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Diurnal activity patterns and feeding ecology of geladas (*Theropithecus gelada*) in Ankober District at Kundi, North Shewa, Ethiopia

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Abstract: *Theropithecus gelada* is a primate species endemic to the central and North-Western highlands of Ethiopia, and is the only extant species of the genus *Theropithecus*. Diurnal activity patterns and feeding behavior of geladas were studied at Kundi, Ankober district, Ethiopia, from August 2017 to March 2018, to cover both wet and dry seasons. The scan sampling method was employed to study the activity patterns and feeding behavior of geladas in the study area. Activity scans were collected at 15-minutes intervals for up to 5-minutes duration from 0700 to 1730h. During each scan, individuals were recorded as performing one of the following behaviors: feeding, moving, resting, playing, aggression, grooming, sexual activity, and others. Descriptive statistics and Chi square test were used in data analysis. During the wet season, geladas spent in grooming 20%, playing 19%, resting 14%, feeding 12%, other activity 11%, moving 9%, and aggression 3%. During the dry season, geladas spent in feeding 27%, moving 21%, other activities 13%, aggression 12%, grooming 7%, playing 7%, and resting 4%. There were significant differences in all activity time budgets between seasons, except for "other activities". The total time spent feeding on grass blades and cereals in the study area was 25.5% and 23.5%, respectively. There was a significant difference between the age and sex classes of geladas in their activity time budgets. Eleven species of plants were recorded as food for geladas in this study area. This study provides baseline information on the behavioral ecology of geladas outside protected areas.

Key words: Activity budget; Ankober; endemic; scan sampling; *Theropithecus gelada*; outside protected areas.

Introduction

Ethiopia is one of the most physically and biologically diverse countries in the world, with remarkable endemic plants and animals that have national and global importance (Abune 2000; Asefa et al. 2020). It contains various wildlife and habitats, ranging from alpine moorlands to lowland savannas, and from arid lands to extensive wetlands (Yalden 1983). The main reason for the presence of diverse wildlife and a large number of endemic

species is the variety of topography in the country. This helped to create isolated and varied ecological situations. The biological resources are distributed in different biomes, mainly the Afrotropical highlands, the Sudan-Guinean, the Sahel-Transitional Zone, and the Somali-Masai Biome (Yalden et al. 1996).

Gelada (*Theropithecus gelada* (Rüppell, 1835)) is one of the 36 endemic mammalian species of Ethiopia (Refera and Bekele 2006). It is endemic to the central and North-Western highlands of Ethiopia and is the only extant primate species of the genus *Theropithecus* I. Geoffroy Saint-Hilaire, 1843 (Beehner et al. 2007; Yazezew et al. 2020). The species' geographic range is narrowly restricted to the high-elevation montane grasslands of the country (Mori and Belay 1990; Fufa et al. 2020).

The relationships among ranging behavior, habitat quality, group size, and diet of a primate species do not always show a consistent pattern (Dunbar 1988; Hunter 2001) due to the ability of different species to cope with resource scarcity and feeding competition in different ways. Increased intragroup feeding competition in scarce resource availability can be coping up by increased foraging efforts, longer group travel distance, changing pace of traveling, and changing seasonal home ranges (Hunter 2001). Some primates could respond to food scarcity without changing their ranging behavior considerably by broadening the diet or by spending more time in each feeding patch (Di Fiore 2003). Many factors influence the activity budgets of primates in natural habitats, most of which are related to the challenges of acquiring food energy. Wild populations of most non-human primates are decreasing globally due to dramatic anthropogenic impacts such as logging, deforestation, hunting, and other such factors (Fufa et al. 2020).

Although the study area is renowned for its historical background, the natural and biological aspect is poorly known so far. In spite of tremendous studies in and around protected areas, very few studies have been conducted regarding the behavioral ecology of geladas and its conflict with humans outside protected areas (Yazezew et al. 2020). Accordingly, the present study aims to organize diurnal activity patterns and human-gelada conflict in Ankober district, which is a non-protected wildlife habitat. The study enhances the understanding of environmental factors like disturbance levels, foraging opportunities, food availability, and habitat quality of the species for future management and conservation of the study area biodiversity. We based our assumption on the following three hypotheses: (1) there is no variation in geladas' time budget for different activities; (2) geladas prefer herbs over grasses; (3) there is no difference in the amount of food between wet and dry seasons.

