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Research Article

The Activity and Ranging Patterns of Gelada Monkeys as Behavioral Responses to the Effects of Livestock Grazing in the Simien Mountains National Park, Ethiopia

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Understanding of behavioral ecology of primates in grazed lands is vital to their conservation and monitoring strategies. Here we investigated how livestock grazing within the Simien Mountains National Park affects the activity time budgeting and ranging behavior of the geladas, a monkey endemic to Ethiopian highlands. This study was carried out from February 2019 to July 2019 by stratifying the study area as grazed and nongrazed sites. Activity time pattern data were collected using 5 minutes instantaneous scan sampling within 15 minutes intervals from 7:00 to 18:00 for 10 days per month in the grazed and nongrazed sites. The ranging data were also collected by tracking the study group and recording GPS points every 15 minutes sample. The effects of livestock grazing on activity time budgets were statistically analyzed by multiple analyses of variance (MANOVA). Daily range length and home range size were estimated by employing the Open Jump toolbox (MOVEAN), and statistically tested by Mann–Whitney U test. From 3427 behavioral scans on the various activities, feeding was the most frequent (43.04%) behavioral activity followed by moving, accounting for 38.06% of the time. The study revealed that grazing has a statistically significant effect on moving and social activity time budgets. The geladas dwelling in the grazed areas of the park spent more time in moving than in the nongrazed areas. The effect of grazing on social behavior is the reverse of moving. Similarly, geladas traveled longer daily range length and cover a wider home range size in the grazed areas. Therefore, these findings of the study imply that livestock grazing is adversely affecting the behavior of gelada monkeys in the park. To minimize such effects on gelada monkeys and harmonize grazing with wildlife habitat conservation, the grazing pressure reduction strategy must be closely monitored and supported by animal feed cultivation technology.

1. Introduction

The gelada (*Theropithecus gelada*) is a dominantly grass-eating primate dwelling in the highlands of Ethiopia [1]. Afroalpine plateau areas are intensively livestock grazed, and this has already affected both biodiversity and ecological processes through soil and vegetation degradation of the habitats [2]. Increasing livestock and human population pressure coupled with inappropriate land use has led to massive destruction of wildlife habitats and reduction in the wildlife population. Wild animals including geladas use the same habitat as livestock for grazing. Consequently, they compete for the same resources. Livestock grazing has been destroying the habitats of wildlife and this has resulted in a lack of enough ranging space, food, and other resources for the conservation of wildlife species [3].

Activity budgets of primates are influenced by many factors in natural habitats, most of which relate to the challenges of acquiring food energy and the availability of food resources [4, 5]. For instance, the decline of wildlife habitat quality [6–8] includes a reduction of perennial grass and herbaceous vegetation covers [9, 10]. Therefore, factors

that influence food availability have a strong effect on time allocation decisions [11, 12].

Livestock grazing is an influential driver of plant population dynamics and community succession. Some primates change their behavioral patterns in response to the integrated effect of grazing with seasonal variations on the availability, relative abundance, and distribution of food plant species [13, 14].

Variations of habitat preferences and movement patterns in primates have been much discussed related to ecological factors [15–17]. There have been relatively few attempts to measure and distinguish resource availability related to livestock grazing and other variables affecting the habitat selection of geladas. However, studies on the behavioral ecology of geladas have been limited and few in Simien Mountains (Sankaber: [15, 18, 19], Gich: [20, 21] and Chennek: [22]) and some of them have looked at grazing effects. Nevertheless, this has been done by comparing results across studies in different areas [19]. Therefore, this research looked at the effects of grazing within the Simien Mountains National Park.

Behavioral responses to grazing pressure remain undescribed despite the fact that this information is critical for the establishment and implementation of effective management and conservation plans for this species. In addition, behavioral patterns of a primate species do not always show a consistent pattern [15, 19, 23]. This may be due to the ability of different species to cope with resource scarcity and feeding competition in different ways.

Determining the activity patterns of the geladas in response to human disturbances is an important step to understand how human impacts on the environment can shape primate ecology and evolution [18]. Similarly, an understanding of the basic natural history of primate species is vital to their conservation, particularly examining the interface of gelada behavioral ecology with competing livestock in human-altered habitats [24]. For instance, data on activity patterns of primates provides an insight into effects of livestock grazing on their behavioral pattern and flexibility on such anthropogenic alteration. Furthermore, data on activity patterns is important to seek management solutions for the negative effects of grazing pressure on the gelada habitats and can help to guide monitoring strategies for threatened primate species. Besides, it can be an input for further studies on the interface of wildlife conservation with livestock production. In line with this, recently the Simien Mountains have been subjected to fluctuations over time in the type and amounts of food that are available for wild animals due to livestock grazing and management interventions (personal observation). Under these varying conditions, the resulting changes in vegetation composition and cover are expected to alter environmental conditions for a variety of wildlife species. Furthermore, to help the conservation of a flagship species like geladas, wildlife managers need to have much more information on their habitat requirements and their behavioral adaptability to the changes in habitat qualities. During times of food scarcity, it is hypothesized that primates may adapt to this situation in two alternative behavioral responses either by decreasing time spent traveling and/or foraging time, day range; or increasing traveling and/or foraging time, day range length, and home range size and sacrificing their social time [25, 26]. Therefore, this study was initiated to examine how gelada monkeys behaviorally respond to their activity time budget and ranging pattern to cope with the livestock grazing competition pressure in either of the above-stated hypothesis.

