Strata Use by Sympatric Macaques (*Macaca assamensis* and *M. mulatta*) in Nagarjun Forest of Shivapuri-Nagarjun National Park, Kathmandu, Nepal

Anisha Shrestha

T.U. Registration No: 5-2-37-1013-2015

T.U. Examination Roll No: 803/076

Batch: 2076

A thesis submitted

In partial fulfilment of the requirements for the award of the degree of Master of Science in Zoology with special paper Ecology and Environment

Submitted to

Central Department of Zoology

Institute of Science and Technology

Tribhuvan University

Kirtipur, Kathmandu

Nepal

May 2023

DECLARATION

I hereby declare that the work presented in this thesis **"Strata Use by Sympatric Macaques (*Macaca assamensis* and *M. mulatta*) in Nagarjun Forest of Shivapuri-Nagarjun National Park, Kathmandu, Nepal"** has been done by myself, and has not been submitted elsewhere for the award of any degree. All sources of information have been specifically acknowledged by reference to the author(s) or institution(s).

Date: May 4, 2023

.....

Anisha Shrestha

T.U. Registration No: 5-2-37-1013-2015

T.U. Examination Roll No: 803/076

Batch: 2076

त्रिभुवन विश्वविद्यालय
TRIBHUVAN UNIVERSITY
प्राणी शास्त्र केन्द्रीय विभाग
CENTRAL DEPARTMENT OF ZOOLOGY
कीर्तिपुर, काठमाडौं, नेपाल ।
Kirtipur, Kathmandu, Nepal.

०१-४३३१८९६
01-4331896
Email: info@cdztu.edu.np
URL: www.cdztu.edu.np

पत्र संख्या :-
च.नं. Ref.No.:-

Central Department of Zoology
T.U., Kirtipur

RECOMMENDATION

This is to recommend that the thesis entitled **"Strata Use by Sympatric Macaques (*Macaca assamensis* and *M. mulatta*) in Nagarjun Forest of Shivapuri-Nagarjun National Park, Kathmandu, Nepal"** has been carried out by Anisha Shrestha for the partial fulfilment 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.

Date: May 4, 2023

.....

Dr. Laxman Khanal
Supervisor, Associate Professor
Central Department of Zoology
Tribhuvan University
Kirtipur, Kathmandu, Nepal

त्रिभुवन विश्वविद्यालय
TRIBHUVAN UNIVERSITY
प्राणी शास्त्र केन्द्रीय विभाग
CENTRAL DEPARTMENT OF ZOOLOGY
कीर्तिपुर, काठमाडौं, नेपाल ।
Kirtipur, Kathmandu, Nepal.
☎ ०१-४३३१८९६
01-4331896
Email: info@cdztu.edu.np
URL: www.cdztu.edu.np

पत्र संख्या :-
च.नं. Ref.No.:-

Central Department of Zoology
T.U., Kirtipur

LETTER OF APPROVAL

On the recommendation of supervisor Associate Prof. Dr. Laxman Khanal, this thesis submitted by Anisha Shrestha entitled **"Strata Use by Sympatric Macaques (*Macaca assamensis* and *M. mulatta*) in Nagarjun Forest of Shivapuri-Nagarjun National Park, Kathmandu, Nepal"** is approved for the examination and submitted to the Tribhuvan University in partial fulfilment of the requirements for Master's Degree of Science in Zoology with special paper Ecology and Environment.

Date: May 4, 2023

.....

Prof. Dr. Kumar Sapkota

Head of Department

Central Department of Zoology

Tribhuvan University

Kirtipur, Kathmandu, Nepal

त्रिभुवन विश्वविद्यालय
TRIBHUVAN UNIVERSITY
प्राणी शास्त्र केन्द्रीय विभाग
CENTRAL DEPARTMENT OF ZOOLOGY
कीर्तिपुर, काठमाडौं, नेपाल ।
Kirtipur, Kathmandu, Nepal.
☎ ०१-४३३१८९६
01-4331896
Email: info@cdztu.edu.np
URL: www.cdztu.edu.np

पत्र संख्या :-
च.नं. Ref.No.:-

Central Department of Zoology T.U., Kirtipur

CERTIFICATE OF ACCEPTANCE

This thesis work submitted by Anisha Shrestha entitled **"Strata Use by Sympatric Macaques (*Macaca assamensis* and *M. mulatta*) in Nagarjun Forest of Shivapuri-Nagarjun National Park, Kathmandu, Nepal"** has been accepted as a partial fulfilment for the requirements of Master's Degree of Science in Zoology with special paper Ecology and Environment.

EVALUATION COMMITTEE

.....

Supervisor
Dr. Laxman Khanal
Associate professor
Central Department of Zoology
Tribhuvan University
Kirtipur, Kathmandu, Nepal

.....

Head of Department
Dr. Kumar Sapkota
Professor
Central Department of Zoology
Tribhuvan University
Kirtipur, Kathmandu, Nepal

.....

External examiner
Dr. Narayan Prasad Koju

.....

Internal Examiner
Prof. Dr. Tej Bahadur Thapa

Date of Examination: May 23, 2023

ACKNOWLEDGEMENTS

It is my pleasure to express my heartfelt gratitude to my supervisor Dr. Laxman Khanal, Associate professor, Central Department of Zoology for his constant supervision, invaluable guidance, encouragement and constructive criticisms have been of invaluable importance for the fulfillment of this work.

I am grateful to Prof. Dr. Kumar Sapkota, Head of Department and Prof. Dr. Tej Bahadur Thapa, former Head of Department for their cooperation and support to carry out this dissertation work. I would also like to express my thoughtful thanks to all the respected teachers and staff of Central Department of Zoology for their supports and encouragements. .

I would like to extend my sincere thanks to Department of National Park and Wildlife Conservation (DNPWC) and Shivapuri-Nagarjun National Park for providing permission to conduct research. I would like to express my sincere gratitude to Mr. Damodhar Lama, Chief of Balaju Garden Park for giving permission to conduct research in the park area.

I would like to express my sincere thanks to Mr. Khadga Bahadur Shrestha for accompanying me throughout the research period. I would also like to thank Mr. Keshab Bhetuwal, Senior Game scout of Nagarjun Forest, Mr. Ram Charan Poudel and Mr. Hem Raj Acharya for their support while conducting the research. I am also thankful to Miss Ashmeeta Shrestha and Mr. Ashim Shrestha who helped me throughout the study.

Finally, I would like to express my utmost gratitude to everyone whom I have missed to remember and have contribution directly or indirectly towards completion of the work for their kind cooperation during my field work and entire study period. Special thanks goes to parents and relatives for unbelievable support and care.