Materials and methods

Description of the study area

This study was conducted in the Ankober district at Kundi, located in the North Shewa Zone of the Amhara National Regional State, in the North-Western highlands of Ethiopia. The district is perched on the Eastern escarpment of the Ethiopian highlands and situated 172 km North of Addis Ababa, the Ethiopian capital, and 42 km to the East of Debre Berhan town (North Shewa Zone capital) between $9^0 34'$-$9^0 41'$N and $39^0 41'$-$39^0 46'$E (Figure 1). The Ankober district is bordered in the North by Tarmaber, South by Asagirt and West by Basona Worana. The Eastern parts share borders with the Gachine Special district of the Afar Region. The elevation of the district ranges from 1,300 m a.s.l. near Addis Alem area to 3,700 m a.s.l. at Kundi Mountain. The district has six major rivers namely Ayrara, Melka Jebdu, Zenbalit, Dinki, Chew Bele and Gindebel that flow all year round.

The annual pattern of rainfall in the area is bimodal, with a mean annual rainfall of

1,254 mm. The mean annual temperature of Ankober is 13.8°C, whereas the mean minimum and maximum temperature values are 8° and 22°C, respectively. The main rock types in the Ankober district (which is part of the central plateau of the Ethiopian highlands) are rhyolites, trachyte, tuffs, ignimbrites and basalts (Mohr 1971). The majority of soil types in the district are of volcanic origin, black and reddish-brown soil types that are mentioned as the dominant soil.

Regarding the vegetation types of the area, the district is home to dense Likmarefia forests and some parts of the Wof-Washa natural forest. The dense forest is located between $9^0 34'$-$9^0 41'$N and $39^0 41'$-$39^0 46'$E, and is the largest natural forest in the Ankober district, which covers a total area of 625 ha. According to the current classification of Ethiopian vegetation, these forests fall in the dry evergreen Afromontane forest and grassland complex type. The vegetation also encompasses Afroalpine species including giant Lobelia (*Lobelia rhyncopetalum,* Hemsl.), *Helichrysum citrispinum* (Del.), and *Helichrysum schimperi* (Sch. Bip. ex A. Rich.) at higher altitudes (>3,500 m a.s.l.) around Kundi and Ememhiret mountains (Friis et al. 2011). The lowlands and foothills of the mountains in the District are under cultivation and are commonly devoid of forest covers (AWFPEDO 2012).

Preliminary survey

A reconnaissance survey and habituation of a band of geladas to human observers were conducted on foot in the study area in the first week of August 2017. Some individuals that have unique natural markings, such as swelling body parts and other identifiable features, were used to identify the study specimens. The actual data collection was conducted from August 2017 to March 2018, to cover both wet and dry seasons. Behavioral data of geladas were
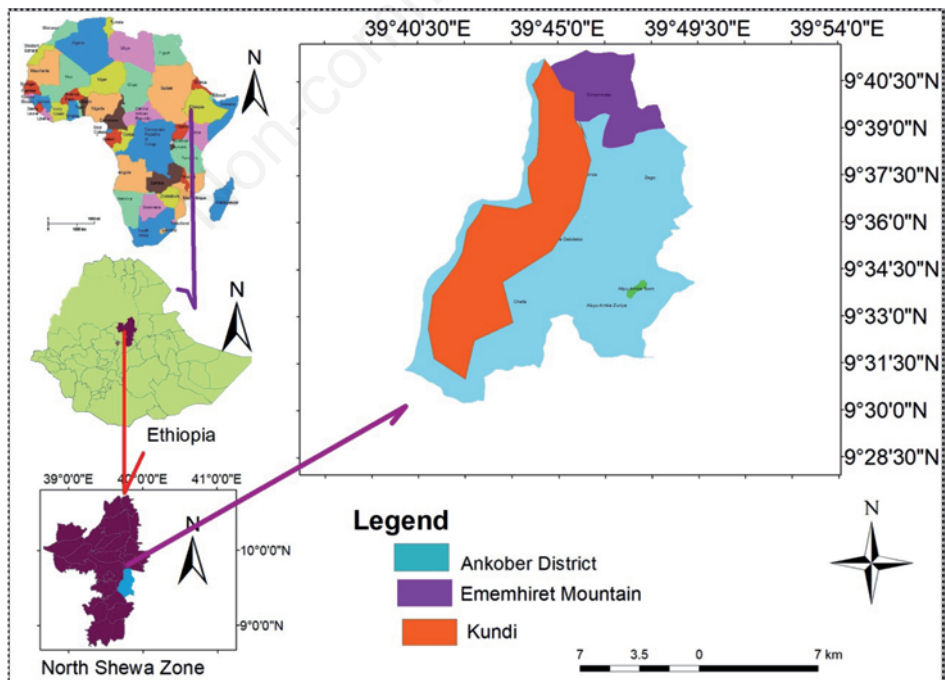

