

**DIURNAL ACTIVITY BUDGET AND RANGING BEHAVIOR OF
RHESUS MACAQUES (*Macaca mulatta*) IN DAUNNE FOREST,
NAWALPUR, NEPAL**



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Submitted to

Central Department of Zoology
Institute of Science and Technology

Tribhuvan University,
Kirtipur, Kathmandu, Nepal

September, 2022

DECLARATION

I hereby declare that the work presented in this thesis “**Diurnal activity budget and ranging behavior of Rhesus macaques (*Macaca mulatta*) in Daunne Forest, Nawalpur, Nepal**” has been done by myself and has not been submitted elsewhere for the award of any degree. All sources of information have been acknowledged by reference to the authors or institutions.

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RECOMMENDATION

This is to recommend that the thesis entitled “**Diurnal activity budget and ranging behavior of Rhesus macaques (*Macaca mulatta*) in Daunne Forest, Nawalpur, Nepal**” has been carried out by Sushmita Kshetri for the partial fulfillment of Master’s Degree of Science in Zoology with special paper ecology and environment. This is his/her original work and has been carried out under my supervision. To the best of my knowledge, this thesis work has not been submitted for any other degree in any institutions.

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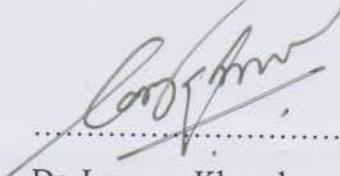
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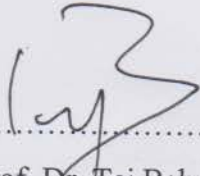
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CERTIFICATE OF ACCEPTANCE


This thesis work submitted by Sushmita Kshetri entitled “**Diurnal activity budget and ranging behavior of Rhesus macaques (*Macaca mulatta*) in Daunne Forest, Nawalpur, Nepal**” has been approved as a partial fulfillment for the requirements of Master’s Degree of Science in Zoology with special paper Ecology and Environment.

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TABLE OF CONTENTS

DECLARATION	ii
RECOMMENDATION	iii
LETTER OF APPROVAL	iv
CERTIFICATE OF ACCEPTANCE.....	v
ACKNOWLEDGEMENTS	vi
LIST OF FIGURES	ix
LIST OF TABLES	x
LIST OF PHOTOGRAPHS	xi
LIST OF ABBREVIATIONS	xii
ABSTRACT.....	xiii
1. INTRODUCTION	1
1.1 General background	1
1.2 Research objectives	2
1.2.1 General objective	2
1.2.2 Specific objectives	2
1.3 Rationale of the study.....	3
2. LITERATURE REVIEW	4
2.1 Diurnal activity budget of macaques.....	4
2.2 Activity budget of macaques at different observational phases.....	4
2.3 Activity budget among different sex classes of macaques.....	5
3. MATERIALS AND METHODS.....	7
3.1 Study area.....	7
3.2 Materials.....	8
3.3 Focal group of rhesus macaques	8
3.4 Methods.....	9

3.4.1 Preliminary survey.....	9
3.4.2 Behavioral data collection	9
3.4.3 Data collection on ranging behavior.....	10
3.5 Data analyses.....	11
4. RESULTS	12
4.1 Diurnal activity budget of rhesus macaques	12
4.1.1 Activity budget of rhesus macaques at different observational phases	12
4.1.2 Activity budget among different sex classes of rhesus macaques.....	15
4.2 Daily path length of rhesus macaques in Daunne Forest	17
5. DISCUSSION.....	20
5.1 Diurnal activity budget of rhesus macaques	20
5.1.1 Activity budget of rhesus macaques at different observational phases	21
5.1.2 Activity budget among different sex classes of rhesus macaques.....	22
5.2 Daily path length of rhesus macaques.....	23
6. CONCLUSION AND RECOMMENDATION	25
6.1 Conclusions	25
6.2 Recommendation.....	25
REFERENCES	26
PHOTOGRAPHS	32

LIST OF FIGURES

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. C. Map showing the Daunne Devi Temple in the Daunne Forest.	8
Figure 2. Overall activity budget of rhesus macaques in Daunne Forest	12
Figure 3. Behavioral activities of the rhesus macaques at different observational phases	13
Figure 4. Box plots showing the differences in time invested by rhesus macaques on A. Resting B. Feeding and C. Moving at different observational phases. ..	14
Figure 5. Behavioral activities among sex classes of rhesus macaques in Daunne Forest	15
Figure 6. Box plots showing the differences in time invested on A. Resting, B. Feeding, C. Moving and D. Grooming among different sex classes of rhesus macaques	16
Figure 7. Frequency distribution of daily path length (n=29 days) of rhesus macaques in Daunne Forest	17
Figure 8. Daily path length of rhesus macaques in autumn, winter and spring season in Daunne Forest.....	18
Figure 9. Heatmap of the area used by the rhesus macaques in Daunne Forest	19

LIST OF TABLES

Table 1. Age-sex categories used in the study	9
Table 2. An ethogram used to record behavioral data of rhesus macaques	10
Table 3. Results of Kruskal-Wallis one-way ANOVA testing the significance of variation in activity budget of rhesus macaques at different observational phases	14
Table 4. Results of Kruskal-Wallis one-way ANOVA testing the significance of variation in activity budget among different sex classes of rhesus macaques	16

LIST OF PHOTOGRAPHS

Photo 1. An adult male rhesus macaque resting on the floor	32
Photo 2. An adult female rhesus macaque grooming another adult female rhesus macaque	32
Photo 3. An adult female rhesus macaque breast feeding the baby	32
Photo 4. Rhesus macaques feeding on the supplemented food.....	32
Photo 5. An adult rhesus macaque playing with water	33
Photo 6. An adult male rhesus macaque threatening the visitors.....	33
Photo 7. Adult female rhesus macaques moving on the ground	33
Photo 8. An adult female rhesus macaque drinking water	33
Photo 9. An adult female rhesus macaque feeding on the flowers of the plant	34
Photo 10. An adult male rhesus macaque feeding on the anthropogenic foods.....	34
Photo 11. GPS Garmin Etrex10 used to record the daily path length of rhesus macaques	34
Photo 12. Observer recording the behavioral activities of the focal animal	34

LIST OF ABBREVIATIONS

Abbreviated form	Details of abbreviations
A.	Afternoon
ANOVA	Analysis of Variance
GPS	Global Positioning System
L.A	Late Afternoon
M.	Morning
MDPL	Mean Daily Path Length

ABSTRACT

Rhesus monkey (*Macaca mulatta*, order: Primates, suborder: Haplorhini, family: Cercopithecidae) is a species of Old-World monkeys native to forests but also found coexisting with humans. *Macaca mulatta* shows a great deal of adaptability. An understanding of how animals allocate their time between different activities throughout the day give information about how they interact with their surroundings and how they have adapted to ensure their survival and reproduction. Information on primate's daily activity budget and ranging behavior helps to design conservation plan more effectively by allowing us to better understand their ecological necessities and behavioral responses to environmental changes. This study determined the daily activity budget and ranging behavior of Rhesus macaque in Daunne Forest, Nepal. The data were collected from October 27, 2021 to May 10, 2022 for 29 days observing the behavior for 227 hours in three phases of the day (morning, 7.00–11.00 am; afternoon, 11.00–2.00 pm; and late afternoon, 2.00–6.00 pm). Behavioral data were recorded by the focal animal sampling method and ranging behavior were recorded using instantaneous scan sampling method with the aid of a GPS. Rhesus macaques of Daunne Forest spent majority of the time in resting (33.83%), followed by moving (26.67%), feeding (22.92%), and grooming (15.42%). Time invested by rhesus macaques in resting, feeding and moving differed significantly among the different observational phases of the day. Males spent major proportion of their time on resting (36.97%) and moving (28.57%), whereas females spent major proportion of their time on resting (29.04%) and feeding (24.72%). The daily path length ranged between 540.1–2905.4 m, with a mean distance of 1590 ± 576.96 m which did not differ significantly among the autumn, winter and spring seasons. Findings of this research will be useful in proper management and conservation of temple primates.

1. INTRODUCTION

1.1 General background

Time is a finite resource that eventually affects how different animals behave (Pollard & Blumstein 2008). Evaluating the proportion of time spent engaged in various activities over the course of a day or year is crucial in studies of a species behavioral ecology (Neha et al. 2021). Activity budget is a technique of determining how animals divide up their time between different activities that are essential for their survival, reproduction as well as for understanding life history features and animal adaptations to their environments (Bernstein 1968, Rodway 1998, Neha et al. 2021). The way animals allocate their time to various activities has a substantial impact on their survival because it reflects the different restrictions on time-energy balances (Xiang et al. 2010). Diurnal primates must allocate their daytime to complete their essential activities (Li et al. 2014).