2. Methods

2.1. Study Area. The Simien massif in Ethiopia is an extraordinary landscape, with endless vistas and rare, endemic wildlife species including gelada monkey. The Simien Mountains have been home to human settlers for thousands of years [27]. The Simien Mountains National Park (SMNP) is found in the northwestern Amhara Region of Ethiopia. The park is found within five Woredas: Debark, Adarkay, Beyeda, Janamora and Telemt, bordering 42 kebele of these Woredas [28]. The Park is an area of great diversity and scenic beauty that was established in 1966 [29] and currently covers an area of 412 km^2. The presence of unique landscapes and a wide range of flora and fauna with the high level of endemism made SMNP a World Heritage Site in 1978. However, 18 years later, in 1996, the SMNP figures on the List of the World Heritage in Danger mainly due to the declining key species population. In just a few years, the ecosystem has rebounded and wildlife populations have rallied [30]. After 21 years of collaborative effort to reducing the grazing pressure and increment of the declined wildlife population, UNESCO removed the park from the list of World Heritage in Danger in 2017 [28].

The park harbors four endemic large mammals of Ethiopia: Walia ibex (*Capra walie*), Ethiopian wolf (*Canis simensis*), Menelik's bushbuck (*Tragelaphus scriptus meneliki*), and Gelada monkey (*Theropithecus gelada*) and are the flagship species of SMNP [30]. Moreover, the Simien Mountains are characterized by a high level of plant endemism and are part of the Eastern Afromontane hotspot of plant diversity. Furthermore, Simien Mountains are central to the botanical history of Ethiopia [31].

2.2. Study Site and Sampling Design. Sites of the Simien Mountains National Park were stratified into sites where livestock grazing is allowed and sites where grazing is strictly forbidden. Chennek, Sankaber, Gich, SebatMinch, RasDejen, and KidusYared are protected from grazing whereas Aynameda, Limalimo, Aterie, Abarie, Arkwaziye, Michiby, and Silki are under intense grazing. To minimize the effect of bio-physical natural differences of the sampling sites on the study's expected results, geographically adjacent sites, Sankaber (nongrazed site) and Michiby (grazed site) were selected. In the 2019 monitoring report of the park, a total of 6,287 livestock was estimated in Michiby. Shoats was the most frequently encountered and most abundant (N) livestock type followed by cattle and lastly equines. An estimated 1.3 TLU's per hectare were found in this area, almost three times higher than the recommended 0.5 TLU's per hectare

for highland ecosystems. In addition, the report indicates that variation across seasons were observed, 1.3 and 1.5 TLU's per hectare were found in the dry and wet season, respectively [32]. Detailed descriptions of these sites are found in Dunbar [18], Hunter [15], and Jarvey et al. [19]. For this behavioral ecology study, nine one-male units (OMU) were taken as focal groups dwelling in grazed and nongrazed sites of the SMNP (Figure 1). Detailed behavioral and ranging data were collected from all adult males and females in these nine one-male units ($N = 73$ females, and 48 males). The geladas in this population have been fully habituated to human observers on foot at a distance of 2m and were individually recognizable by natural markings.

2.3. Behavioral Data Collection and Analysis

2.3.1. Activity Pattern. Activity patterns of geladas in the Sankaber and Michiby areas were collected from Feb 2019 to Jul 2019 (with the exception of April 2019, when no data were collected because of a massive fire blaze in the Simien Mountains). Data collection covered parts of the wet and dry seasons with an average of 10 days per month. In particular, 5 minutes instantaneous scan samples were used at 15-min intervals [33] from 07:00 hr to 18:00 hr to determine the percentage of time allocated to various activities of the sample gelada groups. During the scan sampling, among all visible individuals of the study group, nine ($n = 9$) were sampled, to record their behaviors: feeding, moving, resting, socializing, and others on the standardized data sheet [15, 34].

The percentage of time budget spent on various activities was calculated for each day. Data obtained from all scans were first pooled for each daily sample to estimate the daily activity time pattern in the grazing categories. Then the daily basis pooled activity time budget was statistically analyzed for testing the effects of grazing on the activity time of geladas.

2.3.2. Ranging Patterns. At the time of each scan sample, the geographic center of the group was recorded using a Garmin GPS at 15 minute intervals from 07:00 hr to 18:00 hr during the sampling days mentioned above. The collected GPS data were converted into shapefiles, and the daily travel distance and home range size were estimated using Open Jump (animal movement analysis GIS application) [35].

The daily range length of the sample group was estimated from the track of point-to-point movements of the group between consecutive GPS points. Home range size was estimated using 95% minimum convex polygon (MCP) method [4, 16, 36, 37]. For the home range size estimation, all daily ranges data were combined on a seasonal scale and grazing levels. Total home range size was also determined for each group based on the total locations recorded [38].

2.4. Statistical Analysis. All statistical analyses were performed using SPSS statistical software version 20 (SPSS Inc. Chicago, IL, USA). All data were assessed to determine

whether they fulfilled the assumptions of parametric tests or not. Nonparametric tests were used for the data that did not fulfill the assumptions. Level of statistical significance was set at $P = 0.05$ for all analyses.

To examine the effect of grazing level on the activity time budget of different behavioral responses (feeding, social, resting, moving, and other) one-way Multivariate Analysis of Variance (MANOVA) was used. Pearson correlation analyses were also used to assess relationship between the time budget of different behavioral activities and activity time adjustments of the gelada monkeys to cope with constraints due to the grazing effect. Additionally, the effects of grazing levels on daily travel distance were analyzed using Mann–Whitney U test.