Figure 1. Map of the study area.

collected by direct observation and silent detection throughout the day. Quantitative data were collected on the age and sex categories and activity patterns in the wet and dry seasons.

Diurnal activity budget

Behavioral data on activity budget were collected using scan sampling methods (Altmann 1974) at 15-minute intervals on members of the study band. Activity budget data from the members of the group were collected on an average of five consecutive study days per month (Fashing 2001; Mekonnen et al. 2010; Kifle et al. 2013; Ibrahim et al. 2017; Yazezew et al. 2020). Activity scan samples were collected for up to five minutes duration every 15 min sampling gap between 0600 and 1700h (Fashing 2001; Wong and Sicotte 2007; Kifle et al. 2013; Mekonnen et al. 2018; Yazezew et al. 2020). The age/sex class of the scanned individual was recorded as adult male, adult female, sub-adult male, sub-adult female, and juveniles (Dunbar 1977; Di Fiore 2003; Wong and Sicotte 2007; Yazezew et al. 2020). During scan sampling, individual activity type was recorded as feeding, moving, resting, playing, aggression, grooming, sexual activity, and others, such as drinking, that do not fit into these categories (Fashing 2001; Mekonnen et al. 2018).

Feeding ecology

During activity scan sampling, when geladas were observed feeding, the plant species and the type of food items consumed were recorded (Mekonnen et al. 2010; Ibrahim et al. 2017; Abu et al. 2018; Mekonnen et al. 2018; Yazezew et al. 2020). The plant species and plant parts consumed were recorded to determine feeding behavior. Plants eaten by geladas were identified and recorded in the field, if known, while unidentified species were collected, named by their local name, pressed, and taken to Debre Berhan University for further taxonomic identification.

Data analysis

Statistical Package for Social Science (SPSS) 20.0 software for Windows Evaluation version was used to analyze the data collected during the survey. Non-parametric Pearson Chi-Square test was used to analyze the difference in the amount of time spent on different activities during different seasons.

Results

Diurnal activity budget

A total of 3,960 individual behavioral observations on the different activities were recorded throughout the study period. Geladas engaged in feeding 12%, aggression 3%, grooming 18%, moving 9%, other activities 8%, playing 19%, resting 14%, and sexual activity 17% of their time during the wet season. However, they engaged in feeding 27%, aggression 12%, grooming 7%, moving 21%, other activities 13%, playing 7%, resting 4%, and sexual activity 7% during the dry season (Figure 2). There was a significant difference in feeding between dry and wet seasons (x^2=35.1, df=1, p<0.05). Geladas spent more time on aggression and moving during the dry season than the wet season. There were significant differences between seasons in aggression (=5.4, df =1, p<0.05), moving (x^2=4.8, df=1, p<0.05), grooming (x^2=6.3., df=1, p<0.05), playing (x^2=5.5, df=1, p<0.05), resting (x^2=5.6, df=1, p<0.05), and sexual activity (x^2=4.2, df=1, p<0.05). However, there

was no significant difference in activities labeled as "other activities" between seasons (x^2=0.2, df=1, p<0.05). On average, geladas spent more time on feeding (39%) than other activities, followed by moving (30%) and grooming (27%).