Primates possess the capacity to quickly modify their activity budgets in response to shifting environmental conditions. The quantity of time that primates devote to each activity is influenced by environmental and social circumstances, as well as the individual's physiological status (Li 2009). Environmental limitations including seasonal availability of food sources, the diversity of plant species and physiological restrictions like individual dietary needs and thermoregulation all have an effect on 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 & Ross 1999, Vasey 2005, Li 2009, Albert et al. 2013).

Among primates, ranging behaviors such as home range size and daily path length fluctuate significantly between species even within congeners living in diverse habitat (Milton & May 1976, Clutton-Brock & Harvey 2009). Daily path length (DPL) is often used to assess how well primates use their time, area and energy to defend their territories and acquiring access to resources (Chapman & Chapman 2000). The DPL is generally shown as an average or mean length that has been moved during the day (Kamarul et al. 2014). Primate ranging behavior is typically discussed on how it relates to group size and diet. Generally, frugivores travel longer daily travel distances and

occupy larger home ranges than folivores (Clutton-Brock & Harvey 2009). Additionally, primates have the ability to modify their ranging behavior in response to variations in food availability throughout the year (Strier 1987). However, physical and ecological elements like the season, food availability, the variety of plants eaten, intergroup interactions, and level of terrestriality affect the DPL (Santhosh et al. 2015). Human interference is also an important factor influencing ranging pattern in urban areas (Shoma & Feeroz 2014). Precise ranging information are essential for comprehending the ecology, evolution, and conservation of primates, but they are scarce for many species. (José- Domínguez et al. 2015).

The rhesus macaque (*Macaca mulatta*) is among the most common, widespread and ecologically adaptable primate species on the earth. Rhesus macaque is found in Bangladesh, India, Pakistan, Nepal, Myanmar, Thailand, Afghanistan, southern China, and a few nearby regions (Green 1978). In Nepal, rhesus macaque is found from low-lying flatlands up to 4,000 meters high at the foot of the Himalayas. A significant level of behavioral adaptability in relation to environment and resource diversity were seen in commensal rhesus macaque (Jaman & Huffman 2013). They can adapt well to the human dominated landscapes. Generally, rhesus macaques are found dwelling in different religious sites and cities in Nepal (Chalise 2013). This study evaluates how rhesus macaques budget their time in different activities and determine the ranging behavior of monkeys which will increase the knowledge regarding their ecological behavior in human altered environment and provide a great help in ecological management of macaques in human proximity.

1.2 Research objectives

1.2.1 General objective

The general objective of this study was to document the diurnal activity budget and ranging behavior of rhesus macaques (*Macaca mulatta*) in Daunne Forest of Nawalpur District, Nepal.

1.2.2 Specific objectives

The specific objectives of this study were:

1. To document the diurnal activity budget of rhesus macaques and its variation among sex classes in Daunne Forest.
2. To determine the daily path length (DPL) of rhesus macaques.

1.3 Rationale of the study

Rhesus macaques are a widely distributed and ecologically diverse primate species that receive a lot of attention in terms of research and conservation. The information regarding how they allocate their time can be useful in understanding the species survival abilities under different constraints and their ecological tolerance limits. Comprehensive data on diurnal activity budget and ranging behavior are essential for comprehending the ecology, evolution, and conservation of the species. But no efforts are made to investigate it and very little information is available. Research on rhesus macaques in Nepal have concentrated on population, distribution, conflict, parasites, competition among sympatric primates. However, very few studies have been carried out relating to diurnal activity budget and ranging behavior of rhesus macaques. This research is needed to fulfill the knowledge gap regarding the diurnal activity budget and ranging behavior of rhesus macaques existing in human proximity.

Therefore, a group of rhesus macaques that live in human proximity and are opportunistically omnivorous, consuming provided food as well as a plants from neighboring forest was studied focusing on the diurnal activity budget and ranging behavior. This study provides information about daily activity budget and ranging behavior of rhesus macaques increasing the biological knowledge of species and can play a vital role for the conservation and proper management of rhesus macaques.

2. LITERATURE REVIEW

2.1 Diurnal activity budget of macaques

Rhesus macaques spent the major proportion of their time resting (38.5%). Rhesus macaques spent 25.7% of their time on feeding, 18.4% on moving, 12.8% on grooming (12.8%) and they spent the least time in playing (4.6%) (Neha et al. 2021). In contrast to this, another study have shown that rhesus macaques spent major proportion of their time in moving (42%), followed by resting (26%), feeding (24%), playing (15%), grooming and least time on breeding (1%) (Khan 2017). Khatiwada et al. (2020) found that the rhesus macaques spent the majority of their time engaging in social activities (33.7%) whereas Assamese macaques spent majority of their time in feeding (30.7%). Observation on the long-tailed macaques showed that they spent the 20.27% of their time on moving, 18.78% on feeding, 17.05% on resting, 10.84% on grooming. Whereas, playing, vocalization and mating comprised 10.50%, 10.36%, 7.42% of their time, respectively. And they spent only 4.78% of their time on fighting (Hambali et al. 2012). Similar study on the long-tailed macaque found that the most common activity was feeding (29.94%) and moving (28.88%) followed by resting (19.7%) and they spent least time in other activities (21.41%). Same study also found that the group of dusky leaf monkeys spent the majority of their time feeding (40.81%), resting (38.31%), moving (19.19%) and least time engaging in other activities (1.6%) (Ruslin et al. 2014). Whereas, Japanese macaques allocate 38% of their time on feeding, 32% resting, 16% travelling while they spent only 14% of the time in social interactions (Hanya 2004). Study on the yellow-tailed woolly monkeys conclude that feeding was their most common activity followed by resting (26.3%), travelling (29.0%) and social (2.3%) whereas they spent only 12.8% of their time in other activities (Shanee & Shanee 2011). Activity budgets of *Macaca nemestrina* in two different habitats were very different from one another. Their activity budget was much more dominated by feeding and foraging in the plantation whereas, locomotion, resting, and interactions took place considerably more frequently in the forest (Ruppert et al. 2018).

2.2 Activity budget of macaques at different observational phases

Study on the *Trachypithecus phayrei* revealed that adult females rest more throughout the day as compared to adult males. They spent major proportion of their time resting

in the late morning after the first feeding bouts. The adult male and adult female moved farther at noon as compared to morning, late morning and afternoon to find places with a plenty of food (Naher et al. 2022). Resting and sleeping were most common in the early afternoon because foraging, feeding, and traveling in the late afternoon needed a lot of energy. They rested and went to sleep right after eating. The highest eating time was seen in the late afternoon. They spent most of their time in moving during the early morning in search of food (Khan 2020).

2.3 Activity budget among different sex classes of macaques

Studies on rhesus macaques have shown that activities differed among age-sex classes (Jaman & Huffman 2013, Khatiwada et al. 2020, Neha et al. 2021). Adult females spent majority of their time grooming and less time feeding than adult males (Jaman & Huffman 2013). Neha et al. (2021) found that adult females allocate majority of their time for resting and feeding while adult male spent majority of their time in feeding and moving. Similarly, the significant difference between the activity budget of males and females of rhesus and Assamese macaque was found. Most frequent activity of male Assamese macaque was moving (38%) and females most common activity was feeding (42.5%). Whereas, male rhesus macaque allocate 36.5% of their activity budget on social activities, while females allocate 32.3% of their time on feeding. In both species of macaques, females allocate large portion of their time on feeding as compared to males (Khatiwada et al. 2020). Research on *Rhinopithecus bieti* also found that adult females (44.8%) spend more time feeding compared to adult males (39.5%). Whereas, adult male spent more time on miscellaneous activities (12.5%) in comparison to adult females (3.8%) (Li et al. 2014).

2.4 Daily path length of macaques

Observation of ranging pattern of rhesus macaque suggested that daily path length varied from 1543m to 1716m (mean=1638.43±56.7) (Shoma & Feeroz 2014). In contrast to this study, Khatiwada et al. (2021) found that the daily path length of rhesus macaque was 4000 m which was shorter than the daily path length of Assamese macaque (1600 m). Similarly, another study have shown that the mean daily path length of Assamese macaques (*Macaca assamensis*) was 590–782 m which is significantly lesser in size compared to those seen in other macaque species (Zhou et al. 2014). Mean

daily path length of lion-tailed macaque was $1,512 \pm 262$ m. MDPLs of monsoon and post-monsoon was $1,203 \pm 95$ m and $1,385 \pm 41$ m, respectively. Whereas MDPL of summer was found to be $1,893 \pm 116$ m. In the summer, Lion-tailed macaques (*Macaca silenus*) had longer daily path length than those during the monsoon and the post-monsoon season. The mean daily path length of Lion-tailed macaque varied significantly between the seasons (Erinjery et al. 2015). Observation of high provisioned group and low provisioned group of *Cercopithecus lowei* have shown that high provisioned group travelled significantly less (0.88 km) than the low provisioned group (1.4 km) daily on average. They also reported that their daily path length varied during the dry season and wet season (Badiella-Giménez et al. 2021).

