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Time budgets and activity patterns of the southern gelada (*Theropithecus gelada obscurus*) in a human-modified landscape, Wollo, Ethiopia

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Abstract

Understanding the behavioural ecology of primates in human disturbance areas is crucial to developing conservation management plan. Southern geladas (*Theropithecus gelada obscurus*) are endemic subspecies of geladas that are threatened by habitat loss and degradation in the Ethiopian Highlands. During the 18-months period, we conducted this intensive study in an unprotected area of human-modified landscape to examine the diurnal time budgets and activity patterns of southern geladas. We quantified the time budget data from a band of southern gelada using instantaneous scan sampling method. Southern geladas had an overall diurnal activity budget of 49.5% feeding, 17.5% resting, 16.2% moving, 13.0% grooming and 3.0% socialising. The band spent significantly more time feeding during the dry season than the wet season. However, the band spent significantly more time during the wet season than the dry season in resting and grooming activities. We observed variations in the trend of activity patterns during the daylight hours between the wet and dry seasons. We found consistent relationships between monthly time budget and food availability. Our results contribute to improve our knowledge on the behavioural ecology of gelada populations in human-modified landscape across the Ethiopian Highlands.

KEYWORDS
behavioural flexibility, conservation, human-modified landscape, southern geladas, time budget, Wollo

Résumé

Il est essentiel de comprendre l'écologie comportementale des primates dans les zones de perturbation humaine afin d'élaborer un plan de gestion de la conservation. Les géladas du sud (*Theropithecus gelada obscurus*) sont des sous-espèces endémiques de géladas qui sont menacées par la perte et la dégradation de leur habitat dans les hautes terres éthiopiennes. Nous avons mené cette étude intensive sur 18 mois dans une aire non protégée de paysage modifié par l'homme afin d'examiner les budgets temps diurnes et les schémas d'activité des géladas du sud. Nous avons quantifié les données liées au budget temps d'un groupe de géladas du sud en utilisant une méthode d'échantillonnage par balayage instantané. Les géladas du Sud avaient un budget d'activité diurne global de 49,5 % consacré à l'alimentation, 17,5 % consacré au repos, 16,2 % consacré aux déplacements, 13,0 % consacré au toilettage et 3,0 %

consacré à la socialisation. Le groupe a passé beaucoup plus de temps à se nourrir pendant la saison sèche que pendant la saison humide. Cependant, le groupe a passé beaucoup plus de temps à se reposer et à se toiletter pendant la saison humide que pendant la saison sèche. Nous avons observé des variations dans la tendance des schémas d'activité pendant les heures de clarté entre les saisons humides et sèches. Nous avons constaté des relations cohérentes entre le budget temps mensuel et la disponibilité des aliments. Nos résultats contribuent à améliorer nos connaissances sur l'écologie comportementale des populations de gélada dans les environnements modifiés par l'homme au sein des hauts plateaux éthiopiens.

1 | INTRODUCTION

As the result of land-use change in the tropics, a large proportion of biodiversity occurs in the human-modified landscapes even though threatened (Achard et al., 2014; Asner et al., 2009; Chapman et al., 2010; Gibson et al., 2011; Haddad et al., 2015; Hansen et al., 2013; Johnson et al., 2017; Oates, 2013). Such landscapes comprise mosaic of matrices including human settlements, croplands, livestock pastures and fragmented wildlife habitats (Anderson et al., 2007; Arroyo-Rodriguez et al., 2017; Chapman et al., 2016). The small fragmented landscapes may support limited resources for the existences of wild animals (Chaves et al., 2012; Cowlishaw & Dunbar, 2000; Ding & Zhao, 2004; Riley, 2007). In the other way, the survival of many wild animals may depend on their ability to utilise agricultural and other matrix habitats between fragments (Anderson et al., 2007). Like other wild animals, many primate populations inhabit anthropogenically modified landscapes (Bryson-Morrison et al., 2017; Thatcher et al., 2019b, 2020). As the result of such human population pressure on primate habitat, the potential conservation opportunities available in human-degraded landscapes are dramatically increasing (Arroyo-Rodriguez & Mandujano, 2006; Chapman et al., 2016) in order to implement effective conservation management strategies (Harcourt, 2002; Marshall et al., 2009; Serckx et al., 2015; Marsh et al., 2016; Bryson-Morrison et al., 2017; Thatcher et al., 2020).

Studying the activity time budgets and daily activity patterns of animals help to understand their life history, ecological adaptation and plasticity in response to changing environments (Abu et al., 2018; El Alami et al., 2012; Jonsson & Afton, 2006; Thatcher et al., 2019a; Wright et al., 2010; Zhou et al., 2007). Animals have to deal on a daily basis with the challenge of balancing the time allocated into all the activities necessary for their self-maintenance (Dunbar, 1992). In addition, the time needed for most of the time budget components (feeding, moving, resting and social interactions) is a function of habitat-specific ecological conditions or the competitive regimes, or both, that the animal faces (Dunbar et al., 2009). Similarly, the availability of food and environmental conditions influences the time budget and activity pattern of primates (El Alami et al., 2012; Chaves et al., 2011; Defler, 1995; Hanya, 2004; Jaman & Huffman, 2008; Passamani, 1998). Some primates that persist in fragmented habitats adopt an energy-maximising strategy, spending more time feeding and less time resting (Chaves et al., 2011). Conversely, many other primates that inhabit fragmented habitats adopt an energy minimising strategy, spending less time feeding and traveling and more time resting (Boyle & Smith, 2010; Campera et al., 2014; Palma et al., 2011; Wong & Sicotte, 2007). Thus, an understanding on how primates divide up their activities on daily basis, season or year is important to understand their lifestyles and to indicate how primates invest energy and time for survival and reproduction (Defler, 1995; Jaman & Huffman, 2013).