During the study period, adult females devoted more time to feeding (33%) and sexual activity (32%) than other activity types, whereas males engaged more in grooming (22%) and resting (20%). Juveniles spent 85% of their time playing and none in aggression. Both subadult males and females devoted more time to playing (Figure 3). There was a significant difference in feeding between adult males and females (x^2=4.33, df=1, p<0.05): adult males devoted to it a significantly higher time budget than adult females (x^2=6.5, df=1, p<0.05). Juveniles engaged significantly in playing over other activity types and age categories (p<0.05).

Feeding ecology

During the study period, a total of 11 species of plants belonging to three families were consumed by geladas in the study area. All the 11 species of plants were recorded during the wet season while nine species were recorded during the dry season. Among species of plants consumed by geladas, 81.8% were under the family of Poaceae (Table 1).

During the dry season, the geladas' diet accounted for 43% of long grass blades followed by 17% of short grass blades and 15% of grass roots. However, cereals (30%), short grass blades (22%), grass roots (20%), and unidentified tubers (15%) constituted a higher component of the geladas' diet during the dry season. There was a significant difference in the amount of cereals (x^2=11.3, df =1, p<0.05), grass roots (x^2=6.2, df =1, p< 0.05), unidentified tubers (x^2=7.1, df=1, p <0.05), short grass blades (x^2=5.5, d f=1, p<0.05) and herb roots (x^2=1.3, df=1, p<0.05) between wet and dry seasons. However, there were no significant differences between seasons feeding on herb leaves (x^2=1, df=1, p>0.05) and grass leaves (x^2=0.14, df=1, p<0.05) (Figure 4). On average, the geladas' food was constituted for 62.5% of a grass-based diet.
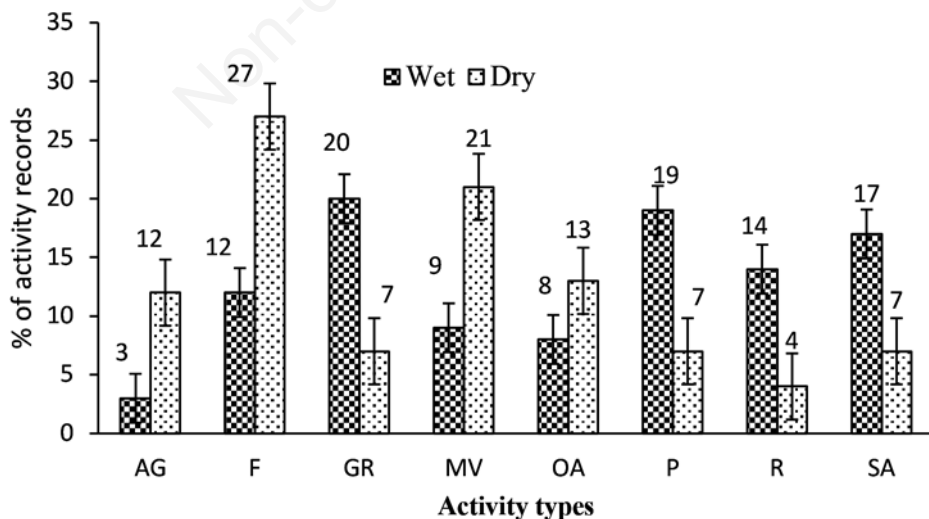

Figure 2. Diurnal activity time budget of geladas between wet and dry seasons. AG = Aggression; F = Feeding; GR = Grooming; MV = Moving; OA = other activities; P = Playing; R = Resting; SA = Sexual activities.

Discussion

Diurnal activity budget

In the present study, geladas devoted more time to foraging than other activities, in line with the previous findings at Wonchit Valley (Kifle et al. 2013), Debre-Libanos area (Abie et al. 2017), and Debre Berhan area (Yazezew et al. 2020). However, this study does not match the study at Guassa Community Conservation Area (Mamo and Wube 2019), where geladas spent less time foraging and invested more in moving and resting. This might be associated with temperature-dependent energy requirements, declining habitat quality (Iwamoto and

Table 1. Plant species consumed by geladas during wet and dry seasons. Food items: CR = Cereals; GB = Grass blades; GR = Grass roots; HL = Herb leaves; HR = Herb roots; LB = Long grass blades; SB = Short grass blades.