3. MATERIALS AND METHODS

3.1 Study area

This study was conducted in Daunne Forest of Nawalpur District (Fig. 1) which lies in Gandaki Province, Central Nepal. Mt. Devchuli (1,937 m) which is the highest peak of Churia range of Nepal lies in this district. It has geographic coordinates of 27°46'32" N and 83°47'59" E. Daunne Devi Temple in the Daunne Forest was selected as the study site. The temple is located in a hill pass between Bardaghat and Dumkibas at an elevation of 1033 meters above sea level. Daunne Devi Temple is a Hindu temple of Durga which also has Shivalaya. It is said that Jung Bahadur Rana founded the temple. The user community has been taking care of the temple since 2049 BC. The current temple was built in 2055 BS.

The study area has subtropical to temperate climate. The hottest months are May and June, while the coldest months are December and February. In average, 150 mm of rain fall occurs yearly. The temple is surrounded by vast forest with variety of flora and fauna. Sal (*Shorea robusta*), Sissoo (*Dalbergia sissoo*), Saj (*Terminalia tomentosa*), Jamun (*Syzigium cumini*), Harro (*Terminalia chebula*), Simal (*Bombax ceiba*), Barro (*Terminalia bellerica*), etc. are the main species of flora that are frequently found in the area (Subedi 2008). The area also supports a wide variety of butterfly, fish, amphibian, reptile, bird and mammal species such as Golden jackal (*Canis aureus*), Leopard (*Panthera pardus*), Rhesus macaque (*Macaca mulatta*), Common langur (*Semnopithecus hector*), Jungle cat (*Felis chaus*), Common mongoose (*Herpestes edwardsii*) Common cobra (*Naja naja*), Indian python (*Python molurus*), Water snake (*Natrix piscator*) Golden monitor lizard (*Varanus bengalensis*) (Baral et al. 2003, Upadhyay 2008).

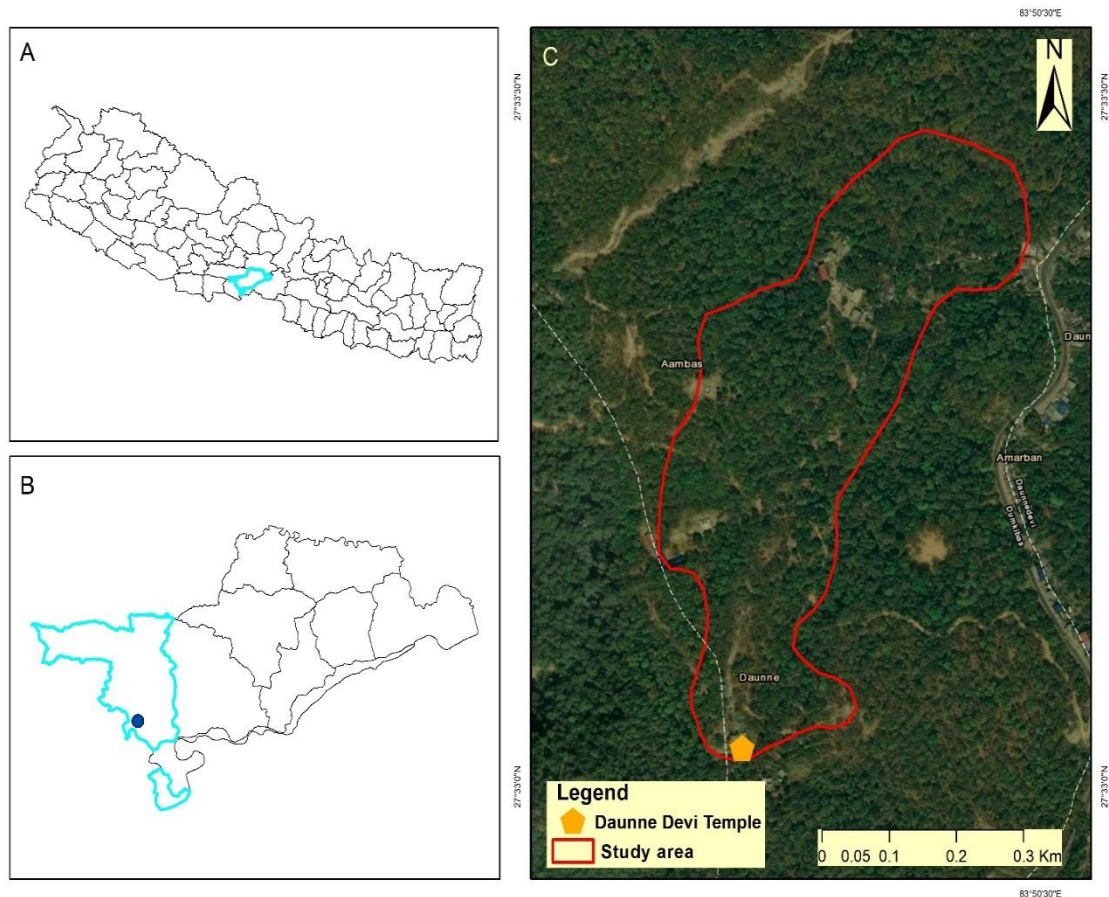


Figure 1. Map of the study area. A. Map of Nepal showing the Nawalpur district. B. Map of Nawalpur district showing Binayee Tribeni rural municipality. C. Map showing the Daunne Devi Temple in the Daunne Forest.

3.2 Materials

Following materials were used during the study for field survey and behavioral sampling.

- i. GPS Garmin Etrex 10
- ii. Ethogram

3.3 Focal group of rhesus macaques

Various groups of rhesus macaques were seen during the observation conducted in the study area. The study group comprised 35 individuals of different age-sex categories (Table 1). The troop constituted six adult males, 13 adult females, six sub-adults, five juveniles, and two infants at the beginning of this study. Furthermore, three infants were

born by end of this study. In addition, one infant died. We identified the macaques of study group using distinctive features of each individuals including their faces, colorations, and scars.

Table 1. Age-sex categories used in the study

S.N.	Category	Description
1.	Adult male	Fully grown with adult morphology (e.g., pink scrotum and prominent testes)
2.	Adult female	Fully grown with adult morphology (e.g., elongated nipples, carrying baby)
3.	Sub-adult	Individuals of near adult size who lacked secondary sexual characteristics
4.	Juvenile	Small, weaned individuals, but still ranged in frequent proximity to a female
5.	Infants	Small individuals nursed by females

3.4 Methods

3.4.1 Preliminary survey

To determine the main area used by the study individuals a preliminary field survey was conducted for seven days during the September 2021. Additional information about the rhesus macaque troops inhabiting the area was collected from the secondary sources and informal interviews with residents of the study area.

3.4.2 Behavioral data collection

Behavioral data were recorded by using the focal animal sampling method (Altmann 1974). During the focal sampling the choice of an individual was randomly determined among the adults prior to the observation. If the focal individual under observation was partially hidden or moved entirely out of sight, then the animal of same age-sex was selected as focal animal (Altmann 1974). A total 29 days of field observations

were conducted from October 27, 2021 to May 10, 2022 recording 227 hours of behavioral data. Field observations were divided into three periods: 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 activities were grooming, moving, resting, playing, aggression, lactating, feeding, mating and others (vocalization, drinking, scratching) and which are explained in the following ethogram:

Table 2. An ethogram used to record behavioral data of rhesus macaques

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

3.4.3 Data collection on ranging behavior

The Instantaneous Scan Sampling Method (Altmann 1974) was used to collect the data on the ranging behavior. We followed the study group from 7.00 am to 6.00 pm or until we lost the group and could not locate them. Data on ranging behavior were also collected simultaneously with the focal animal sampling for 29 days from October 2021- May 2022. On each day we collected ≥ 6 hours of observations. Observations were not made on rainy days. We took geo-coordinates approximately at the center of

the group while following them (Santhosh et al. 2015) using a handheld GPS Garmin Etrex 10 at every 10-minutes intervals.