3. Results

3.1. Activity Budget. A total of 3427 behavioral scans on the various activities were recorded throughout the study period. Feeding was the most frequent behavioral activity from the overall activity budget (Figure 2), which contributed to 43.04% of the time gelada spent on the five main activities recorded. Moving was the next most common activity, accounting for 38.06% of the time. Socializing contributed 11.52% of the time. Resting and others were the least common activity, accounting for 6.40% and 0.98% of the time respectively (Figure 2).

3.1.1. Diurnal Activity Pattern and Influence of Grazing. During the study period, 1926 behavioral observations on the various activities were recorded in nongrazed, and 1501 behavioral observations were recorded in grazed areas from 9 OMUs. Feeding and moving were peaks throughout the day in grazed areas (Figure 3). However, feeding activity indicated an increasing trend during the late morning (10:00–11:00 h) and towards the end of the early afternoon (17:00–18:00 h); and moving was almost constant throughout the day in nongrazed areas (Figure 4). Social activities were peak from 8:00–10:00 h in grazed and nongrazed areas, but a slightly higher proportion was observed in nongrazed areas.

Geladas spent almost equal time feeding (43.42% ± 8.96%) in nongrazed and grazed areas (42.63% ± 6.87%). However, the time spent in moving was higher in grazed than in nongrazed areas, which contributed 42.68% ± 5.96% and 33.66% ± 7.20% of the time, respectively. Resting time was higher in nongrazed areas (7.10% ± 4.99%) than in grazed areas (5.71% ± 4.59%). Social activities were higher (14.92% ± 8.29%) in nongrazed areas than in grazed areas (7.93% ± 5.97%) and other activities were less in nongrazed (0.93% ± 1.34%) than in grazed areas (1.04% ± 1.63%) (Figure 5).

A statistical test showed grazing levels have a significant effect on the differences in the behavior of gelada (feeding, moving, resting, social, and others). The result of the analysis makes clear that grazing level has a statistically significant effect on activity time budget, $F_{[4,73]} = 11.04$, $P < 0.001$, Wilks' $\Lambda = .62$, partial $\eta^2 = 1.0$. This high effect size (partial $\eta^2 = 1.0$)] implies, grazing level has a strong effect on changes
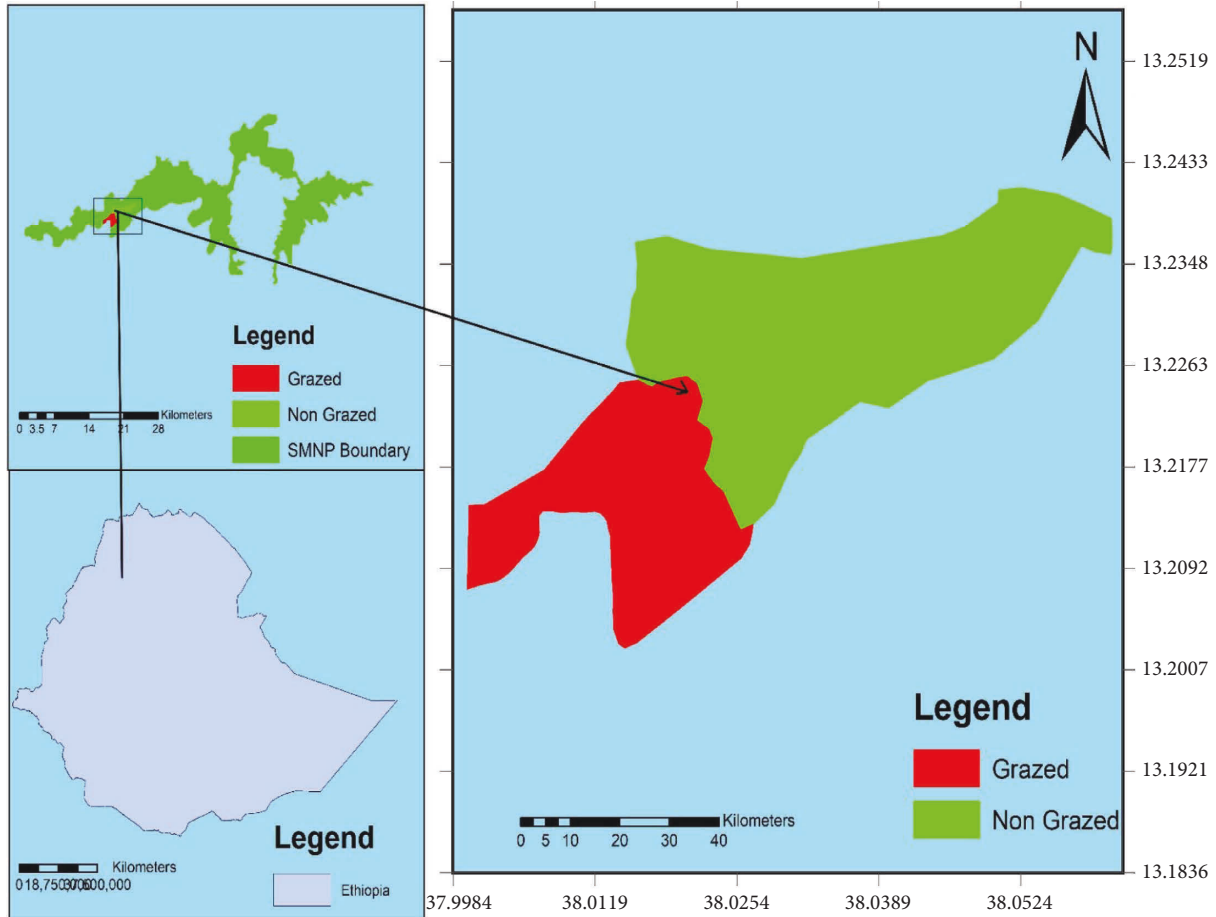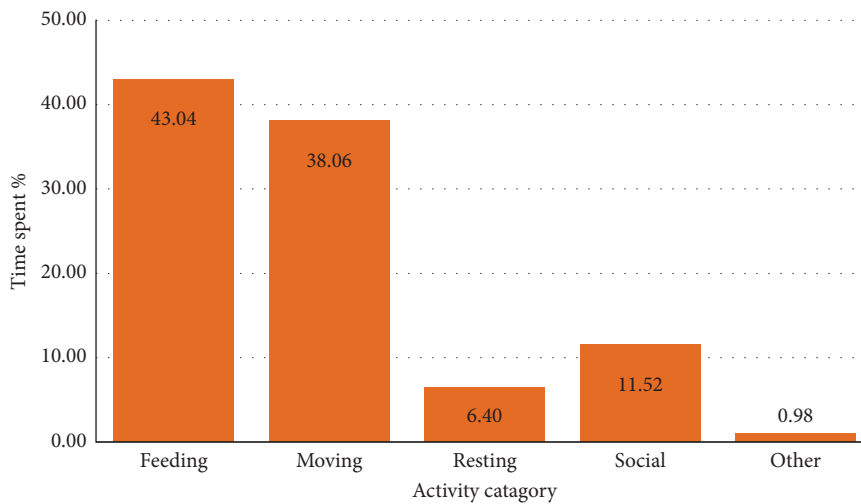
FIGURE 1: Sampling sites of the study.

