

Seasonal Variation in the Activity Budget and Daily Path Length of Semi-Provisioned Rhesus Macaques (*Macaca mulatta*) in Daunne Forest, Nawalpur, Nepal

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Abstract

Rhesus macaques (*Macaca mulatta*, Mammalia: Primates: Haplorhini: Cercopithecidae) show a great deal of adaptability in different types of habitats. Understanding how these animals allocate their time concerning their daily activities and ranging behavior is helpful to the design of effective conservation plans by allowing us to better understand their ecological necessities and behavioral responses to environmental changes. This study examined seasonal variation in the activity budget and ranging behavior of semi-provisioned rhesus macaques inhabiting the Daunne Devi Temple area in the Daunne Forest, a subtropical forest in the mid-hill of central Nepal. Behavioral data were collected on the adult members of the group using focal animal sampling from 27 October 2021 to 10 May 2022 (for a total of 29 days /227 hours of observation) during three time periods of the day: morning, 7.00-11.00 am; afternoon, 11.00-2.00 pm; and late afternoon, 2.00-6.00 pm. Simultaneously, ranging behavior was recorded by instantaneous scan sampling at 10-minute intervals with the aid of a GPS receiver. The adults in the study group spent the majority of the time resting (33.83%), followed by moving (26.67%), feeding (22.92%), and grooming (15.42%). Males spent significantly more time resting and moving, whereas females spent significantly more time feeding and grooming. The time invested by the rhesus macaques in different activities showed seasonal variation but lacked statistical significance. Daily path length ranged between 540.1-2905.4 m (mean = 1590 ± 576.96 m) with a statistically significant seasonal difference that might be attributed to the number of temple visitors and availability of provisioned food. Although the sample size was small and the study duration was short, this is one of only a few studies providing empirical evidence suggesting the seasonal variation in activity budget and daily path length of semi-provisioned rhesus macaques.

Key words: Activity budget, behavior, daily path length, provisioning, rhesus macaques,

1. Introduction

Time is a finite resource that affects how different animals behave (Pollard and Blumstein 2008). Evaluating the proportion of time spent in various activities over a day or year is an essential element in studies of a species' behavioral ecology (Neha *et al.* 2021). An assessment of an animal's activity budget (a summary of how the animal allocates its time among different activities) can provide important information relating to its reproduction and survival, as well as an understanding of its adaptation to its environment (Bernstein 1968; Rodway 1998; Neha *et al.* 2021).

Primates can quickly modify their activity budgets in response to shifting environmental conditions (Li 2009). Environmental factors, including seasonal availability of food sources, the diversity of plant species, and physiological restrictions like individual dietary needs and thermoregulation, affect behavioral activity. Body size, social status, energy expenditure, locomotion, investment in reproduction, and physiological status vary between age-sex categories and have a profound impact on the temporal budget of each individual inside a group (Altmann 1974; Key and Ross 1999; Vasey 2005; Li 2009; Albert *et al.* 2013). How animals allocate their time to various activities substantially impacts their survival (Xiang *et al.* 2010).

Among primates, behaviors such as home range size and daily path length (DPL) fluctuate

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significantly between species, even within congeners living in diverse habitats (Milton & May 1976; Clutton-Brock & Harvey 2009). The DPL, generally presented as the average or mean length that an individual or group travels during a day, is affected by physical and ecological elements like the season, food availability, the variety of plants eaten, intergroup interactions, and level of terrestriality (Santhosh *et al.* 2015). Anthropogenic disturbance is an important factor influencing the ranging patterns of primates (Shoma & Feeroz 2014). Precise-ranging information is essential for understanding primates' ecology, evolution, and conservation, but this information is often scarce for many species (José-Domínguez *et al.* 2015).

Rhesus macaques (*Macaca mulatta*) are among the most common, widespread, and ecologically adaptable primate species. In Nepal, rhesus macaque is found in low-lying flatlands up to 4,000 meters above sea level (asl) in the foothills of the Himalayas. They also dwell at different religious sites and cities throughout Nepal (Chalise 2013). Research on the rhesus macaques in Nepal has typically focused on population density, distribution, human-primate conflict, parasite infection, and competition among sympatric species. However, very few studies

have been conducted on the diurnal activity budget and rhesus macaques' range in the wild or semi-provisioned conditions.