3.5 Data analyses

All statistical tests were carried out using the R studio with significance level $p \leq 0.05$. Normality of all the data were checked using the Shapiro-Wilk test. The proportion of time spent on lactating activity from the overall diurnal activity budget was excluded but included in the activity budget among different sex classes and at different observational phases. In order to test the significance in difference on time spent in each of the behavioral activities among different sex classes and at different observational phases Kruskal-Wallis one-way ANOVA was employed. The GPS was used to register geographic points for each scan sample. These points were plotted on the field site's map, and then, using ArcGIS 10.7.1's Density tool (in Spatial Analyst mode), heat map was created. Kernel density value was broken down into percentage value. Then, kernel density estimation was done under five density classes: 0–10% (very low use), 10%–20% (slightly use), 20%–30% (moderately use), 30%–60% (highly use) and >60% (very high use). Other figures were prepared using Microsoft Excel ver. 2013. Mean daily path lengths (MDPLs) for autumn, winter and spring seasons were calculated from October 2021 to May 2022 using R studio (R-Core-Team 2022).

4. RESULTS

4.1 Diurnal activity budget of rhesus macaques

Rhesus macaques in Daunne Devi Temple area of the Daunne Forest invested majority of their diurnal time on resting (33.83%), followed by moving (26.67%), feeding (22.92%), and grooming (15.42%) (Fig. 2). Aggression, mating and other activities constituted a small proportion of their diurnal time.

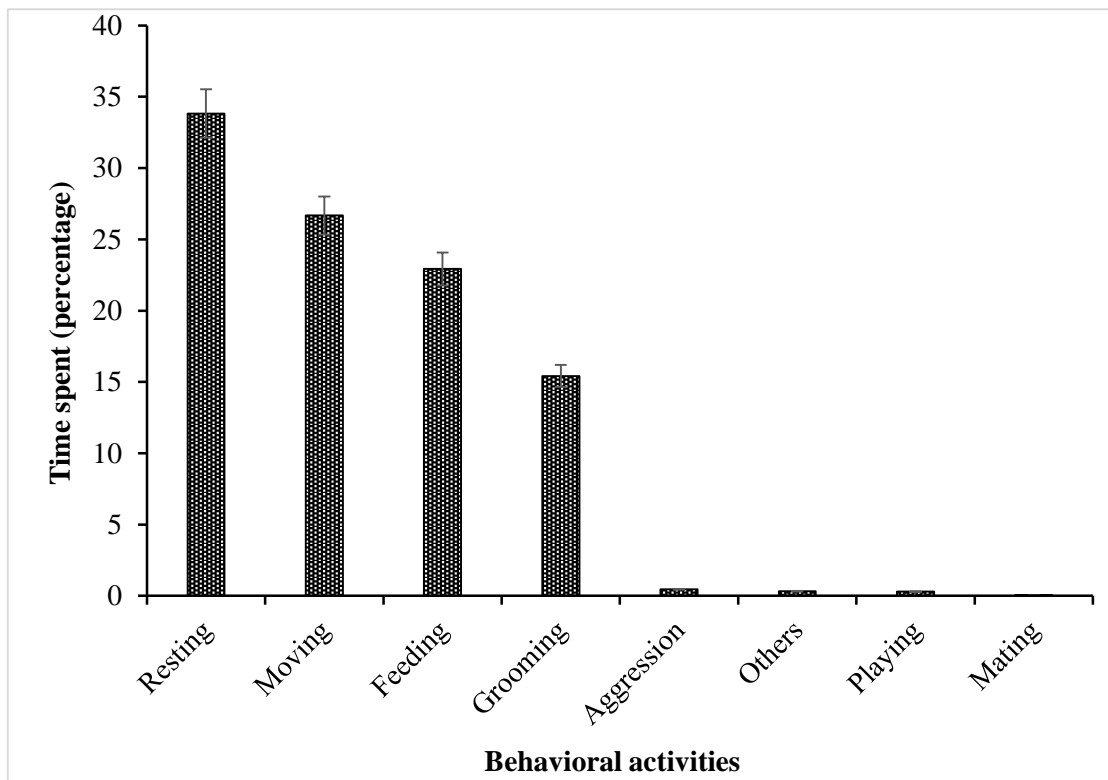


Figure 2. Overall activity budget of rhesus macaques in Daunne Forest

4.1.1 Activity budget of rhesus macaques at different observational phases

The proportion of time spent in the different activities varied during the day. Resting was the highest behavior shown by rhesus macaques in the morning (7.00 to 11.00 am) which accounts for 32.49% of their time budget followed by moving (26.08 %) and feeding (24.97%). Rhesus continued to spend more time resting (29.44%) in the afternoon (11:00 to 2:00), which is followed by feeding (27.09%), moving (22.16%) and grooming (17.03%). Similarly, in the late afternoon (2.00 to 6.00) resting (36.12%) was the most prevalent activity followed by moving (28.91%), feeding (15.48%) and

grooming (15.03%). Time spent on resting and moving were high during the morning and late afternoon while time spent on resting and feeding were high during afternoon. Rhesus macaques spent the least time on mating throughout the day. Time spent on grooming was highest during the afternoon (Fig. 3). Rhesus macaques mostly moved during the morning and late afternoon. Whereas, playing was usually observed in the afternoon and late afternoon.

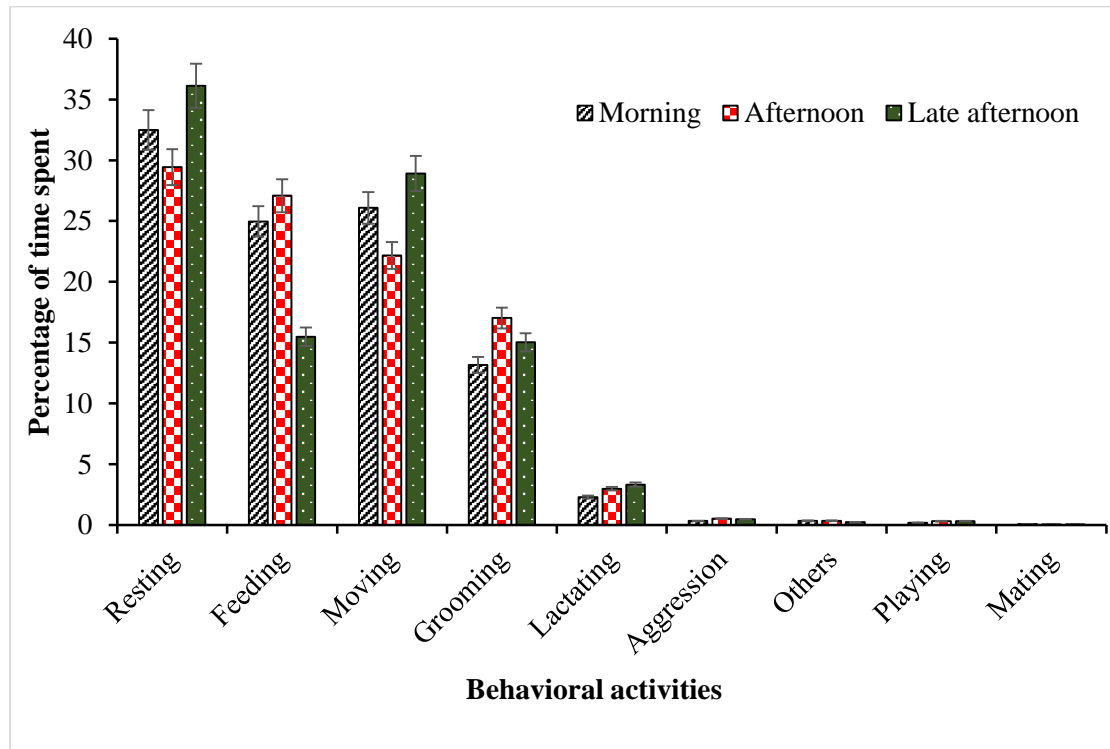


Figure 3. Behavioral activities of the rhesus macaques at different observational phases

Time invested by rhesus macaques in different activities differed among the three observational phases. Such difference was statistically significant for resting, feeding and moving (Fig. 4). However, the differences were not statistically significant for grooming, lactating, aggression, others (drinking, vocalization, scratching), playing and mating during the different times of the day (Table 3).