FIGURE 2: Activity time budget of geladas.

in the activity time budget of different behavior between grazed and nongrazed areas (Table 1). Therefore, livestock grazing significantly influences the activity time budgets of gelada monkeys in Simien Mountains National Park.

Particularly, grazing level has a statistically significant effect on both moving ($F_{[1,76]} = 36.06$; $P < 0.001$; partial $\eta^2 = 0.32$) and social activity time budget ($F_{[1,76]} = 18.06$; $P < 0.001$; partial $\eta^2 = 0.19$). Effect sizes of statistical tests revealed social behavior and moving were highly influenced by grazing level compared to other activities. However, effect of grazing level on the time spent in feeding ($F_{[1,76]} = 0.19$, $P = 0.66$, partial $\eta2 = 0.002$); resting ($F_{[1,76]} = 1.57$, $P = 0.21$,
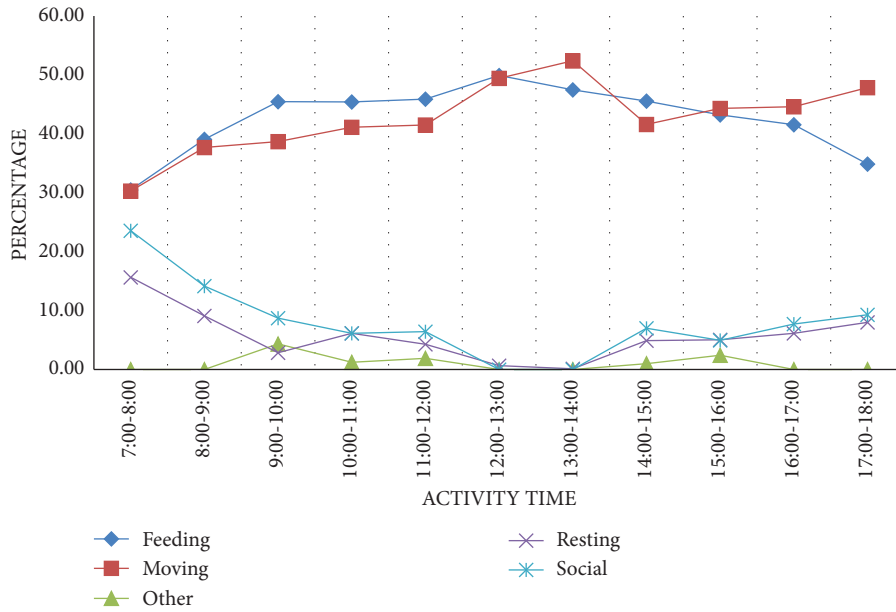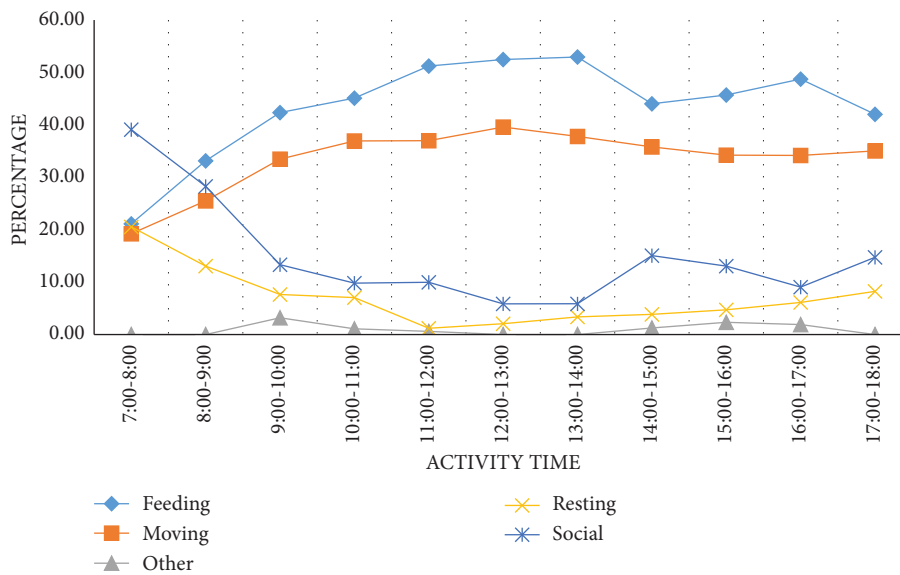
Figure 3: Daily activity pattern in grazed areas.

