Group size	ADM	ADF	SAD	JUV.	INF.	Immat.
Dry season	91	1323	176	586	54	253	254	507
Wet season	71	1307	144	563	97	221	282	503
Mean	81	1315	160	574.5	75.5	237	268	505
Mean %			12.17	43.69	5.74	18.02	20.38	38.4

In the present study, population size of geladas indicated slight but insignificant fluctuations during the census. The largest mean population size (mean = 379, SD ±7.8) of Arsi geladas were recorded in Indetu site during the two censuses. Ademitu was the second rank which comprised a mean of 217, SD ±17 geladas. Arole was the lowest (mean = 32, SD ± 4.2) with individuals in population size during the two censuses (Fig. 9). T-test showed a significant differences in mean population size of geladas at the different census sites during the surveys (t –*test* = 4.155, df = 8, P = 0.003, N = 9).

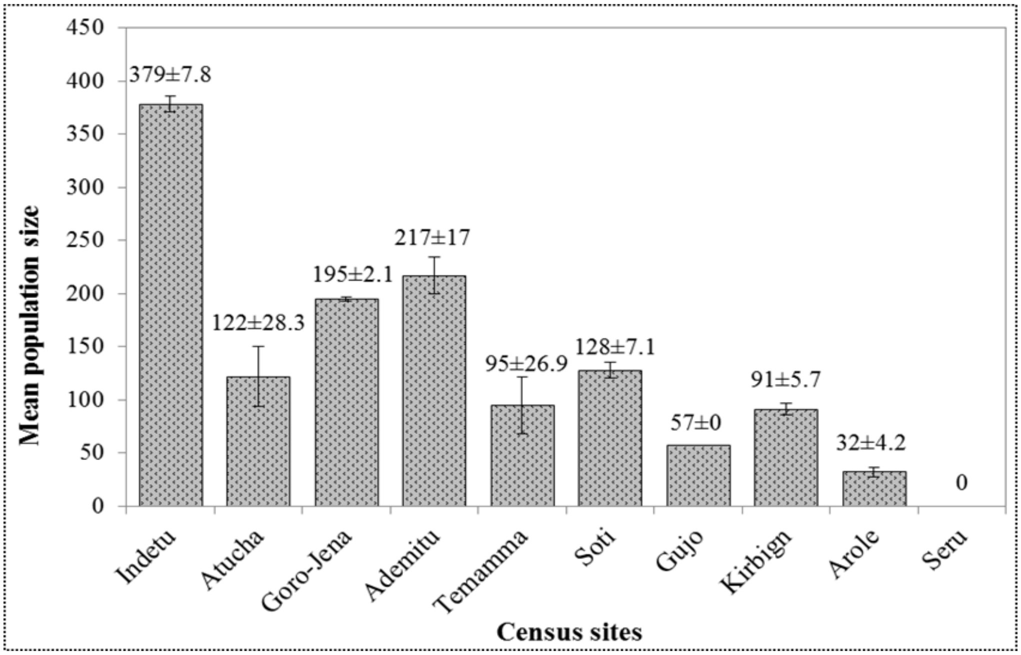

Figure 9. Population size of Arsi gelada in each survey sites during the study period.

The percentage of age-structure of Arsi geladas comprised 43.69% adult females, 18.02% juveniles, 20.38% infants, 12.17% adult males, and 5.74% subadults. Immature (infants + juveniles) individuals were composed of 38.4% of the total population (Table 14). There were a significant differences among the different age groups of Arsi geladas counted in the different sites of eastern Arsi (t-*test* = 3.105, df = 4, P < 0.036, N = 5).

Group composition by age-sex categories of Arsi geladas included 574.5 ±13.44 adult females, 160 ±22.63 adult males, 237±25.46 juveniles of both sexes, 268 ±22.63 infants of both sexes (Table 13). Mean number of adult females and juveniles comprised greater number during the first census of the dry season. In contrast, infants comprised greater number in the second census during the wet season. Mean number of subadults comprised the smallest in the population during the censuses.

Table 13. Percentage and mean age – sex structure of Arsi geladas during the two censuses.

Age-sex	Census I	Census II	Mean	%	SD
Adult females	586	563	574.5	43.69	13.44
Adult males	176	144	160	12.17	22.63
Subadult	54	97	75.5	5.74	27.58
Infant	254	282	268	20.38	22.63
Juvenile	253	221	237	18.02	25.46
Total	1323	1307	1315	100	11.31

The mean ratio of Arsi geladas from all census sites showed that mean ratio of adult males to adult females was 1:4.1 with the highest (1:5.8) in Gujo. The mean ratio of both sexes of immature (including both juveniles, infants) to adults was 1:1.5 with the highest (1:1.7) in Indetu and Gujo, while the ratio of infants of both sexes to adult females was 1:2.3 with the highest (1:2.9) (Table 14).

Table 14. Age-sex ratio of Arsi geladas from different sites during the wet and dry seasons **(**ADM = adult males, ADF = adult female, SAD = subadult, Juv = juveniles, Inf. = infant, Immat= immature).

Sites	AM:AF	IMM:AD	INF:AD	IMM:AF	INF: AF	JUV:AF	JUV:INF
Indetu	1:2.7	1:1.7	1:3.4	1:1.2	1:2.5	1:1.5	1:1
Atucha	1:3.7	1:1.3	1:2.4	1:1	1:1.9	1:2.1	1:1.1
Goro-Jena	1:4.5	1:1.4	1:2.9	1:1.2	1:2.4	1:2.3	1:1
Ademitu	1:3.6	1:1.3	1:2.5	1:1.1	1:2	1:2.3	1:1.2
Temamma	1:4.5	1:1.2	1:2	1:1	1:1.7	1:2.5	1:1.5
Soti	1:4.4	1:1.7	1:2.8	1:1.4	1:2.3	1:3.4	1:1.5
Gujo	1:5.8	1:1.7	1:3.4	1:1.5	1:2.9	1:2.9	1:1
Kirbign	1:3.5	1:1.2	1:2.1	1:0.9	1:1.6	1:2	1:1.2
Arole	1:3.9	1:1.6	1:2.8	1:1.3	1:2.3	1:3	1:1.3
Mean	1:4.1	1:1.5	1:2.7	1:1.6	1:2.3	1:2.5	1:1.2
SD	0.87	0.22	0.49	0.19	0.41	0.46	0.2

A total of 92 groups of geladas were recorded with an average group size (OMU) of 14.38 ± 9.4 animals (range 5 – 60 individuals) from all census sites during the first census (dry season), and 71 groups with an average group size (OMU) of 18.41±16.19 animals (range 2 - 115 individuals) during the second census (wet season). In group sightings, the group was composed of at least one-male unit which comprised at least one adult male, three adult females, juveniles, infants and subadults.

The highest mean group density (0.72, SD±0.12 groups/km^2) of geladas was recorded in Soti, followed by Ademitu (0.52, SD±0.18 groups/km^2) and Goro-Jena (0.5, SD±0.18 groups/km^2) during the census period. The number of group encounter rate (group density) varied from 0.25 to 0.75 per km^2 grid cells surveyed with an average of 0.41 groups/km^2 grid (Fig 10). In a total of 4 km^2, 62 grid cells which cover 496 km^2 were used for the census of two replica including Seru during the entire study period.

The highest mean population density (12.25±0.18 indiv./ km^2) was recorded in Goro-Jena, followed by Soti (10.67±0.6) and Ademitu (7.32±0.61) during the census. The average individual density of geladas was 6.32 per km^2 (range 3.64 - 12.25 individuals per km^2) (Table 15). Geladas at Arsi were more aggregated frequently at plateau top, but distributed across escarpment/cliffs during the crop growing season. Herds split up into two or more groups during times of food scarcity.

Table 15. Encounter rates and density estimates of Arsi gelada in nine different sites.

Census Site	Census Section	No.of grids (2x2 km)	Total grids area (km^2)	Group observed	Mean group size	Encounter rate (groups/km^2)	Population density (indiv./km^2)
Indetu	I	18	72	21	18.29	0.29	5.33
	II	18	72	28	13.32	0.39	5.18
	Mean	18	72	25	15.8	0.34	5.26
Atucha	I	7	28	9	18.64	0.32	5.07
	II	7	28	8	12.75	0.29	3.64
	Mean	7	28	8.5	15.69	0.3	4.36
Goro-Jena	I	4	16	6	32.67	0.38	12.25
	II	4	16	10	19.3	0.63	12.06
	Mean	4	16	8	25.98	0.5	12.25
Ademitu	I	7	28	11	18.64	0.39	7.32
	II	7	28	18	12.72	0.64	8.18
	Mean	7	28	14.5	15.68	0.52	7.32
Temamma	I	4	16	9	12.67	0.56	7.125
	II	4	16	5	15.2	0.31	4.75
	Mean	4	16	7	13.57	0.44	5.94
Soti	I	3	12	10	13.3	0.83	11.08
	II	3	12	8	15.38	0.67	10.25
	Mean	3	12	9	14.22	0.75	10.67
Gujo	I	4	16	4	14.3	0.33	3.56
	II	4	16	4	14.3	0.25	3.56
	Mean	4	16	4	14.3	0.25	3.56
Kirbign	I	4	16	5	17.4	0.31	5.44
	II	4	16	5	19	0.31	5.94
	Mean	4	16	5	18.2	0.31	5.69
Arole	I	2	8	2	17.5	0.25	4.38
	II	2	8	2	14.5	0.25	3.63
	Mean	2	8	2	16	0.25	4

4. 3. Activity budget of Arsi geladas

A total of 18, 217 behavioral records were obtained from 3633 group scans for 16 consecutive months and 1760 observation hours. Geladas spent the largest portion of their time feeding 57.29% ±5.04 (range = 48.01– 63.83), followed by socializing 18.64% ±3.8, (range 12.82 - 25.67%). Allogrooming (social grooming) was the highest (15.24% ±3.4%, range = 10.08 - 21.78%) in socializing (Fig. 10). Arsi geladas spent nearly all of their time (98.44%) on the ground and a limited time (1.56%) on bush and small trees.

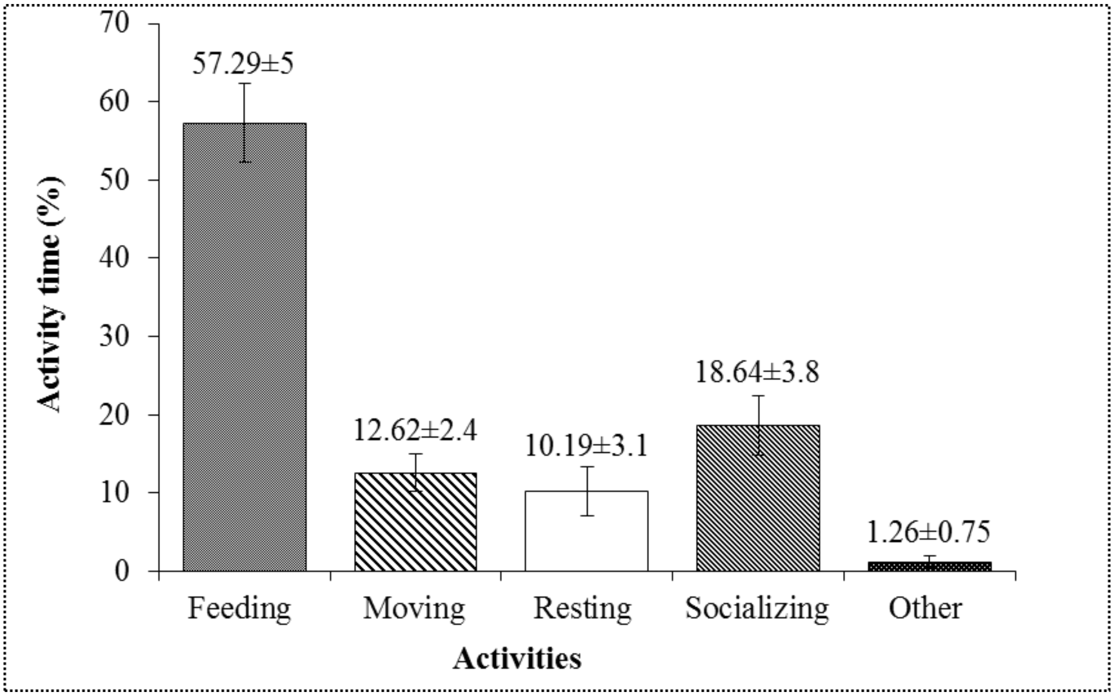

Figure 10. Activity time budget of Arsi gelada at Goro-Jena (n =16 mo).

Monthly activity budget of Arsi gelada was highly varied. Feeding was the highest of all activities recorded in all months. Feeding varied from the lowest 48.01% during February 2015 to the highest 63.81% during April 2014 (Fig. 11). There was significant difference among activity times of geladas across months (ANOVA, F = 677.52, df = 4, $P < 0.05$), however, resting was not significantly differ with moving (P = 0.25) across months.

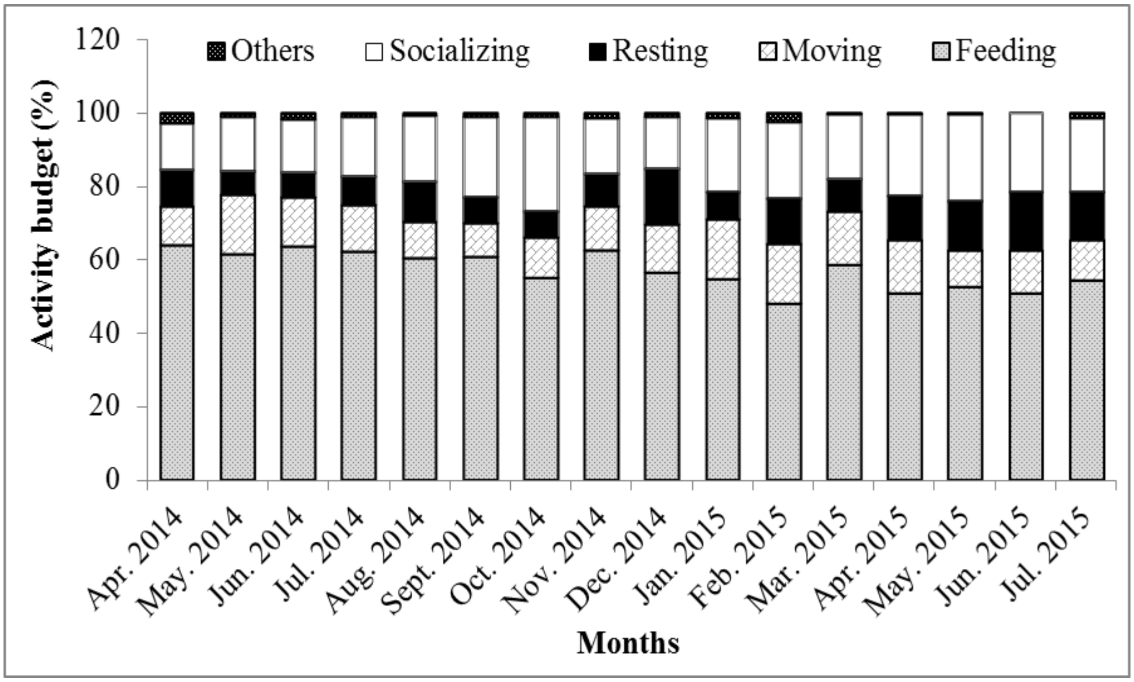

Figure 11. Monthly percentage proportion of time budget of Arsi geladas during the study period

Feeding pattern of Arsi geladas was peak in April 2014 then continued decreasing in curvilinear pattern with slight differences among months. Feeding activity of Arsi geladas was conducted in sitting posture (94.96%) on the ground level. During feeding, geladas shuffle forwards a few paces on its haunches to harvest short grass blades and digging ground. The pattern of social activities shows displayed oscillation across months with peaks from September - October 2014 and April to May 2015 and lower in April 2014 and December 2014. Movement of Arsi geladas included walking (66.94%) in different habitats. Moving pattern of the study group was slightly oscillated across months with higher in May 2014 and January to February 2015. Moving was shorter during August to September 2014 and May to Jun 2015. Resting pattern of geladas was constant with peaks in December 2014 and June 2015 with the lowest during May to June 2014.

The "other activities" activity of geladas was constant with a small peak in February 2015 (Fig.12).

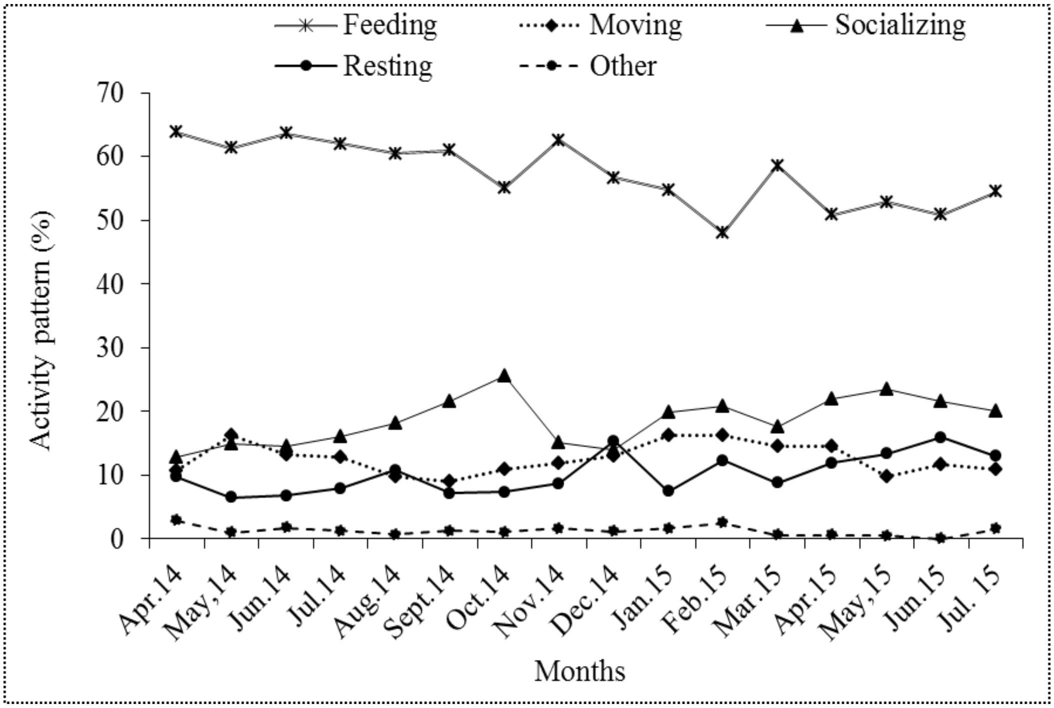

Figure 12. Monthly activity patterns of Arsi geladas during the study period.

Geladas display minimal variation in all activities during the wet and dry seasons. The variation was not significant among the activity budgets of geladas during the wet and dry seasons (Mann-Whitny test, U = 0.4, df =1, P = 0.52). Feeding constituted the highest activity budget. However, moving was significantly different (t-*test* = – 2.34, P < 0.05) during the two seasons. Time spent feeding and socializing was higher during the wet season than the dry season. Geladas spent slightly more time feeding (58.19% ±4.73%) during the wet season than the dry season (56.59% ±5.45%) though there was no significant difference (Fig. 13).

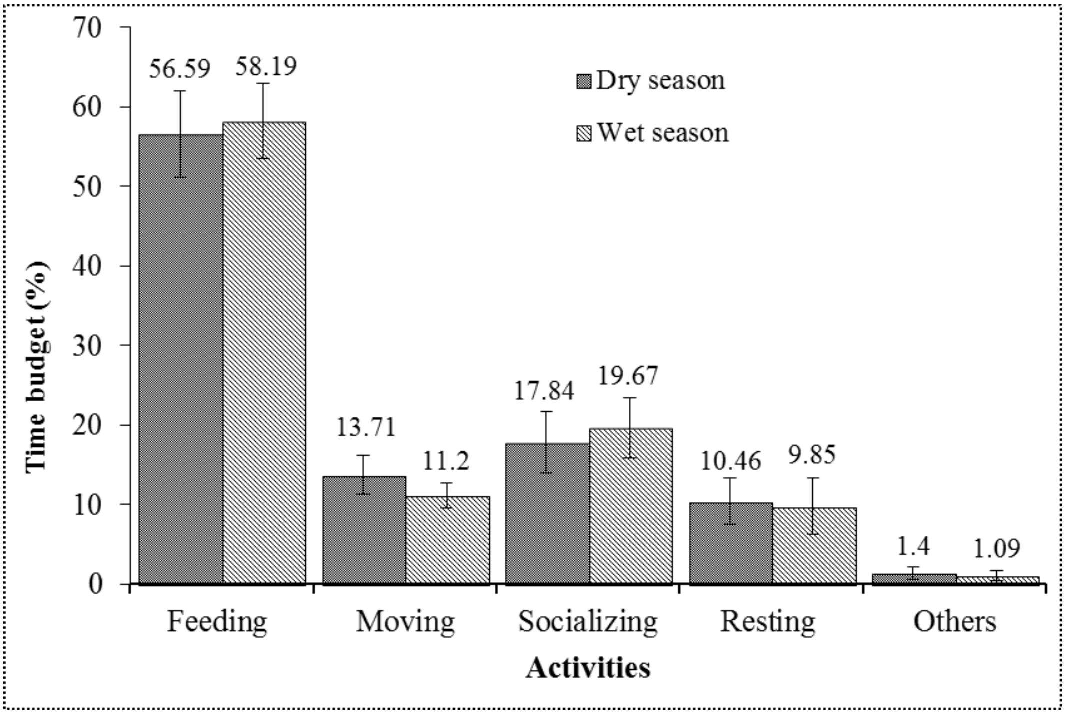

Figure 13. Activity time budgets of Arsi geladas during the wet and dry seasons.

Seasonal feeding pattern of Arsi gelada was the highest both during the wet and dry seasons. Feeding pattern was peak during late dry season during a short rain and decreased progressively across the dry season reaching the lowest in mid-dry season. Socializing was the second highest activity during the study period. Social activity pattern decreased in late dry season during a short rain when feeding time was peak. Moving pattern decreased at the beginning of the dry season but remained constant after minimal increase at the mid of the dry season. During the wet season, feeding pattern was peak at the beginning of the rainy season with a progressive decrease across the main rainy season. Socializing increased consistently with a peak during late wet season.

Time budgets in age-sex categories:

The present study shows different time budget utilized in age-sex categories of Arsi gelada. Adult females spent the highest (58.3%) time feeding, followed by subadult males (57.3%).

Moving was recorded the highest (14.0%) in both subadult males and adult females and the lowest (6.2%) in juveniles. Resting recorded the highest (20.5%) time budget in leader male and the lowest (5.9%) in juveniles. Socializing was recorded the highest (32.3%) time budget in juveniles, followed by subadult male (21%) (Fig. 14). Kruskal-Wallis test showed a significant difference in time budgets of Arsi geladas among age-sex categories ($\chi^2 = 16.74$, df = 4, $P < 0.05$). One sample t - test showed a significant difference of activities (except resting) in each age-sex category in feeding (t - 48.89, df = 3, $p < 0.05$), moving (t - 5.804, df = 0.10, $P < 0.05$), resting (2.93, df = 3, P = 0.61), socializing (t- 6.15, $P < 0.05$) and other activity (t- 3.127, df = 3, $P < 0.05$).

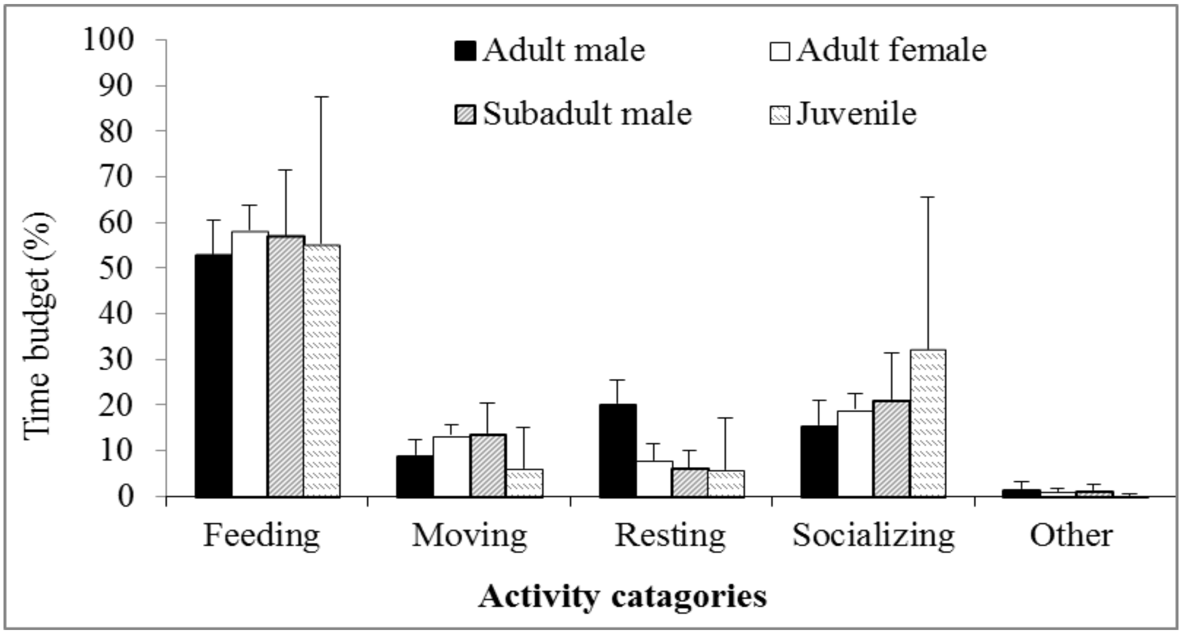

Figure 14. Activity budgets in age - sex categories of the focal group of gelada.