Anisha Shrestha

Exam Roll no. 803/076

Batch: 2076

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ANNEXS

LIST OF PHOTOGRAPHS

LIST OF ABBREVIATIONS

Abbreviated form	Details of abbreviations
AM	Adult males
AF	Adult females
ANOVA	Analysis of Variance
DNPWC	Department of National Parks and Wildlife Conservation
FAM	Females of Assamese macaques
FI	Females with infants
FRM	Females of rhesus macaques
I	Infants
IUCN	International Union for Conservation of Nature
J	Juveniles
MAM	Males of Assamese macaques
MRM	Males of rhesus macaques
SNNP	Shivapuri-Nagarjun National Park

ABSTRACT

Using different habitat is a niche partitioning mechanism utilized by the primates. The use of forest strata by non-human primates is greatly dependent on the age, sex and the activities being performed. Limited studies have explored forest strata use pattern in macaques. This study aimed to compare the diurnal activity budget and forest strata use of Assamese macaques (*Macaca assamensis*) and rhesus macaques (*M. mulatta*) in Nagarjun Forest of Shivapuri-Nagarjun National Park, Kathmandu. Further it tested the difference in strata use brought by the age-sex difference and the behavioral activities. The study was carried out from September 2022 to March 2023. The behavior recorded included (a) feeding, (b) moving (c) resting, and (d) socializing. Data on the behavior of the macaques were collected using the focal animal sampling method. For the forest strata use, instantaneous scan sampling was carried out at every 10 minute interval recording macaques' sex, the height of the forest strata, and their behaviors on each observation. The data for Assamese macaque groups was collected for three consecutive days of every study week before switching to data collection for rhesus macaque groups. Analysis of the data was done using One-way ANOVA, Kruskal-Wallis test and Mann-Whitney U test. The Assamese macaques spent majority of the diurnal time in the trees. Assamese macaques used arboreal strata significantly more (88.4%) whereas rhesus macaques were seen significantly more on the ground (62.72%). The use of strata for different age-sex group and behavioral activity vary significantly for both Assamese and rhesus macaques. Assamese macaques showed preference for ground while feeding and strata between 5–15 m for other behaviors. Rhesus macaques performed feeding, resting, moving and socializing behavior significantly more on the ground. This study showed that there is significant difference in the forest strata use between the sympatric Assamese macaques and rhesus macaques of Nagarjun Forest.

1 INTRODUCTION

1.1 Background

Forest is one of the most diverse and complex ecosystems on the planet, and primates are among the most important groups of animals that inhabit these forests. Primates are known for their ability to use different forest strata, including the ground, understory, mid-story, and canopy, to find food, shelter, and safety from predators (Fleagle 2013). Understanding the ways in which primates use forest strata is important for a number of reasons, including understanding the ecology and behavior of these animals, as well as for conservation and management of forest habitats (Chapman et al. 2020).

Several factors, such as the availability of resources, competition, and predation, can influence primate habitat use and the ways in which they use different forest strata (McGraw & Bshary 2002, Wallace 2008). The study of primate forest strata use can provide insights into these factors, as well as into the complex relationships between primates and their environments. By studying how primates use different forest strata, researchers can gain a better understanding of the importance of different types of forests for different primate species, which can be used to inform conservation and management strategies (Chapman et al. 2020).

Comparative studies of sympatric species are essential to understand the ecological and behavioral adaptations of these species, as well as the mechanisms of coexistence (Zhou et al. 2014) Sympatric species may have evolved different adaptation in their habitat use, which can be observed in their spatial niche or strata to avoid completion for limited resources (Gause 1934, Pianka 1981). Spatial niche or strata separation is an important mechanism evolved in sympatric species as it to reduce competition for resources such as food, water, and shelter and allow for coexistence of the species (Gause 1934). Spatial niche separation among sympatric species play an important role in the coexistence of species and the maintenance of biodiversity (Oviedo et al. 2018). When two or more species occupy different spatial niches or strata, they can coexist more easily because they are not competing for the same resources (Gause 1934). This can increase the likelihood of long-term coexistence and reduce the likelihood of one species excluding or driving out another species thus help to maintain biodiversity and promote the stability of ecosystems. Understanding the spatial niche or strata of different species can be crucial for effective conservation and management of biodiversity.

This study aims to investigate the forest strata use of Assamese and rhesus macaques, with a focus on how the forest strata use pattern are influenced by age-sex class and behavioral activities of the macaques. By studying this relationships between macaques and their environments and how the age-sex class and behavior affect the use of the habitat, this research can contribute to understanding of primate ecology and behavior, and making informed conservation and management efforts aimed at preserving these animals and their habitats (Huang et al. 2015).

1.2 Macaques of Nepal

Assamese macaque, *Macaca assamensis* M'Clelland, 1840, is a species of Old-World monkey. They are found in parts of Southeast Asia, including India, Bhutan, and China. There are two distinct subspecies, eastern Assamese macaque, *M. a. assamensis* and western Assamese macaque, *M. a. pelops* are known. Assamese macaques have darker fur in exposed back area and ashy-white fur in abdominal and inner parts (Chalise et al. 2015). Males and females of Assamese macaques weigh about 5–10 kg, and having a head and body length 51–73.5 cm with 15–30 cm long tail (Chalise 2013). Assamese macaques are primarily arboreal, spending much of their time in trees. They are omnivorous, feeding on a variety of fruits, seeds, insects, and small animals. They live in social groups, with females forming the core of the group and males leaving to join other groups or live alone. The Assamese macaque is listed as "Near Threatened" by IUCN red list category, as it is experiencing population decline brought on by hunting and habitat degradation and fragmentation (Boonratana et al. 2020).

Rhesus macaques, scientifically known as *Macaca mulatta* (Zimmermann, 1780), are a species of Old-World monkey. They are found throughout Southeast Asia, including India, Bangladesh, and China. They occur from low-lying flat lands to the foot of the Himalayas up to 4,000 m (Chalise 2013). They have a brown or grayish-brown fur on their back, with lighter fur on their underbelly. Rhesus macaques have reddish color pattern increased towards anal region. They have a distinctive red or pink face and a short tail. They are medium-sized monkeys, with males typically larger than females. Males have body length 48–64 cm and weigh 6.5–12 kg; whereas, females have body length 45–55 cm and weigh 5.5 kg on average.

Rhesus macaques are omnivores, eating a variety of foods including fruits, leaves, roots, inner barks, seeds, insects and small invertebrates. They live in social groups, with females forming the core of the group and males leaving to join other groups or live alone. Rhesus macaques are known for their intelligence, and are able to learn and use tools in the wild. They are also

known for their adaptability to human environments, and can often be found in urban areas, where they sometimes cause problems by raiding crops or causing damage. Rhesus macaques are listed as “Least concern” in IUCN category because of its wide distribution- tolerant of broad range of habitat and its large population (Singh et al. 2020). They are also considered a nuisance in some areas due to their close proximity to humans.

1.3 Research objectives

The general objective of the study was to investigate the forest strata use pattern of *Macaca assamensis* and *M. mulatta* in Nagarjun Forest of Shivapuri-Nagarjun National Park, Kathmandu, Nepal. The specific objectives of this research were:

1. To compare the diurnal activity budget of sympatric *M. assamensis* and *M. mulatta*.
2. To compare the strata-use pattern of *M. assamensis* and *M. mulatta* with the age-sex difference and behavioral activity.

1.4 Research questions

This research is based on the research questions-

- How does the pattern of forest strata use vary in two sympatric species of macaques?
- Do the behavioral activities have any influence in the strata use?
- How do the forest strata use in the macaques vary according to their age and sex?

1.5 Significance of the study

The study of forest strata use in primates is important for several reasons. It provides insights into the behavioral ecology of primates and their adaptations to the arboreal environment. By understanding how primates use different forest strata levels, researchers can gain a better understanding of their foraging strategies, social behavior, and other ecological adaptations. Studying forest strata use can also help to inform conservation efforts for primate species. Different primate species have unique habitat requirements and are adapted to specific forest strata, so understanding their forest strata use can help identify areas that are critical for their survival. This information can be used to design effective conservation strategies, such as habitat management and protected area planning.