At present, 55 mammalian species are considered to be endemic to Ethiopia (Lavrenchenko & Bekele, 2017). Geladas (*Theropithecus gelada*) are endemic primate species inhabiting the Ethiopian Highlands, and they are the only extant species of their genus. They are the most terrestrial primates that inhabit the human-modified matrices of grassland ecosystems. They are ecologically and behaviourally flexible primates that thrive in a variety of habitats (from Afroalpine to Afromontane types of ecosystems) with variable environmental conditions and habitat alternations. They inhabit areas where human settlements, agricultures and land degradations are extremely high. Like many other tropical primates (Marsh, 2003), almost all of the historical geographic ranges of geladas have been converted into agricultural lands, livestock grazing areas and human settlements, leaving most populations restricted at the edges of their sleeping cliffs by forming small groups (Gippoliti, 2010; Kifle & Bekele, 2021).

Southern geladas (*Theropithecus gelada obscurus*) are one of the endemic subspecies of geladas that are distributed in the northern central cliffy landscape areas of Ethiopia. Most of previous ecological studies were performed on the northern geladas (*T. g. gelada*) in the Simien Mountains National Park (Bergman et al., 2009; Dunbar, 1992; Dunbar & Dunbar, 1975; Hunter, 2001; Iwamoto & Dunbar, 1983; Jarvey et al., 2018; Woldegeorgis & Bekele, 2015). However, less is known on the behavioural ecology of southern geladas in particular on their time budgets and activity patterns in human-modified landscapes of the northern central highlands of Ethiopia. Thus, the purpose of this study was to understand the behavioural ecology of southern geladas in response to habitat disturbances and seasonal variations. By studying the time budgets and activity patterns, we can improve our knowledge on the ecology and adaption of the southern geladas in anthropogenically modified landscapes, and to devise better conservation management plans for them (Marshall et al., 2009; Serckx et al., 2015; Mekonnen et al., 2017; Thatcher et al., 2020).

The current study was conducted in anthropogenic disturbed area. The ecology of the area has been dramatically degraded by human agricultural and livestock grazing practices. Cereal crop cultivation and heavy livestock grazing has eroded the landscape and dramatically reduced the aboveground grass biomass across much of southern geladas' range. Geladas are specialised on grass blades, which become less nutritious in the dry season as it dries out (Jarvey et al., 2018). Thus, in addition to anthropogenic disturbance, seasonal variation in green grass food availability also influences the feeding ecology of southern geladas (Kifle & Bekele, 2021). The objectives of the study were (1) to examine the diurnal activity time budget and activity pattern of the southern geladas in human-modified landscape; (2) to examine how diurnal activity budget and activity pattern vary seasonal; and (3) to investigate how seasonal variations in food availability influence the diurnal activity budget of southern geladas. In the process of addressing these objectives, we predicted that monthly feeding time will be negatively correlated with green grass availability and resting time will be positively correlated with green grass availability. In addition, given the high temporal variability in green grass availability, we predicted variation in activity budget categories, with differences in diurnal activity budget and activity pattern between the wet and dry seasons. Southern geladas can be expected to maintain nutrient intake during the food-scarce dry seasons by (1) increasing time spent feeding and (2) decreasing time spent resting and grooming.

2 | METHODS

2.1 | Study area

The study was carried out at Kosheme near Mekanselam town, the town of Borena *Woreda* (local administrative district), Wollo, Ethiopia. Its geographical location lies at latitude 10°43′51.90′′N and longitude 38°47′2.32′′E (Figure 1), and the altitudinal range of the area is between 1560–2500 m a.s.l. It is part of the watershed area of Yeshume River, the tributary of Abbay River. The area is not officially protected, but basic rehabilitation drainage activities are carried out by the local communities. The local people use the area for settlement, crop farming, livestock rearing and firewood collection. The region is an Afromontane grassland ecosystem consisting of steep escarpments, gorges, valleys and strip of grassland plateaus with limited bushland. The area possesses vegetation like Acacia spp., Ficus spp., Rhus spp. trees, and different shrub, herb and grass species.

The climate of the area is divided into two main seasons: the wet season occurs between June and September, and the dry season occurs between October and May. However, there may be a little rain in some part of dry months especially in March and April. This small rain is erratic and highly variable. Ambient temperature and rainfall data were taken from Mekaneselam Meteorological Station (Figure 2),