Table 3. Results of Kruskal-Wallis one-way ANOVA testing the significance of variation in activity budget of rhesus macaques at different observational phases

S. N	Behavioral category	d.f.	H	p
1	Resting	2	12.2	0.002
2	Feeding	2	8.32	0.015
3	Moving	2	11.87	0.002
4	Grooming	2	0.76	0.682
5	Lactating	2	1.02	0.599
6	Aggression	2	0.54	0.760
7	Others	2	4.88	0.086
8	Playing	2	2.10	0.349
9	Mating	2	1.68	0.431

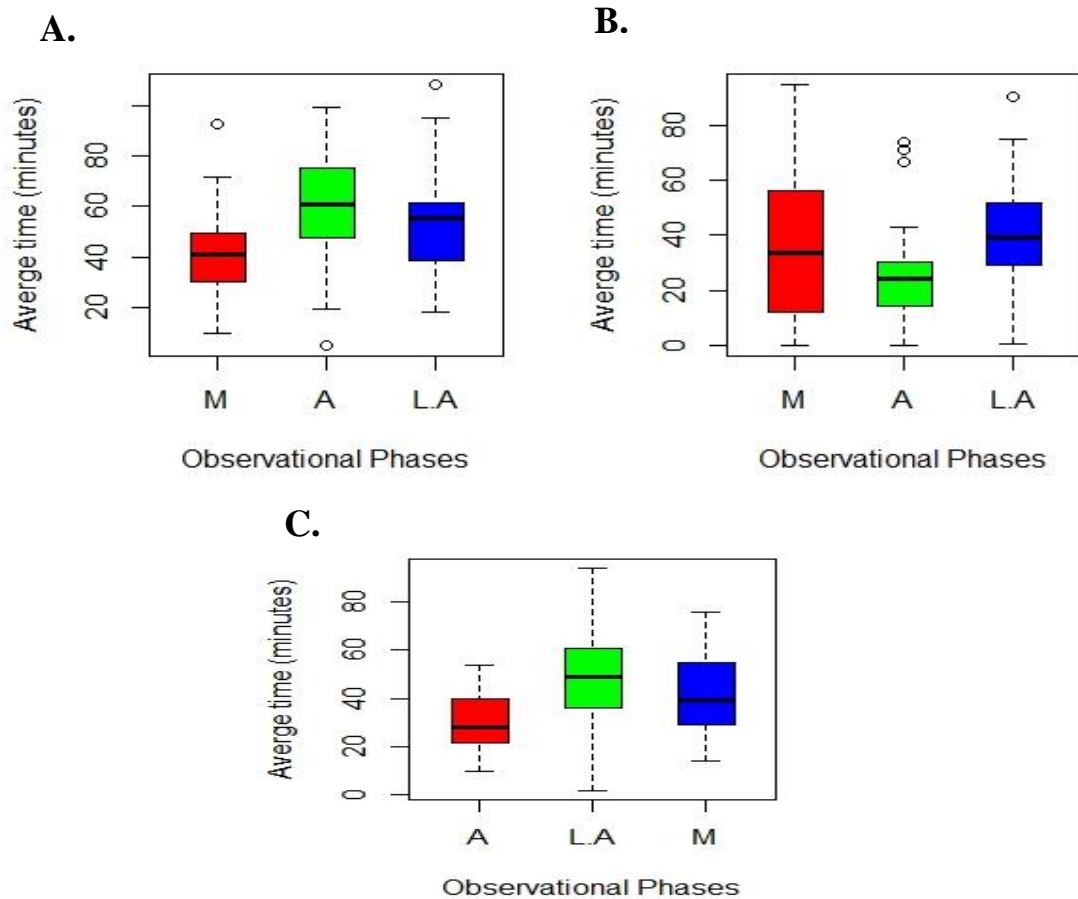


Figure 4. Box plots showing the differences in time invested by rhesus macaques on A. Resting B. Feeding and C. Moving at different observational phases.

4.1.2 Activity budget among different sex classes of rhesus macaques

The proportion of time spent on various activities varied among the sex classes. Both adult males and adult females allocate majority of their daytime on resting, moving and feeding. Adult males spent 36.97% of their time resting which was greater than the time allotted for other activities. Males allocated 28.57%, 19.50% and 13.62% of their time to moving, feeding and grooming respectively (Fig. 5). Similarly, adult females also spent their maximum time (29.04%) in resting followed by feeding (24.72%), moving (23.53%) and grooming (16.19%). Both adult males and adult females spent the least time on resting 0.09% and 0.03% respectively.

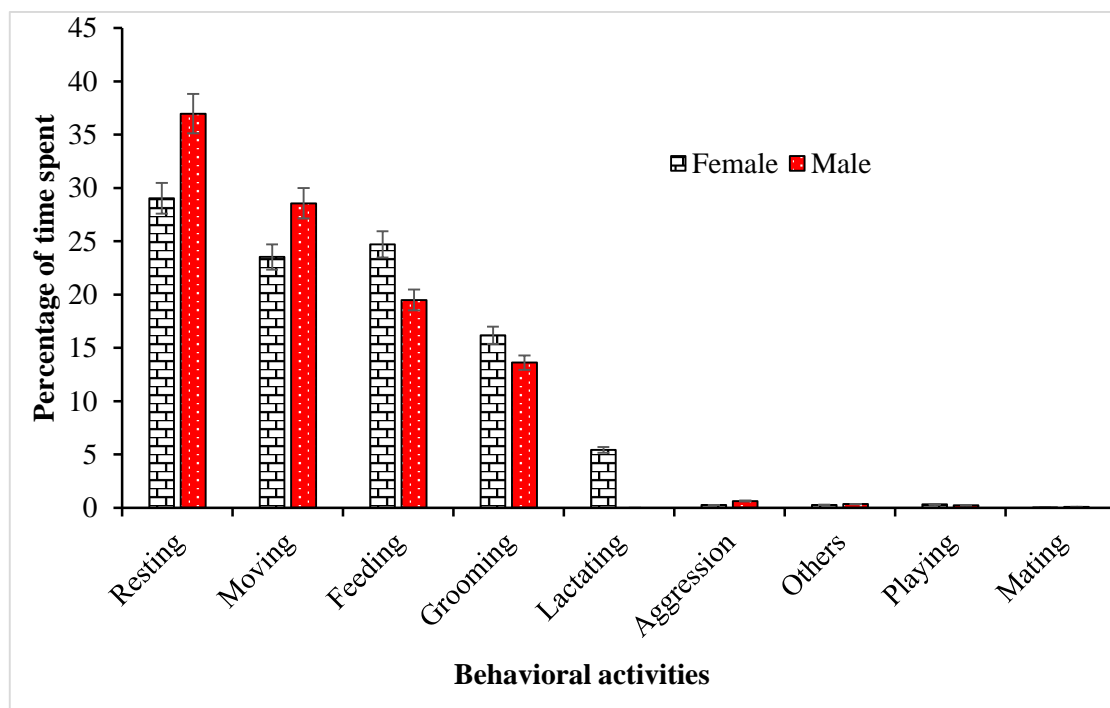


Figure 5. Behavioral activities among sex classes of rhesus macaques in Daunne Forest

Time invested by rhesus macaques in different activities varied among the sex classes. Such difference was statistically significant for resting, feeding, moving, grooming, lactating, mating (Fig. 6). However, the differences were not statistically significant for aggression, playing and others (drinking, vocalization, scratching) during the different times of the day (Table 4).

Table 4. Results of Kruskal-Wallis one-way ANOVA testing the significance of variation in activity budget among different sex classes of rhesus macaques

S. N	Behavioral category	d.f.	H	p
1	Resting	1	33.27	< 0.001
2	Feeding	1	9.37	0.002
3	Moving	1	22.12	< 0.001
4	Grooming	1	8.70	0.003
5	Lactating	1	11.12	< 0.001
6	Aggression	1	1.10	0.292
7	Others	1	0.65	0.417
8	Playing	1	0.97	0.323
9	Mating	1	4.56	0.032