Overall, the study of forest strata use in primates is important for understanding primate behavior and ecology, the niche overlapping on two sympatric species and making informed conservation efforts.

Despite the importance of information on primate forest strata use, there are still many gaps in our knowledge of these animals and their habitats. Some primates, such as those that inhabit the upper canopy, are particularly difficult to study, making it challenging to fully understand their behavior and ecology. Furthermore, changes in forest cover and structure due to human activities, such as logging and land use change, can also impact primate habitat use and distribution, further highlighting the need for ongoing research and conservation efforts. In this situation, the continuous study of the primates and their forest use is very significant.

2 LITERATURE REVIEW

Primates have the most diverse array of morphology in both living and fossils primates ranging from generalized and primitive to having unmatched morphological and behavioral specialization in all mammalian orders (Fleagle 2013). Primates have retained their relatively primitive bodies and have not diverged from the common mammalian body. Primates have a wide range of body sizes ranging from weighing less than 100g like mouse lemur and pygmy marmosets to large gorillas weighing over 200 kg. Fossil records show probability of primates ranging from as small as 20 g to primates over 300 kg e.g. *Giganthopithecus blacki* from Pleistocene of China.

Primates have upper jaw, maxilla and lower jaw mandibles and have bilaterally symmetrical teeth having incisors, canine, premolars and molars on each side of upper and lower jaw which they use to consume wide range of diet. Primates also have complicated bone structures in wrist region which helps them wide range of motion and helps them in grabbing and catching which helps them to move and remain securely in ground and tree (Fleagle 2013).

2.1 Activity budget of macaques

Primates have variation in the behavioral activity pattern. Assamese macaques tend to spend much of their time in foraging and they tend to fight less (Chalise et al. 2015). They also spend great proportion of time in social engagement (Khatiwada et al. 2020). These macaques also tend to travel in smaller range of areas. The behavior of Assamese macaques change in winter as they are shown to groom and play less (Pandey & Chalise 2015). Assamese macaques spend most of the time resting, followed by grooming and foraging (Zhou et al. 2014, Ghimire & Chalise 2021).

Rhesus macaque spend most of their time foraging (Zhou et al. 2014). Another study also reported that rhesus spend majority of the time feeding and resting (Khatiwada et al. 2020). Among the social activities performed, Assamese macaques and rhesus macaques both spend majority of time grooming. Among Assamese and rhesus macaques, rhesus macaques tend to travel large distance in a day than Assamese macaques which could be due to their dietary need and group size.

2.2 Forest strata use

Primates utilize more habitat types than any other terrestrial mammalian group (Fleagle 2013). Different species have different niche in which they spend most of their time. The pattern of the habitat use is vastly different from one species to another. Different primate species use habitat differently along both vertical and horizontal axes. The use of different strata in the canopy is a widespread mechanism of niche partitioning in primates (Schreier et al. 2009). This niche portioning is often influenced by locomotor and anti-predatory behavior of the primates (Rodman 1991, Peres 1994). There are many ecological factors that influence for the forest use in the primates such as forest structure, seasonality (Pontes 1997), habitat differentiation (Rodman 1991), food distribution, predator and predation pressure (McGraw & Bshary 2002, Xiang et al. 2009), mode of locomotion (Bitty & McGraw 2007), age-sex class, body size, group size (Liu et al. 2022) and many more.

Habitat alteration and fragmentation plays a key role in habitat substrate use in the monkey. The types of forest in the habitat of the primates also greatly impacts the pattern of behavioral activity and strata use in the primates. Change is seen on the behavior performed on different forest strata. The pattern in which the species use forest strata varies in different type of forest. In the continuous forest, the Bale monkeys, *Chlorocebus djamdjamensis* tend to spend more time in middle and upper strata whereas in fragmented forest spent significantly more time on the ground and understory forest layer (Mekonnen et al. 2018).

Age-sex differences play important role in substrate preferences, likely due to body weight constraints (Grueter et al. 2013). The behavior such as resting, travelling and foraging also tend to shift the proportion of forest strata use. The use of forest strata is greatly dependent on the age, sex and the activities being performed by the primates. Adult of many primate species tend to use lower strata most of the time than the young ones. Juvenile and infants of *Macaca thibetana* spend their time on ground, lower and middle strata more, where as adults spent majority of their time in ground or forest floor layer (Li et al. 2022).

Adult males of *Rhinopithecus bieti* (snub-nosed monkeys) frequented the ground significantly more often than other age–sex classes (Grueter et al. 2013). Adult males were associated more with solid substrates and less with terminal branches than adult females and juveniles. Juveniles were seen more often on unstable ground and in the upper canopy.

Adults of Assamese macaques was found to use ground more often and rhesus macaques were seen using trees (Huang et al. 2015). Larger monkeys prefer main canopy where there are large

stable support (Bitty & McGraw 2007) and locomotion in large tree branches. Smaller sized monkey usually seen in understory using lianas mode of locomotion (Youlatos 1999, Bitty & McGraw 2007).

Behavior is often influenced by the environment condition. This behavior then influences the habitat use pattern in primates.

Seasonality affects the food availability in the forest. In the absence of food in dry season, *Cebus apella apella* descend to lower strata and often interact with humans for food (Siemers 2000). Foraging was done mostly on ground and travelling was done mostly in lower strata during dry season. The rain brought increase in food availability thus the feeding occurred mostly on upper strata with travelling being distributed to both lower and upper strata.

Primates often change their forest strata utilization when other species are around. The presence of another species of monkeys contributes to a sense of safety and protection to the primates (Bshary & Noë, 1997) and helps to avoid predation which changes the forest strata use of monkeys. Monkeys such as *Piliocolobus badius* and *Cercopithecus diana* move to lower forest strata levels and to the forest floor significantly more often when *Cercocebu atys* are spatially intermingled with them (McGraw & Bshary 2002). This change in forest strata use increases the foraging niche. Chen-Kraus et al. (2022) in their study used human, livestock and dog as the vigilance predictor. *Propithecus verreauxi* spend more time above the ground in the tree when the dog was present.

Riley et al. (2021) pointed humans as one of the influencers in the variation in habitat use. The infrastructure development such as road development increases the chance of human primate interaction with the increase in the chances of human providing food to the primates. Because of this reason, there was increase in the road foraging for human provided food in the *Macaca maura*. This resulted in decreasing the distance of the species from the road increasing home range affecting the distribution and dispersal of the primates.

Huang et al. (2015) found that Assamese macaques fed, rested and groomed majorly on the ground whereas rhesus macaques feed, rested and groomed in low and lower middle forest layer. Justa et al. (2019) and Khatiwada et al. (2020) reported that Assamese macaques were seen on tree canopy as they feed on tree, climbers and vines whereas rhesus which depend on crops, grass and shrubs were seen on the ground majority of the time.

3 MATERIALS AND METHODS

3.1 Study area

Shivapuri-Nagarjun National Park (located between 27°45' and 27°52'N and 85°15' to 85°30' E) is named after Shivapuri Peak of 2,732 m (8,963 ft) altitude and has Shivapuri forest with 144 km^2 area and a separate patch of Nagarjun Forest of 15 km^2 (SNNP 2017). This park lies at the elevation of 1,360–2,720 m above sea level and covers an area of 159 km^2 in the districts of Kathmandu, Nuwakot and Sindhupalchowk. The park is the true representation of the mid-hills as it lies in the transition zone between sub-tropical to temperate regions.