Arsi geladas start their diurnal activities early in the morning (0630 – 1830 h) until dusk before they return to their sleeping site. Allo-grooming was peak early in the morning (0700 – 0900 h) before the group starts other activities. Small peaks were recorded between 1300 – 1400 h and at 1800 h before dusk, respectively (Table 16). Feeding was very rare early in the morning, they usually begin during 0800 – 0900 h. Travelling was peak in the morning (0800 – 1000 h) and continuous with slight decrease in the later time of the day. Another small peak was formed late in the afternoon at (1500 – 1600 h). Resting was peak at early morning (0700 – 0900 h) and at noon (1300 –1400 h). Kruskal-Wallis H test, (H = 48.84, df = 4, $P < 0.05$) indicated that there was a significant difference in diurnal cyclic activities of Arsi geladas during the entire study period. Diurnal cycle of feeding pattern form "**M**" shape with a peak late in the morning (1000 – 1200 h) and second peak in afternoon (1500 – 1700 h), decreasing during the mid-day and then decline immediately after 1800 hr (Fig. 15).

Table 16. Overall diurnal cyclic activity of Arsi geladas during the study period (n = 16 mo).

Hours	**Feeding**	**Moving**	**Resting**	**Socializing**	**Others**
0600-0700	2	17	33	45	-
0700-0800	229	124	359	614	5
0800-0900	639	197	229	448	11
0900-1000	911	204	145	274	16
1000-1100	1017	167	105	263	18
1100-1200	1084	171	103	197	16
1200-1300	1037	197	103	218	19
1300-1400	976	178	137	244	27
1400-1500	869	177	181	303	31
1500-1600	1004	209	118	219	37
1600-1700	1060	222	68	192	27
1700-1800	1130	207	78	109	10
1800-1900	459	217	195	279	9
1900-2000	-	5	13	7	-
Total	10417	2292	1866	3413	229

Overall, the diurnal cycle of feeding activity of Arsi geladas occupied the highest (58.12%) per day with bimodal peaks between 1000 –1300 h and 1600 –1800 h, and the least between 0700 – 0800 h. Socializing (19.77%) was the next most common diurnal activity which includes copulation, agonistic interaction, playing with the dominant allo-grooming. Socializing was peak between 0700 – 0800 h decreasing from 0900 – 1300 h, again increasing between 1400 – 1500 h and from 1800 h. Moving (11.2% ±1.54%) was the lowest during early in the morning between 0600 – 0700 h, start increasing from 0800 – 0900 h, and higher late afternoon and 1600 – 1800 h with a peak at the evening. Resting (9.82% ±3.52%) was peak between 0700 – 0800 h in the morning and at 1800 h onwards, but the least between 1600 –1700 h, late in the afternoon. "Other activities" such as drinking were recorded higher between 1200 – 1500 h with peak between 1400 – 1500 h. Kruskal-Wallis H test, (H = 48.84, df = 4, P < 0.05) showed a significant difference in diurnal cyclic activities of geladas.

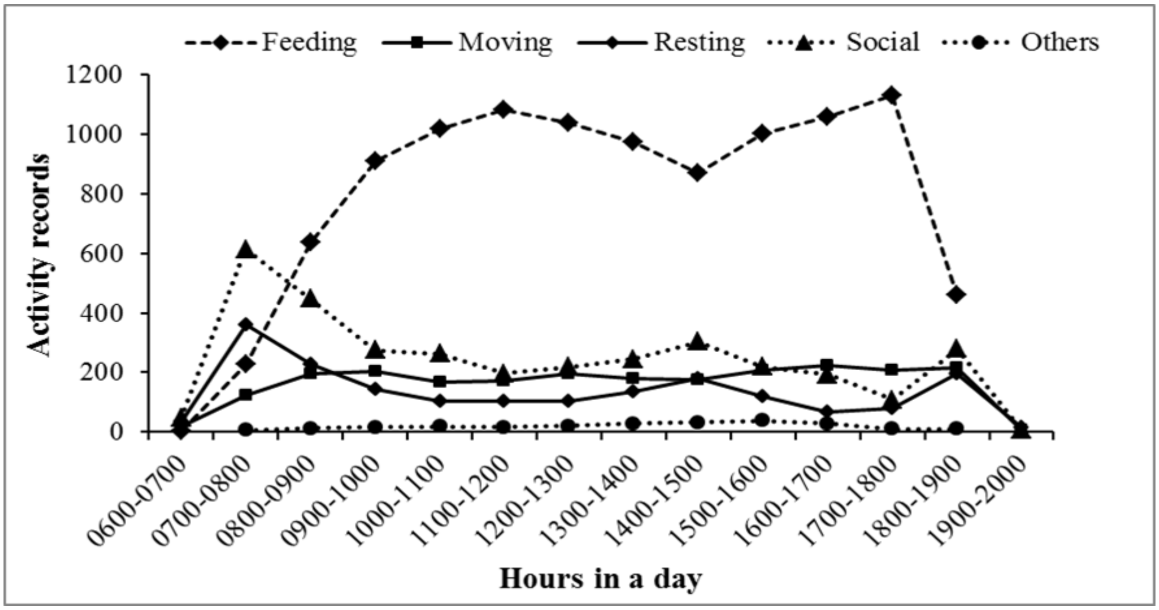

Figure 15. The overall diurnal activity patterns of Arsi geladas during the study period.

The distribution of diurnal feeding activity was lower (0600 – 0800 h) early in the morning and during mid-day (1300–1400 h) with bimodal peaks reaching maximal at 1100 h late in the morning and reached second peak at 1700 h, then decreased immediately. There was a significant difference in diurnal cyclic activities of geladas (Kruskal - Wallis test, H = 33.73, df = 4, P < 0.05) during the dry season.

The seasonal mean diurnal cyclic activity records of geladas was 651.36, SD±267.12 (mean range = 48.5 - 793.5 observations) with the highest 571.71±233.18 (range 49 – 702 observations) and 785.31±232.31 (mean range = 49 – 891 observations) during the wet and dry seasons, respectively. The highest activity records (891 observations) were recorded at 1500 h during the dry season, and 702 observations recorded at 1000 h during the wet season (Table 17). The activity records were limited early in the morning and late in the afternnoon during both the wet and dry seasons. Peak activity of Arsi geladas was recorded from 0900 h in the morning to 1700 h in the afternoon. There was a significant difference in diurnal cyclic activities of the group (Mann –Whitney *U* test, $P < 0.05$) during the wet and dry seasons. The study shows a significant seasonal variations in diurnal activities during geladas of feeding (Mann- Whitney test, $U = 44.5$, $P < 0.05$) and moving (Mann-Whitney test, $U = 17.00$, $P < 0.001$) while nonsignificant seasonal variations in resting (Mann-Whitney test, $Z = -1.667$, $P = 0.095$), socializing (Mann-Whitney test, $U = 59.5$, $P = 0.2$) and other activities (Mann-Whitney test , $U = 43.5$, $P = 0.100$).

Table 17. Seasonal diurnal cyclic activity of Arsi geladas during the entire study period.

Season	**Hours of a day**														
	0600	**0700**	**0800**	**0900**	**1000**	**1100**	**1200**	**1300**	**1400**	**1500**	**1600**	**1700**	**1800**	**1900**	**Total**
Wet	48	620	666	690	702	694	685	679	675	696	684	652	488	25	8008
Ddry	49	711	857	860	868	877	889	883	886	891	885	882	671	-	10209
Mean	48.5	665.5	761.5	775	785	785.5	787	781	780.5	793.5	784.5	767	579.5	12.5	18217

4.4. Feeding Ecology of Arsi geladas

A total of 10,417 feeding records were collected. Overall, Arsi geladas consumed a total of 61 food species grouped in 25 families. These included 57 plant species belonging to 22 families and 4 species of invertebrates from 3 families. Arsi geladas mostly fed on graminoids (27 species), forbs (15 species), cereals (5 species), trees (4 species) and bushes/shrubs (3 species).

Arsi geladas rarely fed on liana or lichen. Graminoid blades were the dominant food items of geladas, especially during the wet season where green leaves availability are maximal. Arsi geladas also fed on subterranean items, fruits/seeds and grass stems during the dry season. They are unique compared to other gelada subspecies in frequent feeding on brown grass during the dry season. Food items and species consumed during the study period are presented in Table 18.

Table 18. Plant forms and food items consumption frequency by Arsi gelada (L= leaf, S = seed, Sm = stem, R = root, I = invertebrates). The consuption frequency of different food items*: (O = often, regular part of gelada diet year round, S = sometimes, regular part of diet seasonally or food itmes consumed at low to moderate levels throughtout the year, R = Rare, more than 5 feeding incidents per year though not a common food item, V = very rare, < 5 feeding incidents per year).*

Local name	**Scientific name**	**Family**	**Category**	**Item**	**Frequency**	**% compo.**
Batula	*Digitaria abyssinica*	Poaceae	Graminoid	L	O	15.1
Godir merga	*Andropogon chrysostachyus*	Poaceae	Graminoid	L	O	12.57
Short mata	*Hyparrhenia rufa*	Poaceae	Graminoid	L, S	O, S	9.01
Gersa	*Themeda triandra*	Poaceae	Graminod	L	O	8.37
Kecha	*Phleum phleoides*	Poaceae	Graminoid	L, Sm	S, S	6.62
Acrma	*Eleusine floccifolia*	Poaceae	Graminoid	L	S	4.70
Ketisa	*Cynodon dactylon*	Poaceae	Graminoid	L, Sm	S, R	4.51
Cactus	*Opuntia ficus-indica*	Cactaceae	Shrub	L, F	O	3.92
Jeldo	*Festuca sp.*	Poaceae	Graminoid	L, Sm	S, S	3.75
Yelamtut merga	*Chloris pycnothrix*	Poaceae	Graminoid	L, S	S, S	3.26
Chincha merga	*Hyparrhenia anthistirioides*	Poaceae	Graminoid	L	S	2.94
Tatisa	*Rhus glutinosa*	Anacardiaceae	Small tree	F	S	2.96
Chekorsa merga	*Penniseturn villosurn*	Poaceae	Graminoid	L	R	1.86
Sendedo merga	*Penniseturn thunbergii*	Poaceae	Graminoid	L, S	O, R	1.81
Thread herb root	*Moraeastricta baker*	Iridaceae	Forb	R-bulb,	S	1.7
Labuche	*Commelina erecta*	Commelinaceae	Forb	S, R	S, S	1.83
Herb1	*Falkia oblangata*	Convolvulaceae	Forb	S, L, F	S, R, V	1.75
Teffsar	*Eragrostis tenuifolia*	Poaceae	Graminoid	L, S	O, S	1.53
Unidentified grass	*Grass sp.*	Poaceae	Graminoid	L	S	0.85
Unidentified herb	*Merendera abyssinica*	Unidentified	Forb	R	S	0.65
Samigrass	*Eragrostis capillaris*	Poaceae	Graminoid	L, S	S	1.43

Senbelet like balemi	*Bothriochloa insculpta*	Poaceae	Graminoid	L	S	1.03
Balemi/gaja merga	*Andropogon abyssinicus*	Poaceae	Graminoid	L	S	0.94
Cypereus	*Cyprees spp.*	Cyperaceae	Graminoid	S, L	R	0.96
Kemedi crop	*Triticum aestivum*	Poaceae	Cereal crop	L, S	S	0.97
Asendabo merga	*Phalaris paradoxa*	Poaceae	Graminoid	L, S	R	0.59
Murie sar	*Sporobolous natalensis*	Poaceae	Graminoid	S	S	0.41
Murie teff merga	*Eragrostis minor*	Poaceae	Graminiod	L, S	S, S	0.28
Herb10	*Dyschoriste radicans*	Acanthaceae	Forb	S	S	0.29
Gishe merga	*Aristida purpura*	Poaceae	Graminoid	S, L	R	0.23
Coarse leaf mata	*Hyparrhenia filipendula*	Poaceae	Graminoid	L, S	R	0.27
Bokolo	*Zea mays*	Poaceae	Cereal crop	S, S	S	0.16
Yewofsar	*Melinis repens*	Poaceae	Graminoid	S	S	0.17
Agamsa	*Carissa spinarum*	Apocynaceae	Small tree	F	R	0.13
Teffi crop	*Eragrostis teff*	Poaceae	Cereal crop	L, S	S, S	0.14
Thick leaf herb	*Plectranthus sp.*	Lamiaceae	Forb	L	R	-
Kilto/ ficus	*Ficus vasta*	Moraceae	Tree	F	S	0.11
Black buri	*Hypoxis villosa*	Hypoxidaceae	Forb	R-tuber	R	0.11
Telba crop	*Linum usitatissimum*	Linaceae	Cereal crop	S	S	0.08
Liana	*Eriosema scioanum*	Unidentified	Liana	L	R	0.07
Ara	*Ficus thonningii*	Moraceae	Tree	F	S	0.07
Gorteb	*Plantago lanceolata*	Plantaginaceae	Forb	L	R	0.06
Shrub 5	*Rhynchosia albissima*	Fabaceae	Shrub	L	V	0.06
Lichen	*Lichen sp.*	Unidentified	Lichen	L	V	0.07
White buri	*Chlorophytum comosum*	Asparagaceae	Forb	R-tuber	S	0.05
Amakitie	*Medicago polymorpha*	Fabaceae	Forb	L	R	0.05
Yayit hareg	Unidentified	Unidentified	Liana	L	V	0.06
Enkrkifo/Kenta	Unidentified	Unidentified	Forb	R-tuber	R	0.06
Tucha merga	*Penniseturn humile*	Poaceae	Graminoid	L	V	0.04
Horse tail merga	*Aristida adoensis*	Poaceae	Graminioid	S	S	0.03
Rose shrub flower	*Hibiscus micranthus*	Malvaceae	Shrub	L	R	0.03
Kortope	*Scorpiurus muricatus*	Fabaceae	Forb	L	R	0.02
Yayit misir	Unidentified herb	Fabaceae	Forb	S	V	0.02
Black seed merga	*Eragrostis botryodes*	Poaceae	Graminoid	L, S	R, R	0.01
Ashekit	*Galium spurium*	Rubiaceae	Forb	L	V	0.01
Abisuada like herb	*Hibiscus trionum*	Malvaceae	Forb	L	V	0.01
Bean crop	*fava bean*	Fabaceae	Cereal crop	L	V	0.01
Anbeta	*Grasshopper sp.*	Acrididae	Invertebrate	I	R	-
Cricket	*Cricket sp.*	Gryllidae	Invertebrate	I	R	-
Beetle	*Beetle sp.*	Insect	Invertebrate	I	V	-
Locust	*Locust sp.*	Acrididae	Invertebrate	I	V	0.98

Graminoids were the major food items consumed (83.33%), which comprise leaves (short graminoid = 52.22%, tall graminoid = 8.2% and brown graminoid = 12.9%), stem (5.9%), seed (3.5%) and graminoid rhizome (0.6%) (Fig.16). Graminoids were the leading food contributors to the diet of Arsi geladas. During months when geladas fed heavily on graminoid leaves, the consumption of forb leaves and underground items was less.

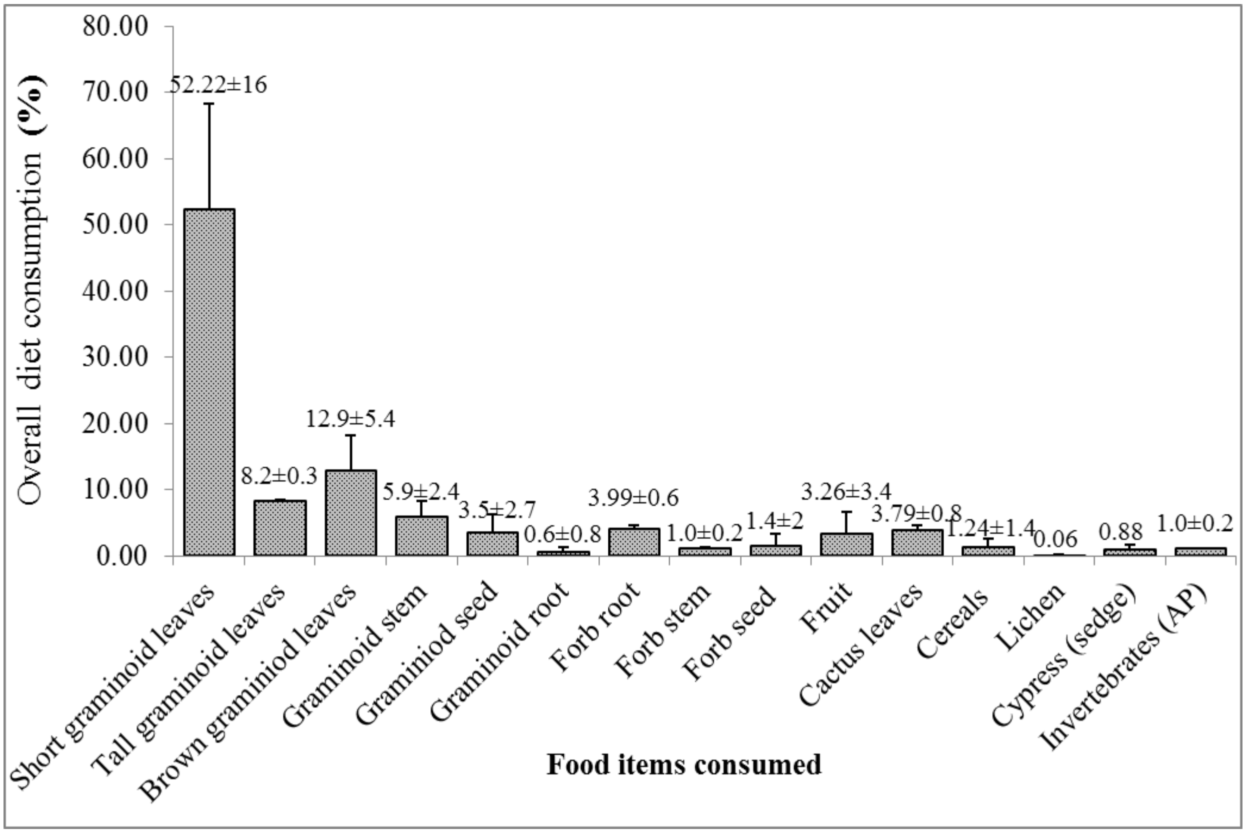

Figure 16. The overall percentage consumption of food items by Arsi geladas

Green graminoid accounted for 60.45% of overall gelada diet comprising short (52.22%) and tall graminoids (8.2%). They spend consuming (12.9%) on brown graminoid with the highest in March, 2015. They also consumed 6.44% of forbs. Lichen, sedge and invertebrates were consumed very rarely during the study period (Table 19). Kruskal Wallis test indicated that there was no significant difference in monthly mean food items consumption of Arsi gelada during the entire study period (χ^2 = 14, df = 14, P = 0.45).

Arsi geladas spent most of their time feeding on graminoid (89.85%) and (76.82%) during both wet and dry seasons, respectively. They spent less time feeding on forbs (4.45%), fruits (0.83%) during the wet season compared to the dry season (8.43%) and 5.68%, respectively. The group spent less time feeding on succulent young leaves (3.19%) during the wet season than the dry season (4.38%) (Table 20). Mann-Whitney test (Z= -1.516, P = 0.137) indicates, there was no significant difference of food items consumed by geladas between the wet and dry seasons.

Table 19. Monthly variation in percentage contribution of food items to the diet of Arsi gelada

Food items	Monthly dietary (%) composition																	
	Apr.14	May,14	Jun.14	Jul.14	Aug.14	Sept.14	Oct.14	Nov.14	Dec.14	Jan.15	Feb.15	Mar.15	Apr.15	May,15	Jun.15	Jul.15	Avr.%	SD
Short graminoid leaves	81.24	67.2	18.77	56.01	74.74	78.54	45.13	42.15	25.92	9.97	8.09	1.35	39.67	92.55	83.27	88.34	52.22	0.312
Tall graminoid leaves	12.7	27.23	9.31	1.13	5.71	12.02	26.11	10.19	17.23	5.74	1.44	0.15	0.66	0.79	-	1.69	8.26	0.089
Brown graminiod leaves	-	-	36.96	23.62	-	-	3.1	2.07	10.75	36.32	30.76	38.17	32.23	-	-	-	12.9	0.162
Graminoid stem	-	0.8	28.94	6.65	8.57	1.29	7.52	3.03	1.33	7.6	12.59	7.04	5.45	-	-	0.15	5.9	0.073
Graminiod seed	-	-	0.57	-	0.75	-	10.03	23	13.7	4.56	5.94	1.65	0.33	-	-	-	3.5	0.066
Graminoid root	-	-	-	-	-	-	-	0.28	-	3.72	3.42	2.4	-	-	-	-	0.61	0.013
Forb root	2.07	0.96	0.29	4.38	4.81	6.72	3.69	6.61	5.6	1.86	3.06	14.37	4.3	0.95	2.7	2.3	4.04	0.034
Forb stem	0.15	0.16	0.14	0.71	3.01	0.86	1.18	1.1	5.74	1.52	1.26	0.75	-	-	0.36	-	1.06	0.015
Forb seed	-	-	-	-	-	-	-	-	3.53	13.18	5.58	3.14	-	-	-	-	1.4	0.035
Fruit	-	0.16	0.14	0.28	0.3	0.57	0.29	7.71	11.93	10.64	9.17	9.58	1.49	0.48	2.88	1.38	3.26	0.045
Cactus leaves	1.33	2.07	3.58	3.25	0.6	-	1.33	0.96	2.06	2.03	3.78	15.12	8.26	3.8	8.99	4.6	3.79	0.039
Cereals	0.15	-	-	-	-	-	1.62	2.48	2.21	2.2	12.95	0.3	-	-	-	-	1.24	0.032
Lichen	-	-	0.14	-	-	-	-	-	-	-	0.18	0.45	0.33	-	-	-	0.06	0.001
Cypress (sedge)	-	0.16	0.14	-	-	-	-	0.14	-	0.17	1.44	4.34	5.45	1.27	1.44	0.61	0.88	0.016
Invertebrates (AP)	2.36	1.27	1	3.96	1.5	-	-	0.28	-	0.51	0.36	1.2	1.82	0.16	0.36	0.92	0.88	0.011
Total	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100.0	

Table 20. Growth forms and seasonal contributions of food items during the wet and dry seasons.

Growth form	Food items	Parts eaten	% composition		Overall comp.
			Wet	Dry	%
Graminoid	Green blades	Green graminoid blades	71.54	49.36	60.45
Graminoid	Brown leaves	Brown graminoid blades	9.10	16.70	12.90
Graminoid	Stem	Graminoid stem	7.59	4.2	5.90
Graminoid	Seed	Graminoid seed	1.62	5.46	3.54
Graminoid	Root	Graminoid root	0	1.09	0.55
Total			**89.85**	**76.81**	**83.33**
Forbs	Root	Forb roots	3.56	4.42	3.99
Forbs	Stem	Forb stem	0.89	1.19	1.04
Forbs	Seed	Forb seed	0	2.83	1.41
Total			**4.45**	**8.43**	**6.44**
Fruit	Fruits	Fruits	0.83	5.68	3.26
Shrub	Succulent leaves	Leaves	3.19	4.38	3.79
Crops	Cereal	Cereal crops	0.23	2.25	1.24
Lichen	Lichen	Lichens	0.02	0.11	0.07
Sedge	Cypress species	-	0.31	1.44	0.88
Animal prey	Invertebrates	AP	1.11	0.88	1.00

Graminoids accounted for 83.33% of the overall diet of Arsi geladas. Forbs made the second largest food items accounted for 6.44%. Young succulent leaf including cactus and liana leaves contributed 3.79% and cereals 1.24% of the overall diet of Arsi geladas. Invertebrates (1.0%), sedge (0.88%) and lichens accounted minimal in the diet (Fig. 17). Kruskall Wallis test, (χ^2 = 6, df = 6, P = 0.423) indicated that there was no significant difference beteween the overall food items consumed by Arsi geladas during the present study.

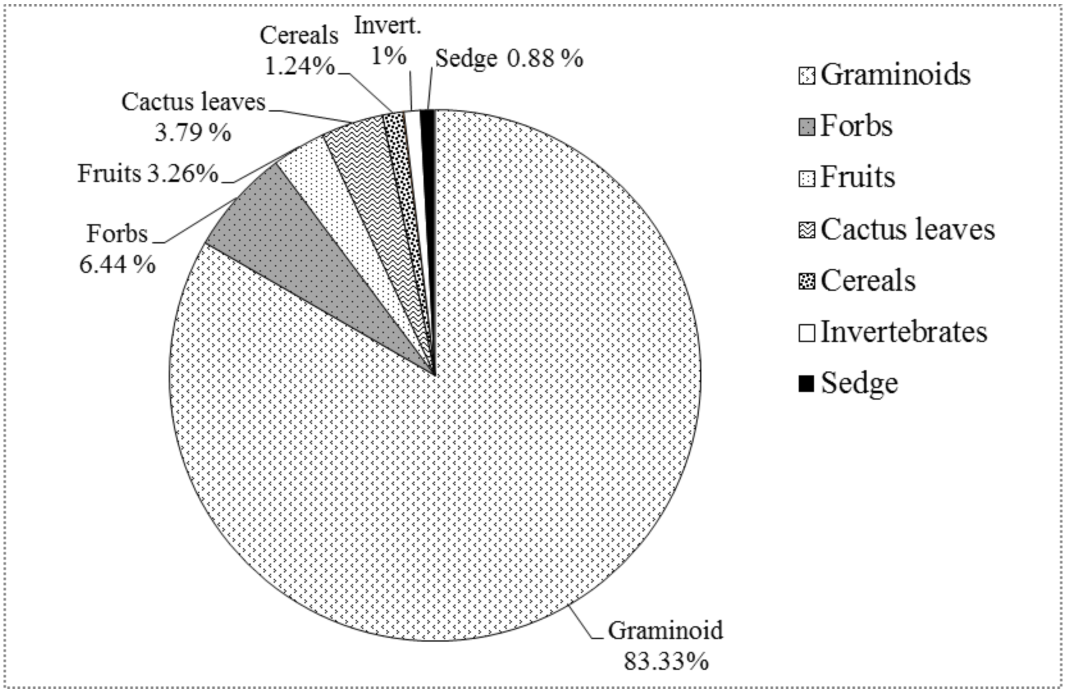

Figure 17. Percentage contribution of food items consumed by the overall diet of Arsi geladas.