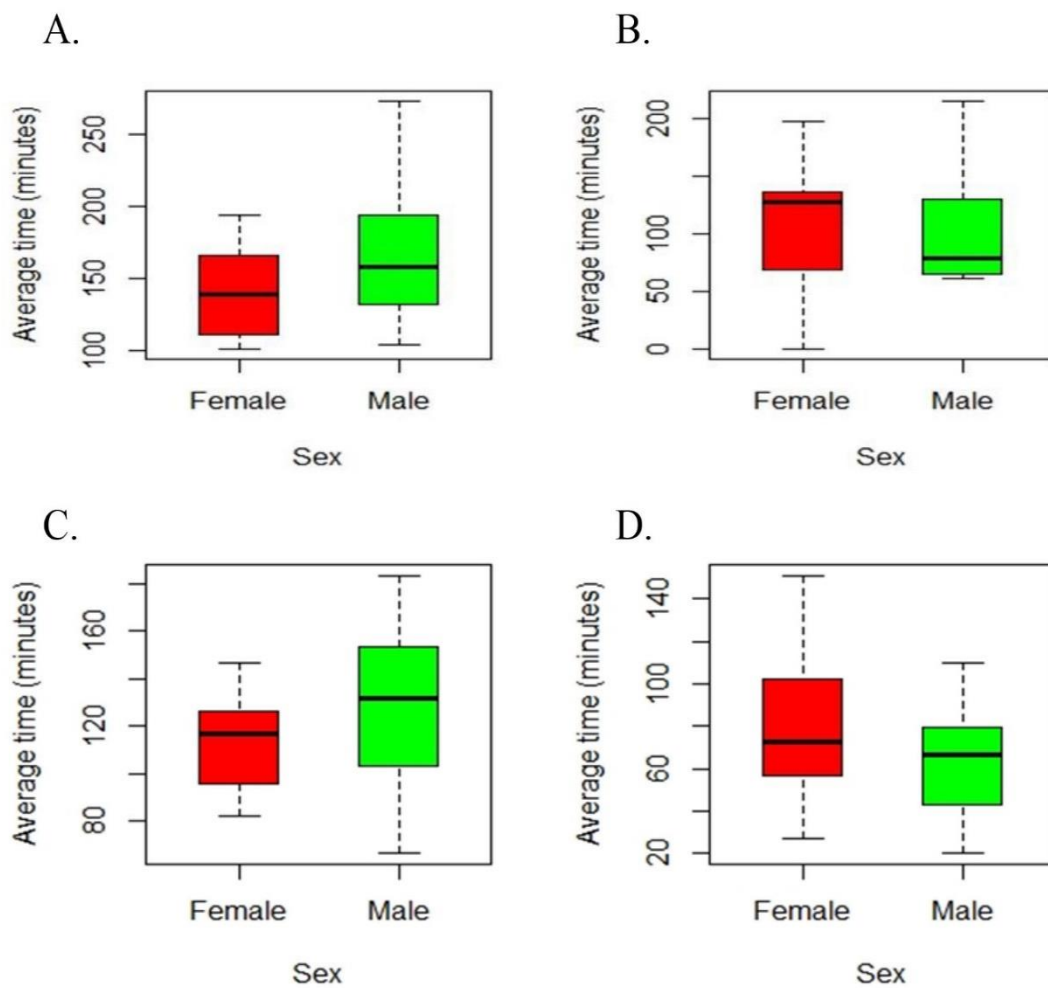


Figure 6. Box plots showing the differences in time invested on A. Resting, B. Feeding, C. Moving and D. Grooming among different sex classes of rhesus macaques

4.2 Daily path length of rhesus macaques in Daunne Forest

A total of 1400 GPS locations were recorded, following each scan sample over 29 days of study period. Rhesus macaques spent only 26.67% of their time moving in their activity budget. The daily path length ranged between 540.1– 2905.4 m, with a mean distance of 1590 ± 576.96 m. The daily path length was rarely less than 1000 m during a sample of 29 days follow-up. Rhesus macaques most frequently traveled 1000 – 2000 m distance during the observation (Fig. 7).

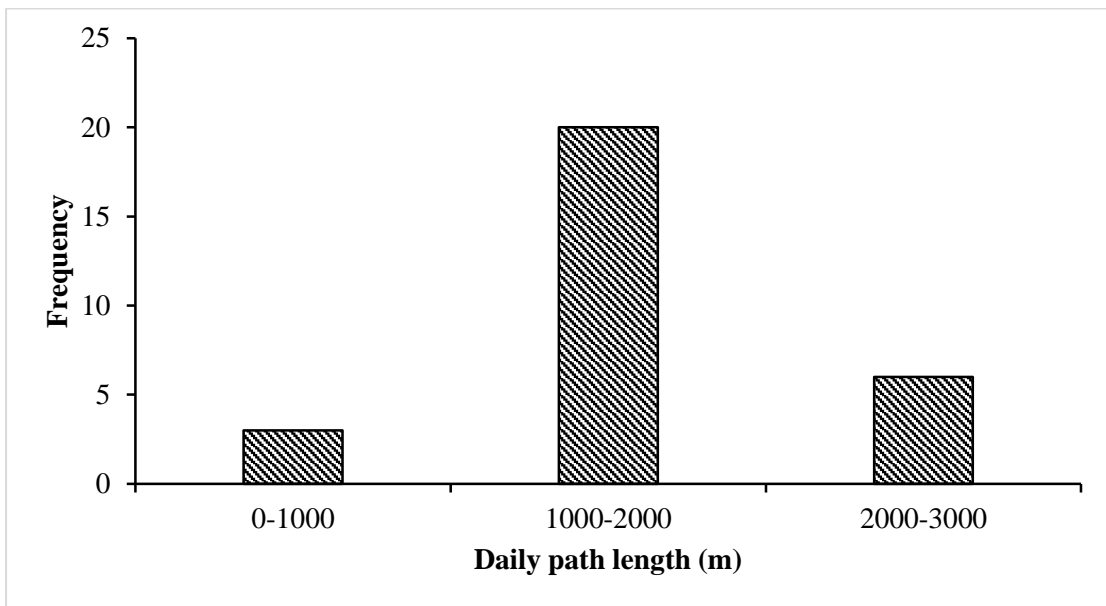


Figure 7. Frequency distribution of daily path length (n=29 days) of rhesus macaques in Daunne Forest

Rhesus macaques travelled longest distance during autumn (mean = 1168.5 ± 1025.70 m) and shortest during spring season (mean = 75.9 ± 237.15 m) (Fig. 8). Seasonal DPLs varied but showed no significant differences ($H=2$, d.f. = 2, $p > 0.05$).

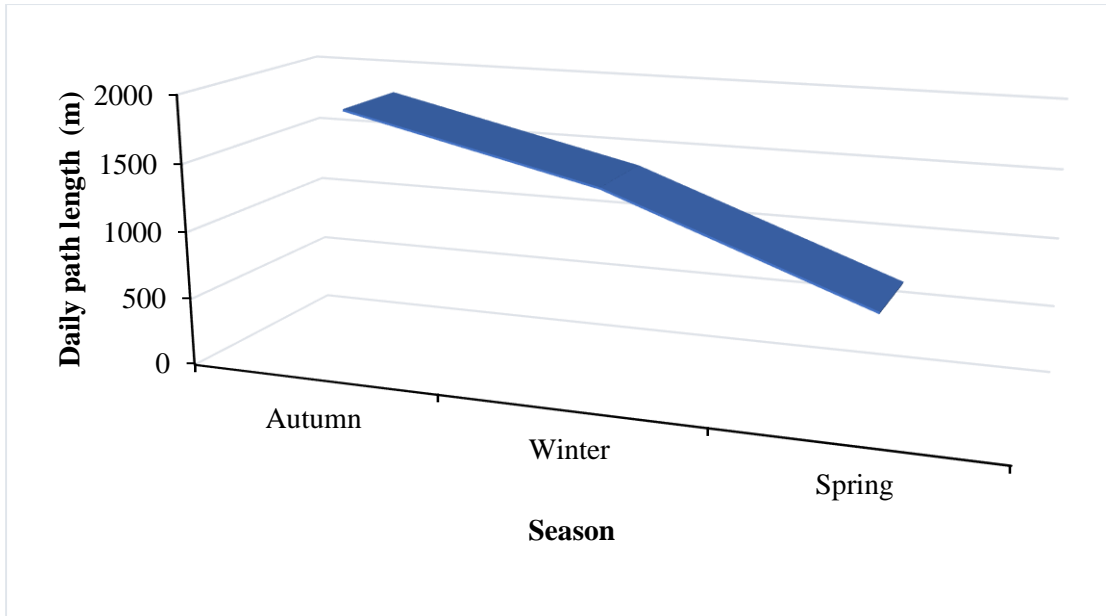


Figure 8. Daily path length of rhesus macaques in autumn, winter and spring season in Daunne Forest

Area used by the rhesus macaques was classified into five main classes as very low use, slightly use, moderately use, highly use and very high use (Fig. 9). Daunne Devi Temple and stair on the way to the temple was found to be highly used area whereas forest area where there was less presence of visitors was found to be very low used and slightly used by rhesus macaques. Main feeding sites receiving supplement food from the temple visitors were observed as highly used area during the study.