The SNNP has 2,122 species of flora including with more than 1250 species of flowering plants, 16 species of endemic flowering plants, 129 species of mushroom and 449 species of vascular plants (DNPWC 2019). This park serves as habitat for the relict Himalayan dragonfly, 24 mammals including 9 threatened species, 318 species of birds, including at least 14 threatened bird species, 106 species of moth and butterflies, and 18 species of herpetofauna have been recorded including a number of rare and endangered species (**Figure 1**).

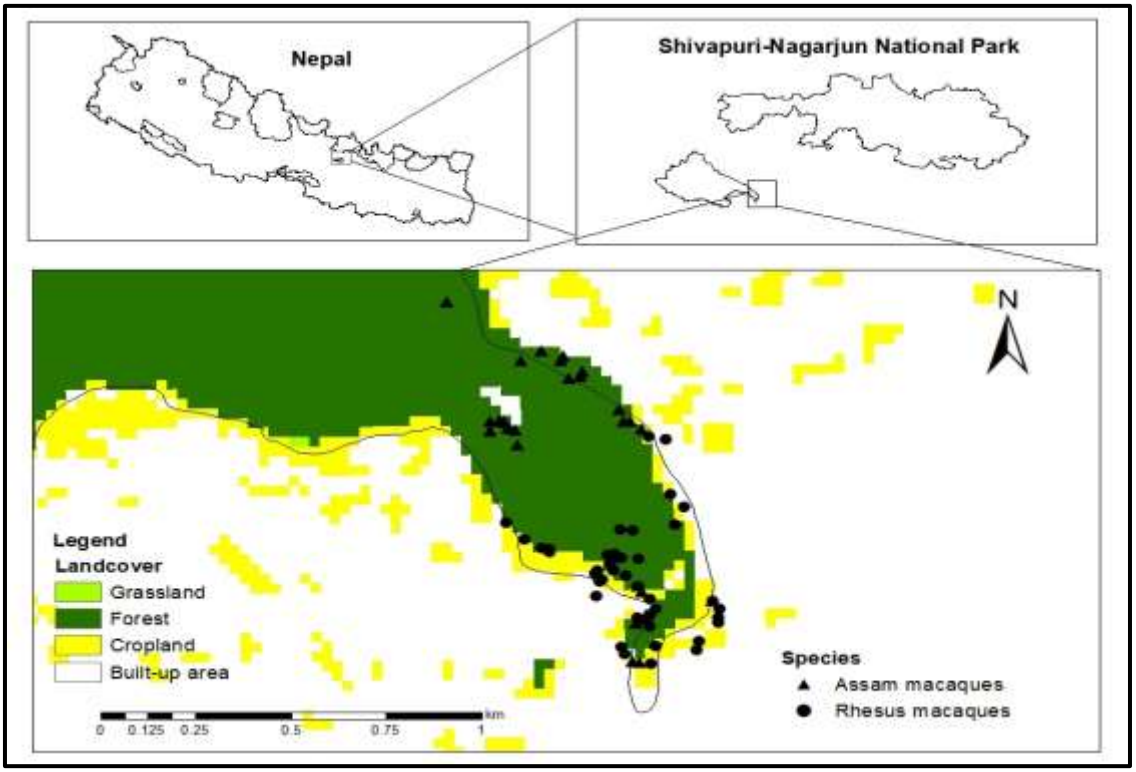


Figure 1. Study sites of Assamese and rhesus macaques in Nagarjun Forest of Shivapuri-Nagarjun National Park (SNNP)

This study was conducted within Nagarjun Forest which is located within 27º43'N to 27º46'N and 85º13'E to 85º18'E, within the elevation range of 1350 to 2732 m. There are four types of forests in Nagarjun Forest: Upper mixed hardwood forest, Oak forest Lower mixed, Chir pine forest and hardwood forest (Kanai & Shakya 1970). Nagarjun Forest is inhabited by both Assamese macaque and rhesus macaque species.

Assamese macaques group residing near Army barrack kitchen and a rhesus macaques group inhabiting nearby Balaju Garden Park were taken as focal troops. Both the study groups were semi provisioned by human. These Assamese macaque troop usually fed on the discards from the Nepalese Army barrack kitchen within the forest premises whereas the rhesus macaque troop frequently got supplements from the visitors in the Balaju Garden.

3.2 Data collection

3.2.1 Materials used

The materials used in the field study were: GPS, Binoculars, Rangefinder, Hygrometer and a watch.

3.2.2 Behavioral data collection

The behavior study of the macaques was carried using Focal sample method**.** In this method, a macaque was randomly selected and their behavior and activity was observed for 30 minutes at a time. The sex, activities by the macaque and the time spent on each activity was recorded. For data collection, only one macaque from the study group was observed at a time. To provide unbiasedness to the result, same subject was not recorded for next two hours after its initial reading.

3.2.2.1 Behavioral category

Following behaviors were included in the observation of the Assamese and rhesus macaques in the study:

Table 1. Ethogram of behavior and sub behavior used for the study

Behavior category		Description
Feeding		**Foraging and consuming food**
Moving		**Moving from one place to another** (Li et al. 2022)
	Climbing	Upward or downward movement on a vertical or steeply angled substrate
	Leaping	Movement between substrates involving free flight in which the hind limbs is used to propel
	Walking	Moving along a substrate (ground or branches) in which all four limbs follow a regular pattern of movement
	Running	Similar to walking, but faster and with a period of free flight in gait
Resting		**Monkey in a stationary posture of sitting or lying down, in the absence of feeding, moving or socializing**
Socializing		
	Monitoring	Monkey monitors the area around itself and/or monitors the activity of the other group members. This includes the continuous movement of head in different directions in short interval.
	Huddle	Two monkeys are facing each other and grab each other by the arms.
	Grooming	One monkey grooms another monkey, i.e. goes through the fur of another monkey with its fingers
	Self-Grooming	A monkey grooms itself
	Self-scratch	Monkey scratches its own body
	Playing	Non-aggressive chasing, bouncing, tumbling, grabbing, wrestling, soliciting, and mock biting of another monkey.
	Contact aggression	Monkey bites, hits or strikes the macaque with a fast movement, can be either by foot (kick), hand (slap) or weapon.
	Non-contact aggression	A monkey displays aggressive behavior toward the macaque such as facial aggressive displays, chase, lunge, grab/throw object to intimidate the macaques (without actual contact).
	Mating	Mounting and/or copulating
	Alarm call	Sounds produced by monkeys possibly due to predators
	Lactation	Mother feeding milk to infant

3.2.3 Forest strata use

Instantaneous scan method was used to collect data on the forest strata use by macaques. In the field, time-point data was taken at every 10 minutes interval for a maximum of three minutes (Altmann 1974, Ma et al. 2020). Forest strata height, a macaque's age-sex class, and the behavioral activities were noted on each observation. The age-sex class of the macaques was

differentiated into five categories which includes Adult males, Adult females, Female with infants, Juveniles and infants according to their body size and behaviors.

Table 2. Description of different age-sex class of the macaques

Age-sex class	Description
Adult male	Macaques that have attained the maximum height and body maturity with large and hanging scrotal sacs.
Adult females	Macaques that have attained the maximum height and body maturity with small head and protruded nipple.
Female with infants	Adult female with clinging infants.
Juveniles	Individuals that are left nipple contact (weaned) and depend on natural foods and mostly following their kin.
Infants	Macaques who still suck the nipple as their main food and following mother.