Figure 4: Daily activity pattern in nongrazed areas.

partial $\eta^2 = 0.02$) and other ($F_{[1,76]} = 0.12$, $P = 0.73$, partial $\eta^2 = 0.002$) was not statistically significant (Table 1).

Pearson correlation analysis in Table 2 demonstrated that the proportion of time spent in resting and socializing was strongly negatively correlated with feeding ($r = -0.631$, $P = 0.001$ and $r = -0.597$, $P = 0.001$) respectively. Resting and socializing were also strongly negatively correlated with moving ($r = -0.524$, $P = 0.001$ and $r = -715$, $P = 0.001$) respectively. Nevertheless, feeding was not correlated with moving ($r = -0.011$, $P = 0.924$). On the other way, resting time was positively correlated with social time ($r = 0.590$, $P = 0.001$). The proportion of time spent on other activities was not correlated with feeding ($r = -0.041$, $P = 0.718$) and resting ($r = -0.216$, $P = 0.058$). However, the proportion of

time spent on other activities was weakly positively correlated with moving ($r = 0.234$, $P = 0.039$). In contrast, time spent on other activities was weakly negatively correlated with the social activity budget ($r = -0.25$, $P = 0.027$).

3.2. Ranging Behavior. The mean daily travel distance of the focal group over the entire course of the study was 1474.05 ± 1100.38 m (Figure 6). The minimum and maximum Monthly mean daily distances traveled by the group were 1141.83 ± 289.1 m (June) and 1903.69 ± 2017.1 m (March), respectively. However, the difference in mean daily travel distance between seasons was not significant ($U = 277$, $P = 0.13$).
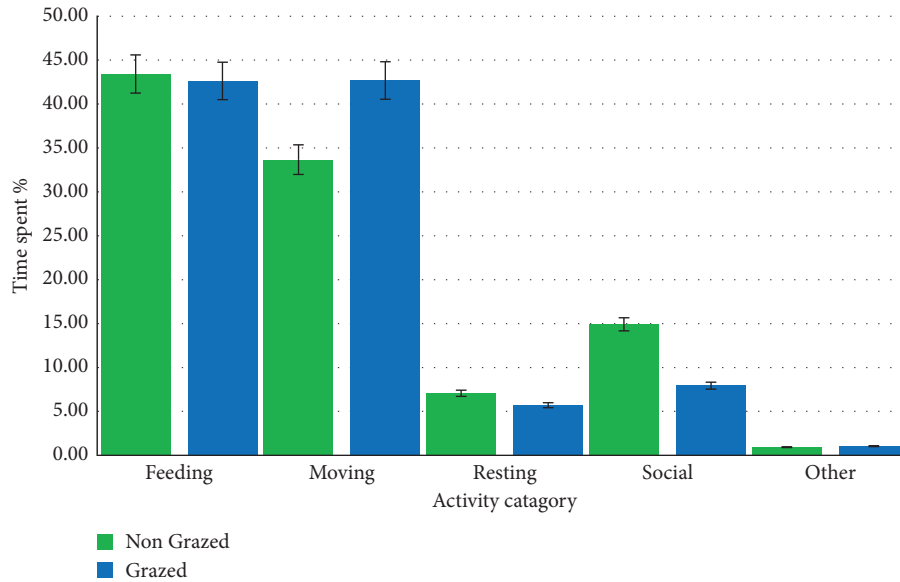
FIGURE 5: Comparison of activity time budget between the nongrazed and grazed areas.

TABLE 1: Multivariate analysis result.