This study evaluated the seasonal variation in activity budget and daily path length of a semi-provisioned group of rhesus macaques. The study aimed to identify: i) the behavioral activities that dominate the diurnal activity budget of semi-provisioned rhesus macaques, ii) the activities that vary with seasons, and iii) the seasonal variation in daily path length of semi-provisioned rhesus macaques. The results of this study should add to our understanding of the behavior of rhesus macaques living in human-altered environments and help with the management of macaques living in shared environments with humans.

2. Materials and Methods

2.1. Study Area

This study was conducted in the Daunne Forest of Nawalpur District (Figure 1), which lies in Gandaki Province, Central Nepal. Daunne Devi Temple (27°46'32" N and 83°47'59" E) in the Daunne Forest was selected as the study site. The temple is located in a hill pass between Bardaghat and

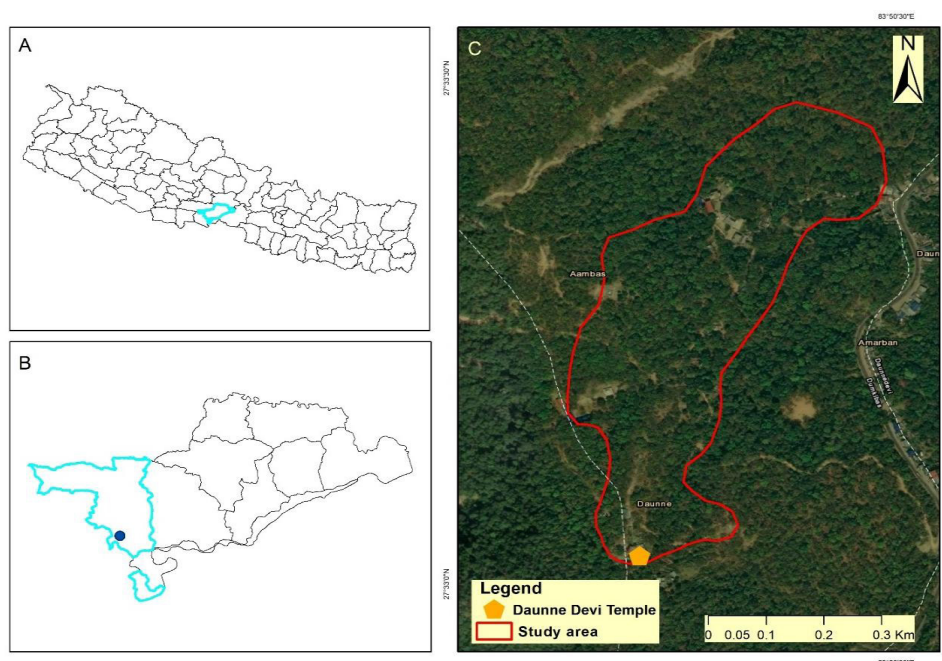


Figure 1. Map of the study area: A. Map of Nepal showing the Nawalpur District; B. Map of Nawalpur District showing Binayee Tribeni Rural Municipality and the Daunne Forest (blue dot); and C. Map showing the Daunne Devi Temple in the Daunne Forest.

Dumkibas at an elevation of 1033 m asl. The study area has a subtropical to temperate climate, with the hottest periods occurring during May and June and the coldest during December and February. The average annual rainfall in the area is about 1500 mm. The forest has a variety of flora and fauna surrounding the temple, such as Sal tree (*Shorea robusta*), Indian rosewood (*Dalbergia sissoo*), Indian laurel (*Terminalia tomentosa*), and red silk-cotton (*Bombax ceiba*) that are the most prevalent tree species in the area (Subedi 2008). The area also supports a diversity of butterflies, amphibians, reptiles, birds, and mammals, including leopards (*Panthera pardus*), rhesus macaques (*Macaca mulatta*), common langurs (*Semnopithecus hector*), Indian cobras (*Naja naja*), and water snakes (*Natrix piscator*) (Baral *et al.* 2003).

2.2. Study Group

The study focused on 35 rhesus macaques, the only group inhabiting the Daunne Devi Temple area. The group consisted of six adult males, 13 adult females, six sub-adults, five juveniles, and two infants at the beginning of this study. During the study period, three infants were born, and one adult died. The 19 adult macaques represented the subjects of observation in this study. We identified the macaques using distinctive facial features, variation in pelage/skin coloration, and scars. The group received supplemental food provisioning from the temple visitors and Hindu priests daily. Additionally, the macaques foraged on natural vegetation in the forest around the temple and its stairway. Hence, we considered them as a semi-provisioned group.