The behavior recorded include (a) feeding, (b) moving (c) resting, and (d) socializing. The data for Assamese macaque groups was collected for three consecutive days before switching to data collection for rhesus macaque groups. The study was carried out from September 2022 to March 2023. The observations began at 09:00, and continued throughout the day, until 17:00.

3.3 Data analysis

The significant difference in the activity budget between the adult male and adult female of Assamese macaques and rhesus macaques was tested using one-way ANOVA. One-way ANOVA was also used to test the difference in the activity budget adult male of Assamese macaques and rhesus macaques and adult females of Assamese macaques and rhesus macaques.

For the data analysis on the forest strata use of Assamese macaques and rhesus macaques the behavioral activities percentage on each stratum was calculated. Kruskal-Wallis test was done to test the difference in strata use in these macaques. The difference in the forest strata use between Assamese macaques and rhesus macaques was tested using Mann-Whitney U test.

The relation between strata utilization and age-sex class is also tested using Kruskal-Wallis test. The percentage of utilization and behavioral records in the forest strata use in different age-sex class of the macaques was calculated and Kruskal-Wallis test was done to test the differences. The statistical significance was set at <0.05 for all the tests.

3.4 Ethical, Legal & Social Implications (ELSI)

All necessary permission to conduct the research was taken from Department of National Park and Wildlife Conservation, Babarmahal, Kathmandu, Nepal. No animals, plants or any form of bios or biomes were harmed while conducting the survey

4 RESULTS

4.1 Activity budgets of sympatric macaques

For the behavioral study, 150 hours of focal animal data were collected from each of Assamese macaques and rhesus macaques. Social behaviors constituted the major proportion of diurnal activity budget for both the species (38.39% for Assamese macaques and 48.64% for rhesus macaques) and it was followed by feeding (28.27%) in Assamese macaques and resting (21.0%) in rhesus macaques (**Annex 3**).

4.1.1 Activity budgets of Assamese macaques

Females of Assamese macaques (FAM) spent higher percentage of time on feeding (30.78%) than males whereas males of Assamese macaques (MAM) spend higher percentage on rest of the behavioral activities (**Figure 2**). Significant difference in the activity budget among male and female of Assamese macaques were found. Females of Assamese macaques spend significantly more time in feeding (One way ANOVA, $F= 9.759$, $p < 0.05$) and males of Assamese macaques spend more time in moving (One way ANOVA, $F= 5.102$, $p < 0.05$) (**Table 3**).

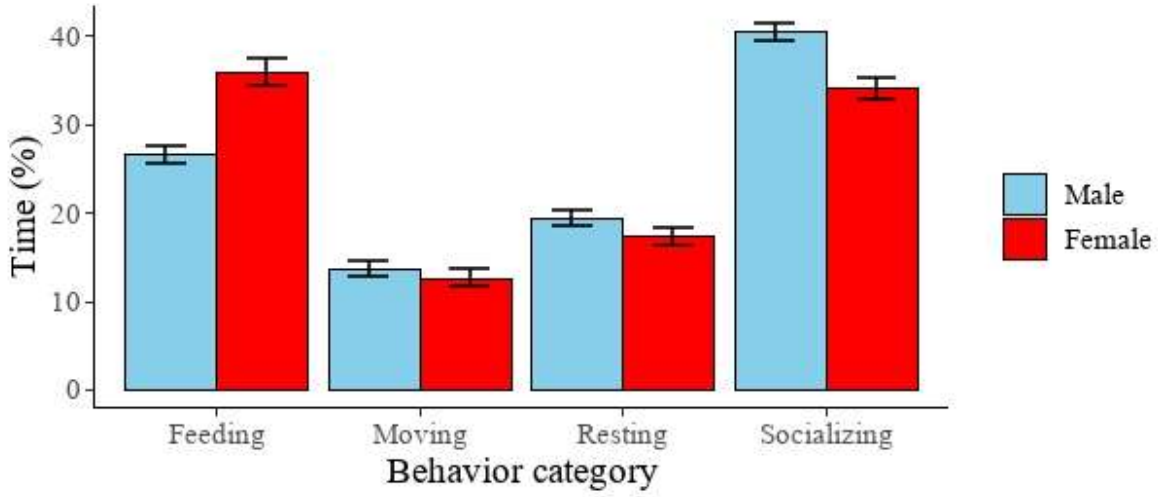


Figure 2. Daily average activity budgets of males and females of Assamese macaques
Error bars indicate 95% confidence intervals

Table 3. Results of one-way ANOVA on activity budgets of males and females of Assamese and rhesus macaques

	Feeding		**Moving**		**Resting**		**Socializing**	
	F	P	F	P	F	P	F	P
MAM vs FAM	9.759	**0.002**	5.102	**0.024**	0.612	0.434	2.192	0.139
MRM vs FRM	0.096	0.757	0.611	0.435	0.046	0.831	6.342	**0.012**

4.1.2 Activity budgets of rhesus macaques

Males of rhesus macaques (MRM) spent higher percentage of time on moving and socializing whereas females of rhesus macaques (FRM) spend higher percentage on feeding and resting than males (**Figure 3**). Significant difference in the activity budget among male and female of rhesus macaques was found. Males of rhesus macaques spend significantly more time in socializing (One-way ANOVA, $F= 6.342$, $p < 0.05$) (**Table 3**).

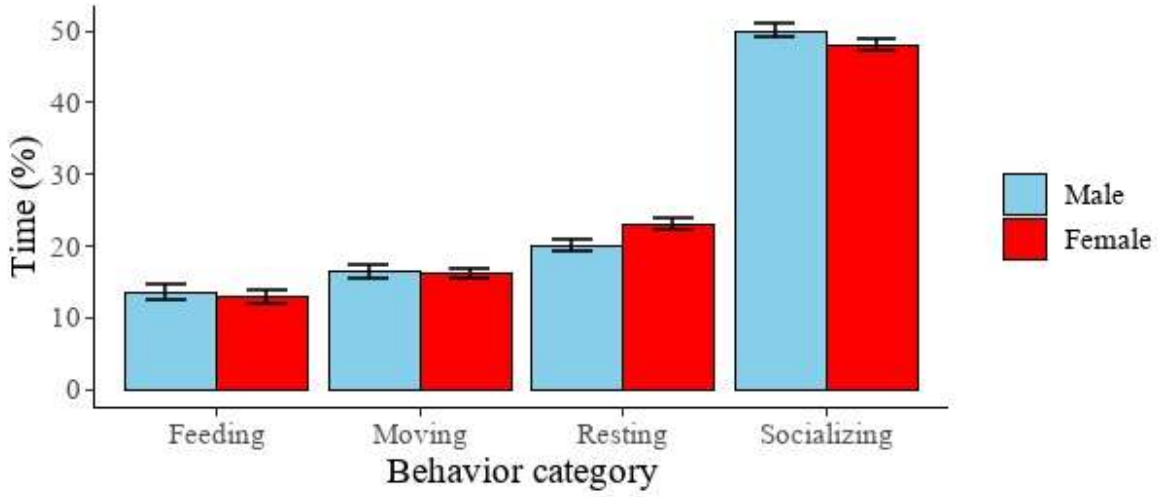


Figure 3. Daily average activity budgets of males and females of rhesus macaques
Error bars indicate 95% confidence intervals

4.1.3 Interspecific difference on activity budgets

Assamese macaques spent higher percentage of time on feeding than rhesus macaques whereas the later spent higher percentage of time on rest of the behavioral states. There was significant difference in the activity budget between males of Assamese macaques and rhesus macaques. Males of Assamese macaques spend significantly more time in feeding (One way ANOVA, $F= 4.657$, $p < 0.05$) and males of rhesus macaques spend more time in moving (One way ANOVA, $F= 9.247$, $p < 0.05$) (**Table 4**).