Arsi geladas of both age-sex categories fed on fruits mainly during the dry season. They grasp fruits using either of the two hands or using their teeth, while the other hands used to hold the tree branch. Arsi geladas also engaged more time feeding on cactus succulent leaf. The percentage contribution of the diet consumed in each plant species is shown in Table 21.

Although geladas at Arsi geladas consume a variety of species, the top twenty most consumed plant species accounted for 90.6% of the overall diets. These comprised 15 graminoid species (78.5%), 3 forbs species (5.3%), 1 cactus species (3.9%) and 1 tree species (2.9%).

Monthly consumption of batula (*Digitaria abyssinica*) was the first selection ranked food of graminoid species which accounted for 15.11% with the highest in May 2014 after short rain. *Andropogon chrysostachyus* graminod ranked second accounted for 12.57% with highest in

April 2014. Kruskal Wallis Test, ($\chi^2 = 59$, df = 58, P = 0.475) showed that the was no significant difference in mean monthly food species consumed by Arsi geladas during the study.

Table 21. List of plant species, food items and percentage contribution and selection rank of the diet of Arsi gelada during the entire study period (L = leaf, R = root, S = seed, Sm = stem, F = fruit).

Local name	**Scientific name**	**Family**	**Category**	**Item**	**% contr.**	**Selec. rank**
Batula	*Digitaria abyssinica*	Poaceae	Graminoid	L	15.11	1
Godir/Merga	*Andropogon chrysostachyus*	Poaceae	Graminoid	L	12.57	2
Small mata	*Hyparrhenia rufa*	Poaceae	Graminoid	L, Sm	9.04	3
Gersa	*Themeda triandra*	Poaceae	Graminod	L	8.37	4
Kecha	*Penniseturn squarnulaturn*	Poaceae	Graminoid	L,Sm,S	6.64	5
Acrma	*Eleusine floccifolia*	Poaceae	Graminoid	L	4.7	6
Ketisa	*Cynodon dactylon*	Poaceae	Graminoid	L, Sm	4.51	7
Abshoka/Cactus	*Opuntia ficus-indica*	Cactaceae	Bush/shrub	L, F	3.92	8
Jeldo	*Festuca sp.*	Poaceae	Graminoid	Sm, L	3.75	9
Yelamtut merga	*Chloris pycnothrix*	Poaceae	Graminoid	S, L	3.26	10
Chincha merga	*Hyparrhenia anthistirioides*	Poaceae	Graminoid	L	2.93	11
Tatisa	*Rhus glutinosa*	Anacardiaceae	Small Tree	F	2.91	12
Chekorsa merga	*Penniseturn villosurn*	Poaceae	Graminoid	L	1.86	13
Sendedo merga	*Penniseturn thunbergii*	Poaceae	Graminoid	L, S	1.8	14
Thread herb root	*Moraea stricta Baker*	Iridaceae	Forb	Bulb,	1.7	15
Labuche	*Commelina erecta*	Commelinaceae	Forb	S, R	1.83	16
Herb1	*Falkia oblangata*	Convolvulaceae	Forb	S, L, F	1.74	17
Teffsar	*Eragrostis tenuifolia*	Poaceae	Graminoid	L, S	1.53	18
Unidentified grass	*Grass sp.*	Poaceae	Graminoid	L	0.85	19
Red stem herb	*Merendera abyssinica.*	Unidentified	Forb	Tuber	0.65	20
Samigrass	*Eragrostis capillaris*	Poaceae	Graminoid	L, S	1.43	21
Senbelet like balemi	*Bothriochloa insculpta*	Poaceae	Graminoid	L	1.03	22
Balemi/gaja merga	*Andropogon abyssinicus*	Poaceae	Graminoid	S, L	0.94	23
Cyperus	*Cyperus spp.*	Cyperaceae	Sedge	S, L	0.96	24
Kemedi crop	*Triticum aestivum*	Poaceae	Cereal crop	L, S	0.97	25
Asendabo merga	*Phalaris paradoxa*	Poaceae	Graminoid	L, S	0.6	26
Murie merga	*Sporobolus pyramidalis*	Poaceae	Graminoid	S	0.37	27
Murietef merga	*Brachiaria serrata*	Poaceae	Graminiod	L, S	0.3	28

Herb10	*Dyschoriste radicans*	Acanthaceae	Forb	S	0.29	29
Gishe merga	*Aristida purpurea*	Poaceae	Graminoid	S, L	0.23	30
Coarse mata	*Hyparrhenia filipendula*	Poaceae	Graminoid	L, S	0.27	31
Bokolo crop	*Zea mays*	Poaceae	Cereal crop	S	0.16	32
Yewofsar	*Melinis repens*	Poaceae	Graminoid	S	0.17	33
Agamsa	*Carissa spinarum*	Apocynaceae	Small tree	F	0.13	34
Teffi	*Eragrostis tef*	Poaceae	Cereal crop	L, S	0.14	35
Thick leaf herb	*Plectranthus sp.*	Lamiaceae	Forb	L	0.11	36
Kilto/ficus	*Ficus vasta*	Moraceae	Tree	F	0.11	37
Black buri	*Hypoxis villosa*	Hypoxidaceae	Forb	Bulb	0.11	38
Linseed	*Linum Lusitatissimum*	Linaceae	Cereal crop	S	0.08	39
Liana	*Eriosema scioanum*	Unidentified	Liana	L	0.08	40
Ara	*Ficus thonningii*	Moraceae	Tree	F	0.07	41
Lichen	*Lichen sp.*	Unidentified	Lichen	L	0.07	42
Gorteb	*Plantago lanceolata*	Plantaginaceae	Forb	L	0.06	43
Shrub 5	*Rhynchosia albissima*	Fabaceae	Shrub	L	0.06	44
Kortope	*Scorpiurus muricatus*	Fabaceae	Forb	L	0.06	45
White buri	*Chlorophytum comosum*	Asparagaceae	Forb	Tuber	0.06	46
Yayit hareg	*Ipomoea tenuirostris*	Unidentified	Liana	L	0.06	47
Enkrkifo/kenta	Unidentified	Unidentified	Forb	Tuber	0.06	48
Amakitie	*Medicago polymorpha*	Fabaceae	Forb	L	0.05	49
Tucha merga	*Penniseturn humile*	Poaceae	Graminoid	L	0.04	50
Horse tail merga	*Aristida adscensisions*	Poaceae	Graminioid	S	0.03	51
Rose shrub flower	*Hibiscus micranthus*	Malvaceae	Shrub	L	0.03	52
Yayit misir	Unidentified herb	Fabaceae	Forb	S	0.02	53
Black seed merga	*Eragrostis botryodes*	Poaceae	Graminoid	L, S	0.01	54
Ashekit	*Galium spurium*	Rubiaceae	Forb	L	0.01	55
Abisuada like herb	*Hibiscus trionum*	Malvaceae	Forb	L	0.01	56
Bean crop	*Fava bean*	Fabaceae	Cereal crop	L	0.01	57
Animal prey	Invertebrate	AP	Invertebrate	I	0.98	

Mata (*Hyparrhenia rufa)* is the third top food species selected which accounted for 9.04% with the highest in September 2014 (Table, 22). Cactus succulent leaves contributed (3.92%) for the overall diet with the highest in March 2015. Geladas fed fruits such as Tatisa (*Rhus glutinosa*) and varieties of cereal crops (Table 22).

Table 22. Monthly percentage contribution of plant species consumed by Arsi geladas

Local name	Species consumed	Apr14	May14	Jun14	Jul14	Aug14	Sept14	Oct14	Nov14	Dec14	Jan15	Feb15	Mar15	Apr15	May15	Jun15	Jul15	Mean%
Batula	*Digitaria abyssinica*	2.95	7.32	6.3	33.95	31.88	25.32	15.78	21.07	5.89	4.56	6.65	2.54	3.64	38.99	8.27	26.69	15.11
Godir	*Andropogon chrysstachyus*	62.48	36.31	5.59	19.52	9.02	2.86	5.31	3.31	5.89	11.82	4.14	1.65	2.15	3.01	10.97	17.02	12.57
Mata	*Hyparrhenia rufa*	15.21	13.54	14.76	10.61	8.87	19.46	8.11	1.52	5.15	5.41	9.35	13.47	3.8	3.01	10.61	1.69	9.04
Gersa	*Themeda triandra*	-	2.39	16.19	3.96	8.72	19.74	5.6	1.24	0.29	1.69	5.22	15.12	15.37	8.4	21.76	8.28	8.37
Kecha	*Phleum phleoides*	3.25	6.53	11.03	3.39	9.02	0.72	12.39	5.65	8.98	6.93	4.32	5.09	10.25	5.39	9.89	3.37	6.64
Acrma	*Eleusine floccifolia*	-	-	-	-	-	-	0.15	1.93	2.95	9.46	13.67	3.14	9.42	7.77	9.71	**17.02**	4.7
Ketisa	*Cynodon dactylon*	-	13.85	0.43	1.84	1.95	1.29	0.88	1.65	6.63	7.43	5.4	0.75	10.08	7.92	4.86	7.21	4.51
Cactus leaf	*Opuntia ficus-indica*	1.33	1.91	3.58	3.54	0.6	-	1.03	0.14	2.06	1.69	3.78	14.82	8.76	4.28	10.25	4.91	3.92
Jeldo	*Festuka sp.*	3.69	8.92	27.51	6.51	5.26	0.43	1.47	0.55	0.44	0.34	0.54	0.6	1.49	0.95	1.08	0.15	3.75
Yelamtut	*Chloris pycnothrix*	-	-	-	-	-	-	11.36	21.76	16.79	1.18	1.08	-	-	-	-	-	3.26
Chincha merga	*Hyparrhenia anthistirioides*		2.87	5.73	1.41	7.82	11.87	3.1	-	-	-	-	-	-	8.56	4.32	1.23	2.93
Labuche	*Commelina erecta*	-	-	2.56	6.72	2.97	1.62	0.15	-	-	3.23	4.42	1.89	1.04	1.37	2.98	0.31	1.83
Tatisa fruit	*Rhus glutinosa*	-	0.16	-	-	-	-	-	7.16	11.34	9.97	8.45	8.53	0.99	-	-	-	2.91
Chekorsa	*Penniseturn villosurn*	-	-	-	2.69	2.41	1.72	5.46	4.13	1.91	6.25	1.8	3.29	-	0.16	-	-	1.86
Sendedo	*Penniseturn thunbergii*	6.35	2.39	0.72	1.13	1.95	0.72	0.74	4.68	0.44	2.2	2.7	1.65	0.83	0.63	0.18	1.53	1.80
Herb1	*Falkia oblangata*	0.15	0.16	-	0.14	2.56	0.72	0.15	0.41	4.12	13.51	5.94	-	-	-	-	-	1.74
Thread-stem herb	*Moraea stricta Baker*	1.33	-	-	2.55	1.2	-	1.47	2.89	3.53	1.01	1.08	10.48	-	-	-	1.69	1.70
Tefi merga	*Eragrostis tenuifolia*	-	-	0.86	0.99	0.3	0.29	0.29	2.89	8.69	7.26	0.54	0.45	0.17	0.63	-	1.07	1.53
Samigrass	*Aira caryophyllea*	-	0.16	0.57	0.85	0.75	1.72	-	-	-	-	-	0.3	10.91	6.97	0.72	-	1.43
Mata like balemi	*Bothriochloa insculpta*	-	0.8	-	-	-	-	-	2.07	1.47	1.18	0.54	0.45	4.3	0.63	1.08	3.99	1.03
Animal prey	*Grasshopper sp*	2.36	1.27	1	3.96	1.5	-	-	0.28	-	0.51	0.36	1.2	1.82	0.16	0.36	0.92	0.98
Cypress	*Cypress sp.*	-	0.16	0.14	-	0.15	-	-	0.14	-	0.17	1.44	4.34	5.45	1.27	1.44	0.61	0.96
Balemi/gaja sar	*Andropogon abyssinicus*	-	-	-	-	-	-	14.9	0.14	-	-	-	-	-	-	-	-	0.94
Wheat crop	*Triticum spp.*	0.15	-	-	-	-	-	0.15	0.96	2.06	1.52	10.43	0.3	-	-	-	-	0.97
Merga	Unidentified spp.	-	0.16	4.3	0.14	0.75	0.57	1.47	0.55	-	1.35	2.34	1.05	0.66	0.32	-	-	0.85
Forb	Unidentified spp.	0.59	-	0.29	0.85	0.45	-	0.29	0.55	1.91	0.84	1.62	1.35	0.66	0.16	0.36	0.46	0.65
Asendabo	*Phalaris paradoxa*	-	-	-	-	0.75	5.01	1.18	1.52	0.44	0.51	0.18	-	-	-	-	-	0.60
Murie merga	*Sporobolus natalensis*	-	-	-	-	-	-	-	-	-	0.17	2.88	0.75	1.82	-	-	0.92	0.37
Murie tefi merga	*Brachiaria seratta*	-	-	-	-	-	-	2.51	1.93	-	-	-	-	-	-	-	-	0.30
Herb10	*Dyschoriste radicans*	-	-	-	-	0.15	0.14	-	-	-	-	0.54	3.74	-	-	-	-	0.29

Gishe merga	*Aristida purpurea*	-	-	-	-	-	-	-	3.58	-	-	-	0.15	-	-	-	-	0.23
Coarse mata	*Hyparrhenia sp.*	-	-	0.43	0.42	0.15	0.14	0.44	-	-	-	0.0018	-	2.48	-	-		0.27
Murie tefi	*Eragrostis minor*	-	-	-	-	-	-	-	0.41	2.36	0.17	0.36	-	-	-	-	-	0.21
Bokolo	*Zea mays*	-	-	-	-	-	-	0.74	0.96	0.15	-	0.72	-	-	-	-	-	0.16
Yewofsar	*Melinis repens*	-	-	0.14	-	-	-	0.59	0.14	-	-	0.36	0.45	0.99	-	-	-	0.17
Agamsa	*Carissa spinarum*	-	-	-	-	0.15	0.57	0.29	0.41	0.44	0.17	-	-	-	-	-	-	0.13
Tef crop	*Eragrostis tef*	-	-	-	-	-	-	-	-	-	0.68	1.62	-	-	-	-	-	0.14
Birie Kulbie	Unidentified herb	-	0.96	-	0.42	-	-	-	-	-	0.34	-	-	-	-	-	-	0.11
Kilto	*Ficus vasta*	-	0.16	0.14	-	-	-	-	-	-	-	-	-	-	-	1.44	-	0.11
Black buri	*Hypoxis villosa*	0.15	-	-	-	-	-	-	-	-	-	-	0.3	-	0.16	1.08	-	0.11
Linseed crop	*Linum Lusitatissimum*	-	-	-	-	-	-	0.74	0.55	-	-	-	-	-	-	-	-	0.08
Liana	*Eriosema scioanum*	-	-	-	-	-	-	0.29	0.55	-	0.17	-	0.15	-	-	-	-	0.07
Ara	*Ficus thonningii*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.07	0.07
Kortope	*Plantago lanceolata*	-	-	-	-	-	-	0.29	0.28	0.44	-	-	-	-	-	-	-	0.06
Shrub 5	*Rhynchosia albissima*	-	-	-	-	-	-	-	0.28	-	0.17	0.36	0.15	-	-	-	-	0.06
Lichen	*Lichen sp.*	-	-	0.14	-	-	-	-	-	-	-	0.18	0.45	0.33	-	-	-	0.07
White buri	*Chlorophytum comosum*	-	-	0.14	0.28	0.15	-	-	0.14	-	-	-	-	0.17	-	-	-	0.06
Amakitie forb	*Medicago polymorpha*	-	-	-	-	-	-	-	0.55	0.29	-	-	-	-	-	-	-	0.05
Yayit hareg	Unidentified liana	-	-	-	-	-	-	-	-	-	-	-	0.9	-	-	-	-	0.06
Enkrkifo/Kenta	Unidentified	-	-	-	0.42	-	-	-	-	-	-	0.18	0.3	-	-	-	-	0.06
Tucha sar	*Penniseturn humile*	-	-	-	-	-	-	0.15	-	0.29	0.17	-	-	-	-	-	-	0.04
Horse tail grass	*Aristida adscensionis*	-	-	-	-	-	-	-	0.14	0.29	-	-	-	-	-	-	-	0.03
Rose shrub flower	*Hibiscus micranthus*	-	-	-	-	-	-	-	-	0.15	-	0.18	0.15	-	-	-	-	0.03
Balankisie	*Scorpiurus muricatus*	-	-	-	0.42	-	-	-	-	-	-	-	-	-	-	-	-	0.03
Yayit misir	Unidentified herb	-	-	-	-	-	-	0.29	-	-	-	-	-	-	-	-	-	0.02
Black seed grass	*Eragrostis botryodes*	-	-	-	-	-	-	-	-	-	-	0.18	-	-	-	-	-	0.01
Ashekit	*Galium spurium*	-	-	-	-	-	-	0.15	-	-	-	-	-	-	-	-	-	0.01
Abisuada like	*Hibiscus trionum*	-	-	-	-	-	-	-	-	0.15	-	-	-	-	-	-	-	0.01
Bean seed crop	*Fava bean*	-	-	-	-	-	-	-	-	-	-	0.18	-	-	-	-	-	0.01

The seasonal percentage of dietary consumption by Arsi geladas is shown in Table 23. Arsi geladas spent most of their time feeding on graminoids during the wet and dry seasons. The top food species consumed by Arsi geladas was Batula (*Digitaria abyssinica*) which accounted for 21.17%±11.12%, followed by gersa (*Themeda triandra*) (12.04%±7.11%) during the wet season compared to the dry season (10.4%±11.41%) and (5.52%±5.76%), respectively. Geladas consumed *Andropogon chrysostachyus* the highest (14.53±19.84) during the dry season (Table 23). *Hyparrhenia rufa* was consumed more (10.59±5.54) both its long blades during wet season and the stem during the dry season. Different parts of graminoid species were consumed during different seasons.

Tatisa fruit (*Rhus glutinosa*) contributed nothing during the wet season. However, it contributed 5.18%±4.51% during the dry season. Cactus (*Opuntia ficus-indica*) was consumed more during the dry season (4.31±4.4). Mann-Whiteny *U* test (P = 0.173) indicated that there was no significant difference in food species consumed by Arsi geladas during wet and dry seasons.

Table 23. Seasonal percentage contribution of plant species consumed by Arsi geladas

Local name	Scientific Name	Wet (%) Mean ±SD	Dry (%) Mean ±SD
Batula	*Digitaria abyssinica*	21.17±11.12	10.4±11.41
Gersa	*Themeda triandra*	12.04±7.11	5.52±5.76
Mata	*Hyparrhenia rufa*	10.59±5.54	7.83±4.87
Godir	*Andropogon chrysostachyus*	10.04±6.25	14.53±19.84
Kecha	*Phleum phleoides*	7.12±4.53	6.27±2.09
Acrma	*Eleusine floccifolia*	3.84±6.84	5.37±4.57
Ketisa	*Cynodon dactylon*	2.64±2.47	5.97±4.31
Cactus leaf	*Opuntia ficus-indica*	3.42±3.52	4.31±4.4
Jeldo	*Festuca sp.*	6.06±9.77	1.95±2.65
Chincha merga	*Hyparrhenia anthistirioides*	5.07±3.81	1.27±2.73
Yelamtut	*Chloris pycnothrix*	1.62±4.29	4.53±7.98
Labuche	*Commelina erecta*	2.47±2.21	1.33±1.51
Tatisa	*Rhus glutinosa*	-	5.18±4.51
Chekorsa	*Penniseturn villosurn*	1.75±2.01	1.95±2.1
Sendedo	*Penniseturn thunbergii*	1±0.59	2.43±1.85
Herb1	*Falkia oblongata*	0.51±0.94	2.7±4.34
Thread stem herb	*Moraea stricta Baker*	0.99±1.01	2.26±3.14
Teffi merga	*Eragrostis tenuifolia*	0.54±0.42	2.29±3.17
Samigrass	*Aira caryophyllea*	0.66±0.58	2.04±3.81
Mata like balemi	*Bothriochloa insculpta*	0.72±1.49	1.27±1.22
Animal prey	*Invertebrate*	1.11±1.38	0.88±0.78
Cypress	*Cypress sp.*	0.34±0.53	1.44±1.93
Balemi /gaja sar	*Andropogon abyssinicus*	2.13±5.63	0.02±0.04
Kemedi	*Triticum spp.*	0.02±0.06	1.71±3.16
Godir	Unidentified spp.	1.03±1.53	0.71±0.72
Forb	Unidentified spp.	0.39±0.26	0.85±0.61
Asendabo	*Phalaris paradoxa*	0.99±1.83	0.29±0.47
Murie merga	*Sporobolus natalensis*	0.13±0.35	0.62±0.98
Murietefi merga	*Brachiaria seratta*	0.36±0.95	0.21±0.61
Herb10	*Dyschoriste radicans*	0.04±0.07	0.48±1.17

Gishe merga	*Aristida purpurea*	-	0.41±1.12
Course mata	*Hyparrhenia sp.*	0.23±0.2	0.3±0.77
Murie teffi	*Eragrostis minor*	-	0.37±0.72
Bokolo	*Zea mays*	0.11±0.28	0.2±0.35
Yewofsar	*Melinis repens*	0.1±0.22	0.22±0.32
Agamsa	*Carissa spinarum*	0.15±0.22	0.11±0.18
Teffi crop	*Eragrostis tef*	-	0.25±0.53
Birie kulbie	*Unidentified herb*	0.06±0.16	0.14±0.31
Kilto/ficus	*Ficus vasta*	0.23±0.54	0.02±0.05
Black buri	*Hypoxis villosa*	0.15±0.41	0.07±0.1
Telba crop	*Linum usitatissimum*	0.11±0.28	0.06±0.17
Liana	*Eriosema scioanum*	0.04±0.11	0.1±0.17
Ara	*Ficus thonningii*	0.15±0.41	-
Kortope	*Plantago lanceolata*	0.04±0.11	0.08±0.15
Shrub5	*Rhynchosia albissima*	-	0.11±0.13
Lichen	*Lichen sp.*	0.02±0.05	0.11±0.16
White buri	*Chlorophytum comosum*	0.08±0.11	0.03±0.06
Amakitie forb	*Medicago polymorpha*	-	0.09±0.19
Yayit hareg	*Unidentified liana*	-	0.1±0.28
Enkrkifo/Kenta	*Unidentified*	0.06±0.16	0.05±0.1
Tucha merga	*Penniseturn humile*	0.02±0.06	0.05±0.1
Horse tail grass	*Aristida adscensionis*	-	0.05±0.1
Rose flower shrub	*Hibiscus micranthus*	-	0.05±0.08
Balankisie	*Scorpiurus muricatus*	0.06±0.16	-
Yayit misir	Unidentified herb	0.04±0.11	-
Black seed grass	*Eragrostis botryodes*	-	0.02±0.06
Ashekit	*Galium spurium*	0.02±0.06	-
Abisuada like	*Hibiscus trionum*	-	0.02±0.05
Bean seed	*Fava bean*	-	0.02±0.06
Total		100	100

Batula (*Digitaria abyssinica)* contributed the top (87.67%) as short green graminoid and lowest (0.04%) in rhizomes. Samigrass (86%), chinch grass *(Hyparrhenia anthistirioides)* (78.2%), ketisa *(Cynodon dactylon)* (70.8%) and godir *(Andropogon chrysostachyus)* (63.63%) contributed highest in the diet of geladas.

Plant species richness of gelada diet was highest (38 species) in November 2014 with monthly average 25.44 (range, 13 – 38 species) during the study period (Table 24). Shannon-Wienner diversirty index (*H'*) indicated that the highest dietary diversity (*H'* = 2.978) was recorded in February and the lowest (*H'* = 1.355) in April 2014 with monthly average diversity (*H'* = 2.411). Simpson index (*1-D*) indicated similar results in plant species diversity recorded with the highest (D = 0.932) in February and the lowest (*D* = 0.578) in April, 2014. Dietary diversity of Arsi geladas showed little variation in months during the study period. The mean monthly dietary evenness index (*J*) was 0.463 (range, 0.298 - 0.624±0.082) with the highest in April 2015 and the lowest in April, 2014 (Table 24). Kruskal Wallis test shows that no significant different in monthly dieary diversity (χ = 15, df = 15, p = 0.451).

Arsi geladas consumed more number of plant species during the dry season (n = 27.44) compared to the wet season (n = 22.86). Shannon Winner diversity index (H) showed that food species was slightly more diverse during the dry season (*H* = 2.482) compared to the wet season (*H* = 2.32). However, Mann–Whitney U test indicate that no significant difference in food species during the two seasons (U = 20, Z = -1.127, P = 0.223). Evenness index, J showed food species of Arsi geladas was slightly more evenly distributed during the dry season compared to the wet season, Mann –Whitney test indicate no significant different (U = 30, Z= - 0.16, p = 0.873) during the two seasons (Table 25).

Table 24. Food species diversity and evenness indice for each month during the study period (*H*' = Shannon-Wienner diversity index, *1-D* = Simpson index, evenness index (H/S), *J* = Equitability).

Months	Obser-Vation	Species consumed	Species proportion	Feeding records	Shannon diversity index, *H*	Simpson index, 1-D	Evenness J
Apr. 2014	10	13	0.0319	677	1.355	0.58	0.30
May 2014	10	19	0.0467	628	2.053	0.81	0.41
Jun. 2014	10	21	0.0516	698	2.192	0.85	0.43
Jul. 2014	10	23	0.0565	707	2.221	0.82	0.40
Aug. 2014	10	25	0.0614	665	2.382	0.85	0.43
Sept. 2014	10	19	0.0467	699	2.092	0.84	0.43
Oct. 2014	10	33	0.0811	678	2.687	0.91	0.45
Nov. 2014	10	38	0.0934	726	2.74	0.89	0.41
Dec. 2014	10	30	0.0737	679	2.812	0.92	0.56
Jan. 2015	10	32	0.0786	592	2.8	0.92	0.51
Feb. 2015	10	37	0.0909	556	2.978	0.93	0.53
Mar. 2015	10	33	0.0811	668	2.733	0.91	0.47
Apr. 2015	10	24	0.0590	605	2.706	0.92	0.62
May 2015	10	21	0.0516	631	2.161	0.81	0.41
Jun. 2015	10	19	0.0467	556	2.413	0.89	0.59
Jul. 2015	10	20	0.0491	652	2.257	0.85	0.48
Mean	160	407	1.0000	10417	2.411	0.86	0.46

H'= Shanon-Winner diversity, D'= Simpson index, J = Eveness index

Table 25. Seasonal food species diversity and evenness indice (*H*' = Shannon-Wienner diversity index, *1-D* = Simpson index, evenness index (H/S), *J* = Equitability).