2.3. Behavioral Data Collection

Behavioral data were recorded using the focal animal sampling method (Altmann 1974) from 27 October 2021 to 10 May 2022, covering autumn, winter, and spring seasons with 227 hours (75.7 hours/season). For each focal sample (30 mins), a focal individual was randomly selected among the adults before the observation. If the focal individual under observation was partially hidden or moved entirely out of sight, another animal of the same sex was selected as the focal animal (Altmann 1974). Behavioral sampling was conducted during three time periods of the day: 1) morning (7.00–11.00 am), 2) afternoon (11.00–2.00 pm), and 3) late afternoon

(2.00–6.00 pm). The recorded behaviors included grooming, moving, resting, playing, aggression, lactating, feeding, mating, vocalization, drinking, and scratching are described in the ethogram in Table 1.

Table 1. Ethogram of behaviors recorded in the study.

S.N.	Behavior	Description
1	Resting	Inactive, whether standing, sitting, or lying down
2	Moving	Any mobile activity, either walking, running, jumping, or climbing.
3	Feeding	Eating or chewing food
4	Grooming	Picking or manipulating fur or skin with hands
5	Playing	Any activity involving recreation, whether it be self-directed or involving others, entailing non-aggressive interaction
6	Aggression	Any aggressive behaviors, including chase, attack, teeth display
7	Lactating	Breast-feeding to the infant
8	Mating	Sexual activity
9	Vocalization	Interaction with each other through sound
10	Drinking	The activity of having water or any other fluid
11	Scratching	Raking or picking the skin of the body quickly with the hand or foot

The study group's range behavior was also collected simultaneously with the focal animal sampling throughout the study period. Each day, the study group was followed from 7.00 am to 6.00 pm or until the group was lost from observation and could not be relocated. The instantaneous sampling method (Altmann 1974) was used to collect the data on the ranging behavior of the group. The geo-coordinates of the group were recorded at 10-minute intervals using a handheld GPS Garmin Etrex-10. Coordinates were recorded for the approximate center of the group (Santhosh *et al.* 2015).

2.4. Data Analyses

The normality of all the data was tested using the Shapiro-Wilk test. Kruskal-Wallis one-way ANOVA was applied to evaluate significant differences regarding time spent in each behavioral

activity by sex class and for the three time periods. We used ANOVA to compare the time spent on different activities during the autumn, winter, and spring seasons. Mean daily path lengths (MDPLs) for autumn, winter, and spring seasons were calculated from the ranging behavior data collected from October 2021 to May 2022. All statistical tests were conducted using the R studio (R-Core-Team 2022) with a significance level of $P \leq 0.05$. In order to analyze the ranging behavior, the geographic points recorded for each instantaneous sample were plotted on the field site's map, and a subsequent heat map was created using the 'Density' tool (in Spatial Analyst mode) in ArcGIS 10.7.1. Kernel density value was broken down into percentage values. Kernel density estimation was then conducted under five density classes: 0–10% (very low use), 10%–20% (slight use), 20%–30% (moderate use), 30%–60% (high use) and >60% (very high use).

3. Results

3.1. Diurnal Activity Budget of Semi-Provisioned Rhesus Macaques

The adult rhesus macaques at the Daunne Devi Temple area of the Daunne Forest spent the majority of their diurnal time resting (33.83%), followed by moving (26.67%), feeding (22.92%), grooming (15.42%) and other activities, including aggression, playing, and mating, constituted a combined total of 1.16% of the observation (Figure 2).

The proportion of time spent on the different activities varied significantly during the three time periods of the day (Figure 2 and Table 2). The most time spent resting occurred during the late afternoon (36.12%). Moving also was highest during the late afternoon (28.91%). Feeding activity and grooming were highest during the afternoon (27.09% and 27.09% respectively).