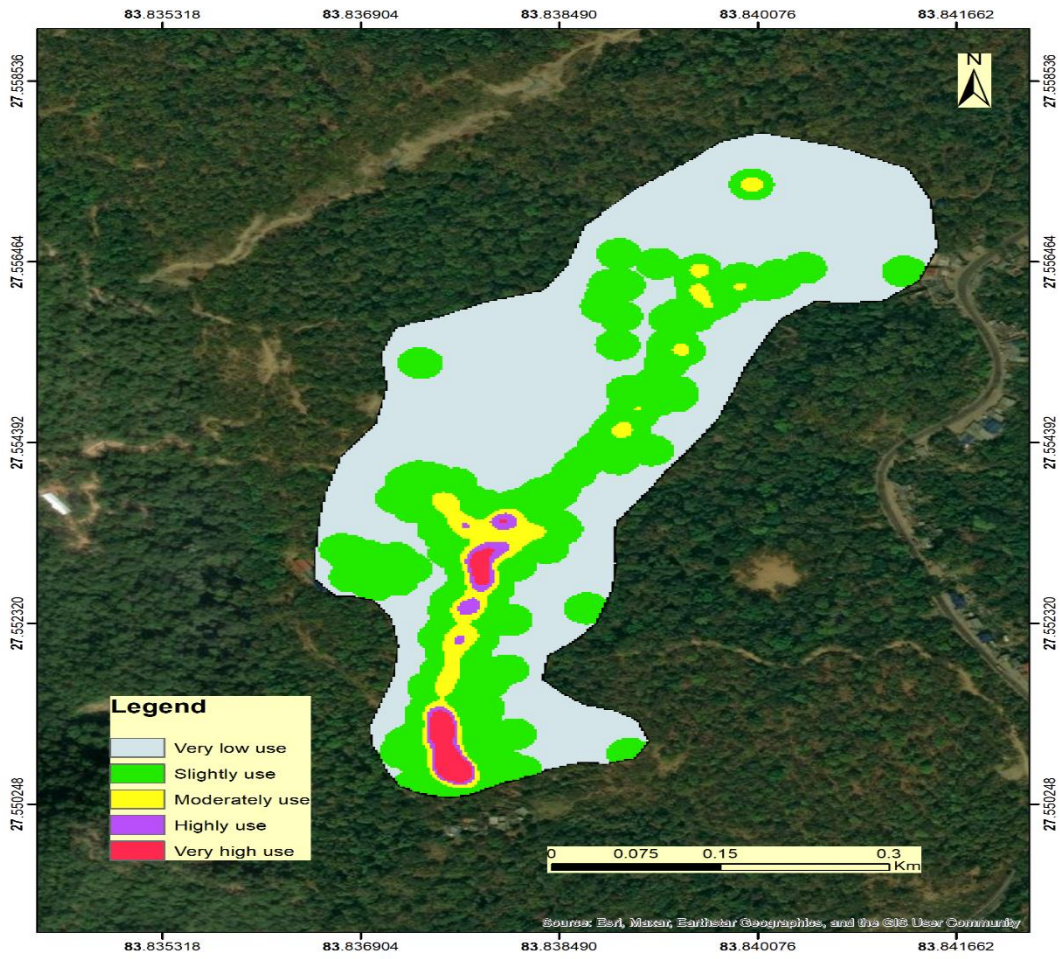


Figure 9. Heatmap of the area used by the rhesus macaques in Daunne Forest

5. DISCUSSION

5.1 Diurnal activity budget of rhesus macaques

Results of this study revealed that most frequently observed daily activity was resting. Similar results were reported by other studies that showed urban rhesus macaques spent majority of their diurnal time on resting compared to other activities (Jaman & Huffman 2013, Neha et al. 2021). The most likely reason for our result was due to the presence of visitors throughout the day. Visitors fed the macaques at the Daunne Devi Temple of Daunne Forest for pleasure and religious purposes. Anthropogenic foods are readily accessible which causes rhesus macaques to wait rather than searching for their own foods, thereby increasing the amount of time spent resting. This was consistent with prior research that found provisioned primates spent less time moving and searching and more time resting (El Alami et al. 2012, Jaman & Huffman 2013, Adhikari et al. 2018, Ilham et al. 2018). Rhesus macaques often rested on the rocks, branches of trees, the roof of the buildings and. However, in contrast to other studies on rhesus macaques (Jaman & Huffman 2013, Neha et al. 2021) moving was recorded as the second highest activity in our study. Usually, the priest and local people in the study site use catapult to throw small stones at the rhesus macaques. High investment on moving might be due to the frequent movement of rhesus macaques to escape from the stones thrown by visitors and locals at the study site. Rhesus macaques spent less time moving compared to resting. This contradicts other macaque studies that have been conducted elsewhere (Hambali et al. 2012). This could be due to the fact that, in contrast to monkeys living commensally with humans, those living in forests were primarily frugivorous, occupied more area, and expended the majority of their time foraging for fruits (Neha et al. 2021). Previous studies on vervet monkeys have found that having access to valuable anthropogenic resources lowers the necessity for foraging and as a result reduce the amount of time spent moving (Saj et al. 1999, Thatcher et al. 2019). Rhesus macaques are nimble, attentive, and ready to move at the first sign of disturbance. Rhesus macaques at our study site were semi-provisioned and obtained human food from visitors at the temple, along a pathway to temple and at a trash dump. To find this food, individuals did not have to move far or engage in extensive foraging. Rhesus macaques allocate the third highest time in their activity budget to feeding. The structure of an animal's activity budgets can vary depending on the changes in its environment. It is

presumed that individuals modify their behavior in reaction to such situations depending on a mix of physiological characteristics that are unique to age and sex. Obviously, if one behavior increases, others must decrease (Jaman & Huffman 2008). It was found that the higher the proportion of time spent on resting, lower the proportion of time spent on feeding. This supported Kurup and Kuram's (1993) claim that feeding time was inversely related to resting time. Feeding occasionally leads to conflicts amongst the individuals as animals were seen competing for food. Rhesus macaques usually engaged in grooming after feeding and while resting and lactating. Mothers are usually found grooming their young. The majority of the time, grooming took place between females. Fifth highest behavior of the rhesus in our study was aggression. During our observation period the rhesus macaques bite and scratch a few people. On the other hand, the local population and visitors also harms rhesus macaques. Aggression was probably due to stiffer competition for the foods given by visitors that it consumed. Our result support previous finding that aggressive behavior of semi-provisioned barbary macaque was related to the clumped human foods (El Alami et al. 2012). Vocalisation was done to alert the group members about the presence of dogs and peoples as well as any possible threats. Members of the group who heard the vocal warning would promptly climb to trees or flee. Rhesus macaques have also been seen to vocalize during fighting and food snatching. Mating comprised the least proportion of their time in the activity budget of rhesus macaques. Males can be found perched on the back of female bodies when mating. Rhesus macaques merely require a few seconds to complete mating process. Rhesus macaques rarely attempt to engage in homosexual interactions between male during the observations. Similar finding was reported by Hambali et al. (2012) from the study of long tailed macaques.

5.1.1 Activity budget of rhesus macaques at different observational phases

We found the significant difference between behaviors at different observational phases. The percentage of time rhesus macaques spent in different activities varied during the day. The most frequent activity that took place throughout the day was resting followed by moving in the morning and late afternoon. This is likely due to the presence of visitors throughout the day which results in rhesus macaques waiting for the food rather than foraging. 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. This might be due to the less availability of food in the Temple which results from the presence of fewer number of visitors during the late afternoon. This leads rhesus macaques to move more in search of food. The adult male and adult female traveled further at late afternoon to find places with a lot of food abundance where the group would stay until sunset. Similar to our results, study on *Trachypithecus phayrei* have found that *Trachypithecus phayrei* spent the highest proportion of time moving in the noon (Naher et al. 2022). Feeding and grooming was more prevalent in the afternoon in comparison to morning and late afternoon. However, Naher et al. 2022 found that grooming was more prevalent in the morning. Lactating, resting, aggression and playing were more in the afternoon and late afternoon than were in the morning. However, mating occurred more frequently in the morning than in the afternoon and late afternoon. Other activities (drinking, vocalization and scratching) were more in the morning and afternoon than were in the late afternoon.

5.1.2 Activity budget among different sex classes of rhesus macaques

Our result showed differences in activity budget of rhesus macaques among sexes. Time spent on behavioral activities (resting, moving, feeding, grooming, lactating, aggression, playing, mating and others) varied between sexes. Resting was the highest activity of both adult male and adult female. Time expended on resting by adult male was higher than the adult female, in which their differences were significant. This is inconsistent with previous study on urban rhesus macaques which found that female spend more time in resting than male (Jaman & Huffman 2013). This study have found that the adult males and adult females allocated the significantly different amount of time on moving. This was likely due to the adult males are 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 on feeding. This may be due to male and female re-productive investments differ significantly, especially in primates. 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). In contrast to our finding, Jaman and Huffman (2013) found that adult male spent more time feeding than females. The amount of time invested on grooming differs between adult males and adult females. The amount of time allocated to grooming was high in adult female than adult male and their differences were

significant. This is supported by the previous studies on macaques (Hambali et al. 2012, Jaman & Huffman 2013). This could be due to the male dominance over females and subordinate male. Interestingly, adult males permitted adult females who groomed to go foraging with them as well. This allowed better access to nutritious food and maximum availability of food (Jaman & Huffman 2013). Generally, adult females are seen playing more than adult males. Mothers are seen playing with their babies. Rhesus macaques engaged in a variety of playful behaviors, including chasing, harmless biting, grappling, hanging on tree branches, and playing with water and various things (plastic, mirror). Female expend the more time on playing than that of male, the differences were insignificant. In the study area, male often displayed higher levels of sexual urge than female. This is consistent with other studies who reported that the male exhibited more sexual behavior than females (Brent & Veira 2002, Okekedunu et al. 2014).