			Multivariate Tests[a]						
Effect		Value	F	Hypothesis df	Error df	Sig.	Partial eta squared	Noncent. Parameter	Observed power[c]
Intercept	Pillai's trace	1.000	90064.828[b]	4.000	73.000	0.000	1.000	360259.311	1.000
	Wilks' lambda	0.000	90064.828[b]	4.000	73.000	0.000	1.000	360259.311	1.000
	Hotelling's trace	4935.059	90064.828[b]	4.000	73.000	0.000	1.000	360259.311	1.000
	Roy's largest root	4935.059	90064.828[b]	4.000	73.000	0.000	1.000	360259.311	1.000
Grazing_Level	Pillai's trace	0.377	11.049[b]	4.000	73.000	0.000	0.377	44.195	1.000
	Wilks' lambda	0.623	11.049[b]	4.000	73.000	0.000	0.377	44.195	1.000
	Hotelling's trace	0.605	11.049[b]	4.000	73.000	0.000	0.377	44.195	1.000
	Roy's largest root	0.605	11.049[b]	4.000	73.000	0.000	0.377	44.195	1.000
			Tests of between-subjects effects						
Source	Dependent variable	Type III sum of squares	df	Mean square	F	Sig.	Partial eta squared	Noncent. Parameter	Observed power[f]
Corrected model	Feeding	12.056[a]	1	12.056	0.187	0.666	0.002	0.187	0.071
	Moving	1583.432[b]	1	1583.432	36.063	0.000	0.322	36.063	1.000
	Resting	36.077[c]	1	36.077	1.567	0.214	0.020	1.567	0.235
	Social	950.498[d]	1	950.498	18.061	0.000	0.192	18.061	0.987
	Other	0.267[e]	1	0.267	0.116	0.734	0.002	0.116	0.063
Intercept	Feeding	144314.298	1	144314.298	2244.316	0.000	0.967	2244.316	1.000
	Moving	113596.529	1	113596.529	2587.192	0.000	0.971	2587.192	1.000
	Resting	3178.161	1	3178.161	138.035	0.000	0.645	138.035	1.000
	Social	10176.748	1	10176.748	193.378	0.000	0.718	193.378	1.000
	Other	75.735	1	75.735	32.918	0.000	0.302	32.918	1.000
Grazing_Level	Feeding	12.056	1	12.056	0.187	0.666	0.002	0.187	0.071
	Moving	1583.432	1	1583.432	36.063	0.000	0.322	36.063	1.000
	Resting	36.077	1	36.077	1.567	0.214	0.020	1.567	0.235
	Social	950.498	1	950.498	18.061	0.000	0.192	18.061	0.987
	Other	0.267	1	0.267	0.116	0.734	0.002	0.116	0.063

TABLE 1: Continued.

Error	Feeding	4886.962	76	64.302
	Moving	3336.952	76	43.907
	Resting	1749.849	76	23.024
	Social	3999.589	76	52.626
	Other	174.854	76	2.301
Total	Feeding	149375.956	78	
	Moving	117904.460	78	
	Resting	4983.579	78	
	Social	15293.755	78	
	Other	250.676	78	
Corrected total	Feeding	4899.018	77	
	Moving	4920.384	77	
	Resting	1785.926	77	
	Social	4950.086	77	
	Other	175.121	77	

[a]Design: intercept + grazing level. [b]Exact statistic. [c]Computed using alpha = 0.05., [a]R squared = 0.002 (adjusted R squared = −0.011). [b]R squared = 0.322 (adjusted R squared = 0.313). [c]R squared = 0.020 (adjusted R squared = 0.007). [d]R squared = 0.192 (adjusted R squared = 0.181). [e]R squared = 0.002 (adjusted R squared = −0.012). [f]Computed using alpha = 0.05.
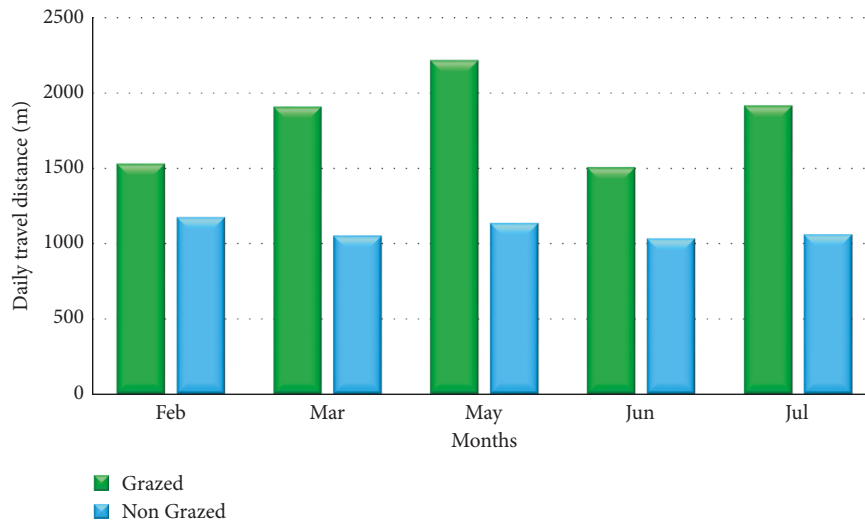

FIGURE 6: Monthly mean of daily travel distances (m) for the study group across grazing level.

In contrast to season, grazing levels have a significant effect on daily range length ($U = 31$, $P < 0.001$). The estimated average day range length of gelada in the grazed areas was 2024.89 ± 977.13 m, whereas that of the nongrazed areas was 1085.02 ± 141.97 m. In the grazed areas, the minimum and maximum range lengths were 1085.60 and 5170.43 m, respectively. The longest daily range length in the nongrazed areas was 1419.32 m, and the shortest was 849.33 m.

The home range size of the focus groups was wider (3.03 km²) in grazed area than in the nongrazed area (1.74 km²). During the dry season, the focal groups used 2.91 km² and 1.45 km² in grazed and nongrazed areas, respectively. However, 1.74 km² and 1.26 km² were used during the wet season in grazed and nongrazed areas, respectively. The home range size of the geladas over the study period was varied seasonally and across grazing levels. Seasonal overlap of home range use was observed in both grazed areas and nongrazed areas 1.67 km² and 0.98 km²

respectively (Table 3). The focal groups in the grazed area extended their home range than the focal groups in nongrazed area as a result of seasonal changes (Figure 7).