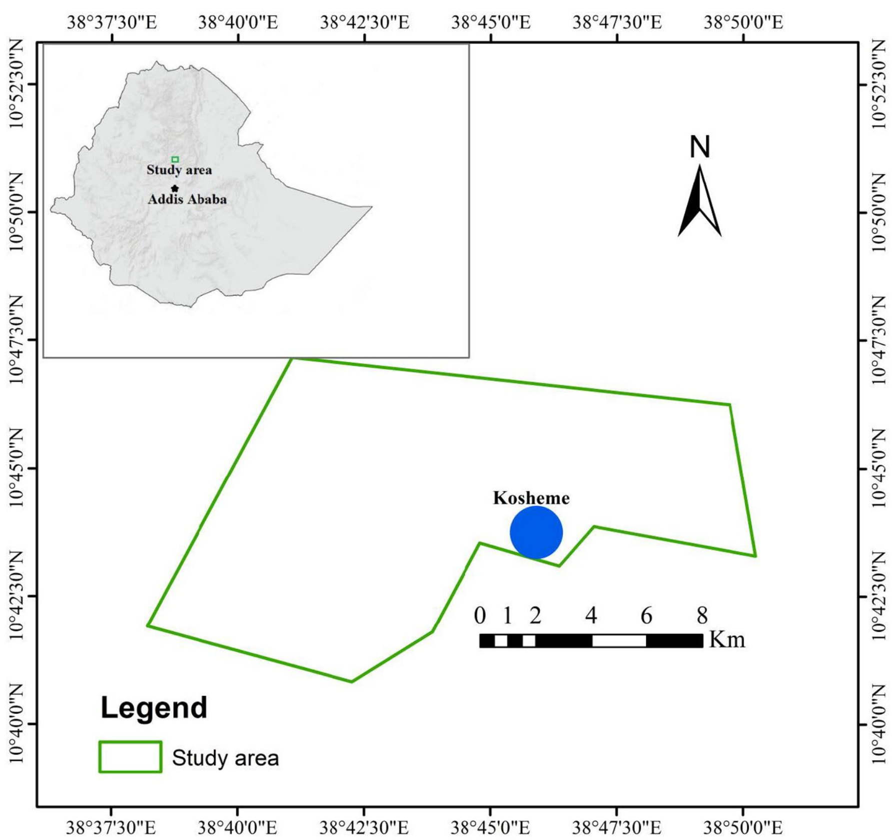

FIGURE 1 Map showing location of the study area in Ethiopia

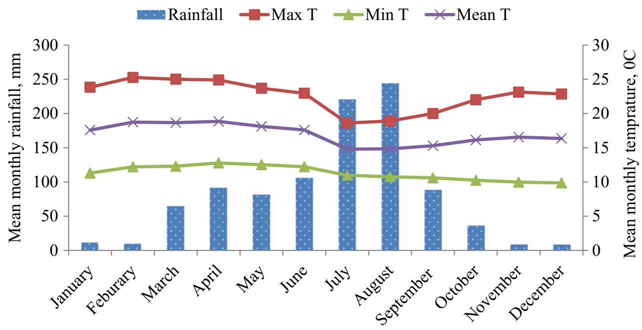

FIGURE 2 Mean daily maximum, minimum and average temperatures, and mean cumulative monthly rainfall at Mekaneselam from January 2007 to December 2016 (data source: National Meteorological Agency, Ethiopia, Addis Ababa, 2017)

about 2.5 km away from the home range of the study band. The mean annual maximum and minimum temperatures are 22.61°C and 11.32°C, respectively. Average annual rainfall of 1004.27 mm has been recorded over ten years (2007–2016) in the area.

2.2 | Study population

We selected a band of southern gelada populations and habituated them to human observers by approaching step by step, while recording the time budget and activity pattern. Our band comprised three dominate 'leader' males with their reproductive females and offspring and one subordinate 'follower' male. The band comprised a total of 37 individuals on average. Since this research was the first to study the behavioural ecology of the southern geladas at the chosen field site, we spent 3 months habituating the band between February and April 2015, prior to starting the actual data collection period. We considered the band habituated when they were tolerating human presence at a distance from 5–10 m and until all fleeing and defensive behaviours disappeared, and movement and feeding behaviours took place in a relaxed manner.

2.3 | Behavioural data collection

Following habituation, we collected the diurnal activity time budget and activity pattern (i.e. the diurnal hour of distribution for performing activities of different behavioural categories) data every month between May 2015 and April 2016 and between May 2016 and March 2017 at a bimonthly interval for a total of 18 months. We collected a total of 90 complete focal band follow up days. We collected data using instantaneous scan sampling method (Altmann, 1974) for five consecutive days per month at 15 min intervals in order to maintain data independence for up to 5 min duration on the first five visible individuals except from yearlings and infants from left to right (Fashing, 2001; Mekonnen et al., 2017; Ménard et al., 2014) to avoid eye caching and possible biases by following the band throughout the daylight hours. We recorded the first activity that lasted for at least 3 s upon viewing each individual (Fashing et al., 2014; Di Fiore, 2003; Mekonnen et al., 2017). An individual was scored no more than once per a particular scan period. We began day follows at early morning (06:30–07:00 a.m.) and ended when the band settled on its sleeping cliff at dusk (06:00–6:45 p.m.). One observation day comprised a minimum of 45 and a maximum of 50 group scan samplings. We made every attempt to keep data collection consistence and balanced across the study months.

During each scan sample, we recorded the following mutual exclusive behavioural categories: feeding (picking, handling or chewing any food items), moving (walking or running in any direction), resting (lying down or sitting or standing without performing any other apparent activity or auto-grooming), grooming (manipulating the hair of another gelada or being manipulated by another gelada with hands), agonistic (when an aggressive behaviour was displayed by an individual gelada and an aggressive or non-aggressive response by the aggressee), playing (mock-chasing or mock-fighting or mock-vocalisation with other individual or individuals), mating (when an adult male mounts an adult female and copulating with or without ejaculation) or other (including drinking water, urinating/defecating and predator alarm) activities (Fashing, 2001; Mekonnen et al., 2017; Riley, 2007).