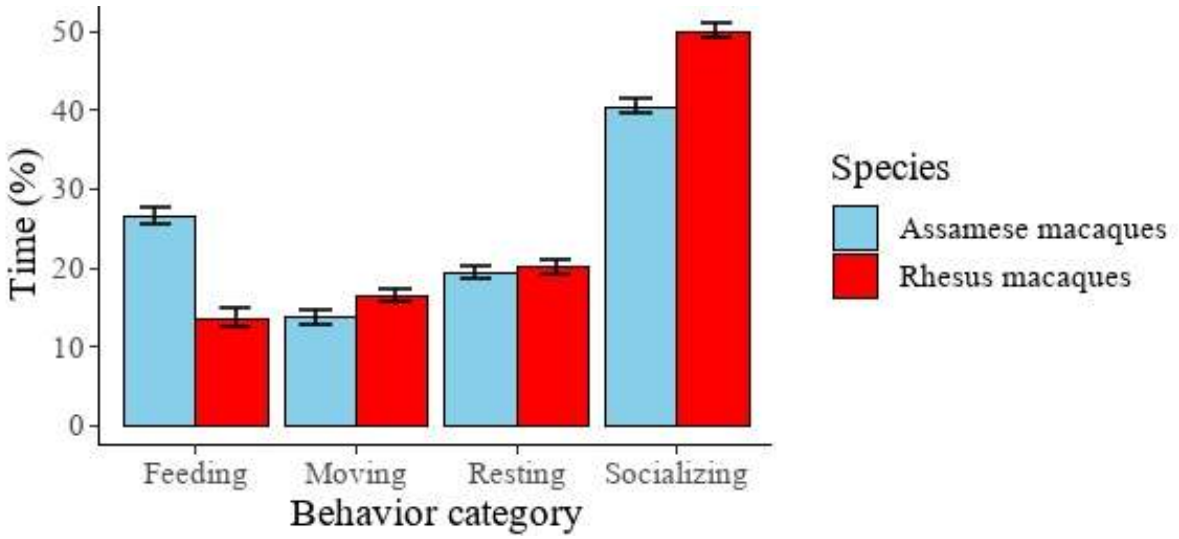


Figure 4 Daily average activity budgets of males of Assamese and rhesus macaques

Error bars indicate 95% confidence intervals

Table 4 Results of one-way ANOVA on activity budgets between males of Assamese and rhesus macaques and between females of Assamese and rhesus macaques

	Feeding		**Moving**		**Resting**		**Socializing**	
	F	P	F	P	F	P	F	P
MAM vs MRM	4.657	**0.032**	9.247	**0.002**	0.725	0.395	5.667	**0.017**
FAM vs FRM	23.025	**<0.05**	2.595	0.108	0.009	0.926	1.544	0.214

Similarly, there was significant difference in the activity budget between females of Assamese macaques and rhesus macaques. Females of Assamese macaques spend more time in feeding (One-way ANOVA, $F = 23.025$, $p < 0.05$) than females of rhesus macaques (**Table 4**)

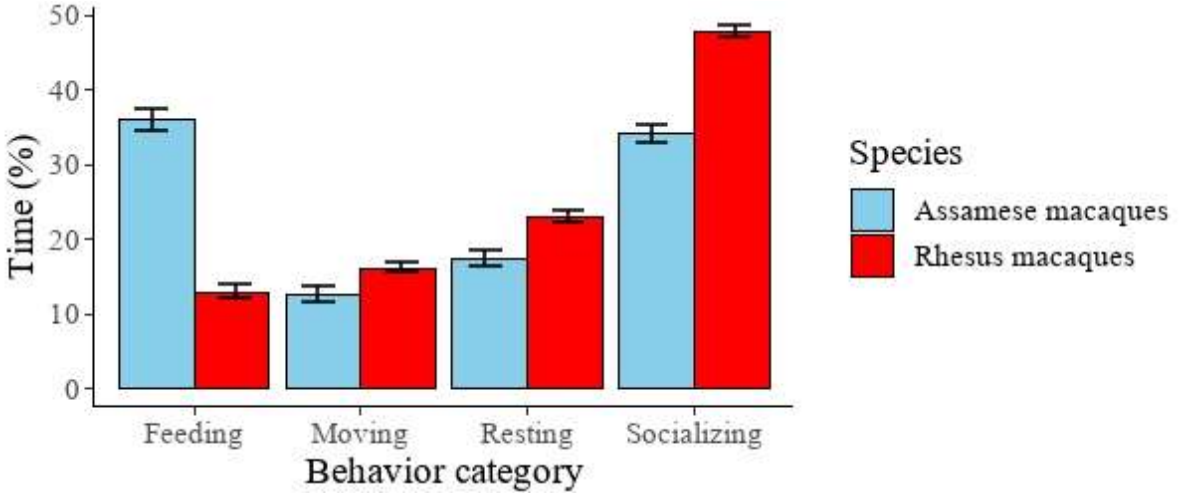


Figure 5. Daily average activity budgets of females of Assamese and rhesus macaques

Error bars indicate 95% confidence intervals

4.2 Forest strata use by the macaques

During instantaneous scans, 2100 scans (1050 scans of Assamese macaques and 1050 scans of rhesus macaques) were conducted and 23322 behavioral records (9856 behavioral record of Assamese macaques and 13475 behavioral record of rhesus macaques) were collected (record=record of one individual in a scan) with 9.3 Assamese macaque on average during each scan (mean: 9.3 ± 3.9, range: 1 to 24) and 13.7 rhesus macaque on average during each scan (mean: 13.7 ± 7.9, range: 1 to 43).

4.2.1 Sightings per strata

Assamese macaques were seen more time on tree than on the ground. Among the forest strata, they used 5–15 m strata more often than other strata (**Figure 6**). Average 80.12±68.42 Assamese macaques were observed on the 5–10 m stratum and 43.1±36.69 Assamese macaques were observed on 10–15 m stratum per day. 32.14±30.93 of them were seen on the ground. Based on the observed data, there was significant difference in the forest strata use by Assamese macaques (Kruskal-Wallis $\chi 2 = 52.163$, df = 6, $P < 0.05$).