4. Discussion

4.1. Activity Time Budget. Time spent on different activities in animals is an indication of balancing the energy budget for various activities. Many factors are known to influence the activity budgets of primates, most of which are associated with the challenges of acquiring sufficient food energy [5]. Variations in the timing of daily activity patterns are characteristics of primates [39]. The daily activity pattern of gelada's was significantly different at different grazing levels over the daytime.

Analysis of daily activity patterns of gelada demonstrated that feeding and moving peaks throughout the day in grazed areas. Nevertheless, feeding activity indicated an increased

TABLE 2: Pearson correlation coefficients for different activity categories.

Activity time		Moving	Resting	Social	Other
Feeding	r_P	−0.011	−0.631****	−0.597**	−0.041
	P	0.924	0.000	0.000	0.718
Moving	r_P	—	−0.524**	−0.715**	0.234*
	P		0.000	0.000	0.039
Resting	r_P		—	0.590**	−0.216
	P			0.000	0.058
Social	r_P			—	−0.250*
	P				0.027

**Correlation is significant at the 0.01 level (2-tailed). *Correlation is significant at the 0.05 level (2-tailed).
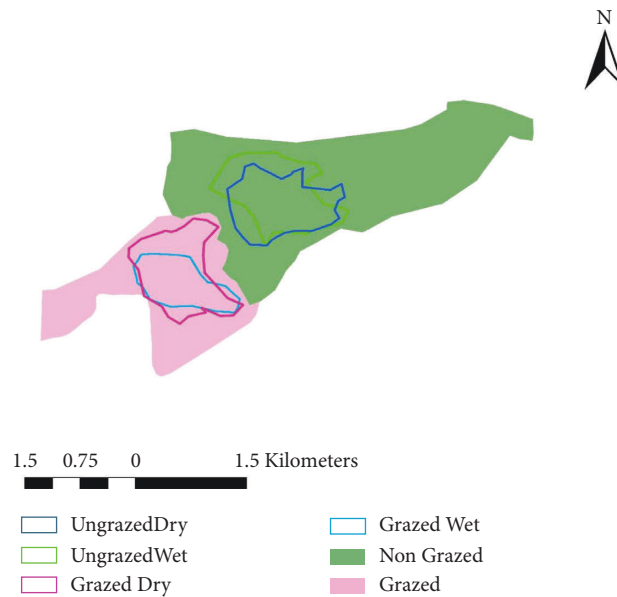

FIGURE 7: Depiction of the 95% minimum convex polygon (MCP) of seasonal home ranges of the study groups in grazed and non-grazed areas.

pattern during the late morning and towards the end of the early afternoon [20]. Conversely, Barrett [40], reported that feeding activity in a different primate species might be peaked at the beginning of the day. Among the daily activity patterns, moving did not show significant variation across the daytime. Similarly, Woldegeorgis and Bekele [21], confirmed that moving was almost higher throughout the day as compared to the other behavioral activities. Social activities peaked from 8 : 00–10 : 00 h in grazed and nongrazed areas but a slightly higher proportion was revealed in nongrazed areas. Woldegeorgis and Bekele [20] also reported that socializing and resting activities peaked during the early morning hours, probably due to the presence of animals in their home range. However, resting and social activities peaked over the midday hours for other primates [40].

Geladas spent almost similar time feeding (43.42%) in nongrazed and grazed (42.63%) areas. The present study has shown that the activity budgets of gelada generally resemble those of geladas studied at other sites [12, 15, 20].

Prioritization of time allocation for feeding is in accordance with the results of other gelada studies by Hunter [15], and Iwamoto and Dunbar [41]. The reason for such a high proportion of time devoted to the feeding activity may be due to the geladas' high degree of dietary specialization on grasses, which may have lower nutritional quality [42]. The bulk feeding strategy of gelada requires a very large proportion of their time to be dedicated to feeding over other activities. Iwamoto and Dunbar [41], have also stated that better habitat quality is associated with decreased feeding and increased resting among gelada groups.

On the other hand, the time allocated for moving was higher in the grazed area (42.68%) than in nongrazed (33.66%) area. Factors that affect food availability have a strong influence on time allocation decisions for different behavioral activities [34, 43, 44]. In this regard, it is predicted that since traveling is an energetically costly activity, the reduction of time spent in moving is expected as an energy-saving strategy to cope up with the resource limitations in

TABLE 3: Home range of geladas across grazing level and season.

Season	Nongrazed (km^2)	Grazed (km^2)
Dry	1.45	2.91
Wet	1.26	1.74
Seasonal overlap	0.98	1.67
Overall	1.74	3.03

food scarce conditions [45]. In contrast to this, to acquire sufficient food energy geladas spent more time for moving in search of food in a site constrained by grazing pressure. This is also supported by the foraging strategy of primates adapted to feed on relatively low nutritious and available food items like grass and corms [46].

In contrast to the effect of grazing on moving, the social time was reduced in the grazed area (7.93%) than in the nongrazed area (14.92%). In addition to the effect of grazing on moving, the social behavior of gelada is negatively influenced. However, the time allocated for resting is not influenced by grazing. This result agrees with Dunbar [34] and Alberts et al. [25], who suggested that ecologically stressed geladas might reduce social times for increased feeding time under poor ecological circumstances. This suggestion is in accordance with the present finding indicating a significant negative correlation of time budget for social behavior with feeding and moving. In the grazed site, the feeding and moving time of geladas were higher, but their social time was lower. Thus, gelada monkeys in SMNP followed a dispensable social time strategy to adapt to the adverse effects of livestock on their behavior. Indeed, such behavioral adaptations might be observed when the gelada monkeys face competition for food with other grazer wild animals dwelling in the park which is not considered our field study.