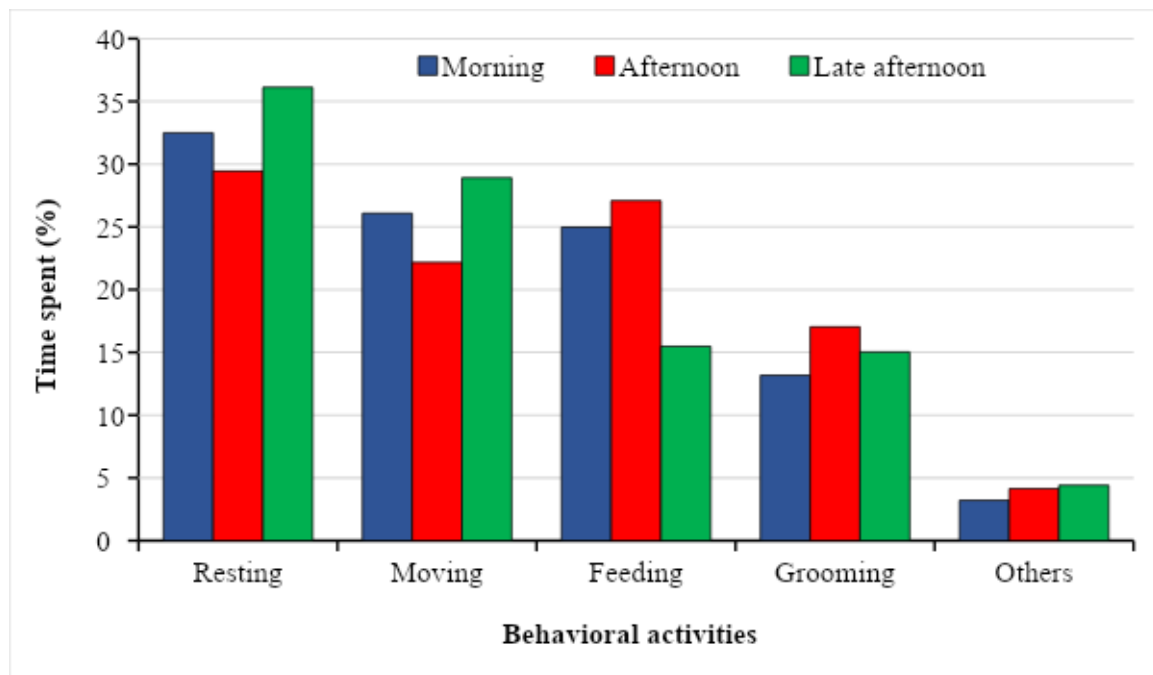


Figure 2. Behavioral activities of the rhesus macaques during the three observational periods

Table 2. Results of Kruskal-Wallis one-way ANOVA testing the significance of variation in activity budget of rhesus macaques at different observational periods and by sex

S. N	Behavioral category	Variation by an observational period			Variation by sex		
		d.f.	H	p	d.f.	H	p
1	Resting	2	12.20	0.002	1	33.27	< 0.001
2	Moving	2	11.87	0.002	1	22.12	< 0.001
3	Feeding	2	8.32	0.015	1	9.37	0.002
4	Grooming	2	0.76	0.682	1	8.70	0.003

17.03%, respectively).

The average diurnal time spent in various activities varied between the males and females (Figure 3). The adult males spent a longer average time resting and moving (Figure 3A and 3B), whereas the females spent longer average time feeding and grooming (Figure 3C and 3D). These differences in resting, moving, feeding, and grooming also were statistically significant (Table 2).

The percentage of time spent in different activities varied among the seasons (Figure 4), although the seasonal variations were not statistically significant ($F = 0.0218$; d.f. = 2, 24; $P = 0.9784$). During autumn and winter, the macaques spent the most time resting (31.64% and 36.41%, respectively). During the spring season, feeding (32.86%) was the highest percentage of behavior.

3.2. Daily Path Length of Rhesus Macaques in Daunne Forest

We recorded 1400 GPS locations over the 29 days of the study period. The daily path length (DPL) ranged between 540.1–2905.4 m, with a mean distance of 1590 ± 576.96 m. The group most frequently traveled 1000–2000 m during a daily observation (Figure 5A).

The rhesus macaques had the longest average DPL during autumn (mean = 1851.2 ± 575.8 m) and the shortest during the spring season (mean = 733.7 ± 251.99 m) (Figure 5B). There was a significant difference in the seasonal DPL of this semi-provisioned group ($H = 9.371$, d.f. = 2, $P = 0.009$). The heat map analysis revealed that Daunne Devi Temple and the stairway leading to the temple (areas of high visitor presence and provisioning) represented