2.4 | Monitoring temporal patterns of food availability

We monitored phenological data on the grass greenness levels within the home range of study band to evaluate patterns of temporal change in food availability at monthly intervals (Fashing et al., 2014; Jarvey et al., 2018). We collected the phenological data from the randomly selected permanent plots (each 50 × 50 cm). We constructed 22 plots to follow up the levels of greenness and desiccation of grasses using visual inspections. Depending upon their patterns of temporal greenness changes, we assigned a score for each plot from 0–3, where 0 = 0% (absence of green grass within any particular plot), 1 ≤ 33% (brown grass with slight green), 2 = 34%–66% (light green grass) and 3 ≥ 67% (strictly green grass) after detailed inspections (Hunter, 2001). Monitoring of each plot was tightly correlated with behavioural observations of the study periods.

2.5 | Data analyses

We analysed the time budget of each category in percentage. We calculated the proportions of time spent on different activities by dividing the number of behavioural records for each activity category with the total number of activity records. We used behavioural records of the band to calculate the time budgets per day and averaged within each month to construct monthly time budgets. We computed monthly time budget by averaging daily value with each 5 day follow. The grand mean proportions of monthly budgets provided the wet and dry seasons and the overall time budget for the entire study period. Agonistic, playing and mating activity categories were pooled together as 'socialising' for the purpose of data analyses because some of these individual behaviours accounted for <1.0% of the total monthly, seasonal and overall time budget. For seasonal analysis, we included the months of October through April as the dry season, and months from May through September as the wet season. Although May typically is known as a dry season in the site, we included it into the wet season as a result of unusually heavy rains during the study period.

We calculated the average percentage of time allocated for each of the four main activities (feeding, resting, moving and grooming) in hourly classes to analyse the diurnal activity patterns. We divided daylight hourly time budget data into 6 blocks at 2 h intervals as early morning 06:00–08:00, late morning 08:00–10:00, midday 10:00–12:00, early afternoon 12:00–14:00, mid-afternoon 14:00–16:00 and late afternoon 16:00–18:00 to express the diurnal activity patterns of southern geladas. The division of daylight into 2 h blocks provides a suitable separation for statistical comparison (Vasey, 2005).

We carried out all statistical tests using SPSS version 20 software (IBM SPSS Inc). All tests were two tailed with significance level $p \leq 0.05$. We tested data for normality using the Shapiro–Wilk test and homogeneity of variances using the Levene test ($p > 0.05$). We used Chi-square goodness of fit model to assess whether monthly observed time budget of each category differ from the expected frequencies of the even distribution of our null hypothesis. We used One-way ANOVA model tests to compare seasonal differences between time budgets and among daylight hour time pattern blocks. When the assumptions of parametric tests on the proportional activity data were not met, arcsine square root transformations were performed prior to statistical analysis to fulfil those assumptions (Sokal & Rohlf, 1981). We used Mann-Whitney U tests to compare seasonal differences between activity pattern daylight hour blocks.

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

3 | RESULTS

3.1 | Overall and monthly diurnal activity time budget

We recorded a total of 21,135 individual behavioural activities with the mean of 1174.17 ± 24.75 per month. This yielded a total of 4227 group scans with the mean of 234.83 ± 4.95 per month for a total of 1056.75 h across 90 days. The overall diurnal time budget for southern geladas at Kosheme was 49.5% feeding, 17.5% resting, 16.2% moving, 13.0% grooming, 3.0% socialising and 0.9% other. Southern gelada at Kosheme exhibited wide monthly fluctuation in time budget (Table 1). The band spent most of their monthly time feeding (36.5%–58.4%) followed by

TABLE 1 Monthly and overall activity time budgets of southern geladas at Kosheme from May 2015–March 2017 (N = activity records)

		Frequency of occurrence of activities (%)							
Month	N	Feeding	Grooming	Moving	Resting	Agonistic	Mating	Playing	Other
May2015	1155	44.3	16.8	14.1	17.1	1.0	2.2	2.9	1.7
Jun 2015	1130	40.5	18.6	16.5	20.4	0.7	0.0	2.8	0.5
Jul 2015	1150	36.5	15.7	16.8	26.9	0.4	1.7	1.8	0.1
Aug 2015	1155	45.7	17.3	13.8	18.1	1.5	1.6	1.8	0.2
Sep 2015	1145	43.4	14.9	16.8	19.1	1.1	1.6	2.6	0.5
Oct 2015	1165	56.9	12.0	12.9	14.5	1.4	0.2	1.0	1.1
Nov 2015	1160	42.8	15.3	17.8	20.3	1.0	0.8	1.3	0.7
Dec 2015	1185	53.9	15.8	16.9	10.6	0.7	0.4	0.9	0.8
Jan 2016	1185	45.9	12.9	17.4	17.6	1.6	1.4	2.5	0.8
Feb 2016	1200	55.4	9.8	16.8	13.8	1.0	0.2	1.7	1.5
Mar2016	1190	56.4	11.1	13.7	15.6	0.6	0.2	1.1	1.3
Apr 2016	1215	58.4	11.7	13.7	13.7	0.6	0.0	1.1	0.9
May2016	1220	56.6	10.2	14.8	15.4	0.6	0.6	1.4	0.5
Jul 2016	1160	54.1	11.8	11.4	20.7	0.7	0.1	1.0	0.3
Sep 2016	1185	47.6	12.3	13.7	23.6	0.7	0.2	1.1	0.8
Nov 2016	1170	52.7	7.8	18.8	17.5	0.7	0.0	1.3	1.2
Jan 2017	1165	45.8	10.5	23.0	17.5	0.4	0.3	1.4	1.2
Mar2017	1200	53.2	9.1	22.8	12.1	0.8	0.0	0.5	1.7
Mean		49.5	13.0	16.2	17.5	0.9	0.6	1.6	0.9
SD		6.6	3.1	3.1	4.0	0.4	0.7	0.7	0.5