4.2. Ranging Pattern. The results of this study indicate that geladas adjust their ranging length in response to grazing level. Daily ranging behavioral response depends on how much travel time would need to increase while maintaining the energy requirement of the animal [47], how foods differ in quality and spatial distribution [48], and the general foraging strategy of the animal. In line with the activity time budget for moving, the mean daily travel distances of the study group in grazed areas were greater (2.02 km), than the daily travel distance in nongrazed areas. This indicates that geladas increased their daily range length to meet their nutritional requirements as a strategy. As a result, geladas are not adapted to reduce energy expenditure in resource-scarce areas but rather to maximize their daily travel distance.

In agreement with this result, Dunbar [36] and Woldegeorgis [49] reported that habitat quality due to livestock grazing influences daily journey length (i.e., animals have to cover proportionately longer areas to find the food they need as the sources decline). The present study also showed that geladas move less when food availability is high in nongrazed areas; but when food scarcity occurs, geladas roam larger areas in search of food which is in concordance with a previous study [45, 50]. The longer daily travel distance of the group may reflect increased foraging effort, due to disturbed conditions of the area and thus low resource availability [15, 36, 51]. In contrast, Iwamoto and Dunbar [41], Hunter [15], Abu [52], and Kifle et al. [53] noted that geladas move for only a short distance a day, which is 0.8–1.56 km, compared to other baboons and with the present study. These might be associated with the variations in food availability and band size in the respective study area and period of study.

The home range size of geladas varied among grazing levels in the study area. The variations of resources in Simien Mountains National Park in the grazed and nongrazed areas had an impact on the ranging behavior of geladas. The present study revealed that the home range size of the geladas in grazed areas was wider (3.03 km^2) than in non-grazed areas (1.74 km^2). The larger home-range size of the focal group in grazed areas was primarily related to the overall low availability of green grass and other resources in the study area. In the grazed areas of the park, geladas were constrained by grazing competition due to livestock grazing which affects the habitat quality and above-ground biomass. As a result, geladas move from one patch of land to the other and increased home range size in disturbed areas [37]. Kifle et al. [53] have also reported variations in the extent of home range of geladas between habitats because of human-induced activities.

In addition to anthropogenic influence, seasonal variation has the influence to widen or narrow the home range of the gelada over the study period. Abu [52], Kifle et al. [53] and Moges [54] have also reported variations in the extent of the home range of geladas between seasons. Hunter [15] and Dunbar [55] noted that the use of the extended home range during the dry season might be due to a more patchy distribution of green grasses. However, home-range size is also dependent on other factors, including group size [56], energy requirements of animals [10] and intragroup interactions [57]. Reuse frequency or overlap of home range was higher in grazed areas than nongrazed areas during the dry season and wet season. This indicates more intensive use of the home range even if that is disturbed because geladas cannot extend their home range beyond this as the habitat is cliffy and disturbed [15].

5. Conclusion

Livestock grazing is a major challenge for the conservation of geladas in the afro-alpine areas because livestock of the local people graze and compete with the gelada populations. Therefore, understanding the behavioral

flexibility of primates in response to livestock grazing is crucial to develop an effective conservation management strategy. Our study found that grazing has a negative effect on the activity time budget and ranging behavior. Particularly, geladas who dwell in grazing areas spent more time for moving and reduced their social time as compared to geladas who inhabit in nongrazed areas. Moreover, the daily travel distance and home range size of geladas in grazed areas were greater than in non-grazed areas. Thus, grazing affects geladas by costing energy for more time on moving and traveling longer daily travel distance. Besides the energy cost, grazing constrained their social behavior which is taken as an important social glue to maintain a larger group size in geladas. On the other hand, the significant negative correlation on the time budget for moving and social time is an indication of behavioral activity time budget tradeoff to cope with the effect of grazing on their energy balancing adaptation.

Increased livestock free grazing in a protected area costs the conservation and also reduces the satisfaction of livestock herders [58]. Similarly, free grazing pressure leads to habitat loss and degradation of the resources at SMNP and its surrounding. As a result, the food availability and quality of the geladas' habitat are being affected. However, the study was done in a short study time period to come up with a very strong scientific evidence that helps to adequately evaluate the effect of grazing on the behavior of Gelada monkeys at a seasonal level. Thus, we can suggest long time study that has at least annual data collected monthly is required to evaluate the behavioral adjustment patterns of gelada in response to grazing effect on the food availability or biomass in their home range. Therefore, habitat restoration in the Simien Mountains by reducing the free grazing pressure is crucial for the survival of the wildlife in particularly vulnerable species like the gelada monkey and ensuring sustainable development of local people whose livelihood is dependent on livestock ranching. This might be possible by supporting the local people to reduce their free grazing practice by allowing them using cut-carry animal fodder collection in the park in the managed way or by practicing a controlled grazing strategy in a period when above-ground biomass is higher and not easily degraded by livestock. Moreover, improving the livelihood of local communities who have lost the access to livestock grazing is another strategy contributing for wildlife conservation effectiveness of the Park. For instance, strengthening their engagement on the tourism activity and on off-farm activity or small-scale animal husbandry to assure food security of the inhabitants are badly needed.

Data Availability

The data used for this study are available from the corresponding author upon reasonable request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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