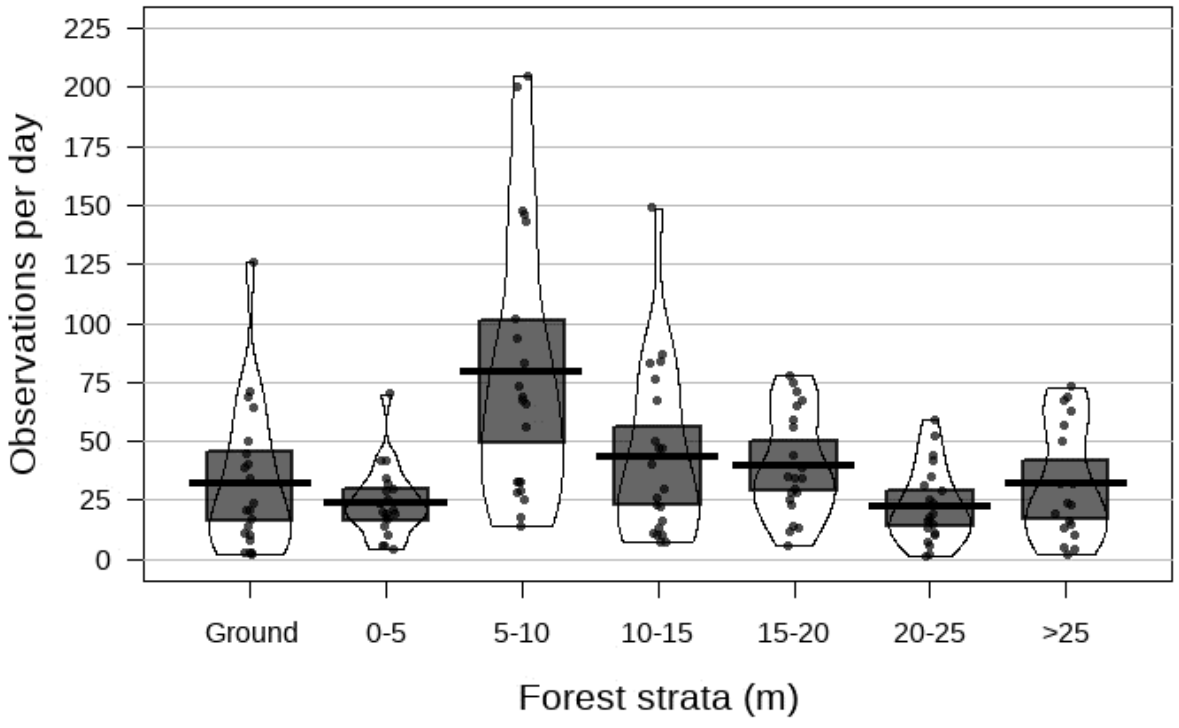


Figure 6. Sighting of Assamese macaques in each forest stratum in Nagarjun Forest of Shivapuri-Nagarjun National Park

Rhesus macaques did not use the strata evenly (**Figure 7**). The number of observation on forest floor or ground was significantly higher than the observation in trees. Average 184.6±94.09

rhesus macaques were seen on the ground floor per day. After the ground floor, rhesus macaques were mostly seen in the forest strata low 10 m. 46±25.52 rhesus macaques were seen on 0–5 m strata each day. There was significant difference in the forest strata use by the rhesus macaques (Kruskal-Wallis $\chi 2 = 101.83$, df = 6, P <0.05).

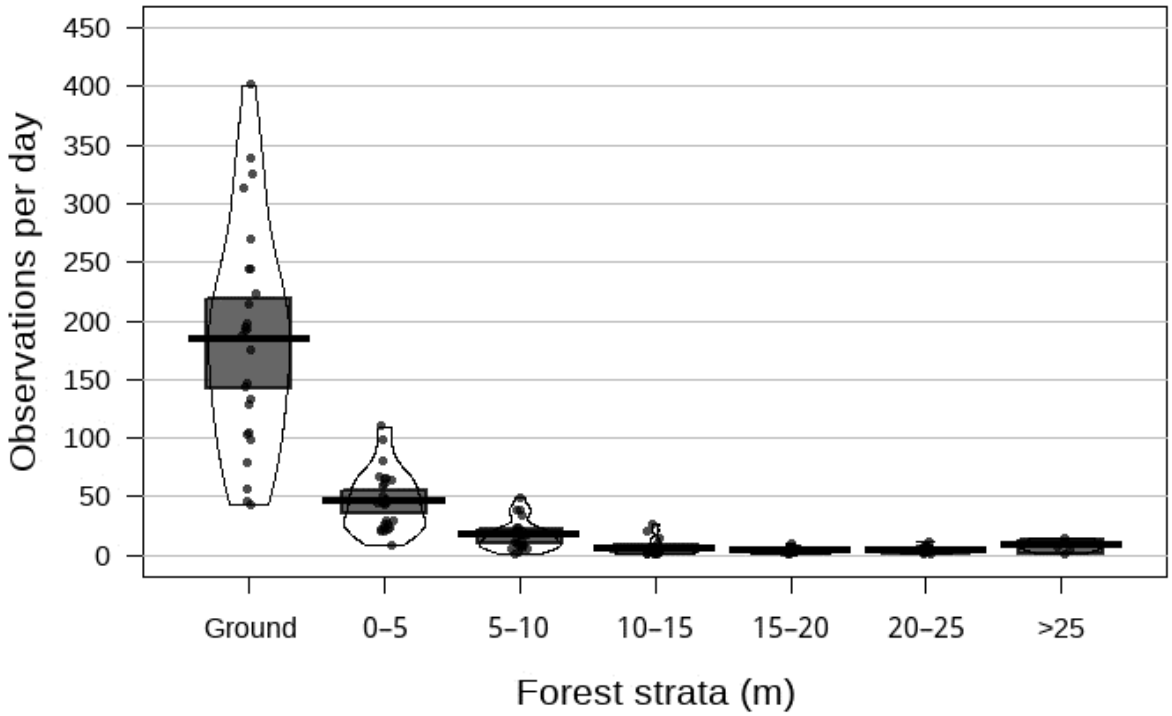


Figure 7. Sightings of rhesus macaques in each forest stratum in Nagarjun Forest of Shivapuri-Nagarjun National Park

4.2.1.1 Interspecies comparison of forest strata use

Assamese macaques used the higher forest strata more often than the ground. The Assamese macaques spend more than 88.4% of their time in arboreal habitat whereas rhesus spend more than 62.72% of their time in forest floor (**Figure 8**). There was a significant difference (Mann-Whitney U test, W = 16655214, P <0.001) between the forest strata use in the Assamese macaques compared to rhesus macaques.