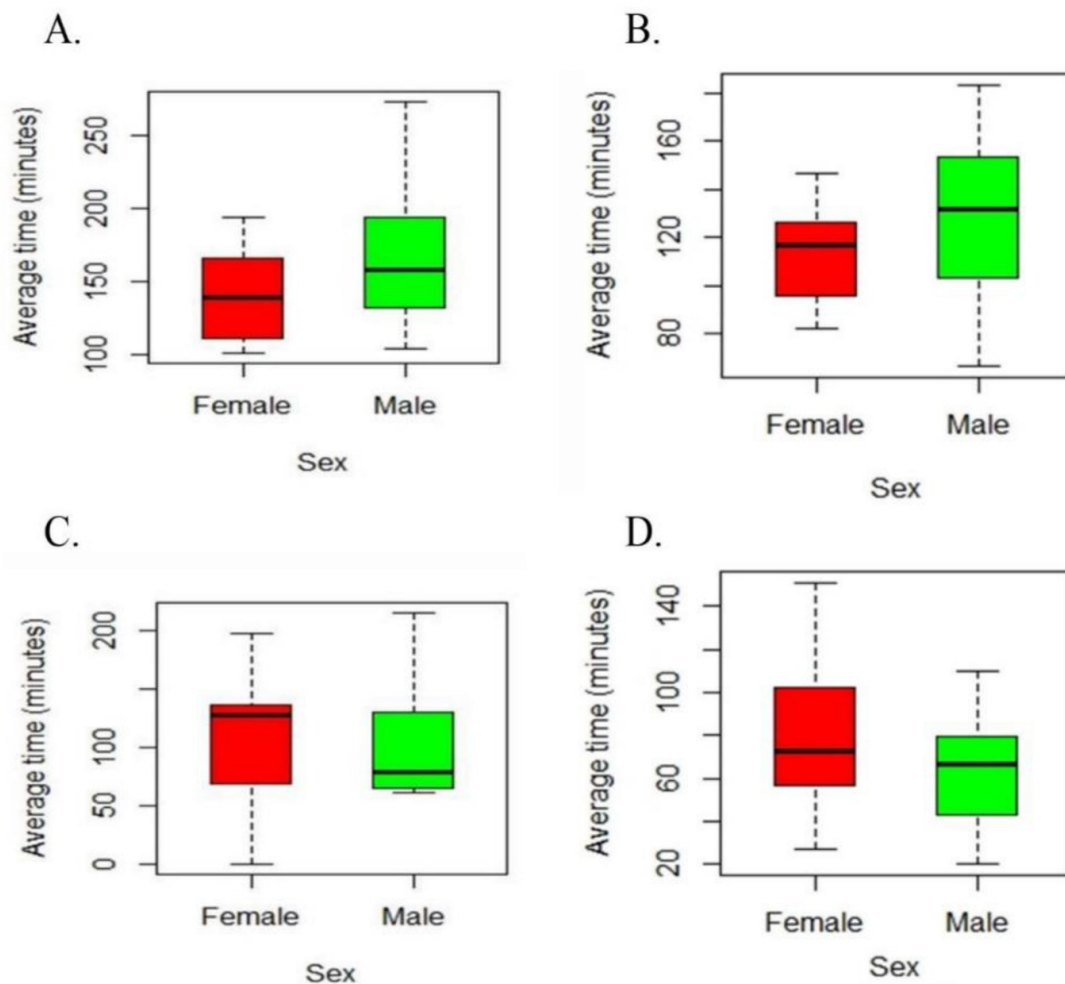


Figure 3. Boxplots showing average diurnal time (minutes) spent by male and female rhesus macaques A- Resting, B- Moving, C- Feeding, and D- Grooming.