Seasons	Obser-Vation	Species consumed	Species proportion	Feeding Records	Shannon index, H	Simpson index,1-D	Evenness J
Wet	70	22.86	0.056	4655	2.321	0.859	0.459
Dry	90	27.44	0.067	5762	2.482	0.854	0.469

H'= Shanon-Winner diversity, D'= Simpson index, J = Eveness index

Rainfall patterns strongly affect the diets of geladas at Goro-Jena. The amount of rainfall during the previous rainy month was significantly correlated with the monthly percentage consumption of short graminoid leaves in subsequent rainy months (Table 26). Spearman's Correlation showed a significant negative correlation between rainfall and dietary diversity of gelada in Goro-Jena ($r_s = - 0.651$, df = 14, $P < 0.05$). Dietary diversity increased during the dry season compared to the wet season. Monthly feeding diversity of gelada diet was recorded high during the dry months with a peak in February, followed by December. The lowest dietary diversity was recorded during the wet months with the lowest in April (short rain). Dietary diversity is negatively correlated with the percentage of time feeding ($r_s = – 0.556$, $P < 0.05$).

Correlation analysis indicated that there was a strong significant negative correlation between dietary diversity and composition of gelada diet in Arsi on the mean monthly values ($r_s = – 0.877$, $P < 0.05$). Dietary diversity increased during the dry season starting from October 2014 to April 2015 with a peak in February (mid of the dry season) and lower during wet season showing least in April 2014 (short rain). The sprouting flush short grass blade was highest at plateau top. In contrast, diet composition increased during the wet season. There was a negative correlation between dietary diversity and short graminoid blade ($r_s = - 0.685$, $P < 0.05$), but insignificant negative correlation between dietary diversity and tall graminoid ($r_s = - 0.167$, $P = 0.539$). Correlation analysis indicated that feeding records of short green graminoids of the diet of Arsi gelada showed a strongly significant correlation with the rainfall in the rainy months during the study period. In contrast, the monthly percentage consumption of brown graminoid blades, graminoid seed, cereals, rhizomes (graminoid root), forb seed and fruits were significantly negatively correlated with the rainfall during the rainy months (Table 26; Appendex 4). Instead, gelada increased consumption of short graminoids during the rainy months. Consumption of tall graminoid leaves, graminoid stem, forb roots, forb stem, cactus leaves and invertebrates were not directly associated with rainfall during the rainy months (Table 26). However, the diet consumption of forbs increased during the dry period.

Table 26. Correlation between percentage of feeding records (food items) of Arsi gelada and rainfall of previous months at Goro-Jena ($P < 0.05$, significant).

Food items	Feeding records (%)	Correlation (r_s)	P-value
Short green graminoid	50.81	0.717**	0.002
Tall graminoid leaves	8.23	-0.103	0.704
Brown graminoid	13.38	-0.597	0.015
Graminoid seed	3.78	-0.584	0.017
Graminoid root	0.61	-0.748**	0.001
Cereals	1.37	-0.711	0.002
Graminoid stem	6.63	-0.277	0.299
Forb root	4.04	0.049	0.858
Forb stem	1.06	-0.225	0.403
Forb seed	1.59	-0.742**	0.001
Fruits	3.56	-0.566	0.022
Succulent leaves	3.86	-0.236	0.379
Invertebrates	0.98	0.122	0.653

** Strong correlation between food item consumption and rainfall

4.5 Ranging Ecology and Habitat use

A total of 3633 GPS locations were recorded from the focal group during the entire study. The mean observation time ranged from 10:00 - 12:00 hrs and recorded a mean of 22.71±0.98 GPS locations per day and 227.1 GPS locations per ten days. The monthly mean day path length (DPL) was 1439.7±494.68 m/d (range 385.9 – 2779.1, N =16 mo) over the entire study period. It varied considerably from a minimum of 385.93 m to a maximum of 2779.12 m distance in June

2015 and November 2014, respectively. Day path length is derived from 160 full-day follows during the behavioral study of geladas at Goro-Jena. Day path length of the study group varied each month during the study. The study group travelled a mean monthly minimum of 834.47 m, SD±268.38 and means maximum 2161.14 m, SD ±380.5 (Table 27). However, Kruskal-Wallis test ($\chi^2 = 15$, df = 15, P = 0.451) indicated that there was no significant difference in the mean monthly day path lengths of the group acros months.

Table 27. Mean monthly DPL (m) and GPS location of gelada in Goro-Jena (DPL= day path length).

Months	Seasons	No. GPS/mo	Mean DPL (m)	SD	Minimum	Maximum
Apr. 2014	Dry	214	1707.40	498.52	950.08	2491.00
May, 2014	Dry	207	1484.20	618.9	542.06	2395.95
Jun. 2014	Wet	222	1138.70	461.85	618.61	2058.59
Jul. 2014	Wet	230	1511.50	440.55	735.76	2061.43
Aug. 2014	Wet	222	1161.90	298.33	520.29	1580.71
Sep. 2014	Wet	229	1102.80	364.61	565.43	1703.00
Oct. 2014	Wet	224	1331.30	320.33	763.78	1684.32
Nov. 2014	Dry	231	1674.60	628.84	1053.68	2779.12
Dec. 2014	Dry	240	1654.70	504.06	1015.05	2449.89
Jan. 2015	Dry	217	1641.80	316.33	1350.18	2220.23
Feb. 2015	Dry	233	1518.40	432.34	1039.54	2440.45
Mar, 2015	Dry	229	1636.10	551.30	785.82	2535.60
Apr. 2015	Dry	238	1657.80	348.33	1189.38	2399.08
May. 2015	Dry	238	1461.40	410.05	1010.15	2174.68
Jun. 2015	Wet	219	847.72	366.97	385.93	1476.85
Jul. 2015	Wet	240	1505.00	476.23	825.82	2127.32
Mean		3633	1439.7	494.68	834.47	2161.14
SD		227.1	253.18		268.38	380.5

Geladas traveled 18.13% of the total distance shorter than 1 km per day, 40% of the total distance traveled was in a range of 1 - 1.5 km per day. 28.13% of the total distance was traveled in a range of 1.5 – 2 km distance per day, and 13.75% of the total distance was traveled longer than 2 km per day. The study group travelled more often in a range of 1-1.5 km per day during the study period (Fig. 18).

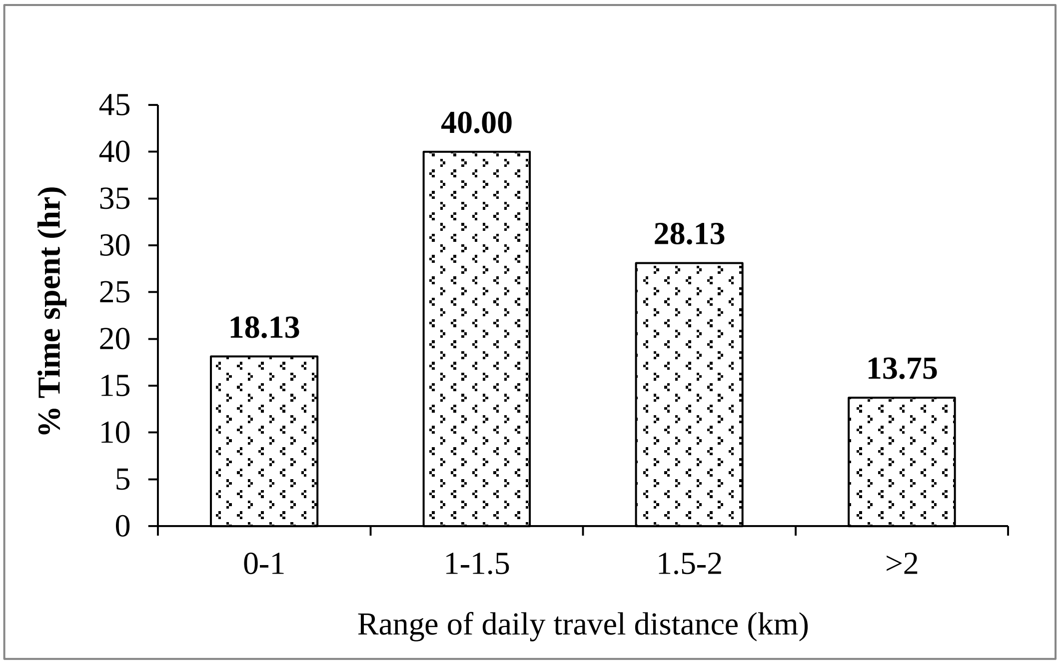

Figure 18. Percentage of time spent and daily distance traveled by Arsi geladas.

Day path length of geladas varied seasonally. The mean seasonal day range length of geladas was longer during the dry season than the wet season. The mean seasonal day path length of geladas was 1228.42 m, SD±389.84 (range = 385.93 – 2127.32 m, N = 7 mo), n =1586 GPS points during the wet season, and 1604.04 m, SD±478.74 (range = 542.06 – 2779.12 m, N = 9 mo), n = 2047 GPS points during the dry season. Arsi geladas travel zigzag pattern with smaller frequent peaks and bottom return of travel during the wet season (Fig. 19). Mann-Whitney U test

(Z = - 2.911, P < 0.05) showed that the day path length of the focal group was significantly different during the wet and dry seasons at Goro-Jena.

The study group of geladas displayed pattern during the study period. Overall movements of geladas in mean monthly day path length were characterized by a zigzag pattern with frequent alternative peak returns of the group travel to areas visited in previous days (Fig. 19). Sleeping sites of the study group changed frequently and scattered in the home range and aggregated at rocky cliffs. The focal group uses the same sleeping site at maximum of 2-3 consecutive sleeping nights. Otherwise they change sleeping sites.

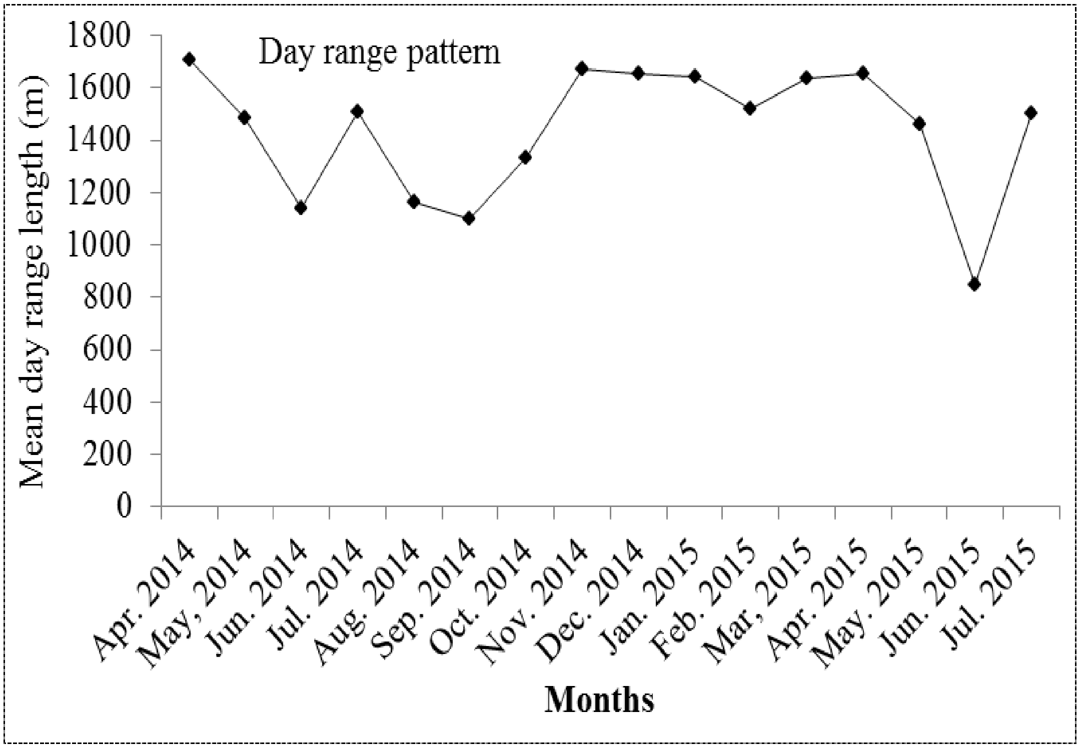

Figure 19. Monthly day range pattern of the focal group of gelada at Goro -Jena.

Above ground food availability was positively correlated with rainfall. Rainfall increased green graminoid production, availability and decreased the range size of geladas. High ambient temperature decreased food production and quality, and consequently increased the range size of the focal group in Goro-Jena. Linear correlation test indicated that a significant negative association between rainfall and day path length (Spearman: r = - 0. 641, df = 12, P < 0.05) of geladas at Goro-Jena. Percentage of green grass availability was a significant strong positive correlation with cumulative rainfall from two previous rainy months (Spearman: r = 0.713, df = 12, P < 0.05) (Fig. 20). However, rainfall of one previous month showed insignificant weak correlation with percentage of green grass availability (Spearman: r = 0.385, df =12, P = 0.174). Cumulative rainfall of the two previous months showed a strong negative correlation with brown grass (Spearman: r = - 0.917, df = 12, P < 0.05).

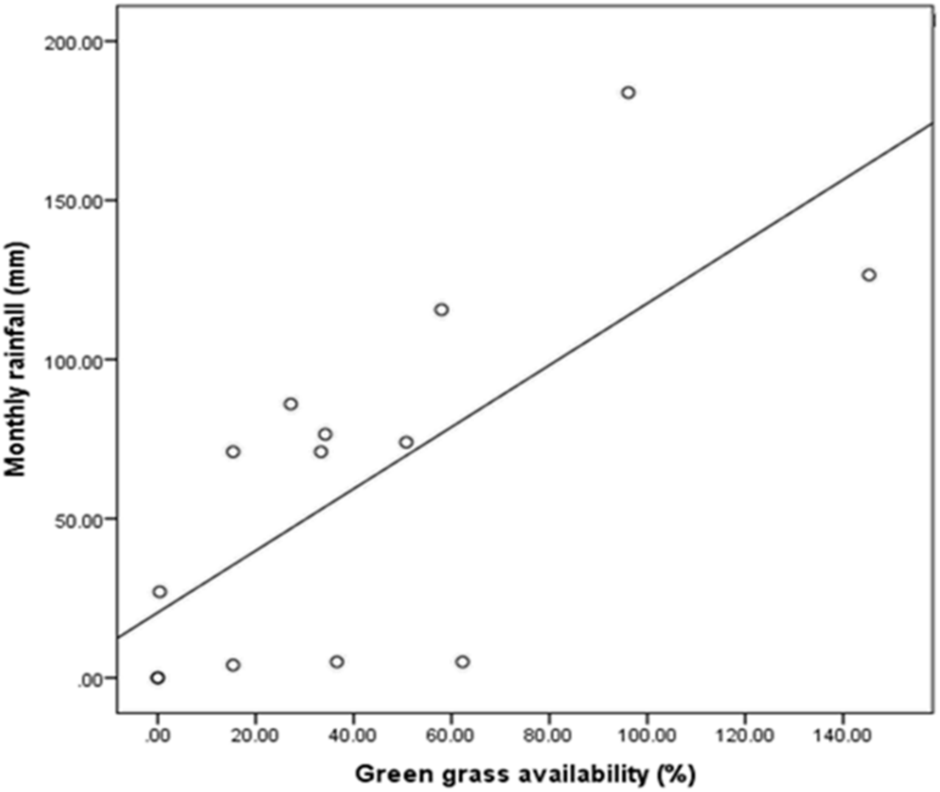

Figure 20. Monthly rainfall pattern and percentage green grass availability in Goro-Jena

The result indicate that there was no significant correlation between percentage green grass availability and monthly day path length of the focal group of geladas (Spearman: r = - 0.343, df = 12, P = 0.23) in Goro-Jena (Fig. 21). A small tree fruit availability in Goro-Jena displayed a significant correlation with monthly day path length of the focal group (Spearman: r = 0.637, df = 12, $P < 0.05$) at the area.

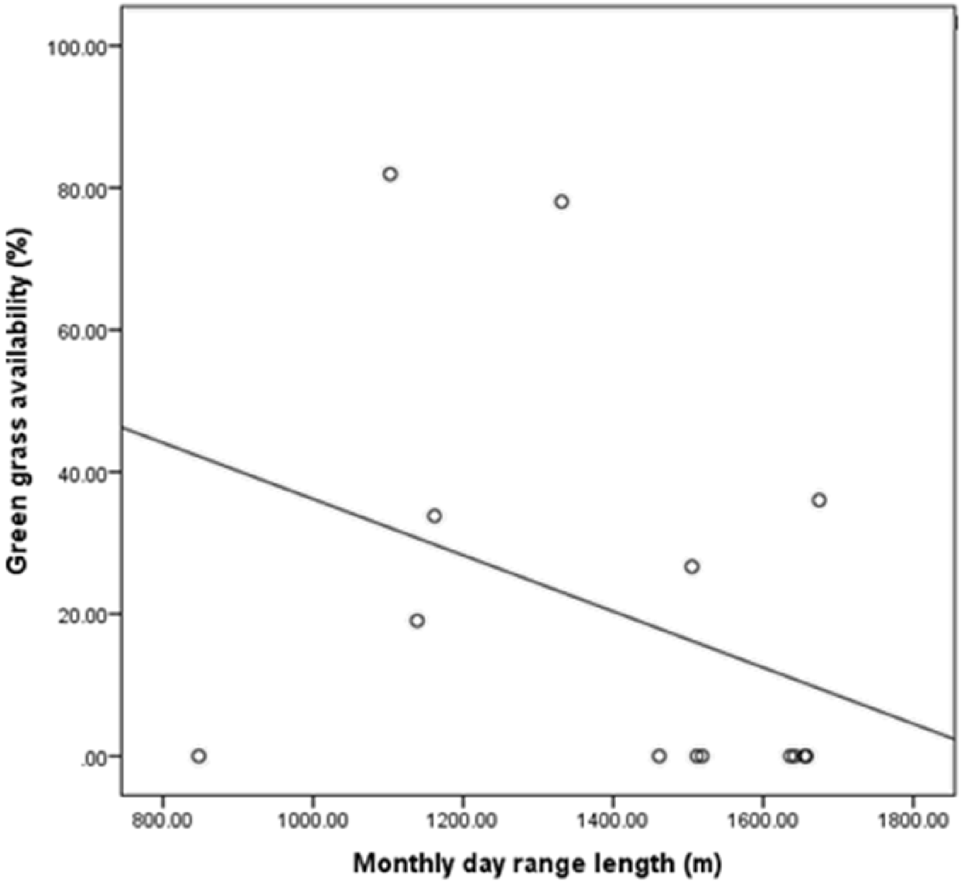

Figure 21. Linear correlation test between percentage green grass availability and monthly day path length of geladas.

High ambient temperature in the present study area showed a significant positive correlation with day path length of geladas (Spearman: r = 0.515, df = 12, $P \leq 0.05$) at Goro-Jena. Day path length of the focal group increased at high ambient temperature. The result of the study showed a significant strong positive correlation between temperature and percentage of brown grass (Spearman: r = 0.753, df = 12, $P \leq 0.05$) (Fig. 22).

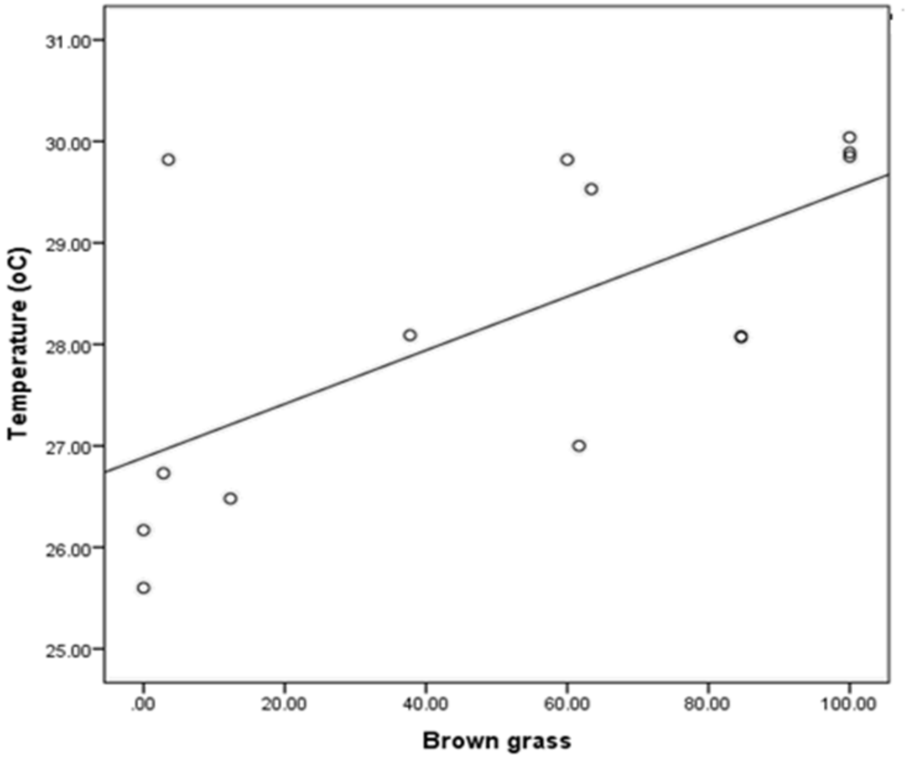

Figure 22. Correlation between ambient temperature and percentage of brown grass in Goro-Jena.

4.5.1 Home range size and spatial analysis

The overall 95% KDE utilization distribution of the study group of geladas from 3573 GPS location records was 134.4 ha. 50% KDE core area utilization distribution was 27.2 ha (Table 28). 100% MCP analysis overestimates the home range (Fig. 24). It comprised large area not actually utilized by the group. 95% MCP estimate is more appropriate for home range analysis than 100% MCP. 95% MCP estimate (180 ha) is more inclusive compared to 95% KDE (134.4 ha) of geladas. 50% KDE covered 27.2 ha. 50 % KDE core area was utilized by the focal group more frequently and concentrated at three locations in the home range (Fig. 23). The 95% KDE home range formed a W- shape landscape which was comprised from two interconnected U-shape valleys, where two seasonal rivers traverse the cliffs (Fig. 23). The 95% KDE home range area comprised larger perimeter – to – area ratio (Table 28). It has tremendously elongated and irregular shape of the cliff edge of the home range with shape index 26.75.

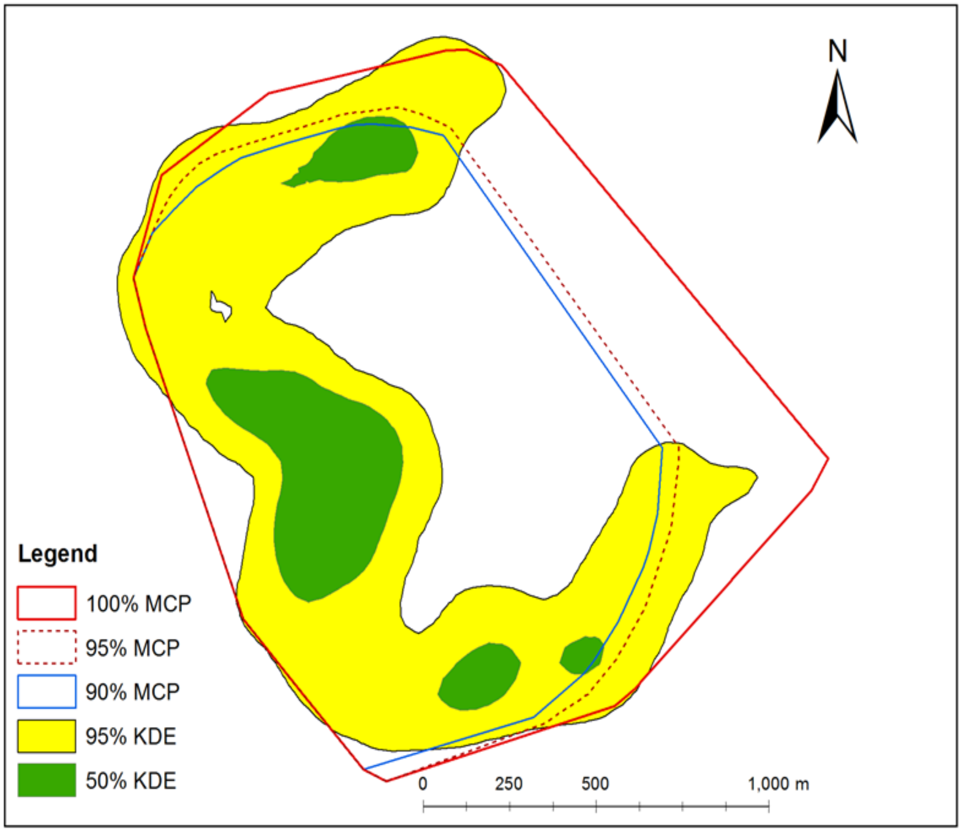

Figure 23. Overall home-range (95% KDE), core area (50% KDE) and MCPs (100%, 95%, and 90%) sizes of a focal group of Arsi gelada at Goro-Jena continuous red line (100% MCP), broken red line (95% MCP), blue line (90% MCP), yellow highlight (95% KDE), and green highlight (50% KDE).