either moving (11.4%–23.0%) or resting (10.6%–26.9%). The observed percentage value of time spent feeding differed significantly from the expected value ($\chi^2 = 219.16$, df = 17, $p < 0.001$), resting ($\chi^2 = 168.59$, df = 17, $p < 0.001$), moving ($\chi^2 = 123.29$, df = 17, $p < 0.001$), grooming ($\chi^2 = 131.15$, df = 17, $p < 0.001$), socialising ($\chi^2 = 137.21$, df = 17, $p < 0.001$) and other ($\chi^2 = 54.97$, df = 17, $p < 0.001$).

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

3.2 | Seasonal time budget

Across the study period, feeding activity was the most frequent behavioural activity during both the wet and dry seasons. The band spent significantly more time during the dry season than the wet season in feeding (52.2% vs. 46.2%, ANOVA, $F_{1,16} = 4.53$, $p = 0.049$; Figure 3). The band also spent significantly more time during the wet season than the dry season for resting and grooming activities (resting: $F_{1,16} = 9.65$, $p = 0.007$; grooming: $F_{1,16} = 5.69$, $p = 0.030$). Although the band spent more time moving during the dry season than the wet season, the difference was not significant ($F_{1,16} = 3.70$, $p = 0.072$). Similarly, the band spent more time socialising during the wet season than the dry season, but the difference was not significant ($F_{1,16} = 4.06$, $p = 0.061$).

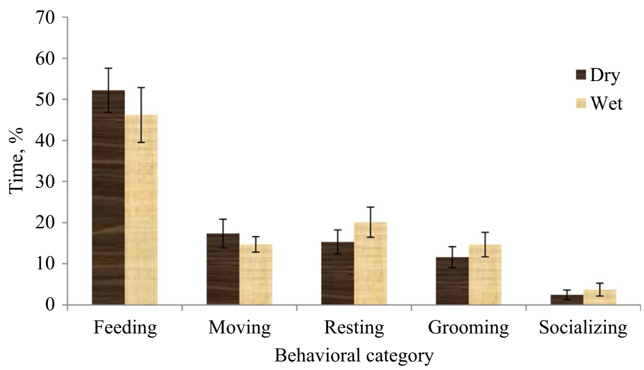

FIGURE 3 Seasonal differences spent in each behavioural category of time budget at Kosheme during the wet and dry seasons; values represent the mean ± SD (standard deviations)

3.3 | Relationship between time budget and grass phenology

The monthly pattern of greenness level of grasses affected the time budget of the southern geladas at Kosheme (Table 2). The higher percentage availability of strictly green grass plots was significantly positively correlated with the monthly percentage of resting (Spearman rank correlation coefficient: $r_s = 0.653$, $p = 0.003$) and grooming activities ($r_s = 0.541$, $p = 0.021$). Contrary to this, it was significantly negatively correlated with the monthly percentage of feeding activity ($r_s = -0.493$, $p = 0.038$). Monthly percentage of resting and grooming activity was significantly negatively correlated with higher percentage availability of non-green plots (resting: $r_s = -0.588$, $p = 0.010$; grooming: $r_s = -0.594$, $p = 0.009$). However, monthly percentage of moving activity was significantly positively correlated with the presence of higher percentage of non-green plots ($r_s = 0.517$, $p = 0.028$).

3.4 | Activity time patterns

The daily diurnal activity pattern of the band showed that resting and grooming activities were constant throughout the daylight hours (Figure 4). Feeding time pattern started at early morning around 07:00 and increased spontaneously till its peak around 08:30. This

TABLE 2 Relationship between the level of greenness of grasses and time budget

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

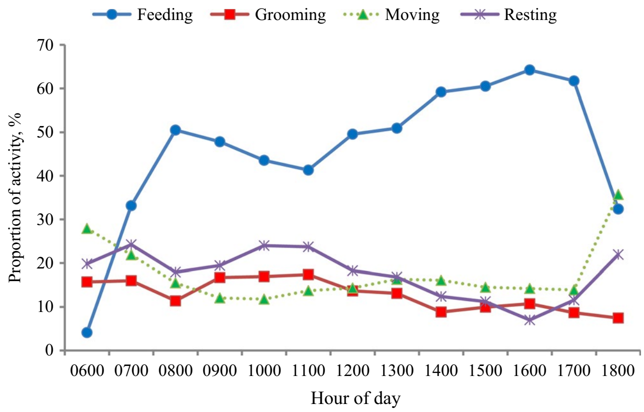

FIGURE 4 Overall diurnal activity pattern for the band

TABLE 3 Overall daily activity pattern based on daylight hour blocks (B = hour block, B1 = 06:00–08:00, B2 = 08:00–10:00, B3 = 10:00–12:00, B4 = 12:00–14:00, B5 = 16:00–14:00, B6 = 16:00–18:00 h)