| Local name	Species	Family	Parts used	Wet	Dry
Akirma	*Eleusine floccifolia*	Poaceae	GB	❖	❖
Wisha sar	*Sporobolus pyramidalis*	Poaceae	GB	❖	❖
Wisha sindodo	*Pennisetum thunbergii*	Poaceae	GB, GR	❖	-
Serdo	*Cynodon dactylon*	Poaceae	GR, LB, SB	❖	❖
Gaya	*Chloris pycnothrix*	Poaceae	GB	❖	❖
Gita	*Pennisetum sphacelatum*	Poaceae	GR	❖	❖
Maget	*Trifolium temnense*	Fabaceae	GB	❖	-
Chifrig	*Sida Schimperiana*	Malvaceae	GB, HR	❖	-
Gaja	*Andropogon distachyos*	Poaceae	HL, GR	-	❖
Barely	*Hordeum vulgare*	Poaceae	CR	❖	❖
Wheat	*Triticum* spp.	Poaceae	CR	❖	❖
Unid. tubers	-	-	-	❖	❖
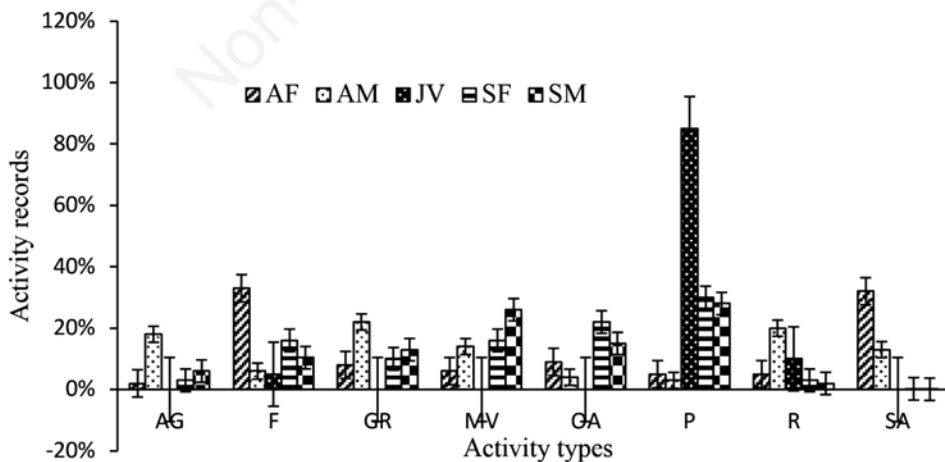
Figure 3. Overall activity budgets among different age and sex classes of geladas. Age categories: AF = Adult female; AM = Adult male; JV = Juvenile; SF = Subadult female; SM = Sub adult male. Activity types: AG = Aggression; F = Feeding; GR = Grooming; MV = Moving; OA = other activities; P = Playing; R = Resting; SA = Sexual activities.

Dunbar 1983), intensive human disturbance, and competition with livestock in this habitat in an unprotected area. This is in accordance with the theory that states geladas spend more time resting and grooming than feeding and moving when they easily obtain food. Moreover, the variation in time spent on different activities indicates the balancing energy budget of the animals (Dunbar 1992). Feeding time increases in response to the decrease in the protein content of the dry season forage. In contrast, geladas require less time to feed when the productivity of the habitat increases during the wet season (Iwamoto and Dunbar 1983).

According to the present study, geladas showed significant differences in feeding time budget between wet and dry seasons. The plausible reason for budgeting more time for feeding during the dry season might be associated with scarce resources and low food quality. According to Moges (2015), the percentage of time spent feeding and traveling during the dry season was longer than in the wet season. The time spent on feeding, moving, and aggression was significantly more during the dry season than the wet season. However, geladas spent more time grooming, playing, resting, and doing sexual activities during the wet season than in the dry season. Similar findings have been reported in previous studies (Hunter 2001; Kifle et al. 2013; Moges 2015; Abie et al. 2017; Yazezew et al. 2020). The possible reason might be the reduced availability and quality of food during the dry season, which leads the animals to devote more energy and time to travel and search for food to satisfy their nutritional demands. Shorter travel time during the wet season might be associated with the availability of quality green grass and the restriction in small escarpments at the border of farmland areas.