Table 28. Overall home-range (95% KDE) and core area (50% KDE) sizes of a focal group of Arsi gelada at Goro-Jena between April 2014 and July 2015.

Measuring	Study Site	Group size	No. of study days	No. GPS Locations	Overall Home Range (ha)	
					95% KDE	50% KDE
Area	Goro-Jena	15	160	3573	134.4	27.22
Perimeter (m)					8147.9	3845.7

The study group frequently utilized open grassland to consume short graminoids. They dig for subterranean food items during the dry season. Escarpment/cliff was utilized frequently next to open grassland relative to home range size. However, the study group spent more time in the escarpment during the crop growing period when farmers chase geladas away from areas nearby crop fields. Cultivated land was occupied seldom during post-harvesting by the group to geladas pick residual crop seed. The study group occupied patchy forest at cliff bottom in gorges rarely during the fruiting, dry season.

Seasonal range and spatial analysis Home range utilization of Arsi geladas at Goro-Jena was slightly different in the two seasons. Home range area covered 147.4 ha and the 50% KDE core area covered 30.66 ha, both comprised cliffs and open grasslands (Table 29). 50% KDE core area was utilized more frequently by the focal group. 50% KDE core area was placed at three separated adjoining cliffs and grasslands in the home range of the study group (Fig. 25). During the wet season, 95% KDE home range area utilized 118.23 ha, and 50% KDE core range area covered was 22.27 ha in adjoining cliffs and grassland habitats in the home range of the study group. Compared to the wet season, the 95% KDE analysis of the home range (147.4 ha) and the 50% KDE core area (30.66 ha) had greater coverage during the dry season. However, 50% KDE core area comprised more in cliffs during the wet season than the dry season (Fig. 24). The home range area utilized by the study group was greater during the dry season (Fig. 24; Table 29).

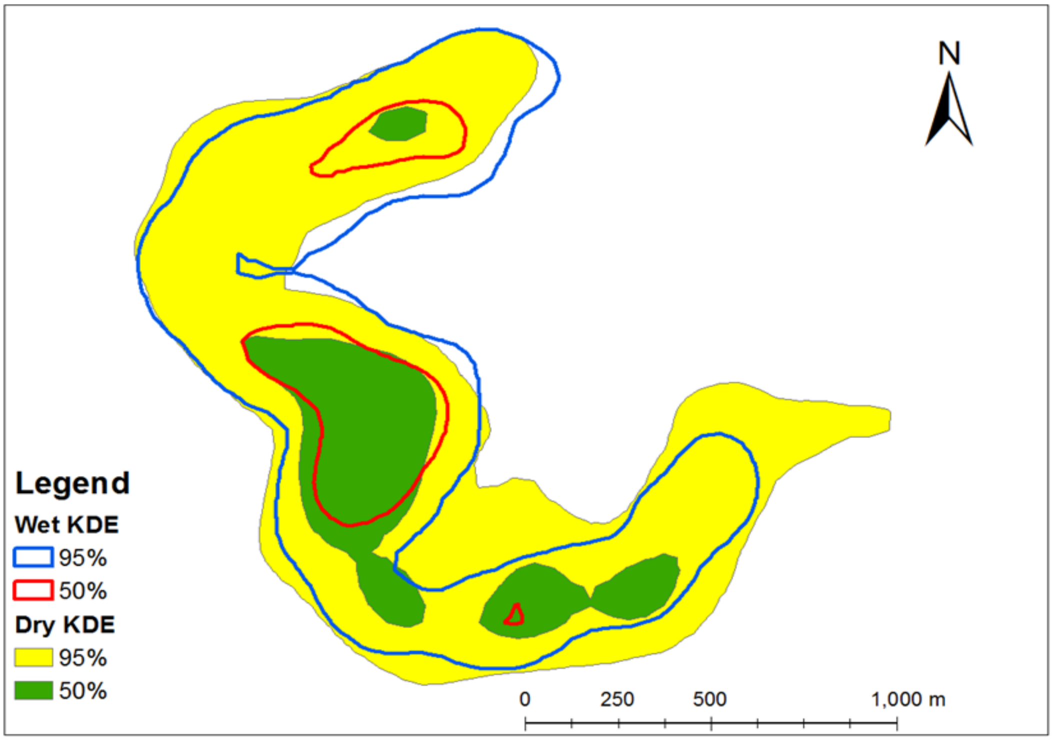

Figure 24. Seasonal home range (ha) of geladas in Goro-Jena: Continuous blue line (95% KDE), continuous red line (50% KDE), yellow highlight (95% KDE, dry season home range), and green highlight (50% KDE, dry season core area).

Table 29. Comparison of seasonal home-range (95% isopleth) and core-range (50% isopleth) sizes of the focal group of geladas at Goro-Jena between April 2014 and July 2015, as calculated by kernel density estimates (KDE).

Seasons	Measuring	Group Size	No.of Days	No. GPS Location	Seasonal Home range (ha)	
					95% KDE	50% KDE
Wet	Area	15	70	1586	118.23	22.97
	Perimeter (m)				8017.23	2988.23
Dry	Area	15	90	2047	147.401	30.66
	Perimeter (m)				8020.91	4249.3

Spatial analysis of habitat use The W-shape of 95% KDE home range area of the focal group of geladas in Goro-Jena comprised three different habitats including escarpment/cliffs, open grassland and cultivated land (Fig. 25; Table 30). Cliffs covered the largest part 71.3 ha (52.89 %) of the home range. However, cliffs were poorly used by the study group with respect to its percentage representation in the home range. Geladas utilized cliffs less than the expected by chance. Open grassland habitats covered 39.56 ha (29.35%) of the home range. The grassland habitat was utilized by geladas for foraging more frequently than expecetd. Grassland was utilized more significantly than expected based on its percentage representation in the home range. Though grassland accounted smaller in size than cliffs, the group utilized most frequently than expected by chance. Cultivated land covered the smallest size 23.95 ha (17.77%) of the home range, and least utilized by the geladas than the expected (Table 30). Overall, the study group spent limited time on cultivated land than other habitats in their home range (Table 30).

Table1 30. Total area of available habitat types (ha) and their percentage representations within 95% KDE home range of the study group.

Study Group	Habitat types	Area (ha)	Area (%)	Observed GPS pts.	Observed use %	Expected GPS pts.	Expected use %	Selection ratio	Selection Status
OMU	Grassland	39.56	29.35	1662	46.54	1048.68	29.35	1.59	Selected
	Cliff	71.3	52.89	1783	49.9	1889.76	52.89	0.94	No selection
	Crop land	23.95	17.77	128	3.57	634.92	17.77	0.20	Avoided

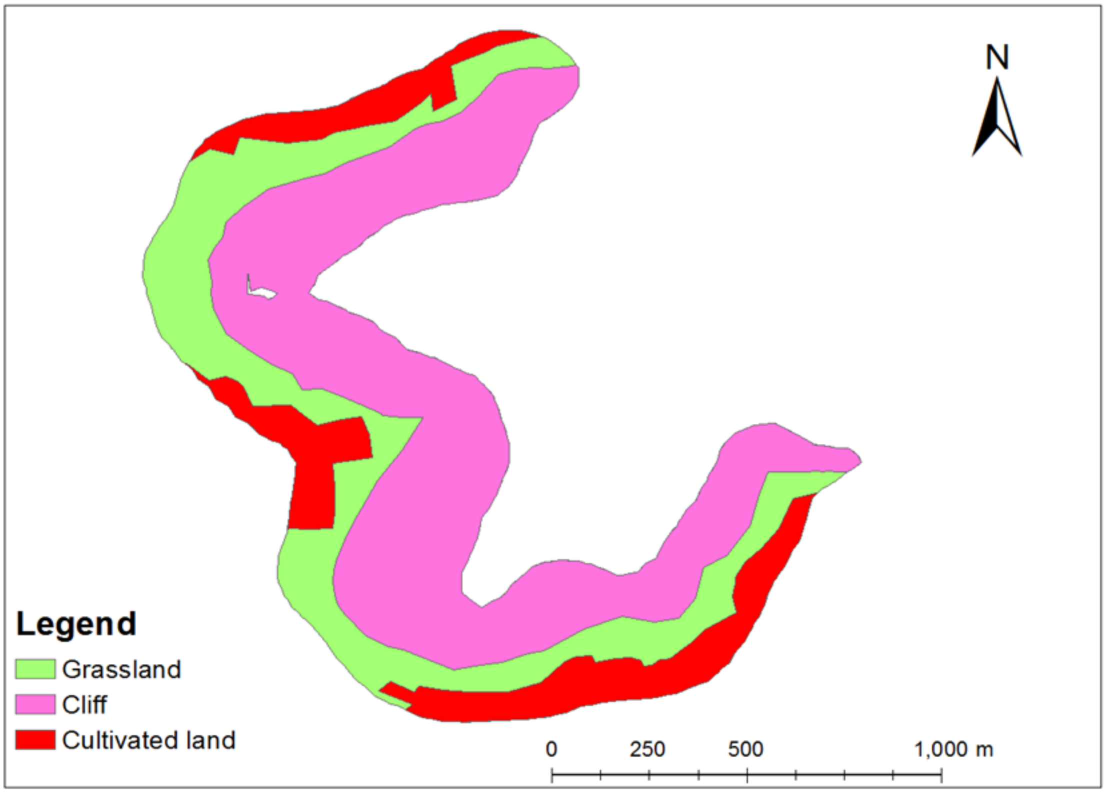

Figure 25. Map of available habitats in the home range of Arsi gelada in Goro-Jena.

According to the encounter rates, the focal group spent much time on open grassland (51.16% ±16.46) and the least on cultivated land (0.99% ±2.06) (Fig. 26). The group mostly occupied grassland (80.1%) in November 2014, the escarpment/cliffs (85.13%) in June 2014 and cultivated land (8.15%) in February 20145 for different activities (Table 31).

Table 31. The percentage habitat occupancy of geladas in Goro-Jena during the study period.

Months	Grassland	Cliff	Cultivated land
Apr. 2014	64.49	35.51	0
May,2014	53.62	46.38	0
Jun. 2014	14.86	85.13	0
Jul. 2014	69.13	30.87	0
Aug. 2014	52.70	47.29	0
Sep. 2014	45.41	54.59	0
Oct.2014	44.64	54.02	1.34
Nov.2014	80.09	19.91	0
Dec.2014	58.33	39.59	2.08
Jan.2015	64.52	35.03	0.46
Feb.2015	43.78	48.07	8.15
Mar.2015	34.50	63.32	2.18
Apr.2015	39.50	60.08	0.42
May,2105	50.84	47.90	1.26
Jun.2015	33.33	66.67	0
Jul.2015	68.75	31.25	0
Mean	51.16	47.85	0.99
SD	16.46	16.22	2.06

The focal group seldom occupied patch forest gorge at the bottom of cliffs. Rocky cliffs were utilized for sleeping sites. Grasslands were used more frequently during the dry season. Gelada herds forage frequently on open grassland during food availability (Plate 1). During the harsh dry season local people as well as geladas suffer from shortage of drinking water in the area.

Geladas utilized more frequently on the escarpment/cliffs during the wet season when the local people chase them away from the crop fields. Geladas avoided utilizing dense forest gorge during the wet season. Steep rocky cliff provides geladas as sleeping site. Geladas frequently forage on gentle slope nearby the cliff top rather than at the bottom of the escarpments (Plate 2).

Plate 1. Gelada herd on open grassland at Goro-Jena during the dry season (Photo: Amera M., 2014).

Plate 2. Geladas feeding long green graminoids nearby cliff top (Photo: Amera M., 2014).

Geladas consume mixed green grasses under the tree sheds at patchy forest gorge found at the bottom of the cliffs during the dry season (Plate 3). Geladas utilized the patch forest gorge during the dry season to escape from high heat load under the tree shade. They consume mixed green grasses under the tree shade and fruit from tree branches. Geladas drink stagnant water from seasonal streams when available.

Plate 3. Riverine gorge at the bottom of the cliff habitat in Goro-Jena (Photo: Amera M., 2014)

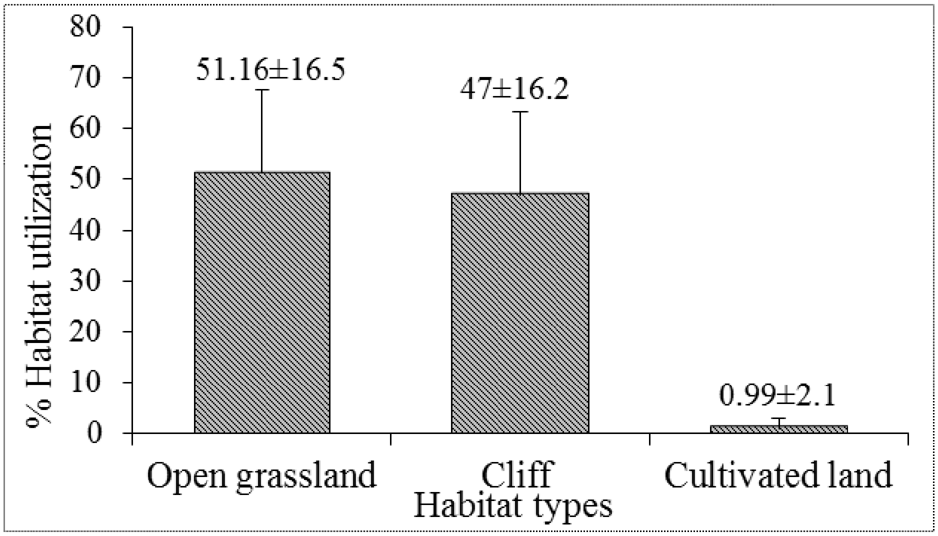

Figure 26. Percentage of habitat occupancy of geladas during the study period

Maximum occupancy (80.1%) of grassland habitat was observed in November, followed by July 2014 (69.13%) and July 2015 (68.75%). The lowest occupancy (14.86%) of grassland was recorded in June 2014. The focal group occupied cliffs at maximum frequency (70.72%) in June 2014, followed by June 2015 which accounted for 66.67%. The lowest frequent occupancy (19.91%) of the group was recorded in November 2014, followed by January 2014 (20.28%). Maximum utilization 8.15% of cultivated land by the group was recorded in February during post-harvesting when the crop fields are left free from human disturbances. However, geladas raid crops occasionally when the farmers move away from the crop field. The focal group utilizes different habitats at different frequency. However, there was insignificant difference in the utiliziation of cliff and open grassland habitats (t- 0.572, df = 30, P = 0.57)(Fig. 27).

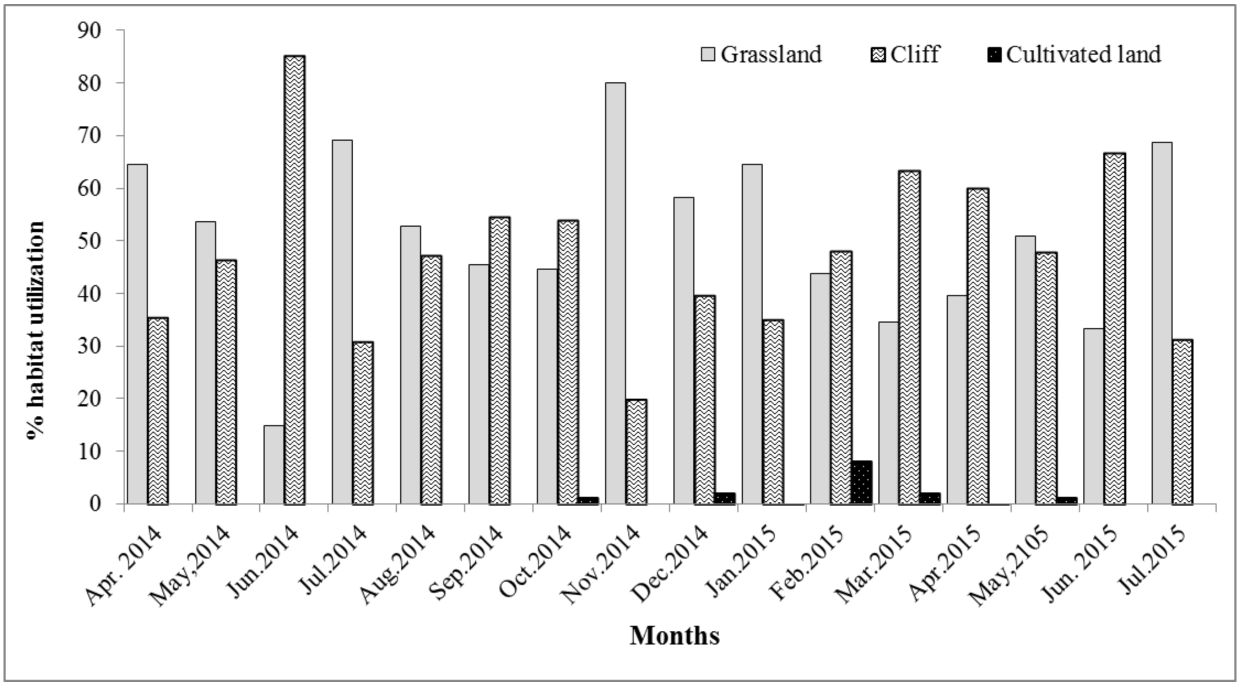

Figure 27. Habitat utilization frequency of geladas in three study habitats in the home range

Geladas at Goro-Jena utilized three habitats with different frequency during the wet and dry seasons. The focal group occupied cliffs and open grasslands more frequently during the wet and dry seasons (Fig. 28). However, there was no significant difference in the utilization cliffs and grassland habitats. Cultivated land was utilized the least (0.19% ± 1.6) during wet season. Mann-Whitney test (U = 267, P = 0.731) showed there was no significant differences in utilizing their habitats during the wet and dry seasons.

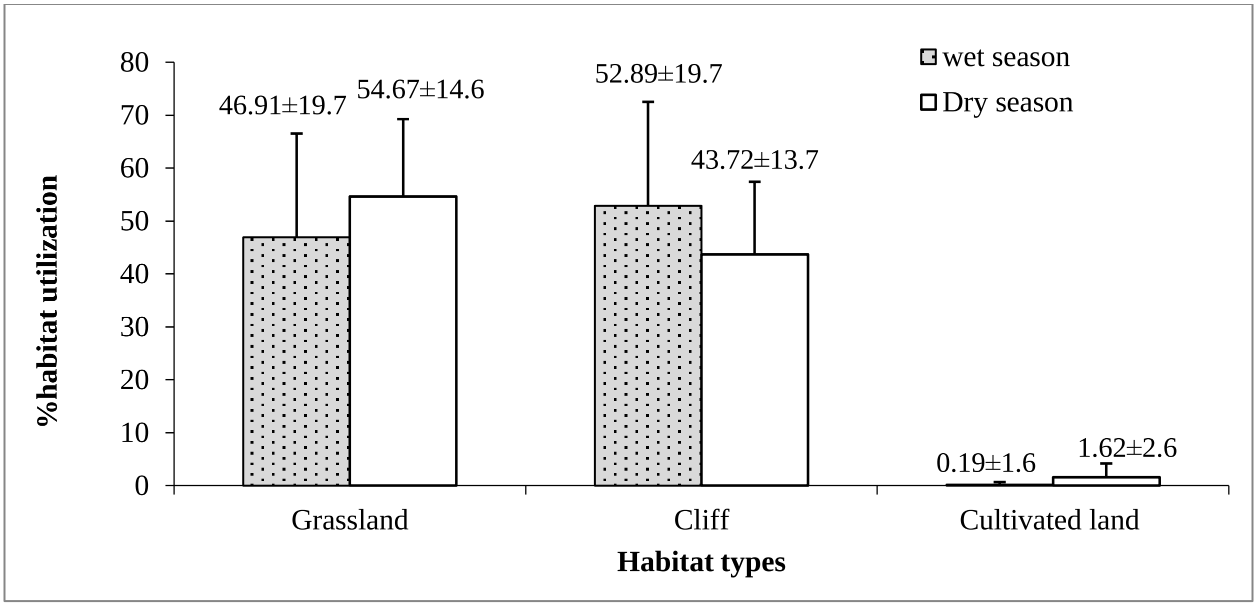

Figure 28. Habitat utilization of geladas in Goro-Jena during the wet and dry seasons.

5. DISCUSSION

5.1 Distribution pattern and population size

This is the study on the distribution pattern, population size and behavioral ecology of an isolated population of Arsi geladas in southeast of the Rift Valley in East Arsi. The present study showed that Arsi geladas are distributed discontinuously over limited ranges at different localities in East Arsi. Geladas confined mainly to hill steep cliffs along Wabi-Shebelle and Robe rivers. Studies showed that geladas inhabit cliffs and open grass plains where there is less human intervention and rarely at gorges (Dunbar and Dunbar, 1974; Dunbar, 1977a; Iwamoto and Dunbar, 1983; Beehner *et al*., 2007; Gippoliti, 2010). Currently, Arsi geladas are highly confined to cliffs compared to the northern populations. The possible reason might be due to human interference, habitat conversion, agricultural land expansion and high human settlement nearby the gelada habitats. Similar finding was reported by Mori and Gurja Belay (1990), Beehner *et al*. (2007), Kassahun Abie and Afework Bekele (2017) and Kelil Abu *et al*. (2018).

The present study showed that Arsi geladas occupied three adjacent administrative districts in East Arsi along the Wabi-Shebelle and Robe River cliffs. All the three districts have more or less similar in altitude and biophysical factors (similar vegetation composition). However, the riverine habitats are denser with broad leaf trees; escarpments/cliffs are rich in tall and coarse grasses. However, plateau tops have short grass and forbs. Most of the gelada groups were observed as a single unit on escarpments/cliffs and/or bands of small group size and rarely in herds at open grass plains. This is contrary to geladas north of the Rift Valley where herds consist of a large number of geladas (Iwamoto and Dunbar, 1983; Fashing *et al*., 2014; Desalegn Ejigu and Afework Bekele, 2017). More population size of geladas was found in Robe district in different administrative Kebeles. More number of geladas in Indetu may be due to large area cover of localities. Gelada counts varied in different survey sites. This variation might be due to the variations in food abundance, availability, the landscape, water sources in the areas and habitat disturbance. More density of geladas in Goro-Jena might be better water sources and less human disturbances in the area. Similarly, Beehner *et al.* (2007) and Kassahun Abie and Afework Bekele (2017) also reported that geladas occupied in less disturbed and resource available areas. Local migrations of geladas to adjacent areas where better food sources occurs to avoid human disturbance and predator risk. Studies showed that anthropogenic factors and seasonal variations in food availability affect the spatial distribution and population size of geladas (Iwamoto *et al.,* 1996; Mori *et al.* 1999; Kelil Abu *et al.*, 2018).

Populations of Arsi geladas were found more concentrated at three geographic ranges: the first subpopulation was found at Indetu localities along the Wabi-Shebelle cliffs. The second was found in adjacent areas at Ademitu, Amigna, Goro-Jena and Atucha areas, northwest of the Indetu population along the two sides from Robe River. The third subpopulation was found at Kirbign and Arole in Bele district, north of Indetu which is located in the opposite sides of Robe River cliff. It is believed that the three subpopulations in different geographic ranges were presumably isolated due to physical barriers including intensive cultivation, human settlement, cliffs and big gorges between the ranges (Fig. 8).

The distribution of geladas increased in Ademitu and Goro-Jena presumably due to better food availability and water sources and less disturbance. Local farmers chase geladas away from their crop field. Yet, geladas often attempt to come to the plateau top and intrude the crop field (Mori *et al.,* 1999). The limited distribution range of geladas at Atucha might be due to poor food availability, limited water resource and high human disturbance. A very small population size of geladas at Bele might be due to the habitat features and low resource availability. Geladas in Arsi compete with domestic livestock grazing on plateau top. High seasonality and harsh weather condition in the area affect food and water availability throughout the year. In addition, habitat loss, fragmentation and disturbance limit the distribution pattern and population size of Arsi geladas. Similar findings are reported by Mori and Gurja Belay (1990), Beehner *et al.* (2007) and Addisu Mekonnen *et al.* (2012). Currently, the local farmers in the study have conducted extensive crop cultivation surrounding cliffs. They have converted grassland habitats into cultivation near to cliffs. Consequently, Arsi geladas were most frequently found aggregated along the cliff edge and the surrounding plateau. The absence of geladas from Seru district may be due to intensive cultivation and human encroachment on cliffs and the extream dry weather condition in the lowland (Mori and Gurja Belay, 1990).

Previous estimation of Arsi geladas before two decades was about 600 individuals from limited sites (Gurja Belay and Mori, 1998). Kelil Abu *et al.* (2018) suggested that Arsi geladas are not more than 1000 individuals. In the present study, the actual total counting in both historic and new gelada sites showed a mean of 1315±11.3 individual geladas in the entire study area. Mori and Gurja Belay (1990) and Gurja Belay and Shotake (1998) reported geladas existed in Indetu, Gado-Goro (now called Goro-Jena), Ademitu and Temamma. However, in present study, new geladas have been recorded in new sites including Atucha, Gujo, Soti localities and Kirbign and Arole in Bele District (Fig. 8).

In the present study, both mean unit size (OMU) and band size of Arsi geladas comprised small number of individuals compared to units and band size north of the Rift Valley. The band size of Arsi gelada is composed of only few units and individuals compared to the northern and central gelada bands. In the present study, a band size comprised a mean of 26.04 and 31.19 individuals during the two censuses from the entire study periods (Appendix 2). It is smaller than investigated by Mori *et al*. (1999) at Goro-Jena with a mean band size and unit size of geladas comprised 55 and 7.9 geladas, respectively. Ohsawa and Dunbar (1984) reported that an average band size of geladas at Arsi and Bole Valley was more or less similar. However, Iwamoto and Dunbar (1983) reported that a band size of geladas at higher altitude (e.g., Sankaber, SMNP) is about 265 individuals (Appendix 2). Variations in group size are associated with differences in behavior and demography (Hill *et al*., 2000). Band size is associated with food availability (Iwamoto and Dunbar, 1983), social factors (Ohsawa and Dunbar, 1984). Gelada bands may split into units when low food availability in a degraded habitat (Iwamoto and Dunbar, 1983). In present study, different groups of geladas may fused together when more abundant food at cliff top. In addition, when joined with other groups, they move relatively long distances beyond their usual home range during the dry season.