	Activity pattern in different hours of daylight, hour blocks, %					
Activity	**B1**	**B2**	**B3**	**B4**	**B5**	**B6**
Feeding	29.3	45.7	45.4	55.1	62.4	47.1
Grooming	14.4	16.8	15.5	11.0	10.3	8.1
Moving	21.8	11.9	14.0	16.2	14.5	24.8
Resting	20.7	21.7	21.0	14.6	9.1	16.8

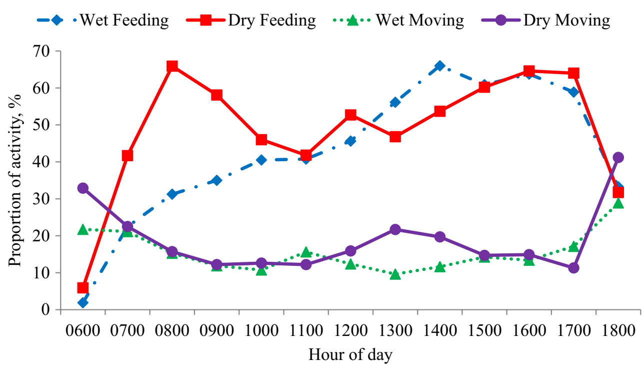

FIGURE 5 Feeding and moving activity pattern during the dry and wet seasons

activity then started to decline and reached lower stage around 11:30. Feeding activity again gradually increased from 12:00 onwards until the band returned back to the sleeping site. Moving started in the early morning and then declined in the late morning and took place linearly throughout the daylight hours until before reaching peak in the late afternoon when the band returned back to its sleeping site.

The overall percentage of time allocated to feeding at different hours of the daylight blocks showed significant differences ($F_{5,102}$ = 12.17, $p < 0.001$) during the study period (Table 3). The overall percentage of time allocated to grooming at different hours of daylight showed significant differences ($F_{5,102} = 4.45$, $p = 0.001$). The overall percentage of time allocated to moving at different hours of the daylight showed significant differences ($F_{5,102} = 9.34$, $p < 0.001$). Lastly, the overall percentage of time allocated to resting at different hours of the daylight showed significant differences ($F_{5,102} = 5.91$, $p < 0.001$).

3.5 | Seasonal variation in activity patterns

The schedule of activity pattern showed slight changes during the wet and dry seasons. During the dry season, there were morning and beginning of late afternoon feeding peaks (Figure 5). However, there was only a mid-afternoon feeding peak during the wet season. During the wet season, feeding time increased gradually step by step from morning to the next hours of the day. Feeding activity pattern showed significant differences between the wet and dry seasons in the early morning (06:00–08:00 h) (Mann-Whitney *U* test $Z = -2.622$, $p = 0.009$) and late morning (08:00–10:00 h; $Z = -2.577$, $p = 0.010$; Table 4). The trend of moving activity pattern was almost identical during the wet and dry seasons. There were morning and late afternoon moving peaks during both the dry and wet seasons. Although seasonal moving pattern occurred in similar manner, the data revealed significant difference between the wet and dry seasons during early afternoon (12:00–14:00 h) of daylight hours.

Grooming activity pattern showed variations in the morning during the wet and dry seasons (Figure 6). During the wet season, there was grooming peak in the late morning, however, grooming reached its peak at midday during the dry season. During the dry season, short early morning grooming peak showed and declined dramatically in the late morning. During both seasons, the grooming activity pattern took place in a similar manner after late morning. The morning grooming activity pattern was significantly different between seasons. Resting activity pattern showed variations in the morning between the wet and dry seasons. During the wet season, there was resting peak in the early morning and late afternoon; however, during the dry season resting had 3 peaks in the early morning, midday and late afternoon. During the dry season, the short early morning resting peak declined dramatically during the late morning. There were also midday and late afternoon peaks. Starting from midday, resting pattern seemed almost identical during both the wet and dry seasons. Although seasonal variations occurred in the morning session on activity pattern of resting, data showed no significant differences between the wet and dry seasons in any of the daylight hours (Table 4).

4 | DISCUSSION

To maintain a certain level of daily energy intake, primates should adjust their activity budgets in response to changing ecological conditions and habitat alternations. Changes in primate activity budgets are often associated with anthropogenically disturbed

TABLE 4 Seasonal variations in diurnal activity patterns via Mann-Whitney *U* test between wet and dry seasons

	Feeding		Moving		Resting		Grooming	
Hours	*Z*	*p*	*Z*	*p*	*Z*	*p*	*Z*	*p*
0600–0800	−2.622	0.009	−1.689	0.091	−1.133	0.183	−.489	0.625
0800–1000	−2.577	0.010	−.445	0.656	−1.823	0.068	−2.045	0.041
1000–1200	−.934	0.350	−.712	0.476	−.489	0.625	−1.023	0.306
1200–1400	−1.577	0.120	−2.628	0.009	−.489	0.625	−.134	0.894
1400–1600	−.533	0.840	−.623	0.534	−1.155	0.248	−1.025	0.305
1600–1800	−.311	0.756	−1.160	0.246	−.800	0.423	−.134	0.894