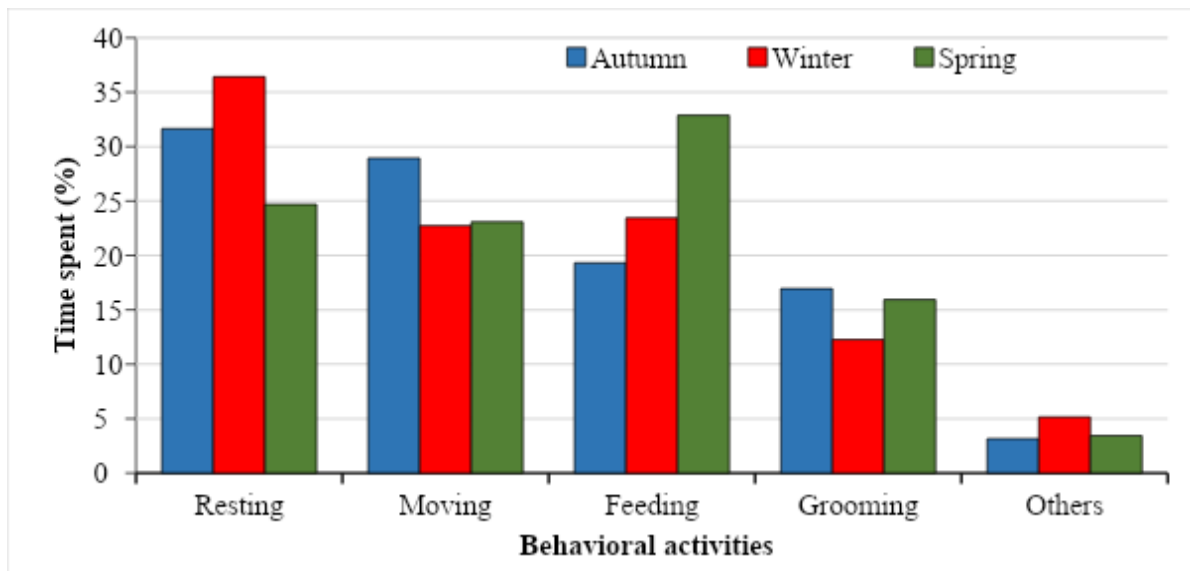


Figure 4. Seasonal variation in behavioral activities of rhesus macaques

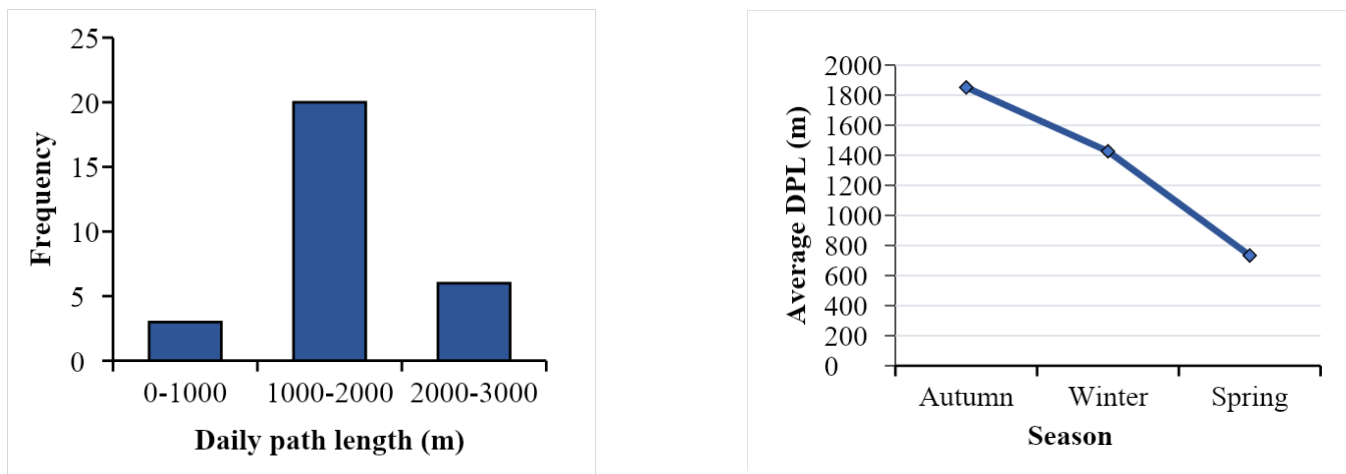


Figure 5. The daily path length of rhesus macaques. A- Frequency distribution of daily path length (n = 29 days); B- Seasonal variation in daily path length.

an area of high use by the macaques. Conversely, the forest area, where visitor presence was much lower, was commonly used by the macaques. Thus, the areas where supplement food provisioning occurred most often were the areas of highest use by the macaques. (Figure 6).

4. Discussion

This study explored the daily activity pattern and ranging behavior of a semi-provisioned group of rhesus macaques at the Daunne Devi Temple in the Daunne Forest of the central mid-hills in Nepal. Resting was the most frequently observed diurnal activity of the group. The most likely explanation

for this is the readily available food supply from the temple visitors throughout the day. Given this easy accessibility to food, the rhesus macaques tended to wait for handouts rather than searching for food, increasing the time spent resting. This behavior is consistent with other studies showing provisioned primates spent less time moving and searching and more time resting (Saj *et al.* 1999; El Alami *et al.* 2012; Jaman and Huffman 2013; Adhikari *et al.* 2018; Ilham *et al.* 2018; Thatcher *et al.* 2019). Interestingly, moving was the second-highest recorded activity for the temple rhesus macaques in Daunne Forest. This behavior may result from the priests and local people at the study site who used slingshots to throw pebbles at the rhesus macaques, thus resulting in frequent