The smaller unit size and band size of Arsi geladas might be due to the harsh environmental condition and lower food availability. Similarly, Dunbar and Dunbar (1974) in Bole Valey and Kelil Abu *et al*. (2018) in Indetu reported that gelada unit and band size declined due to harsh climate and limited resources availability in the areas. In contrary, studies in central geladas at Guassa intact habitat (Fashing *et al*., 2014) and in northern geladas (e.g. Sankaber, Dunbar, 1977a; Hunter, 2001; Gich, Ohsawa,1979; Iwamoto, 1993) showed that geladas increase their units as well as large stable band size due to resource abundance and availability, and less habitat disturbance. Contrary to the prevous report by (Beheener *et al*., 2007), more recent study of geladas in Siemien Mountains showed a gradual increase of the population due to an increase in conservation activities (Desalegn Ejigu and Afework Bekele, 2017).

Low rainfall and high ambient temperature decrease the abundance and quality of diets (Dunbar, 1992a; 1998; Hill, 1997). Low food availability and poor quality diet in warmer and harsh environments at Arsi with lower elevation may cause nutritional bottleneck for geladas (Ohsawa and Dunbar, 1984; Dunbar and Bose, 1991; Dunbar, 1992b). Further, population size is possibly affected by infanticide risk (Mori *et al*., 1997), predation (Iwamoto *et al*., 1996) and killing in response to crop feeding behavior. Poor habitat quality and food availability might allow Arsi geladas to form unstable and loose band.

In the present study, group size of geladas increased during early dry season. Large band sizes forage together at plateau top where food availability is more abundant and the plateau is free from human disturbances. Geladas remain free to move and congregate on patches of pastures and crop fields at post-harvest. Dunbar (1977a) and Zewdu Kifle *et al.* (2013) at Simien Mountains and Wonchit valley, respectively reported that geladas frequently fed on seed fall on crop fields at post-harvesting. During wet season, geladas at Arsi are confined to cliff edge due to high human disturbances. Most open plains surrounding cliffs are intensively cultivated by the local community. The small size of gelada units either forages at the small belt on the plains or retreat to the steep cliff during the crop-growing season.

The present study showed that large numbers of gelada were recorded in areas where better food resources, less habitat disturbance and better sleeping sites occur. Group size is a response to predator pressure (Iwamoto *et al.,* 1996) and abundant food availability (Dunbar and Dunbar, 1974). Similarly, Mori and Gurja Belay (1990) and Mori *et al*. (1999) reported that a band size increased at cliff edge and at plateau top where better resources are available. Consistently, in the present study, larger foraging geladas (herd) were frequently observed at plateau top during abundant food availability. However, the herds are formed only for a short time at the plateau top to minimize competition within the band. In low quality habitats, gelada herds split up soon into OMUs and AMGs, and then forage separately. Evidence suggested that population dispersion of geladas at different places and seasons are largely a function of suitable habitat and food availability (Jarvey *et al.*, 2018).

Group size in geladas is associated with various benefits and costs for group members in relation to food availability and predators (Majolo, *et al.*, 2008). Larger groups should be free to gain access to and better able to monopolize food sources than smaller groups. When group size increases, the chance of individuals being attacked by predators decreases (Iwamoto, 1979; Majolo, *et al.*, 2008). However, larger groups should face greater competition for food within the group than smaller groups (Majolo, *et al.*, 2008). Larger groups travelled long distances per day and spent more time feeding than smaller groups (Iwamoto, 1979; Majolo *et al*., 2008).

The lower population density and size of Arsi gelada in the current study might be related to habitat loss and fragmentation, low productivity and quality of graminoids, agriculture expansion due to human population growth, competition with domestic animals and killing of gelada in response to their crop raiding behavior (Dunbar and Dunbar, 1974; Dunbar and Bose, 1991; Beehner *et al*., 2007; Kassahun Abie and Afework Bekele, 2017; Kelil Abu *et al*., 2018). Similarly, studies showed that the abundance and density of primates were related to food quality and availability and habitat quality (Bartone *et al*., 1992; Wallace *et al.* 1998). Three decades ago, in southeastern Ethiopia, male geladas were being shot for their mane and capes (Dunbar, 1993). However, such trend is uncommon in the range of Arsi geladas. But, currently, the local farmers have killed geladas for a response to crop raiding (Amera M. pers.obs.).

Population composition of Arsi geladas consists of unequal age-sex ratio with greater number of adult females. The possible reason may be due to early maturity of females into adults and their philopatry behavior (females remain in natal unit) (Ohsawa and Dunbar, 1984). Instead, males depart from their natal group once they reach sexual maturity. Predation pressure on adult males may also cause reduction in male population (Iwamoto *et al*., 1996). Further, males may be frequently killed by the local farmers when they try to steal crops. The proportion of juveniles is less than infants. This is presumably because infants may get great care from the mother. Juvenile males are likely to leave their natal units under normal circumstances to join all-male groups (Dunbar and Dunbar, 1975). The adult sex-ratio of Arsi gelada is higher than the northern population (1.3) (Beehner *et al*. (2007), but more or less similar with Debre Libanos geladas (Kassahun Abie and Afework Bekele, 2017), 1:3.4 compared to 1:4.1(this study). Populations in less stable environments showed more disparate sex-ratios than those in more stable ones (Crook, 1966). In Arsi, one or more follower males are common in OMUs (Mori *et al*., 1997).

The present study showed that density and population size of gelada have been markedly reduced in Arsi compared to elsewhere. The highest mean density (12.25 indiv./km^2) was observed at Goro-Jena. However, Mori *et al*. (1999) reported 16.6 indiv./km^2 geladas in the same site before two decades. Currently, the intense human activity in Goro-Jena might be a cause in decline the populationsize of gelads. Dunbar (1977b) reported 15.8 indv./km^2 density of geladas at Debre Libanos. High (36.1 indiv./km^2 at Gich and 69.3 indiv./km^2 at Sankaber) density of geladas were reported in Simien gelada population compared to the southern population. This might be due to the harsh and warmer environment of Arsi area leading to the decline of food resources. This might reduce the fertility of geladas. Iwamoto and Dunbar (1983) and Beehner *et al*. (2007) reported higher density of gelada in Simien Mountains. The long wet and cool season in the highlands provide better food availability where graminoid remain green and soft for several months. This might lead to increase population size and density of geladas in the highlands compared to the lowland habitats. In contrast, the higher ambient temperature in the present study area causes graminoids to desiccate shortly after the rainy season. This causes poor quality habitat in Arsi and could not support a large number of geladas per area. This might decrease the fecundity and growth of geladas. In recent time, Beehner *et al.* (2007) found that population decline of geladas in Simien Mountains is primarily due to habitat loss, human disturbance and competition with domestic livestock.

Anthropogenic activities and dense human population have negative impact on the existence of Arsi geladas. Disturbances were higher at all census areas, particularly during crop growing season. Local farmers are continuously converting gelada habitats into farmlands. The human-gelada conflict and killing might affect population density of geladas. This is also supported by the study of Mesele Yihune *et al*. (2009). Thomas (1991) reported that habitat disturbance determines primate density.

Previously, Arsi geladas were unknowingly categorized together with *T. g. obscurus* and considered as least concerned in IUCN Red List (Gippoliti, 2010). However, more recently, studies discovered that Arsi geladas are an isolated and distinct subspecies (Shotake *et al.*, 2016; Kelil Abu *et al*., 2018, Zinner *et al*., 2018). Arsi geladas are among the world's least-known primates (Kelil Abu *et al*., 2018). They are extremely restricted in their distribution with small remaining population in the wild. They inhabit in anthropogenically degraded habitat and harsh and warmer environmental conditions (Kelil Abu *et al*., 2018) and may ultimately warrant listing them among the world's most endangered primates (i.e., Schwitzer *et al.*, 2015).

The presence of accurate data on the population count of animals is very crucial for determining future conservation and management of the species (Muoria *et al*., 2003). The current population census will help to evaluate the IUCN Red List status of Arsi geladas. However, further research is urgently needed to assess the suitable habitats for Arsi geladas, to help create new protected area to ensure the long-term survaival of this endemic, rare and enadangerd primate in eastern Arisi.

5.2 Activity pattern and time budget of Arsi geladas

As graminivore specialist, geladas spend more time feeding on graminoids to satisfy their daily energy requirements (Iwamoto, 1979). Feeding time of geladas at Goro-Jena is similar to geladas inhabiting lower elevation in Wollo area (Ayalew Yonatan, 2009) and Debre Libanos (Kassahun Abie *et al*., 2017) due to similarity in altitude to the present study areas. However, Arsi geladas spent less time feeding than the northern geladas (Iwamoto, 1979; Iwamoto and Dunbar, 1983). This might be due to a higher ambient temperature in Arsi that requires lower energy expenditure for thermoregulation. Yet, Arsi geladas spent more time feeding (57.29%) than other activities as poor food availability in the area. Studies have shown that during a decline of the quality and availability of foods, primates spent more time for foraging to obtain enough energy (Guo *et al*., 2007). Compared to geladas at Goro-Jena, geladas in Indetu spent 41.7% of their time for feeding (Kelil Abu *et al*., 2018) and at Bole Valley spent 37% (Dunbar and Dunbar, 1974) where these both sites occur at degraded habitat with harsh environments. The different results of time feeding of geladas at Goro-Jena compared to geladas at the two sites might be due to the length of the study periods and/or variation in year of study and status of habitat disterbances.

Geladas devote more time feeding on low nutritious food items to meet their daily nutrient requirements (Iwamoto and Dunbar, 1983; Dunbar, 1992a). The activity time budget of geladas varies depending upon altitudinal range and weather conditions. Studies show that geladas increase feeding time at higher altitude due to increase thermoregulatory cost (Iwamoto and Dunbar, 1983). In contrast, geladas in lower altitude with warm temperature require lower energy for thermoregulation (Dunbar and Bose, 1991). However, in contrast to higher altitude, the food availability of graminoids in high temperature and lower altitude area is very poor. Geladas spend longer time feeding at Goro-Jena (where there is low availability and poor quality diet) to fulfill the daily nutrient requirement. Feeding time increased over other activities as feeding is the major activity for survival.

During the dry season, low rainfall and strong sunlight radiation increases the fiber content of plant items leading to the decline in digestibility. This increases the time spent feeding to compensate the required nutrients, including bulk feeding. Iwamoto and Dunbar (1983) suggested that feeding time increases in response to the decrease in protein content during the dry season. Dunbar and Bose (1991) reported that bulk food items are ingested for a prolonged time to compensate the daily nutrient requirements. Dunbar (1992b) suggested that the decline in digestibility of graminoids at lower altitudes can have a significant impact on the animals' time budget. In the present study, geladas spent more time feeding on bulk of fibrous and desiccated food items to obtain the daily nutrient requirements.

Food quality has a significant influence on the feeding time of geladas (Dunbar, 1992a). Studies indicate that feeding time is influenced directly by temperature and indirectly by vegetation quality and distribution (Dunbar, 1998; Dunbar *et al*., 2009). As vegetation quality declines, more time is devoted to feeding to obtain the same amount of nutrients. Similarly, at Goro-Jena lower altitude and harsh environment, geladas spend more time feeding on desiccated food items to obtain the daily nutrient requirements. At Goro-Jena graminoids and forbs start to desiccate early dry season (November - March). Geladas spend more time plucking and pinching the scattered green graminoid mixed with brown and dry graminoids. In addition, geladas prefer feeding on short and soft graminoids when available, and spent more time searching for the scattered short and soft graminoids. Similarly, Dunbar and Dunbar (1974) reported that geladas in Bole Valley spent more time feeding on short and soft graminoids.

The availability and quality of diet determines traveling time and movement patterns of primates. Arsi geladas move a longer distance during dry season to forage on preferred food items. Moving time of geladas increased when there are limited food resources.

Geladas spent the second higher time budget for socializing (mainly allo-grooming) during the wet and dry seasons. Socializing in Arsi geladas helps to maintain the social unit (Dunbar and Dunbar, 1975; Dunbar, 1992a). Individuals in the unit groom early in the morning. Study showed that animals spend more time for social interactions in resource richer habitats (Dunbar, 1992a). However, time spent for socializing in geladas decreases when the resource availability declines. At Goro-Jena, time spent for socializing declined due to the corresponding increase for time spent feeding and moving during scarcity of resources. Resting is a reserve time may be converted into other major activities. Studies showed that resting time presumably converted into foraging and moving time (Dunbar, 1992a; Dunbar and Dunbar, 1988). In open habitats and hot climate, high radiation loads appear to force animals to rest and consequently decrease time spent for feeding. Allo-grooming maintains social relationships in a social unit. Studies suggested two hypotheses on socializing of primates with respect to food stress. Foley (1987) found that nutritional stresses lead to reduce socializing. Socializing decreased during the dry season with a corresponding increase of feeding time and moving. However, Dunbar and Dunbar (1988) and

Dunbar (1992a) suggested that primates conserve social time to maintain cohesion of a social group. Instead, resting could be converted into feeding time. However, Social time might serve as the emergency reserve category of time, if resting is constrained (Dunbar and Dunbar, 1988). The result of the present study supported the first hypotheses that social time is converted into feeding and moving time during the scarcity of food resources. In diurnal activity, social time and resting increased at noon in a corresponding decline of feeding time (this study).

In the present study, geladas at Goro-Jena spent 18.64% of their time for social activity with a slight difference compared to northern geladas (20.5%), and similar to Bole Valley (18.5%) and Indetu geladas (19.0%) (Iwamoto and Dunbar, 1983; Kelil Abu *et al.*, 2018). Geladas at similar altitudinal ranges spend more or less similar time for socializing. Allo-grooming (socializing) is the highest time spent for unit maintenance in a reproductive unit (Dunbar and Dunbar, 1988). Social grooming is a more intense social activity (~15%) in Arsi geladas. It is a typical pattern in cercopithecine primates (Hanya, 2004). Dunbar (1991) suggested that for catarrhine primates, social grooming is the principal mechanism to keep groups together. Adult females frequently groom their infants and other females. This might be due to the reason that females maintain cohesion of the social unit. Grooming between adult females and leader male might be a reason for mating and access to protection of the unit from predators and bachelor males. Agonistic fighting is frequent between former leader male and new leader male in the study group. This may be possible to prevent his offsprings from being injured and harassed by the new leader male (e.g., Dunbar, 1984). The former leader male carries his offspring on his back when moving (Amera M, pers. obs). The new leader male often kills unweaned infants to bring mothers rapidly back into oestrus (Beehner and Bergman, 2008).

Moving activity of geladas in Goro-Jena was consistent throughout the day. However, small peaks were recorded when the group moves up cliff top in the morning until the afternoon, and when they come down to their sleeping site in the evening. A similar finding was reported by Dunbar (1977a) in northern geladas. Dunbar and Dunbar (1974) found that geladas move consistently from one clump of food resources to another. In the present study, geladas at Goro-Jena forage the whole day. Arsi geladas spend more time moving when searching for patchily distributed preferred food items and limited water sources during the dry season.

In the present study, geladas spend less time moving short distance and forage on open grass plains during better food resources, and human disturbance during the crop growing season. Geladas occupy a narrow range when the local farmers chase them away from the crop fields. Geladas limit their movement under tree shade during extreme heat. Geladas increase traveling when less human disturbances and scarce resources. This is consistent with Iwamoto and Dunbar (1983) that geladas moved longer distances when food resources were limited. Geladas in Goro-Jena might use two adaptations, either increase moving long distance searching for preferred food or split up the group into independent units during low food availability. This is also supported by Iwamoto and Dunbar (1983) and Kelil Abu *et al*. (2018). The present study showed that geladas in Goro-Jena spend more time moving as well as forging as independent units when food availablity is low. Similarly, Iwamoto and Dunbar (1983) reported that large band size of geladas in Simien Mountains National Park expend more time moving longer distances to obtain the daily nutrient requirement in limited resources. The present study showed that geladas decrease their group size to obtain their sufficient nutrient in limited food sources. Yet, the scattered distribution and lower quality food and the limited water sources in Goro-Jena force the geladas to spend more time moving during the dry season.

Resting time acts as a reserve of uncommitted time that can be converted into other core activities (feeding, moving or socializing) when required (Dunbar *et al*., 2009). Primates reduce time spent for resting and social activities in a corresponding increase of time spent foraging (Oates, 1987). Geladas at Goro-Jena spend less time resting than geladas in Bole Valley, Indetu and Sankaber (Simien) (Iwamoto and Dunbar, 1983; Kelil Abu *et al*., 2018). This might be due to spending longer time for feeding to obtain the daily neutrient requirments. Lower time spent for resting in Goro-Jena may be the convertion of reting time into feeding time to collect food items in poor habitats. Consistently, Iwamoto and Dunbar (1983) reported that geladas in Simien Mountains spend less time resting at the expense of more time feeding for thermoregulation. Similar findings were suggested by Dunbar and Dunbar (1988). Excessive heat load during the warmer season at Arsi may force geladas to reduce their time of feeding to remain at rest.

Diurnal primates allocate their time for different activities as available hours of daylight are limited (Hill *et al*., 2004). Dunbar *et al*. (2009) reported that geladas allocate the day time into feeding, moving, resting, socializing and other activities. The present study showed that geladas at Goro-Jena begin their diurnal cyclic activities early in the morning (0630 h). They spend the highest time in socializing and resting early in the morning (Dunbar, 1977a). Allo-grooming (socializing) was displayed predominantly early in the morning before geladas move up the cliff top. Feeding activity replaces socializing and resting late in the morning, and continues late in the afternoon after a small decline at noon (Iwamoto, 1993). The feeding pattern peaks late in the morning and afternoon and resting peak at mid-day that represent an adaptation to temperature variation (Zhou *et al*., 2007). The result showed that geladas move fast late in the morning to climb the cliff and during evening when they return to their sleeping site. Moving was more or less uniform during the remaining time of a day. A similar finding was reported by Dunbar

(1977a; 1978) that geladas always move at highest speed when ascending the cliff top in the morning and descending to their sleeping cliff early in the evening. Similarly, Kelil Abu *et al*. (2018) suggested that Arsi geladas increase diurnal movement searching for preferred food items and limited water sources in the current study area.

Once geladas reach cliff top, feeding activity gradually becomes dominant peaking from 1000 to 1200 h. Results showed that the feeding pattern of diurnal cycle of Arsi geladas is similar with geladas in the northern highlands (Dunbar, 1977a; 1978). However, the difference is that geladas in northern highlands forage in large group size which might be a result of better food availability in the highlands (Iwamoto and Dunbar, 1983). The other difference may be that Arsi geladas rest at mid-day to escape from high heat load and high sunlight radiation during the dry season. Consequently, the present study shows that geladas reduce feeding activity during mid-day as high ambient temperature with corresponding increase time of resting and socializing at mid-day. Arsi geladas spend considerable time for resting under tree shade to avoid high heat load. Similar finding is reported by Dunbar (1992a). Studies indicated that guenons and macaques spent some time resting during the mid-day (Crook and Aldrich-Blake, 1968). Moving pattern of geladas increased during the dry season compared to the wet season to collect a patchily distributed food and search for water sources (Iwamoto and Dunbar, 1983; Kelil Abu *et al*., 2018).

The distribution of diurnal activities of Arsi geladas did not show significant fluctuation among months and between seasons. Yet, feeding activity was low early in the morning, but increase in the remaining day times. In contrast, socializing and resting activities peak early in the morning but decrease late afternoon in a corresponding increase of feeding and moving. Other activities such as drinking, defecation, looking to observer and suckling accounted for a small portion of diurnal activities. Studies indicated that diurnal cyclic activity pattern of baboons is affected by temperature, home range size, human disturbance rainfall (Chivers, 1977; Richard, 1977), group size and habitat quality (Dunbar, 1992a; Isbell and Young, 1993). Iwamoto and Dunbar (1983) found that primates alter their activity levels in response to thermoregulatory needs. Hunter (2001) reported that the diurnal cyclic activity is slightly varied in age-sex categories.

Activities in age-sex categories of Arsi geladas spend different time budgets. Isbell and Young (1993) found that primates often differ in activities between males and females. The present study shows that adult females spend more time feeding, socializing and moving but lower time resting than adult males. Hunter (2001) reported that females feed more than leader males on an annual basis in Simien. Subadult males spend the highest time in moving. They frequently interact with other groups in a band. Juveniles spend the highest time in socializing, playing with peer groups both within the same group and with juveniles of different band. Similar finding was reported by O'Brien and Kinnaird (1997) that juveniles of macaques spend the highest time in socializing (playing) and the lowest time in resting. They spend longer time playing with peers.

Studies showed that adult females spent more time for feeding than adult males to increase the metabolic demands for pregnancy and lactation (Portman, 1970; Iwamoto, 1979; Hunter, 2001). O'Brien and Kinnaird (1997) examined that female macaques maximize reproductive success via food acquisition. In the present study, adult females spend larger time feeding and a corresponding decrease time spent in resting and socialing. However, Hunter (2001) found that social time is higher in females compared to male geladas in Sankaber where better food is available. The leader males of OMUs of Arsi geladas spend more time resting. The leader male is a frequent vigilant guarding the group from all-male units (AMGs). Reed *et al.* (1997) reported that a leader male in macaque spend more time resting and guarding mates in the group.

Studies indicate that monkeys with pregnant or lactating females tend to consume more diets (Gautier Hion, 1980; Dunbar *et al*., 2002). Lactating females spend more time feeding than non-lactating females (Dunbar and Dunbar, 1988). Altmann (1980) suggested that female primates devote increasing time to feeding to offset the increasing demand of lactation. A lactating mammal must increase her nutritional intake up to two-folds (Randolph *et al*., 1977). Vasey (2005) found that lemur adult females use energetic costs associated with pregnancy and lactation.

Primates can regulate their time budgets in response to seasonal changes at lower food availability and climatic change (Di Fiore and Rodman, 2001; Hanya, 2004; Li and Rogers, 2004). The present study showed extreme seasonality in association with a combination of low rainfall and high ambient temperature. The fiber content of plants increased during the dry season, resulting in decline in digestibility (van Soest, 1982). However, geladas display insignificant seasonal variation in most activity budgets with the exception of socializing during the study period. During the present study, the usual wet season months (June and July) had receved low rainfall and high warm temperature. As a result, most graminoids desiccated similar to the dry months. This may affect the seasonal activity of geladas in the present study.

Time budgets of primates vary seasonally in response to change in abundance, quality or dispersion of food resources (Isbell and Young, 1993; Di Fiore and Rodman, 2001; Hanya, 2004). Geladas adjust their feeding time in months when food quality decreases to compensate for a reduced nutrient intake. In the present study, the vegetation cover often desiccated starting from early dry season (November). The fiber content of plant items increased as a consequence, decline in digestibility of the graminoids. Primates adjust the time spent feeding and other activities on a seasonal basis (Hanya, 2004; Riely, 2007; Jarvey *et al*., 2018), attaining an optimal or tolerable energy balance. Geladas increase feeding time to consume low quality and availability food item to achieve the nutrient intake (Dunbar and Bose, 1991). As a result, geladas move further to search for preferred food items (Dunbar, 1977a). Studies showed that animals must devote more time foraging and feeding during a decline of food availability as a result of seasonal variation (Iwamoto, 1979, 1993; Iwamoto and Dunbar, 1983; Fashing *et al*., 2014; Jarvey *et al*., 2018).

Seasonal variations in food availability, water sources and weather conditions may contribute shifting the activity patterns of primates and switching food items. Similar findings were reported by Dunbar (1977a) and Jarvey *et al*. (2018). Study shows that animals are exposed to more stressful conditions during the dry season (Hemingway and Bynum, 2005). The low rainfall and high temperature in Arsi lower altitude leading a decline habitat feature and quality during the dry season. Feeding budget of geladas in Goro-Jena was higher during both the dry and wet seasons, suggesting that lower food quality and availability in both seasons increased feeding time to obtain the required nutrient. There was no significant variation of feeding time of geladas with a small increase during the wet season. Geladas may require more energy for thermoregulation during the wet season (Iwamoto and Dunbar, 1983). This may be a possible reason that Arsi gelada spend more time feeding during the wet season than dry season in the current study. This might be a reason that Arsi geladas consumed more food during the cold weather during the wet season for energy expenditure. Iwamoto and Dunbar (1983) reported similar finding that geladas consumed more during cold weather for thermoregulation. A similar finding is reported by Zewdu Kifle *et al*. (2013) in the harsh area where feeding activity of geladas was lower during the dry season. Felton *et al*. (2008) reported that some primates spend more time feeding during the rainy season. However, in contrast to the present study, the northern geladas (at Sankaber and Gich) increase the time spent feeding during the dry season (Iwamoto and Dunbar, 1983; Iwamoto, 1993). Geladas at high altitude feed more time to obtain more energy for thermoregulation.

Primates adopt foraging strategy to cope with seasonal variation in food availability (Dasilva, 1992). Optimal foraging theory predicts that when preferred foods become limited, primates make adjustments including adapting their activity pattern (Riely, 2007), switching their diet to fallback foods (Marshall *et al.*, 2009; Jarvey *et al*., 2018), travelling into a different habitat where resource abundance is higher (Dunbar, 1977a). The present study showed that Arsi geladas switched their food items from green graminoid to brown graminoid, fruits and underground food items during the dry season. Similar to Kelil Abu *et al.* (2018) that geladas in warmer area consumed underground food items and fruits during decline green graminoids.

Geladas occupying high altitude need more energy for thermoregulation during the cold weather (Iwamoto and Dunbar, 1983). Iwamoto and Dunbar (1983) reported that geladas in Gich (3900 m asl) spent high percentage (62%) of their time feeding compared to geladas at Sankaber (3300 m asl). Geladas at lower elevation in Bole Valley (2300 m asl) and Indetu (1800 – 2320 m asl) spend less time (36%) and (41.7%) feeding, respectively (Kelil Abu *et al*., 2018). The present data in Goro-Jena are vital for a comparison (Appendex 3). Geladas at Goro –Jena (2400 m asl) spend lower time (57%) feeding than geladas at Gich (62%) (Iwamoto and Dunbar, 1983) and at Sankaber (60%)(Hunter, 2001). Perhaps, Iwamoto and Dunbar (1983) reported that a lower time (45%) feeding of geladas in SMNP was underestimated compared to other studies as it was conducted for a short time period. Though similar elevation and habitat features, percentage time feeding of geladas in Goro-Jena was more than geladas in Bole Valley and Indetu (Appendex 3).