5.2 Daily path length of rhesus macaques

The distance moved within the area that the animal covered in a single day is known as daily path length (DPL) (Weerasekara & Ranawana 2017). The mean daily path lengths of 1590 ± 576.96 m we recorded for rhesus macaques at Daunne Devi Temple are similar to those observed in Bangladesh (1638.43 m) (Shoma & Feeroz 2014). Inconsistent with our study, daily path length of rhesus macaques at Shivapuri Nagarjun National Park in Nepal was 4000m (Khatiwada et al. 2020). These variations may occur for a variety of ecological reasons, such as seasonal variations, rainfall, food availability, and food distribution, as well as other intergroup interactions like competition, territoriality, and troop size variations (Weerasekara & Ranawana 2017). Anthropogenic factors like habitat modification and provisioning also have an impact on macaques movement (Santhosh et al. 2015). Another factor influencing our study group's daily path length might be the selection of sleeping site at night time. Although we do not observe rhesus macaques at night. The study group typically prefers to sleep on the large and tall trees, particularly *Shorea robusta*, which is abundant in the study area. It was discovered that the study group left their sleeping locations as early as 7:00 am and arrived back at the locations at 6:00 pm. Keeping track of the study group throughout the day has given specific details on their everyday travel in the study area. The study group prefers to travel short distance and within close proximity to the study site, as seen by their daily movement patterns. These outcomes might be the result of accessibility to anthropogenic food resources. This is supported by the previous studies

conducted on macaques (Sha & Hanya 2013, Kamarul et al. 2014, Shoma & Feeroz 2014). The daily route of the study group was a pathway to the temple which was extremely strongly associated with the distribution of food. The amount of time rhesus macaques group spent waiting for visitors to arrive in the Temple may have limited the amount of time to forage for natural foods, which in turn reduced their daily travel lengths. The visitors feed the monkeys with artificial food and utilize food as an enticement to go closer to them, which causes them to shrink the size of their home range and daily travelled distance (Asquith 1989). When the visitors become fewer in the Temple rhesus macaques move down to the village or they go back in the forest for foraging. Similar result was found in the the study of *Cercopithecus Lowe* (Badiella-Giménez et al. 2021). Moving from one tree to another tree by jumping was observed in our study group. Newborn baby who are still nursing are typically carried by their mother. However, adult rhesus macaques constantly observe and make sure everyone in the group is secure when they are moving. The study group's preferred habitat could be seen by the highly use and very high use area as shown in Figure 7. The Daunne Devi Temple and stairs on the way to temple was found to be highly use by the rhesus macaques. This might be due to the presence of anthropogenic foods as these were the spots visitors usually used to feed the rhesus macaques. In this study, Rhesus macaque daily path length varied but was not significant between autumn, winter and spring season. In human-altered habitats, the impact of seasonality on primate behavior is lessened in the presence of anthropogenic foods (Sha & Hanya 2013). In contrast to our results, another study have found the significant difference between the daily path lengths of lion-tailed macaques in different seasons (Erinjery et al. 2015).

6. CONCLUSION AND RECOMMENDATION

6.1 Conclusions

Resting, moving, feeding and grooming were the most common daily activities of rhesus macaques in Daunne Devi Temple area of Daunne Forest. The activity budget of rhesus macaques varied among sexes. Adult male spent more time of their daily activity budget in resting than adult female. Similarly, significant difference was found in the daily activity budget of rhesus macaques at different observational phases of the day. Resting was the most time invested activity of rhesus macaques throughout the day. Mean daily path length of rhesus macaques in Daunne Forest was found to be 1590 ± 576.96 m which did not vary significantly with seasons.

6.2 Recommendation

A longer study, in which environmental variables are analyzed, along with comparative analysis with other groups, would be appropriate to investigate the detailed information about rhesus macaques. Increased group size and a greater dependency on people at Daunne could lead to future conflicts between the macaques and the locals, which poses a serious risk to the macaque population. Furthermore, these interactions might raise the chance of disease transmission that occurs both ways. Therefore, by using the proper management strategies, the interaction between humans and monkeys should be managed for the welfare of both species.

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PHOTOGRAPHS



Photo 1. An adult male rhesus macaque resting on the floor



Photo 2. An adult female rhesus macaque grooming another adult female rhesus macaque

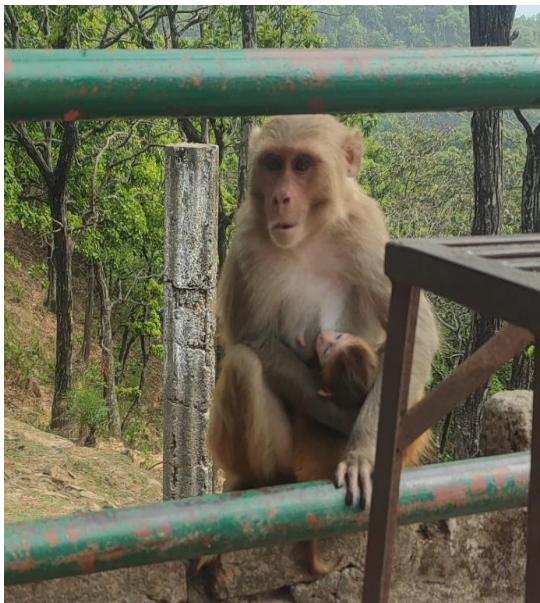


Photo 3. An adult female rhesus macaque breast feeding the baby

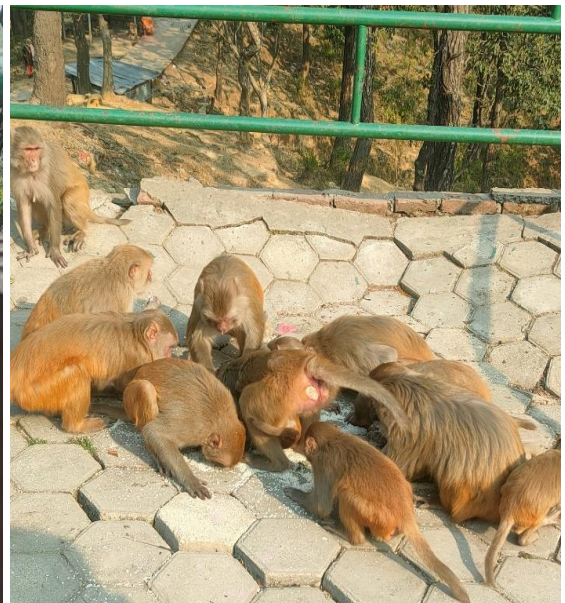


Photo 4. Rhesus macaques feeding on the supplemented food



Photo 5. An adult rhesus macaque playing with water



Photo 6. An adult male rhesus macaque threatening the visitors



Photo 7. Adult female rhesus macaques moving on the ground



Photo 8. An adult female rhesus macaque drinking water

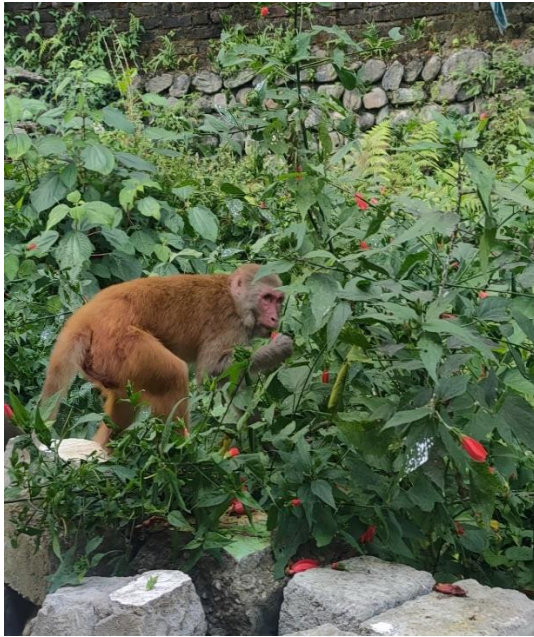


Photo 9. An adult female rhesus macaque feeding on the flowers of the plant



Photo 10. An adult male rhesus macaque feeding on the anthropogenic foods



Photo 11. GPS Garmin Etrex10 used to record the daily path length of rhesus macaques



Photo 12. Observer recording the behavioral activities of the focal animal