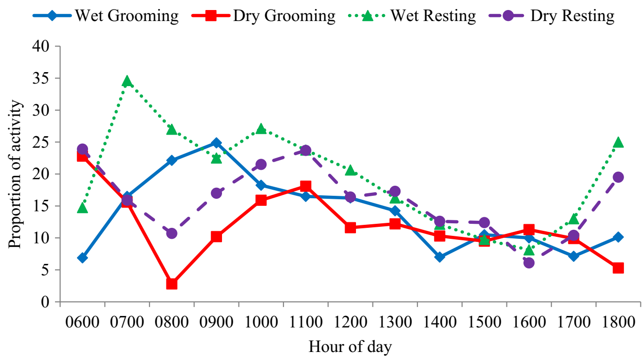

FIGURE 6 Grooming and resting activity pattern during the dry and wet seasons

environments (Bryson-Morrison et al., 2017; Thatcher et al., 2019b). At Kosheme, we found that southern geladas spent 49.5% of the daytime feeding. The study indicated that geladas devote half time feeding over the other activities (moving, resting, grooming, socialising and others) in order to maximise energy gaining strategies for their daily metabolism. The high proportion of time allocated in feeding activity is due to gelada's dietary specialisation on grass blades (Dunbar & Bose, 1991; Hunter, 2001), and the digestive system of gelada is poor at extracting nutrients from grasses (Dunbar & Bose, 1991). In addition, southern geladas should adopt energy-maximising adaptation to survive in human-modified landscapes where the availability food is expected to be low as a result of competition with the livestock as well as habitat loss. Dunbar (1992) suggests that the availability of food and its energy content are critical determinants of time budgets. Thus, in the degraded habitat, geladas might invest more time in feeding in order to fulfil their daily energy requirements from the available resources. Similarly, in deteriorated habitats primates take more time to satisfy their energy demands (Nakagawa, 2009). The greater proportion of time spent foraging most likely reflects the necessary adjustment in the search for food in a human altered habitat where resource availability is low (Riley, 2007).

In the current study site, geladas spent less or more or comparable time feeding compared to other study sites (Table 5). For example, feeding time of 80.0% (Kawai & Iwamoto, 1979), 62.3% (Iwamoto & Dunbar, 1983) and 56.6% (Woldegeorgis & Bekele, 2015) were recorded at Gich. This result is relatively higher than Bole (35.7%) and Sankaber (45.2%) population (Iwamoto & Dunbar, 1983) and Arsi (41.7%) population (Abu et al., 2018). But most of these studies have taken place in short duration (lasting a few weeks or few months). In addition, the difference in sampling time/season might be the other reason for having variable findings by different researchers even at a single study site. As human activities affect the habitat of geladas, the availability of food decline in that area, which in turn it may affect the time budget of geladas allocating more time for feeding.

In the current study site, the band spent more time moving compared to Gich (9.0%: Kawai & Iwamoto, 1979; 14.7%: Iwamoto & Dunbar, 1983) sites (Table 5). The current study negated the findings of Kawai and Iwamoto (1979) on moving time budget. As the grassland area became fragmented, geladas inhabiting human-modified landscapes should move from one patch grassland to the other in order to use the available resources in turn increasing moving time.

The time spent resting for the band was 17.4%. But, previous studies on the geladas showed that the time budget of resting was only 2.0% (Kawai & Iwamoto, 1979), 5.2% (Iwamoto & Dunbar, 1983) and 10.7% (Woldegeorgis & Bekele, 2015) at Gich (Table 5). However, it was 26.3% at Bole (Iwamoto & Dunbar, 1983). The current finding does not fall in line with these studies. The duration of data collection might have contributed for different results. In addition, resource availability, degree of human interference and level of temperature may alter the resting time of geladas at different study sites. The difference in time budget on resting is likely to be related with the abundance and distribution of resources (El Alami et al., 2012).

Our results indicate seasonal variations in the time budgets of the southern geladas at Kosheme. These variations might be related to seasonal changes in the availability of diets as well as human activities related with crop production time near the habitat of geladas. Environmental variables like climatic conditions and temporal distribution of food influence the amount of time primates spend in different seasonal activities (Canteloup et al., 2019; Dunbar et al., 2009; Hunter, 2001; Iwamoto & Dunbar, 1983; Jaman & Huffman, 2015; Poulsen et al., 2001; Shah, 2003; Zhou et al., 2007). Geladas at Kosheme spent more time feeding and moving during the dry season than the wet season by reducing the resting and grooming activities. Arsi geladas also showed an increase in time spent feeding and

TABLE 5 Overall mean gelada time budget at different study sites in Ethiopia

Study site	Altitude (M)	Months	Time in each activity, % Feeding	Moving	Resting	Grooming	Socialising	Other	References
Kosheme	2440	18	49.5	16.2	17.4	12.9	3.0	0.9	This study
Gich	3390	–	62.3	14.7	5.2		(16.0)	–	Iwamoto & Dunbar, 1983
Gich	3390	–	80.0	9.0	2.0		(8.0)	–	Kawai & Iwamoto, 1979
Sankaber	3330	–	45.2	20.4	13.8		(20.5)	–	Iwamoto & Dunbar, 1983
Bole	2300	–	35.7	17.4	26.3		(18.5)	–	Iwamoto & Dunbar, 1983
Arsi	2060	9	41.7	20.3	19.0		(19.0)	0.0	Abu et al., 2018
Wonchit	2570	4	65.2	16.5	4.5		(13.8)	–	Kifle et al., 2013
Gich	3900	12	56.6	14.1	10.7		(17.5)	1.1	Woldegeorgis & Bekele, 2015
Guassa	3450	–	41.5	21.2	7.3	14.6	8.3	7.2	Moges, 2015