This variation might be due to a combination of the length of the study period, variation in habitat quality and anthropogenic disturbances. Similar finding was reported by Jarvey *et al*. (2018) that northern geladas switch to fallback food when decline/scarce preferred food, may be due to seasonal change and anthropogenic factors. Iwamoto and Dunbar (1983) determined that geladas decline of percentage time spent feeding of geladas from higher to lower altitude due to an increasing temperature at lower elevation. Kelil Abu *et al*. (2018) suggested that activity budget difference between Indetu and Bole may be from the extremely degraded habitats of Indetu. The greater feeding time in Goro-Jena than Indetu might be due to high human disterbances and livestock grazing and forced geladas to marginal habitat.

5.3 Diet compositions and feeding behavior

Vegetation composition and food availability determine the feeding behavior of geladas. In the present study, rainfall increased vegetation cover. Dunbar (1992a) found that rainfall and temperature are environmental variables that determine feeding ecology of primates. Rainfall increases both plant biomass and net plant productivity. In the present study, above ground biomass on open plains could not be measured due to overgrazing of grass cover by domestic livestock. However, biomass increases with rain during the wet season. Cliffs possess higher aboveground biomass particularly during the end of wet season, presumably due to the absence of cattle grazing on the cliff. Rainfall distribution across months determined vegetation cover and food availability in the current study area. Similarly, Fashing *et al*. (2014) showed that vegetation cover increases with rainfall. Vegetation availability is influenced by the total amount and pattern of rainfall (Boutton *et al*., 1988; Fashing *et al*., 2014). The small amount and short rainfall in Goro-Jena reduced the green graminoid availability in the area. Geladas consume dominantly on monocotyledon grass blades which correlate strongly with the amount and pattern of rainfall. The availability of green forage for gelada varies between months and seasons. Deshmukh, (1984) and Boutton *et al*. (1988) determined that the vegetation often dies off during the long dry season due to the effect of lack of water and high radiation loads in the harsh and warm environment. Such conditions are usually associated with an increase in the fiber content of plants and a consequent decline of digestibility (van Soest, 1982; Dunbar and Bose, 1991). Animals increase their feeding time and have to consume more to achieve the same nutrient intake during the dry season. Similar finding was reported by Iwamoto and Dunbar (1983) that geladas spent more time feeding to obtain the nutrient requirements.

In the present study area, monthly rainfall has been correlated strongly with primary productivity. Similar findings were reported by Hunter (2001) and Fashing *et al.* (2014) that the percentage of green cover in different habitats correlated with the measure of rainfall in the preceding month or months. It is reported that lag effect has stronger correlations between grass availability and rainfall in the preceding month/months. Open grassland typically responds to rainfall rapidly (Boutton *et al*., 1988). Vegetation responds to seasonal fluctuation in various weather conditions. Gaynor (1994) suggested that high percentage of fruits in the diet of baboons might account for three month lag between rainfall and food production. The effect of rainfall can be observed for three months after the rainfall and the production of fruit.

In the present study area, unusual decrease in the amount of rainfall was recorded in June 2014 (71.5 mm). This may not be enough to grow fresh grass to maintain the green cover of open grassland. However, this small amount of rainfall may be enough for sprouting fresh grasses in warmer areas where grasses regenerate quickly compared to the highlands. Fashing *et al.* (2014) and Jarvey *et al.* (2018) reported that the mean percentage green cover correlated most strongly with the total rainfall of the previous three months. However, in Goro-Jena, the strongest correlation between green cover and rainfall was observed in two previous rainy months. Boutton *et al*. (1988) examined that open grassland responds rapidly to rainfall. In the present study, the response of green cover of graminoids on the open plateau is faster than the response of green cover of trees and bushy vegetation on the cliff. The percentage of green cover on grass plots at plateau top correlates strongly with the rainfall. The present study showed significant positive correlation between rainfall and green vegetation cover.

The green-weight and dry-weight of gramineae are described in the percentage of the total above ground biomass for each month and season. In the present study, the above ground green weight and dry-weight have been estimated on the cliffs. Grass biomass in cliff at Goro-Jena was comparable with the biomass estimate at Sankaber (Simien) by Iwamoto (1979). The biomass of the tall grasses (>10 m) is higher at the escarpment/cliff in Goro-Jena. This is highly associated with rainfall during the wet season. The availability of graminoids for geladas is the highest on cliffs compared to open plains. This is presumably due to the absence of grazing in cliffs. Yet, the local people clip the grass from the cliff during late wet season for their cattle forage. Above ground grass biomass at open grassland is very low due to intensive grazing by the domestic livestock year round. Grazing is intensive at open plains in Goro-Jena.

The biomass of green grass begins to increase from July, reaches a maximum of 433g/m^2 in October when a peak of growth and then a general decrease as dry months progress. Iwamoto (1979) found an increase of biomass from August reaching a maximum in November at Sankaber which is extended by a month from the present study. This might be due to the extended rainfall and lower temperature in Sankaber compared to Arsi where high temperature desiccates the graminoids following the end of rainy season. In the present study at Goro-Jena, the dry-weight of plants tends to accumulate starting from June and reach peak in

December, suggesting that the growth of graminoids is correlated with the previous rainy month/months and no growth of graminoids in the absence of rainfall during the dry season. Desiccation of graminoids is very fast at open plains compared to escarpment/cliff due to a direct exposure of short graminoid to sunlight radiation. Graminoids desiccate completely during the dry season. In contrast, Iwamoto (1979) found that green biomass at high altitude in Sankaber stayed for a long time even until the end of the dry season. The lower ambient temperature at higher elevation allowed graminoids stay green compared to at lower elevation. Plants desiccate very slowly in the highlands. Consequently, availability of green graminoids is more in Simien Mountains National Park and in Guassa Community Conservation area compared to the current study area, Arsi (Hunter, 2001; Fashing *et al*., 2014).

The availability and quality of graminoids and forbs for gelada diets in Goro-Jena is worse than elsewhere where geladas inhabit. This is possibly due to low rainfall, higher ambient temperature at lower elevation, and overgrazing by domestic livestock. Geladas usually prefer short and soft green graminoid blades at the plains. Tall graminoids on cliffs are less selected by the Arsi geladas. However, green graminoids at plateau top desiccate more rapidly compared to the escarpment/cliffs during the dry season, suggesting that food resources in the form of green graminoids might be patchy distributed/or declined during the dry season. This is contrary to Dunbar (1977a) and Iwamoto (1979) that gelada food resources are evenly distributed. Yet, geladas in Goro-Jena are more flexible. They consumed brown graminoids, fruits, graminoid stem, seed, underground items and cactus leaves during the dry season when the preffered green graminoid blades are declined.

Seasonal variation in food availability: Above ground grass biomass weighs maximum at the end of the rainy season due to maximum water moisture. The grass biomass decreased in progress during the dry season. The dry weight of graminoids is smaller during the wet months compared to the dry month, constituting more water moisture. The above ground food item at cliff varied seasonally. However, the dry-weight was peak in December. This variation aligns with the range in percentage of green cover during the wet season. This indicates that graminoids are unevenly distributed in the habitats.

In the present study, phenological assessment showed green grass availability of Arsi gelada increased diets during high rainy season (from August to October) with peak in September and October which was highly associated with rainfall. Similar findings were reported by Hunter (2001), Fashing *et al*. (2014) and Jarvey *et al*. (2018). However, rainfall has no immediate effect on the growth of graminoids. Variation of the level green graminoid cover on open grazing habitat showed the strongest correlation with rainfall in the preceding months. Boutton *et al*. (1988) reported similar finding that open grassland typically responds rapidly to rainfall. Geladas consumed highest percentage of green graminoids during the wet season because of availability and digestability. Dunbar and Dunbar (1974), Iwamoto and Dunbar (1983) and Iwamoto (1993) reported that geladas feed more than 90% of the total time on green graminoid during the wet season. The level of green graminoids and forb cover in Goro-Jena showed a seasonal shift in rainfall and ambient temperature. From November onwards green graminoid availability declined fast especially from the open plateau top where graminoids are exposed to sunlight. Green grasses under the shade of trees and bushes on the cliff face remain green for some time during the dry season. The poor quality food item (brown grass) of gelada diets was peak in March in all habitats during a peak ambient temperature.

During rainfall, grassland exhibited phenological activity and increased green biomass (Pandey and Singh, 1992). Rainfall influences the availability (Pandey and Singh, 1992) and quality (van Soest, 1994) of gelada food items. Results in the present study showed that short graminoid at plateau top responds quickly to rainfall. Post (1982) reported that rainfall fluctuations affect food abundance and quality.

Studies in the highlands of Ethiopia reported that geladas are graminoid specialists (Dunbar, 1977a; Iwamoto, 1979; Iwamoto and Dunbar, 1983; Hunter, 2001; Fashing *et al*., 2014). Graminoid remained green relatively for long period in the highlands due to moderate temperature and cold weather condition.The geladas consumed highest percentage of green graminoid blades. However, the present study on Arsi geladas showed that they consumed different species (plants and animals) and food items in addition to higher percentage of graminoids. Arsi geladas are flexible feeders. The lower elevation and warmer climate in Arsi altered the green graminoid and desiccate soon after the wet season. Consequently, geladas at Goro-Jena switch food items into brown grass blades, seeds and stems, forb root and seed, fruits, cactus leaves and animal preys when the preferred food (green graminoids) availability declined and become scarce due to seasonal change. Feeding is opportunistic. Fruit production and availability are low in the area. Geladas spend much time in digging to obtain subterranean food items during the dry season. Further, geladas obtain water from cactus leaf and from underground storage food during the dry season. Similar findings was reported by Dominy *et al*. (2008) and Jarvey *et al*. (2018) that geladas consume underground storage organs to obtain stored water and carbohydrates.

5.3.1 Feeding behavior of Arsi gelada

Geladas show a higher level of diet specialization relying in low-quality graminoid (grass and sedge) leaves for most of the year (Dunbar, 1977a; Iwamoto, 1979; Hunter, 2001; Fashing *et al*., 2014; Jarvey *et al*., 2018). Dunbar (1977a) and Iwamoto (1979, 1993) found that gelada diet comprise over 90% graminoid leaves. In the present study, Arsi geladas in Goro-Jena spend most of their time for feeding on graminoids (83.33%). Graminoid consumption increased with its availability and decreased during its scracity. Despite their predominant graminivory, geladas display some dietary flexibility typically corresponding with seasonal shift or resource scarcity. Thus, geladas consumed more brown graminoids during the dry season. Studies showed that dietary variability of geladas is associated with seasonal decline in graminoid leaf availability (Dunbar, 1977a; Iwamoto, 1979; Hunter, 2001; Fashing *et al*., 2014; Jarvey *et al*., 2018). Though graminoids are bulk diet of geladas, they are selective both with the species and the quality of graminoids they consumed. Fashing *et al*. (2014), Jarvey *et al*. (2018) and Addisu Mekonnen *et al*. (2018) reported that specialized foragers showed some flexibility in response to change of food availability and/or during food shortage. Coarse grasses were never eaten by geladas (Dunbar and Dunbar, 1974). However, during the dry season when decline and change of green grass cover at open plains, geladas feed on brown blades, grass stems and grass seeds in addition to feeding on fruits, cactus and subtranean items. Studies have shown that geladas consumed underground storage items during the dry season when green graminoid leaf availability was low and scarce (Iwamoto, 1993; Jarvey *et al*. 2018). Geladas in Guassa consumed highest forbs (Fashing *et al*., 2014).

Geladas at Arsi displayed varieties of feeding behaviors. Geladas use different adaptations to increase the feeding efficiency from lower quality food items. They have long thumps and short second index finger which permits them to pluck and pick grass blades quickly (Dunbar, 1977a). Geladas use both hands simultaneously and repeated pick of only green blades selectively by using their thumbs and forefingers. Geladas use slow movement (shuffling) forward to get new ungrazed graminoid leaf. Iwamoto (1979) and Fashing *et al.* (2014) reported that geladas pick grass blades repeatedly several times and keep between fingers until the blades are taken to the mouth. These permit geladas to exploit a grassland habitat much more efficiently than other ruminants. Geladas use short and robust phalanges for digging underground food items in the absence of green graminoids. Arsi geladas grind more fibrous graminoids using their molars as pointed out by Jolly (1972). Bulk feeding offers gelada to obtain the required level of nutrition from a relatively poor diet (Iwamoto and Dunbar, 1983; Dunbar and Bose, 1991; Iwamoto, 1993).

Geladas at Goro-Jena frequently consume brown graminoids and grass stems frequently during dry season. The harsh weather condition and more seasonal habitat with low rainfall and warmer climate in Arsi desiccate green graminoids which affects the feeding behavior of Arsi geladas (Mori *et al*., 1999; Kelil Abu *et al.*, 2018). In contrast, geladas at Simien Mountains National Park with higher altitude geladas rarely consume dry graminoid blade compared to Arsi gelada (Dunbar, 1977a; Iwamoto, 1979; Hunter, 2001).

Geladas at Goro-Jena consumed > 57 plant species and 4 species of invertebrates. The major species and food items comprised graminoids (≥ 26 species) and forbs (≥15 species). The overall Arsi geladas spend peak time consuming dites > 83.33% comprising graminoids. Similar findings were reported by Dunbar (1977a), Iwamoto (1979, 1993), Hunter (2001), Fashing *et al*. (2014) and Jarvey *et al.* (2018) that geladas spend more time consuming graminoids. They also consumed other items. The diverse species and food items consumed showed that geladas occupy different habitats and seasonal changes in food availability. Arsi geladas displayed dietary flexibility. This feeding flexiability presumably is associated with the changing of food availability due to the highly seasonal environment and anthropogenic effects. Studies showed that animals may switch from one food type to another to optimize nutrient intake or because of decrease in the abundance and quality of preferred food items (Jarvey *et al*., 2018). Geladas are unique among primates in their adaptation to graminivorous feeding, terrestrial life and occupying cliffs and grasslands (Dunbar, 1977a; Iwamoto, 1979; Zewdu Kifle *et al.*, 2013; Fashing *et al*., 2014; Jarvey *et al.*, 2018). Arsi geladas consumed “fallback food” which are available for long period when the absence or decline of green graminoid blades.

Seasonal changes in the dietary composition of Arsi gelada are highly associated with low rainfall and high ambient temperature. Studies showed that geladas consumed alternative food items during the dry season when the preferred food items (green graminoids) decline (Dunbar and Dunbar, 1974; Iwamoto, 1979; Iwamoto and Dunbar, 1983). The distinct wet and dry seasons in Arsi led to extensive seasonal desiccation of green graminoids. The seasonal changes alter the physical structure of habitats and the resource availability. Dunbar (1992a) and Hill (1997) indicated that seasonal variation was observed in diets, water sources, change of vegetation composition and availability and temprature. The predominant green graminoids of gelada diets changed into brown and declined especially from the open grassland. Dunbar and Bose (1991) and Hunter (2001) found a dietary shift of geladas to more subterranean food resources during the dry months. Geladas at Goro-Jena respond to the dry season food scarcity by shifting to lower-quality food items. In the present study area where limited preferred food items (green graminoids blades), geladas consumed brown graminoid blades, grass stem, subterranean items, cactus leaves and fruits during the dry season during complete desiccation of graminoids with high temperature. Similar findings were reported by Iwamoto (1979, 1993), Iwamoto and Dunbar (1983) and Jarvey *et al*. (2018). Seasonal changes result in increase time spent moving of geladas to collect scattered green graminoid blades mixed with brown blades. Post (1978) suggested that time spent for foraging in baboons increases during the dry season.

The present study showed that *Digitaria abyssinica* is the most preferred diet/selected of Arsi geladas due to its soft and easy digestibility. *Hyparrhenia rufa* and *Themeda triandra* are highly consumed graminoids at the escarpment. In contrast, geladas in Guassa and Simien consumed *Festuca* grass species and *Trifolium* (Iwamoto, 1979, 1993; Iwamoto and Dunbar, 1983; Fashing *et al*., 2014). Elevation and habitat types in association with specific vegetation determine the species and food items of gelada diets. Unlike the northern geladas, Arsi geladas never consumed *Trifolium* species. The species is infrequently found in Goro-Jena. It is suggested that habitat featurs rarely between the northern and the Arsi gelada populations due to differences in elevation. The habitat of Guassa gelada is also quite different from the Arsi gelada habitats. Guassa is an intact and non-disturbed habitat where graminoids and forbs stay green for long periods. An intact habitat might be more appropriate site for the natural behavioral study of geladas than anthropogenic disturbed areas (Fashing *et al*., 2014). Geladas in Goro-Jena and Bole Valley consumed similar diets grass species including *Hyparrhenia*, *Penniseturn*, *Cynodon* and *Andropogon* species. Geladas in Arsi and Bole Valley utilized similar plant species and food items as the two sites have similar elevation and weather conditions. Though similar in food species in the two sites, feeding bugets of geladas was qiute different (Dunbar and Dunbar, 1974).

In the present study, geladas in Goro-Jena consumed small portions of forbs at different seasons. Arsi geladas consumed forb roots and seeds more during the dry season. Forbs provide more nutrients. Yet, they comprise lower food proportion of Arsi geladas as they are less availabile and less abundant due to high temperature. Forbs dried in few months during the dry season due to warmer climates.

Seasonal dietary composition of gelada comprised different species of graminoids, forbs, cactus leaves, fruits and invertebrates. Studies showed that dietary composition is constrained by the impact of warm weather conditions on vegetation structure (Hill and Dunbar, 2002). Green graminoid blades were dominant diets of Arsi geladas during the rainy season. Geladas shift to other species and food items when the green graminoid desiccate (Dunbar and Dunbar, 1974; Dunbar, 1977a; Iwamoto, 1979; 1993). Geladas at Goro-Jena consumed brown graminoid blade, stem and seed during the dry season. Similar finding was reported by Crook and Aldrich - Black (1968) that geladas in Debre Libanos consumed fresh grass blade during the rainy season, and dry grass blades, stems, and rhizomes during the dry season.

The diet of gelada at Goro-Jena was more diverse during the dry season than the wet season. Geladas in Goro-Jena feed on less number of preferred food species primarily graminioids during the wet season. The lowest dietary diversity was recorded when geladas feed on few graminoid species that sprout young flushes blades during the short rain in April. A study showed that dietary diversity was greatest during late dry months and the lowest during the wet months (Hill, 1997).

Hunter (2001) found that when green grasses become less available, geladas increase dietary diversity and increase their intake of above ground and underground food items. Yeager (1989) pointed out that dietary diversity increased in association to food scarcity. However, some studies reported that dietary diversity is high during rainy season. Post (1981) reported that monthly dietary diversity is correlated with monthly rainfall and higher during the rainy months than the dry months. On the other hand, dietary diversity was unaffected by season in macaque (O'Brien and Kinnaird, 1997).

Dietary diversity of Arsi geladas in Goro-Jena is greater than the study at Indetu area (Kelil Abu *et al.*, 2018). This might be due to the difficulty of study site to get closer to identify the food species consumed by geladas in Indetu, habitat disturbance and poor grass availability. Kelil Abu *et al.* (2018) found that geladas at Indetu feed only few plant species. Studies noted that in disturbed habitats, diet of primate is often less diverse or lower quality than in intact habitats (Riles, 2007; Dereje Tesfaye *et al*., 2013). Geladas at intact habitat of Guassa consumed more varied diets than geladas at more human-dominated sites else where (Fashing *et al*., 2014). In the present study at Goro-Jena, geladas utilized different microhabitats to consume different species.

Gelada diets are highly variable across study sites. The proportion of graminoid leaves varies substantially. Geladas at highest elevation in Simien (Gich and Sankaber) and in lower elevation (Arsi, Bole and Wonchit) spend more time feeding on graminoid leaves during the wet season than geladas at Guassa. Gelada at Guassa consumed the highest forbs. The intact habitat of Guassa is more for forbs. Underground food comprised a large part during the dry season than wet season diets. Geladas at higher elevations with less anthropogenic disturbance depend less on underground foods during the dry season. Geladas in lower altitude of Arsi and Bole Valley consumed brown graminoids, shrub leaves (cactus) and fruits during the dry season (Appendex 4).

Differences of gelada diets in different studies might be due to the length of the study period. Short time period of a study may cause a missing of the variations in ecological conditions across the year. Changes in weather conditions (rainfall and temperature) in different years possibly contribute to the differences between studies. Different status of human disturbances in different study sites is likely to contribut differences in gelada diets. Altitudinal variation can cause dietary variation within a species of geladas. Temperatures decrease with increasing elevation causing energetic costs for thermoregulation to rise correspondingly (Kleiber, 1961; Grow *et al*., 2014), geladas increase consuming higher proportion of graminoids for increased energetic demands. Iwamoto and Dunbar (1983) and Jarvey *et al*. (2018) found that geladas at higher elevation consumed more diet for thermoregulation.

Studies showed that composition of gelada diets may differ between individuals, groups and populations as a result of local habitats, seasonal fluctuations in resources and altitudinal variations (Dunbar and Dunbar, 1974). Data on feeding ecology provide information on the individual food species and give insights into its level of dietary specialization (Caro, 1998).

5.4 Ranging behavior and habitat use

Arsi geladas are suffering from shortage of preferred food and drinking water, warmer weather condition and seasonality. Each habitat type in the home range differs in resource availability, human disturbance and sleeping site location. Study showed that primates use their home range in uneven manner, spending a disproportionately large amount of time concentrated in relatively small areas (Kaplin, 2001; Wallace, 2006). In the present study, geladas select best open grassland habitat though smaller size compared to other habitats in the home range.

Encounter rate of scan sample records during group follows showed that geladas utilized habitats in different frequency. Habitat utilizations of geladas in Goro-Jena were related with vegetation cover, food availability, habitat disturbances and elevation. Similar finding was reported by Hunter (2001) in Sankaber (Simien) that geladas utilized different habitats. Geladas at Goro-Jena prefer to utilize open grassland more than cliff habitat compared to its availability. However, high human disturbance forces geladas to confine at cliff edge during crop growing season (Kassahun Abie *et al*., 2017). Local farmers guard their crop fields starting from sowing till harvesting. They chase geladas frequently from crop fields and adjacent grassland during growing season. Geladas utilize cultivated land only very rarely because local people guard it during the crop-growing season. Geladas avoid utilize patchy forest gorge at cliff bottom during the wet season. It is denser understory and occupies coarse grass. Predator risks such as leopards may also discourage geladas from utilizing forest gorges during the wet season. Dunbar and Dunbar (1974) revealed that geladas at Bole Valley did not occupy forest edge.

Geladas spend more time on open grassland when more food is available and there is less human disturbance, but spend less time during high heat load and complete desiccation of graminoids. During high ambient temperature all graminoid and forb leaves desiccate. Consequently, geladas move down the cliff under tree shade. Geladas in Goro-Jena used shade opportunistically in the home range. Geladas may obtain semi-green grasses under the tree shade, and fruit from tree branches on the cliff face and at patchy forest gorges. Similarly, Hunter (2001) noted that geladas in Sankaber (Simien) consumed green graminoids under the tree shade during the dry season.

Geladas occupy escarpment/cliffs more frequently during the rainy months. Although more hot temprature during the dry season, Arsi geladas occupy more often the open grassland due to decline human disturbances. Cultivated land is abundaned during post-harvesting. Geladas pick residual fall seeds from the crop field. Similar finding was reported by Dunbar (1977a) that geladas in Simien moved seldom far distance from the cliff edge during post-harvesting. Geladas extend their range size and form large foraging group across crop fields and at open grassland. Big herd of geladas may frequently be formed at open grazing plain to avoid predation pressure and wider exploitation of their habitats.

Habitat conversion, cultivation, habitat disturbance and competition with domestic livestock are very intense in Goro-Jena (Amera M. pers. Obs.). Similar finding was reported by Beehner *et al.* (2007), Mesele Yihune *et al.* (2009), Kelil Abu *et al.* (2018) and Addisu Mekonnen *et al*. (2017). Currently, grassland habitats are being converted into farmlands and human settlement due to high human population pressure and the need for more land for agriculture. Studies showed that agricultural land expansion is the major source of conflicts between humans and non-human primates (Crook, 1966; Dunbar, 1977a; Cowlishaw and Dunbar, 2000). Dunbar (1998) and Beehner *et al.* (2007) reported that geladas are at high risk of extinction due to intensive agricultural activities and climate change.

5.4.1 Ranging behavior and spatial analysis

Study showed that group size is an important factor for home range size and day path length. Small group size of geladas in Goro-Jena travel shorter distance compared to large group size in SMNP. Large group sizes travel longer distance to exploit sufficient food as increase feeding demand (Hunter, 2001; Moua, 2015). Similarly, Dunbar (1977a) and Iwamoto and Dunbar (1983) found that day path length of geladas increased with group size to obtain the daily food requirements. Barton *et al.* (1992) reported a positive correlation between group size and day path length of baboons. Riley (2008) and Strier (1987) found that group size to be a major factor affecting ranging behavior in primates. The present study indicated that geladas increased day path length during poor food resource availability to consume selected items. This is consistent with Iwamoto and Dunbar (1983) that each animal in a group covered constant area each day to obtain its daily nutritional requirement. Similarly, Struhsaker (1967) reported that day path length increased for groups living in poor quality habitats where scarce resources. White *et al*. (2010) showed that selective feeders of terrestrial primates may move greater distances to find patchily distributed food resources and waterholes.