Adult females and males devoted nearly similar proportions of time to feeding. Adult females spent significantly more time feeding than adult males. Many of the adult female individuals were either pregnant or had dependent offspring, which probably caused the increased feeding time due to the extra nutritional requirements of neonatal nourishment. Juveniles spent significantly more time playing than other age classes.

Feeding ecology

Geladas are unique among the primates due to their high degree of specialization for a graminivorous diet (Dunbar and Bose 1991). During the present study, a total of 11 plant species were recorded as food for geladas. This low number of forage species may be due
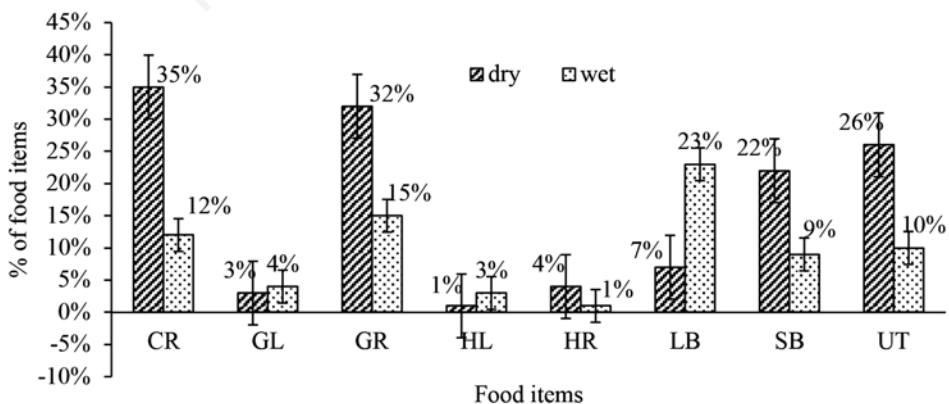

Figure 4. Percentage composition of food items consumed by geladas during the wet and dry seasons. CR = Cereals; GL = Grass leaves/blades; GR = Grass roots; HL = Herb leaves; HR = Herb root; LB = Long grass blades; SB = Short grass leaves; UT = Unidentified tuber.

to the low level of diversity. The finding of this study contrasts with the study at Wonchit Valley, Ethiopia by Kifle et al. (2013), who reported about 60 species in 20 families of plants and three species of animals, Guassa Community Conservation Area by Moges (2015) with 18 species of plants, Debre Libanos by Abie et al. (2017) with 19 species of plants, and Debre Berhan area by Yazezew et al. (2020) with 41 plant species in 17 families. However, comparable figures (12 species of plants) had been reported in the diet of geladas from Indetu, Ethiopia by Abu et al. (2018).

Grasses are the preferable diet of geladas in the study area, constituting 62.5%. This is similar to previous findings (Kifle et al. 2013; Abie et al. 2017; Abu et al. 2018). Geladas shift their food preferences to cereals, short grass blades, grass roots, and unidentified tubers when green grasses are unavailable during the dry season. Geladas feed on long grass blades and herb leaves as long as they remain green, shifting to other food items when their preferred foods are no longer available,(Marshall et al. 2009; Yazezew et al. 2020).

Conclusions

The Ankober district is located in the Ankober-Tarmaber escarpment hotspot of the Ethiopian highlands, home to diversified species of mammals, birds, and reptiles, including iconic endemic species like gelada. Data collected in the present study provided important information on the diurnal activity budget of geladas in the Ankober district at Kundi. The study helps corroborate the biodiversity conservation and the historical aspects of the area to enhance the area for the benefit of the local community and the biodiversity of the area. The diversity of food plant species in the area is very poor though it needs further verifications. Geladas feed on different food items with varying preferences according to the season. Based on the results of the present study, the following recommendations and suggestions are made for the conservation of biodiversity, including geladas outside protected areas: conservation efforts of gelada must include habitat protection and the trade-off between human livelihood and wildlife conservation.

Conflict of interest

The authors declare that they have no competing interests with respect to the research, authorship, and/or publication of this article.

Authors' contributions

GT collected, analyzed the data, and was a major contributor to writing the draft manuscript. DY organized the manuscript and checked the data collected and analyzed for final submission. GD revised both the draft manuscript and the final version. All authors read and approved the final manuscript.

Availability of data and materials

All data generated or analyzed during this study are included in this published article.

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