moving more during the dry season than the wet season (Abu et al., 2018). Similarly, François' langurs (*Trachypithecus francoisi*) spent a greater proportion of time on feeding and less time on resting and grooming during the dry season than in the wet season (Zhou et al., 2007). Other tropical primates often reduce energy expenditure during the dry season by spending more time resting, an energy-saving activity and less time traveling, an energetically costly activity (Asensio et al., 2009; Dunbar et al., 2009; Korstjens et al., 2006, 2010; Masi et al., 2009). In the contrary, other studies also suggest that some primates spend more time feeding during the wet than dry seasons (Chaves et al., 2012; Felton et al., 2009). The current study, however, suggested that time spent feeding is directly related to the less proportion of availability of diet specifically green grass blades in the environment. Thus, southern geladas might adopt an energy-maximising strategy when green grass blades were scarce during the dry season. As human disturbances become less during the dry season geladas move from one patch of grassland to the other thus increasing moving time. In addition, fruits from *Ficus* trees are important diet for geladas at Kosheme (Kifle & Bekele, 2021), thus geladas move further distance that needs extra time for moving to consume those fruits since the trees grow in sparsely patterns in the area.

Time budget engaged in resting and grooming also significantly varied between the wet and dry seasons at Kosheme. Both resting and grooming significantly decline during the dry season. Hunter (2001) also reported that both resting and grooming time were reduced significantly during the dry season compared to the wet season. During the dry season, geladas spent more time in feeding thereby reducing the activities spent for resting and grooming. Most of the extra time in feeding comes from resting (Hunter, 2001; Iwamoto & Dunbar, 1983). Similarly, since the band spent less time invested in movement during the wet season, the band had more time available for resting and grooming. As the environment becomes very harsh in terms of availability of food during the dry season, gelada spent less time for grooming and resting in order to have more time feeding in order to compensate the daily energy requirements. Masi et al. (2009) pointed out that forest primates spend more time resting during the dry season than the wet season to reduce energy expenditure through travelling. Generally this suggests that seasonal variation in food availability affects the time budget of southern geladas in human-modified landscapes. During the lengthy dry season when green grass availability declines and changes into to brown and non-green forms, southern geladas significantly increased their feeding time budget at Kosheme.

In this study, southern geladas were observed to feed more early in the morning and late in the afternoon. The time spent grooming and resting occurred almost in a constant level with less clear peak at midday throughout the daylight hours. Likewise, some terrestrial species, like *Papio anubis* and *P. cynocephalus*, showed less marked activity pattern peaks in their diurnal activity patterns (Dunbar & Dunbar, 1974; O'Brien and Kinnaird, 1997). Thus, daily flexibility in activity pattern may represent an adaptation of geladas in human disturbed landscapes. Flexibility in activity pattern is an important aspect of primates' ability to survive in varying environmental conditions (Ilham et al., 2018).

The present study showed that geladas regulate their activity pattern in response to seasonal food variability as well as human disturbances. Southern geladas adjust their temporal diurnal activity pattern across seasons in varying trend depending on seasonal variation in food availability, climate condition as well human activities in the area. This indicates that southern geladas are flexible to respond to the seasonal variation. The diurnal activity patterns showed significant seasonal variations in the morning session: early feeding peaks occurred during the dry season, while there was a continuous increment until it reached feeding peak mid-afternoon during the wet season. This might be related to seasonal variations in the type of food sources (fruits from fig trees during the dry season and grass blades during the wet season) and temperature. Similarly, activity pattern of morning and afternoon feeding peaks, with midday resting peak may be an adaptation to temperature differences between seasons (Huang et al., 2003). Midday resting peak during the dry season might be also related to breakfast feeding of fruits, which are more nutritious compared to grass blades. Midday resting peak in diurnal activity pattern of François' langurs may be an adaptation strategy to avoid the hot noon temperature as well as fibrous food digestion after morning feeding peak (Zhou et al., 2007).

5 | CONCLUSIONS AND CONSERVATION IMPLICATIONS

The value of protected area for primate conservation is indispensable (Estrada et al., 2017), but the exclusion of the anthropogenic matrix of unprotected area from conservation initiatives is questionable for primates (Nekaris et al., 2017). Understanding the behavioural patterns of primates in response to human-modified environment is important information to plan effective conservation management strategies. Our study reveals that plasticity in diurnal time budgets and activity patterns are key factors for the survival strategies of geladas in human-modified environments. The behavioural patterns of southern gelada are related with the seasonal availability of food. Our results indicated that southern geladas adopt energy-maximising strategies to live in human-modified landscapes, that is they spent more time feeding, and less time moving, resting and grooming. This study also indicated that seasonal modification of activity pattern is an adaption strategy used in this region.

The conservation implications of this study revealed that long-term behavioural and ecological studies of southern geladas in human-modified landscape is essential to determining if life in human-modified landscape is an evolutionarily adaptation strategy for the species. From the conservation perspective, much of the habitats of southern geladas are greatly overlap with the local farmers' daily activities. Thus, the preservation of this landscape should be considered highest priority for the conservation and persistence of this endemic primate. To sum up, we recommend better conservation interventions and actions like small scale industries for youths as alternative employment mechanisms and community based conservation initiative approaches to conserve the remaining grassland habitats of the northern central highlands of Ethiopia to minimise local extinction of southern geladas and other wildlife in the human dominated landscapes of the region.

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CONFLICT OF INTEREST

The authors acknowledge that they have no conflict of interest.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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