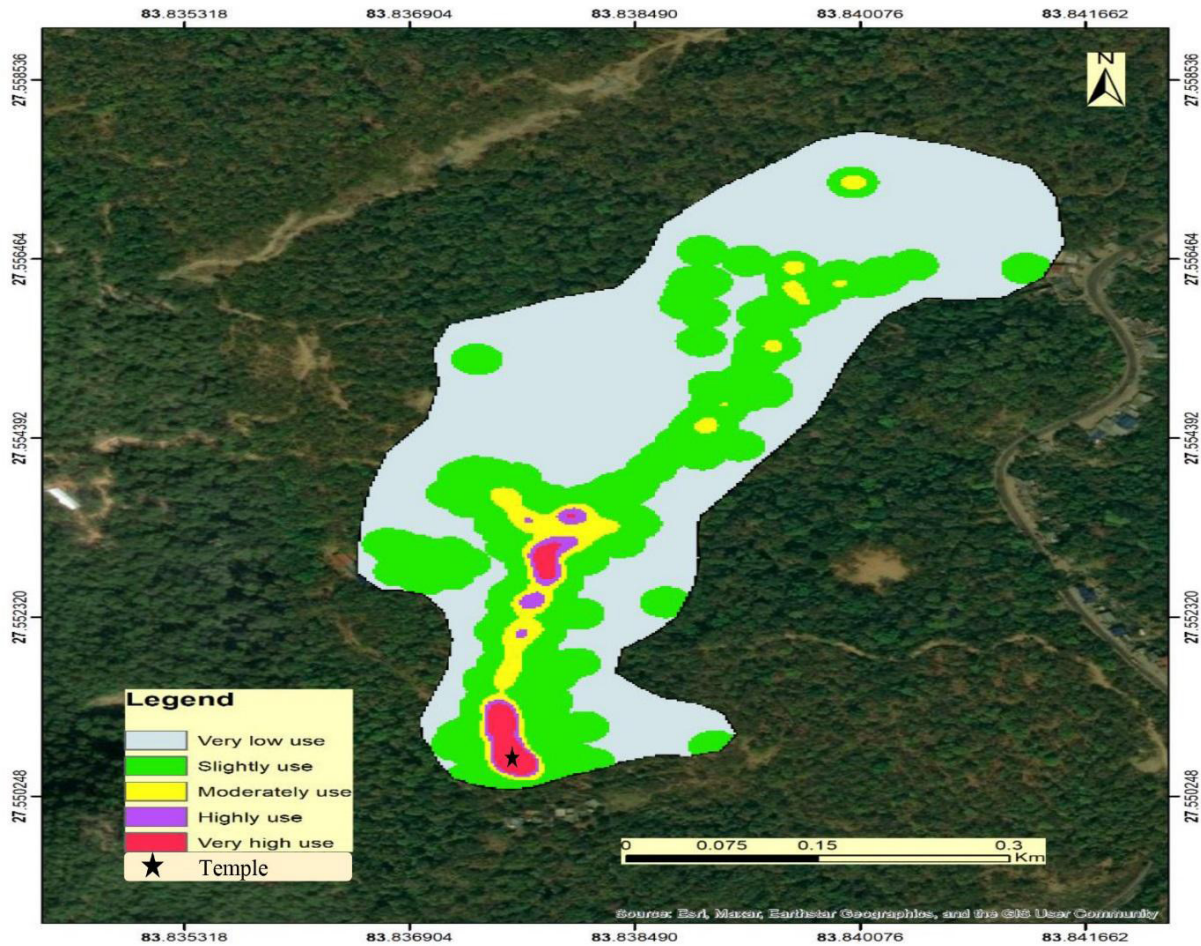


Figure 6. Heatmap of the area used by the rhesus macaques in Daunne Forest, Nepal

movement by the rhesus macaques to avoid being hit by the pebbles.

Rhesus macaques allocated the third highest percentage of time to feeding. It was found that the higher the proportion of time spent resting, the lower the proportion spent feeding. This finding supports Kurup and Kumar's (1993) claim that feeding time is inversely related to resting time.