The present study indicated that Arsi geladas respond to lower quality and limited food resources by increasing their day range and/or switching to other food items. Geladas travel long distances to collect more dispersed green graminoids (Dunbar, 1988). Hunter (2001) suggested that food availability is a primary determinant of home range size and habitat selection of geladas. Jiang *et al*. (1991) reported negative correlations between range size and habitat quality of primates. Dunbar (1988) described that primates may either increase day range for preferred food or decrease the day range by reducing energy requirements. In contrast to Arsi geladas, Strier (1987) reported that primates may reduce energy expenditure by decreasing day range during scarcity of resources. Some studies found negative associations between day path length and food abundance (Clutton-Brock, 1975), no association (Post, 1978), or positive associations (Richard, 1977).

Study indicates that the day path length and home range size of geladas are associated with group size and food availability. Geladas in lower altitude at Arsi and in Bole Valley travelled short distances and utilized smaller home range size compared to geladas in higher altitude (Guassa, Gich and Sankaber) (Iwamoto and Dunbar, 1983; Hunter, 2001; Moua, 2015). Gelada bands

(220 – 265 individuals) at Sankaber and at Guassa travel larger distances per day compared to geladas at Arsi and Bole with small band size (31 - 80 individuals), the lower elevation and limited resources (Appendix 2). The smaller home range size of Arsi geladas might be due to habitat loss and human disturbances. The smaller foraging size and unstable band of Arsi gelada might be a response to lower food availability and habitat quality in the warmer temperature and low rainfall area compared to geladas in Gich and Sankaber. Unstable band and small unit size of Arsi geladas might be an adaptation to live in harsh and warmer climate (Mori and Gurja Belay, 1990; Kelil Abu *et al*., 2018).

Altitude range affects group size and food availability. Studies showed that at highest elevation where higher cold weather (in Gich) and at lower elevation with warmer weather (in Goro-Jena), decline the food quality and availability to support large group size of geladas (Iwamoto and Dunbar, 1983; Dunbar, 1998). Consequently, the small group size of geladas occupied small home range and travel shorter day path length at Gich and in Goro-Jena compared to gelada sites at middle elevation (such as at Sankaber where larger group size of geladas)(Dunba and Dunbar, 1974; Iwamoto and Dunbar, 1983). Food production and quality decreased both at extreme higher altitude range with lower temperature, and at lower altitude with higher temperature (Iwamoto and Dunbar, 1983; Dunbar, 1998). The two extreme altitude ranges (Gich and Goro-Jena) have low production and support relatively smaller group size of geladas compared to the altitude range in Sankaber and Guassa (Dunbar, 1992b; Appendix 2). However, study showed that larger group size of geladas in Sankaber (Simien) travelled long distances during limitation of resources on consume on new grazing ground (Crook, 1966; Dunbar, 1977a; Iwamoto and Dunbar, 1983). Dunbar (1977a) suggested that geladas in poor habitats either forage in small group size or travel long distance due to lower density of grass cover.

5.4.2 Seasonality in ranging behavior of Arsi gelada

Range size of Arsi geladas is influenced by seasonality. Baboon showed marked shift in range use pattern across season (Barton *et al*., 1992). Rainfall increases graminoid production (Coe *et al*., 1976; Hunter, 2001; Fashing *et al*., 2014). The present study showed that day path length and home range size of Arsi geladas is correlated negatively with green grass production and positively with high ambient temperature and poor quality brown graminoid. Green graminoid production is highly correlated with the two previous rainy months (60 days), but shows negative correlation with the day path length of geladas. It is consistent with Hunter (2001), Fashing *et al.* (2014) and Jarvey *et al*. (2018) that graminoid production is strongly correlated with two previous rainy months. These relationships have been attributed to influence food resources on ranging behavior of Arsi geladas. Geladas decreased their range size when green graminoids are abundant during the rainy months. However, Arsi geladas increased day path length during the absence of rainfall causing decrease in abundance of green graminoids and increase brown graminoids. Louw (1972) and Dunbar (1998) found that grasses in high temperature habitats lose water as a result of desiccation during the dry season.

The home rang size and day path length of Arsi geladas was influenced by seasonal variations in food availability and temperature. The patchily distribution and quality of preferred food resources determine the range of Arsi geladas. Weather condition (rainfall and temperature) influenced their range. The present study showed that seasonal home range of geladas in Goro-Jena is associated with resource availability, human disturbances and ambient temperature. Geladas at Goro-Jena increased both their day path length and home range size during the dry season to find preferred food sources. Riley (2008) reported that food availability predicts DPL better than group size. Crook (1966) and Dunbar (1977a) reported that geladas in Simien extend their range size to obtain additional food sources during limitations. Barton *et al.* (1992) suggested that seasonal changes in day range length of baboons is likely to be related to patch effect on resources.

The 95% KDE home range size of geladas in Goro-Jena was greater during the dry season (147.4 ha) than wet season (118 ha). High ambient temperature and low rainfall correlate with a rapid desiccation of green graminoids and forbs. Green graminoids are sparsely distributed during the dry season. Sunlight radiation change green grasses into brown and lead to decline nutrient in quality. Studies suggested that abundance and quality of graminoids decreased during the dry season Iwamoto (1979; 1993; Iwamoto and Dunbar, 1983; Dunbar, 1998). Increasing of day path length and home range size of Arsi geladas during the dry season might be due to two major reasons. First, during the dry season the availability of green graminoids and forb leaves were desiccated. Consequently, geladas move long distance to search for the scattered green graminoids and forbs to obtain the daily nutrient requirements. Most water sources in the home range dried during the late dry season, suggesting that geladas moved further to get access to water. The other resean may be due to reduction in human disturbance after crop harvesting during the dry season. Crop fields as well as adjacent open grasslands are left free of humans during the dry season. Geladas extend their home range across crop fields to feed on fallen seeds. Similar finding was reported by Dunbar (1977a) and Iwamoto (1993) that geladas in Simien increased their home range size after crop harvesting during the dry season. Clutton Brock (1977) reported that primate home ranges may increase in size in response to food scarcity.

Geladas at Goro-Jena forage long time at same place when abundant and preferred food sources during wet season. Consequently, they presumably decrease day path length and home range size during the wet months. Iwamoto and Dunbar (1983) showed that geladas at SMNP travel smaller distances during the wet season due to food availability compared to the dry season. The present study showed that monthly mean day path length is negatively correlated with green grass availability. Geladas increase monthly mean day range length to consume on dispersed distribution of fruit on the cliff face during the dry season. Hunter (2001) reported similar finding from SMNP. In Goro-Jena, geladas are confined to a limited range on cliff face and cliff edge during the wet season due to high human disturbance. The home range is adjacent to human settlement and encroachment. It has more exposed edge effect to human disturbance. This might result in decrease range size of geladas. Similar finding was reported by Kassahun Abie *et al*. (2017) that geladas in Debre Libanos decreased their range size during better resource, and during human disturbances. Human-wildlife conflict involving primates reflects today's realities: previous primate habitat has been suddenly turned into human dominated habitat (Dunbar, 1977a; Cowlishaw and Dunbar, 2000).

6. CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion

Arsi gelada is an isolated population found in limited geographic ranges southeast of the Rift Valley. They comprised a very small population size and patchily distributed along the Wabi-Shebelle and Robe River cliffs. Arsi geladas inhabit in three districts in eastern Arsi administration Zone. They are confined in marginal habitats due to high human population density and high anthropogenic impacts at different localities. Arsi geladas particularly occupy cliffs and the narrow belts in the remaining grasslands adjacent to cliff edge where intense grazing by the domestic livestock is practiced.

Geladas shrink their home range size and day path length during the wet season and/or during intense human disturbances. They extend their home range size during less resource availability and reduce anthropogenic disturbances. Habitat loss and anthropogenic factors led Arsi geladas to confine to marginal habitats and cliff face and cliff edge.

Warmer temperature and low rainfall influence food preferences of Arsi geladas in Goro-Jena. Seasonal variations increase the decline of food production and quality. Arsi geladas are at high risks due to seasonal change of food production and availability. Habitat features and food composition change due to harsh weather condition during the dry season. Arsi geladas are ecologically flexible that swich into alternative food items when the preferred green graminoids desiccated/decline during limited rainfall and harsh weather. Geladas switch to consume brown graminoid leaves and stem, fruits, bush/shrub (cactus) leaves, forb roots and seeds in warmer climate. Crop raiding of geladas is intense during habitat conversion.

Arsi geladas are highly threatened due to high seasonal weather conditions which result in decline habitat quality and resource availability and serious anthropogenic impact. Intense livestock grazing is another impact for geladas in Arsi. Consequently, they change their feeding behavior and socio-ecology compared to other two well known gelada subspecies found at higher elevation north of the Rift valley. Arsi geladas comprised small unit size and unstable band size of geladas due to less food availability, habitat disturbances and habitat degradation. Human activities such as extensive cultivation, livestok grazing and human settlements are major impacts which affect group instability of Arsi gelada. A frequent split of gelada bands is possibly an adaptation to reduce competition among groups/individuals and to utilize lower food resources. According to the present finding, the population size of Arsi gelada seems to be increasing compared to the previous estimations. However, the previous estimates of geladas were conducted for a few days survey on accessible sites. The population of Arsi geladas may be extriminated in the near future unless urgent conservation actions are taken. In sum, knowledge on accurate population size, distribution and behavioral ecology of Arsi geladas are crucial to develop management plans and implement successfull conservation strategies.

The present study of Arsi geladas showed a more detailed study conducted more than a year cmpare to the previous study by Kelil Abu *et al.* (2018). The results in species and food items and feeding budgets of Arsi geladas in present study are higher than the previous study though the study habitats in both studies have similar land features and elevation.

6.2 Recommendations

- Due to their unique taxonomy, restricted distribution, small population size, anthropogenic threats, Arsi geladas require urgent management plan and implementation of conservation strategies to ensure the chance of long-term survival in the region.

- The local government agencies, rural development and agricultural office and wildlife authorities should be responsible to prepare conservation strategies to protect the endangered and a little known Arsi gelada and its habitats.
- Gelada is one of the charismatic endemic species of the country and frequently visited species. Thus, Arsi geladas and their habitats should be protected.
- Tourism is the most significant sources of national revenue generation in many developing countries. Thus, the local government and wildlife officials should facilitate and promote to attract tourists to benefit the local communities.
- In addition to protection and restoration of the gelada cliffy habitats along Wabi Shebelle and Robe Rivers, other wildlife and their habitats should be conserved.
- Concerened officials with locals should work together to establish protected area for Arsi geladas.
- Land-use and land-cover changes in Arsi have forced wildlife to be restricted to those few areas that were preserved naturally due to rugged topography. Thus, the wildlife professional should create awareness to the local community to develop ownership and protect the wildlife and their habitats.
- Conservationists and wildlife professions should be aware of diet and feeding behavior of Arsi geladas inhabited in degraded habitat at lower elevation to design proper management plan and for effective conservation work in the area.
- Repeated study on human–wildlife conflict should be conducted and change the attitude of the local community towards the wildlife.
- A way should be sought to minimize agricultural dependency into industrial production. So that agricultural land expantion and loss of wildlife habitats should be minimal.

- In addition, research will also be crucial on the nutritional analysis of geladas to determine why geladas preferred certain plant species. It is also vital to determine the gelada parasite infection that has a possibility to transmit to local human population live close to the gelada habitat and vice versa.

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8. APPENDICES:

Appendix 1. Commonly found edible and non-edible plant species in the study habitats

Local name	**Family name**	**Botanical name**	**Life form**	**Category**
Asoka/Cactus	Cactaceae	*Opuntia ficus-indica*	Shrub	Leaf
Black seed grass	Poaceae	*Eragrostis botryodes*	Graminoid	Leaf
Abesuda like herb	Malvaceae	*Hibiscus trionum*	Forb	Leaf
Acrma merga	Poaceae	*Eleusine floccifolia*	Graminoid	Leaf
Agamsa	Apocynaceae	*Carissa spinarum*	Tree	Fruit
Amakita herb	Fabaceae	*Medicago polymorpha*	Forb	Leaf
Ara	Moraceae	*Ficus thonningii*	Tree	Fruit
Asendabo merga	Poaceae	*Phalaris paradoxa*	Graminoid	Leaf, Seed
Ashikit	Rubiaceae	*Galium spurium*	Forb	Leaf
Balemi merga	Poaceae	*Andropogon abyssinicus*	Graminoid	Leaf
Batula merga	Poaceae	*Digitaria abyssinica*	Graminoid	Leaf
Black buri	Hypoxidaceae	*Hypoxis villosa*	Forb	Bulb
Chekorsa merga	Poaceae	*Penniseturn villosurn*	Graminoid	Leaf
Chincha merga	Poaceae	*Hyparrhenia anthistirioides*	*Graminoid*	Leaf
Cypress sedge	Cyperaceae	*Cyperus rigidifolius*	Sedge	Stem, Leaf
Embacho	Polygonaceae	*Rumex nervosus*	Shrub	Flower
Gersa merga	Poaceae	*Themeda triandra*	Graminoid	Leaf
Getemie	Araliaceae	*Steganotaenia araliacea*	Tree	Non-edible
Gishe merga	Poaceae	*Arstida purpula*	Graminoid	Leaf, Seed
Murie like merga	Poacea	*Eragrostis minor*	Graminoid	Seed
Godir merga	Poaceae	*Andropogon chrysostachyus*	Graminoid	Leaf
Gorteb herb	Plantaginaceae	*Plantago lanceolata*	Forb	Leaf
Kortobe	Fabaceae	*Scorpiurus muricatus*	Forb	Leaf
Herb1	Convolvulaceae	*Falkia oblonga*	Forb	Leaf, flower
Herb10	Acanthaceae	*Dyschoriste radicans*	Forb	Seed
Horse tail merga	Poaceae	*Aristida adoensis*	Graminoid	Seed
Jeldo grass	Poaceae	*Festuka sp.*	Graminoid	Stem, Leaf
Ketissa	Poaceae	*Cynodon dactylon*	Graminoid	Leaf, Stem
Labuche	Commelinaceae	*Commelina erecta*	Forb	Stem, Root
Murie merga	Poaceae	*Sporobolous natalensis*	Graminoid	Seed

Samigrass	Poaceae	*Eragrostis capillaris*	Graminoid	Leaf, Seed
Short mata	Poaceae	*Hyparrhenia rufa*	Graminoid	Leaf, Stem
Large mata	Poaceae	*Hyparrhenia filipendula*	Graminoid	Leaf, Seed
Senbelet like balemi	Poaceae	*Bothriochloa insculpta*	Graminoid	Leaf, Seed
Sendedo merga	Poaceae	*Penniseturn thunbergii*	Graminoid	Leas, Seed
Shrub5	Fabaceae	*Rhynchosia albissima*	Bush/shrub	Leaf
Shrub6	Lamiaceae	*Otostegia erlangeri*	Bush/shrub	Leaf
Kecha	Poaceae	*Phleum phleoides*	Graminoid	Leaf, Seed
Tatisa	Anacardiaceae	*Rhus glutinosa*	Tree	Fruit
Teffsar	Poaceae	*Eragrostis tenuifolia*	Graminoid	Leaf, Seed
Thread herb root	Iridaceae	*Moraea stricta Baker*	Forb	Bulb
Tuchasar	Poaceae	*Penniseturn humile*	Graminoid	Leaf
Thick leaf herb	Lamiaceae	*Plectranthus sp.*	Shrub	Leaf
Red flower shrub	Malvaceae	*Hibiscus micranthus*	Shrub	Leaf
Unidentified liana	Fabaceae	*Eriosema scioanum*	Liana	Leaf
Yelamtut grass	Poaceae	*Chloris pycnothrix*	Graminoid	Seed, Leaf
Yewofsar	Poaceae	*Melinis repens*	Graminoid	Seed
Enkrkifo herb	Unidentified	Unidentified	Forb	Tuber
White buri	Asparagaceae	*Chlorophytum comosum*	Forb	Tuber
Red stem herb root	Unidentified	*Merendra abyssinica*	Forb	Tuber
Kemedi	Poaceae	*Triticum spp.*	Crop	Cereal
Teffi	Poaceae	*Eragrostis teff*	Crop	Cereal
Bokolo	Poaceae	*Zea mays*	Crop	Cereal
Telba	Linaceae	*Linum Lusitatissimum*	Crop	Cereal
Kilto	Moraceae	*Ficus vasta*	Tree	Fruit
Yetirs bursh like	Poacea	*Harpachne schimpei*	Graminoid	Leaf, Seed
Dhittacha	Sapiadaceae	*Dodonaea angustifolia*	Bush/shrub	Non-edible
Bisana	Euphorbiacaea	*Croton macrostachyus*	Tree	Non-edible
Digita	Fabacae	*Calpurnia aura*	Bush/shrub	Non-edible
Embacho	Polygoneceae	*Rumex nervoseus*	Bush/shrub	Non-edible
Gatra	Cupressaceae	*Juniperous poricera*	Tree	Non-edible
Egerssa	Oleaceae	*Olea Africana*	Tree	Fruit
Eculaptous	Myrtaceae	*Myrtaceae oblique*	Tree	Non-edible
Unidentified	Anacardiaceae	Rhus tenuinervis	Shrub/shrub	Non-edible

Appendix 2**.** Comparison of group size and age-sex ratio of gelada among populations from different regions (ML= leader male, AF = adult female, AM = adult male, Jv. = Juveniile, Inf. = Infant, Immat. = immature, Ad = asult)

Site	Within unit ML/AF	Within whole AM/AF	Jv./AF	Inf./AF	Immat./AF	Immat./Ad	Unit size.	Band size	Population	References
Present (2018) wet- unit	3.66	-	2.05	2.26	1.08	1.37	9.42	-	1323	This study
Present (2018) wet-band	-	3.32	2.5	2.38	1.22	0.63	-	26.04	1323	This study
Present (2018) dry-unit	4.33	-	2.24	1.99	1.05	1.29	11.45	-	1307	This study
Present (2018) dry-band	-	4.12	2.79	1.99	1.16	-	-	31.19	1307	This study
Gado-Goro:	-	-	-	-	-	-	-	-	-	
January-94	3	2.7	-	0.7	-	-	7.5	-	-	Mori *et al*., 1999
January-95	3	1.5	-	1.13	-	-	9.5	-	-	Mori *et al.*, 1999
January-96	3.1	2.2	-	0.9	-	-	7.9	-	-	Mori *et al.*, 1999
Bole	5.9	4.2	-	0.9	-	-	-	60.3	-	Iwamoto and Dunbar,1983
Sankaber (1971)	3.4	2.7	-	1.52	-	-	10	262	-	Ohsawa and Dunbar, 1984
Sankaber (1974)	4.9	2.4	-	-	-	-	14.7	256	-	Ohsawa and Dunbar ,1984
Gich (1973)	2.68	2.12	-	1.1	-	-	9.93	105	-	Ohsawa and Dunbar ,1984
Debre Libanos (2018) -wet	-	3.47	1.89	2.67	-	-	-	-	1642	Abie and Bekele 2018
Debre Libanos (2018) -wet	-	3.68	1.87	2.79	-	-	-	-	1573	Abie and Bekele 2018
Simen Mountain	3	4.2	-	-	-	-	-	-	4264	Beehner *et al*., 2008

Appendix 3. Comparasion of ranging behavior of geladas across different sites (DRL= day range length, HR = home range, ha = hectar, mo = months, m = meter, F = feeing, M = moving, R = resting, S = socialiingz, O = others).

Species name	Study site	Elev. (m)	Duration (mo)	Band size	Range size		Activity budget (%)					References
					DRL (m)	HR (ha)	F	M	R	S	O	
Arsi gelada	Goro-Jena[1]	2400	16	80	1439	134	57.29	12.26	10.19	18.62	1.26	This study
Arsi gelada	Indetu[2]	2060	9	34	-	-	41.7	20.3	19	19	0.0	Abu e al., 2018
T. g. obscures	Bole, Debre Libanos[3]	2300	6	60	630	84	35.7	17.4	26.3	18.5	2.1	Dunbar and Dunbar 1974
T. g. obscures	Guassa[4]	3400	60	220	3495	912	-	-	-	-	-	Moua, 2015
T. g. gelada	Sankaber, Simien Mts.[5]	3250	-	262	2160	-	45.2	20.4	13.8	20.5	0.0	Iwamoto and Dunbar 1983
T. g. gelada	Gich, Simien Mts.[5]	3900	-	112	1008	-	62.3	14.7	5.2	16	0.0	Iwamoto and Dunbar 1983
T. g. gelada	Gich, Simien Mts.[6]	3900	9	-	1890	178	79.55	-	-	-	-	Kawai and Iwamoto, 1979
T. g. gelada	Gich, Simien Mts.[7]	3300	3	844	2645	100	66.25	-	-	-	-	Iwamoto 1979, 1993
T. g. gelada	Sankaber, Simien Mts.[8]	3250	6	-	2056	928	59.75		15.35	20.15	0.0	Hunter2001

[1] This study conducted for 15 months from April 2014 - July 2015.

[2] Abu *et al*. (2018), conducted over10 month period (August10 – May11) (excluding March).

[3] Dunbar and Dunbar (1974), study conducted 82 h of observation during 3 non-contiguous period of1–3 months.

[4] Moua (2015), tudy conducted conducted from January 2010 - December 2011

[5] Iwamoto and Dunbar (1983), tudy conducted 3 wet season and 3 dry season months.

[6] Kawai and Iwamoto (1979), tudy conducted from 3 several days to 2-week periods during 5 months.

[7] Iwamoto (1979, 1993), conducted from 3 noncontiguous months (1 wet season and 2 dry season months).

[8] Hunter (2001), conducted from 3 wet seasons and 3 dry season months

Appendix 4. Overall and seasonal diets (%) of Theropithecus geladas at different geographic areas in different elevation

		Overall mean diets (%) of geladas									
Subspecies	Study site	Period (mo)	Elev. (m)	Graminoid	Forbs	Shrub	Fruits	Insects	Underground	Others	References
Arsi gelada	Goro-Jena[1]	16	2400	83.45	2.04	3.86	3.56	0.98	4.65	1.4	This study
Arsi gelada	Indetu[2]	9	2400	77.8	15.8	-	3.6	-	2.7	-	Abu et al., 2018
T. g. obscures	Bole, Debre Libanos[3]	6	2300	96.9	0.6	-	2.1	-	-	0.5	Dunbar and Dunbar 1974
T. g. obscures	Guassa[4]	15	3600	52.8	28.7	-	-	2.8	11.5	3.8	Fashing et al., 2014
T. g. gelada	Sankaber, Simien Mts.[5]	5	3250	68.2	1.4	-	1.0		25.9	3.5	Dunbar 1977
T. g. gelada	Sankaber, Simien Mts.[6]	12	3250	77.6	7.1	-	-	-	14	1.3	Jarvey et al., 2018
T. g. gelada	Sankaber, Simien Mts.[7]	6	3250	57	5.6	-	3.3	-	32.5	1.9	Hunter, 2001
T. g. gelada	Gich, Simien Mts.[8]	3	3700	73.7	15.7	-	-	-	10.5	0.1	Iwamoto, 1979,1979
T. g. gelada	Gich, Simien Mts.[9]	12	3700	74.9	2.8	-	-	-	18.3	3.8	Woldegeorgis and Bekele (2015)
T. g. obscures	Wonchit valley [7]	4	2600	83.8	-				11.6	4.6	Kifle et al., 2013

	Mean wet season food items (%)									**Mean dry season food items (%)**							
Study site	Period (mo)	Elev. (m)	Gram.	Forbs	Shrub	Fruits	Insects	Undergr.	Others	Gram.	Forbs	Shrub	Fruits	Insects	Undergr.	Others	References
Goro-Jena [1]	16	2400	91.16	0.89	3.19	0.83	1.11	3.56	0.25	78.25	4.01	4.38	5.68	0.88	4.42	2.36	This study
Indetu[2]	9	2400	71.33	13.9	-	6	-	8.13	-	80.94	16.92	-	2.17	-	-	0	Abu et al., 2018
Bole, Debre Libanos[3]	6	2300	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Dunbar and Dunbar 1974
Guassa[4]	15	3200	67.9	20.1	-	-	-	5.9	6.1	45.5	32.4	-	-	-	17.5	4.6	Fashing et al., 2014
Sankaber, Simien Mts.[5]		3250	93	0.3	-	-	-	3.3	3.4	55.9	2	-	-	-	37.2	5	Dunbar 1977
Sankaber, Simien Mts.[6]	12	3250	88.8	6.6	-	-	-	3.8	0.8	66.3	7.6	-	-	-	24.2	1.9	Jarvey et al., 2018
Sankaber, Simien Mts.7	6	3250	85.6	2.1	-	-	-	8.3	4.3	28.3	9	-	-	-	56.6	6	Hunter, 2001
Gich, Simien Mts.[8]	3	3700	94.7	2.6	-	-	-	2.7	0	63.3	22.2	-	-	-	14.4	0.2	Iwamoto, 1979, 1993
Gich, Simien Mts.[9]	12	3700	84.7	1.2	-	-	-	8.9	5	65.1	4.3	-	-	-	27.7	2.7	Woldegeorgis and Bekele (2015)
Wonchit valley [10]	4	2600	92.3	-	-	-	-	1.3	5.5	74.2	-	-	-	-	22.2	3.6	Kifle et al., 2013

[1] This study, mean annual diets from April 2014 - July 2015

[2] Abu et al. (2018), overall dites from August 2010 - May 2011(excluding March)

[3] Dunbar and Dunbar (1974), mean diet from 82 observation hours over 3 sampling periods of 1–3mo

[4] Fashing et al. (2014), the overall and seasonal diets from 15 contiguous study months from February 2007- April 2008

[5] Dunbar (1977), mean overall from 3 sampling periods (1 wet season, 2 dry seasons)

[6] Jarvey et al. (2018), mean annual diets from 12 contiguous study months from Jarvey 2015 - Jarvey 2016

[7] Hunter (2001), mean overall and season diets from 3 wet seasons and 3 dry season months

[8] Iwamoto (1979, 1993); mean overall diets from 1 wet season and 2 dry season months

[9] Woldegeorgis and Bekele (2015); mean annual diets from 12 contiguous study months from May 2013 - April 2014

[10] Kifle et al. (2013), mean overall and season diets from 2 wet seasons and 2 dry season months.