The activity pattern when observed at different periods of the day. The most frequent activity throughout the day was resting, followed by moving in the morning and late afternoon. These activities are likely due to the presence of visitors throughout the day. The rhesus macaques were waiting for food rather than foraging. The second highest time rhesus macaques spent in their activity budget is moving. The proportion of time rhesus macaques spent moving was highest during the late afternoon, which might be attributed to fewer visitors during the late afternoon and less availability of anthropogenic food. This activity leads rhesus macaques to move more in foraging during the late afternoon. Similar to our

results, a study on *Trachypithecus phayrei* revealed the highest proportion of time spent moving in the noon (Naher *et al.* 2022). Feeding and grooming were more prevalent in the afternoon than in the morning and late afternoon.

The time spent resting by the adult males was higher than the adult females, whose differences were significant. This finding is inconsistent with the previous study on urban rhesus macaques, which found that females spend more time resting than males (Jaman and Huffman 2013). This study has revealed that adult males and adult females allocate a significantly different amount of time to moving. It was likely because adult males were physically dominant over others and were seen moving a lot to defend their territory from nearby groups. Compared to adult males, adult females allocated more time to feeding. In primates, male and female reproductive investments are significantly different. Due to the additional energy expenses involved with pregnancy, nursing, and infant transportation, female reproductive strategies may need them to spend more time feeding (Vasey

2005). The amount of time allocated to grooming was higher in adult females than in adult males, and their differences were significant. It could be because of male dominance over females and subordinate males. Interestingly, adult males permitted the adult females who groomed them to access human foods. This behavior also allowed better access to nutritious food and maximized availability to those females (Jaman and Huffman 2013).

There was no significant difference in time invested by rhesus macaques in different activities between the autumn, winter, and spring seasons. It might be because of anthropogenic food in the study area. The influence of seasonality on primate behavior is reduced in human-altered habitats due to the availability of provisioned foods (Sha and Hanya 2013).

This study also recorded a mean daily path length of 1590 ± 576.96 m for the rhesus macaque group at the Daunne Forest. Our results were similar to those observed for rhesus macaques in Bangladesh (1638.43 m) (Shoma & Feeroz 2014). Others, however, have reported much longer DPLs for wild rhesus macaques, such as those at Shivapuri Nagarjun National Park in Nepal, with a DPL of 4000 m (Khatiwada *et al.* 2020). These variations may occur for various ecological reasons, such as food availability and distribution, seasonal differences in observation, rainfall, and other intergroup interactions like competition, territoriality, and group size variations (Weerasekara & Ranawana 2017). Anthropogenic factors like habitat modification and provisioning also impact macaque movement (Santhosh *et al.* 2015) and activity budgets (Adhikari *et al.* 2018). Our study group's shorter DPL may indicate a preference to remain closer to the temple and stairway, likely due to the accessibility of provisioned food resources (Sha and Hanya 2013; Kamarul *et al.* 2014; Shoma and Feeroz 2014). The daily route of the study group followed a pathway to the temple that was strongly associated with the availability of food from the temple visitors.

The semi-provisioned rhesus macaques in this study showed significant variation in the DPL across the autumn, winter, and spring seasons. Macaques under the anthropogenic influence often show seasonal variation in home range and DPL that is further influenced by human food resources (Klegarth *et al.* 2016). For example, positive human encounters have been shown to reduce travel distance

by vervet monkeys (Thatcher *et al.* 2019), and greater anthropogenic disturbance reduces home range size in long-tailed macaques (Sha and Hanya 2013). We observed an increase in visitor numbers at the Daunne Devi Temple during the spring season after the easing of travel restrictions imposed due to COVID-19. This increase in visitors resulted in greater food availability and, in turn, a shorter DPL of the macaques.

Additionally, the heatmap analysis for habitat use by the macaques revealed that the temple area and its stairway was the area of greatest use. These findings suggest that food provisioning shortens the DPL of semi-provisioned macaques. We hope to expand this study by examining additional environmental variables and a larger sample of macaque groups to provide a greater understanding of the dynamics influencing the behavior and ranging patterns of semi-provisioned rhesus macaques.

This study revealed that the activity budget of semi-provisioned rhesus macaques varies between sexes. Adult males spent more time resting than adult females. No significant differences were found in the daily activity budget of rhesus macaques in the autumn, winter, and spring seasons. The mean daily path length of the rhesus macaques varied significantly with seasons and was longest during autumn and shortest during spring when visitor numbers and food provisioning were the greatest. We conclude that human food provisioning shortens the daily path length of semi-provisioned macaques.

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Authors' contribution

LK conceptualized the study. SK and ST performed the behavioral sampling, analyzed data, and prepared the manuscript. LK and RCK improved and finalized the manuscript. LK supervised the research. All authors approved the manuscript for submission.

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