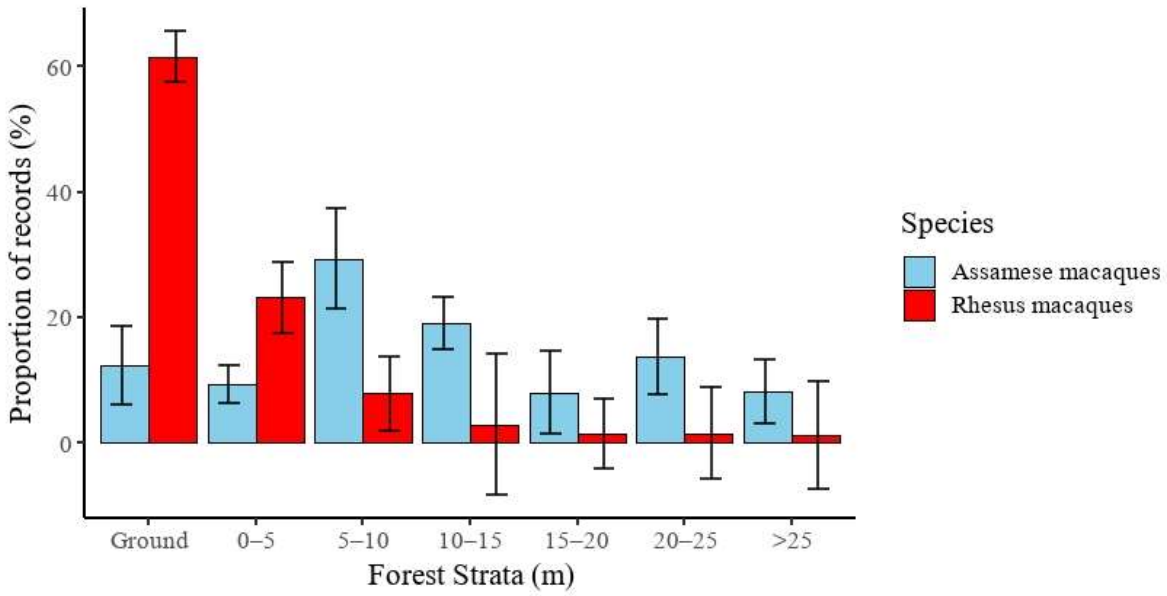


Figure 8. Monthly average forest strata use of Assamese and rhesus macaques in Nagarjun Forest of Shivapuri-Nagarjun National Park

Error bars indicate 95% confidence intervals

4.2.2 Forest strata use by macaques for various behaviors

4.2.2.1 Forest strata use by Assamese macaques

All age sex group of Assamese macaques did not use forest strata evenly except females with infants and infants. There were significant difference proportion of the forest strata use by different age-sex group of Assamese macaques (Kruskal-Wallis test, AM: $\chi2 = 17.262$, df = 6, P <0.05; AF: $\chi2 = 14.542$, df = 6, P <0.05; FI: $\chi2 = 11.964$, df = 6, P = 0.063; J: $\chi2 = 20.475$, df = 6, P <0.05; I : $\chi2 = 3.9147$, df = 6, P = 0.688).

Assamese macaque spent most of the time in the ground for feeding. When on ground, Assamese macaques engaged in feeding (47.64%), moving (34.23%), and socializing (11.41%), and rarely in resting (6.49%) (**Figure 9**). On forest stratum, Assamese macaques spend, on average, 5.29% of time feeding (range: 1.99%–12.13%), 30.93% of moving resting (range: 22.46%–40.83%), 29.38 % resting (range: 27.24%–32.57%) and 34.4% on socializing (range: 18.93% –41.32%). Assamese macaques were also engaged in different behaviors when using different strata (Kruskal-Wallis test: feeding, $\chi2 = 25.38$, df = 6, P < 0.05; moving, $\chi2 = 9.5534$, df = 6, P =0.1448; resting, $\chi2=29.676$, df=6, P<0.05; socializing, $\chi2 = 11.739$, df = 6, P =0.068).

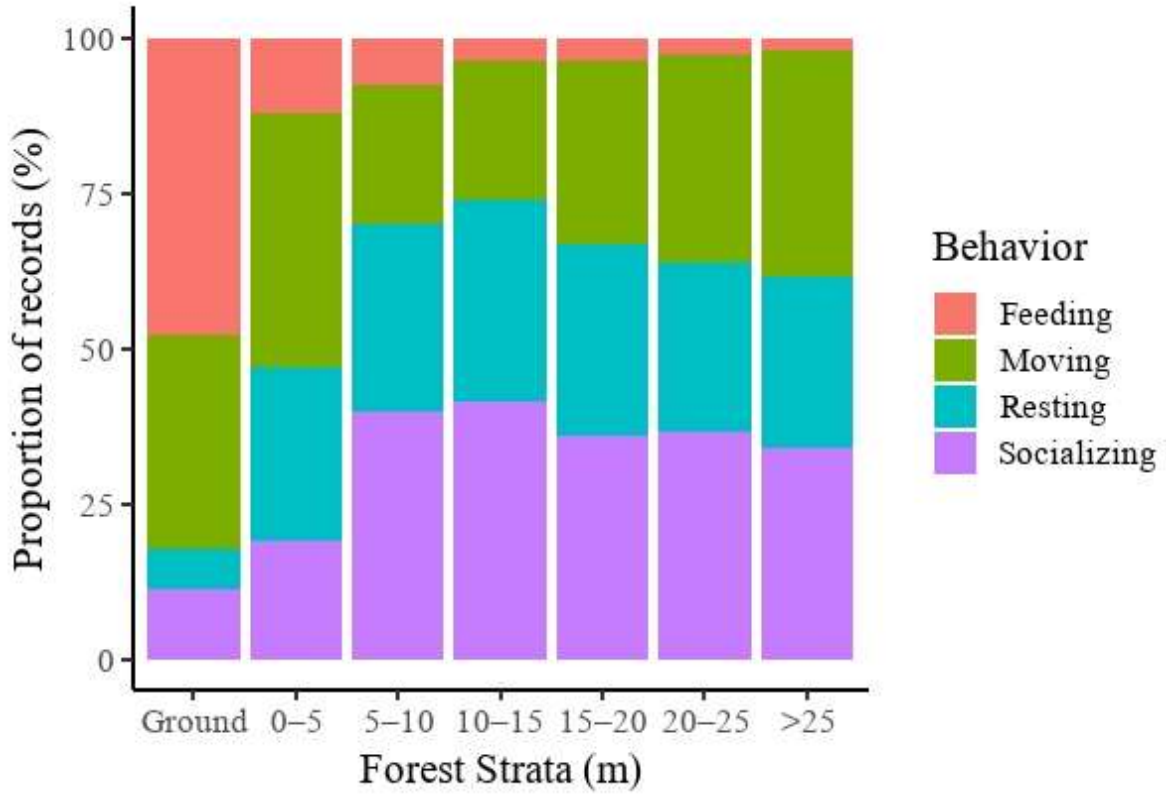


Figure 9. Strata use patterns of Assamese macaques in Nagarjun Forest of Shivapuri-Nagarjun National Park when engaged in different activities

4.2.2.2 Forest strata use by rhesus macaque

All age sex group of rhesus macaques did not use forest strata evenly. There was significant difference in proportion of the forest strata use by different age-sex group of rhesus macaques (Kruskal-Wallis test, AM: $\chi2 = 28.275$, df = 6, P <0.05 ; AF: 14.702, df = 4, P <0.05; FI: $\chi2 = 24.757$, df = 6, P <0.05 ; J: $\chi2 = 13.131$, df = 5, P <0.05; I : $\chi2 = 11.709$, df = 4, P <0.05).

Rhesus macaques perform most of their behavioral activities in the ground layer (**Annex 2**). Rhesus macaque spent majority of the time in the ground. When on ground, rhesus macaques engaged in feeding (7.86%), moving (40.56%), resting (26.06%) and socializing (25.52%) (**Figure 10**). On forest stratum, rhesus macaques spend, on average, 14.06% of time feeding (range: 4.05%–42.86%), 30.46% of moving (range: 24.14%–42.31%), 41.42 % resting (range: 14.29%–58.33%) and 16.41% on socializing (range: 8.33% –31.175%) (**Figure 10**). Rhesus macaques were also engaged in different behaviors when using different strata (Kruskal-Wallis test: feeding, $\chi2 = 14.677$, df = 6, P < 0.05; moving, $\chi2 = 33.347$, df = 6, P <0.05; resting, $\chi2=26.456$, df=6, P<0.05; socializing, $\chi2 = 26.609$, df = 6, P < 0.05).

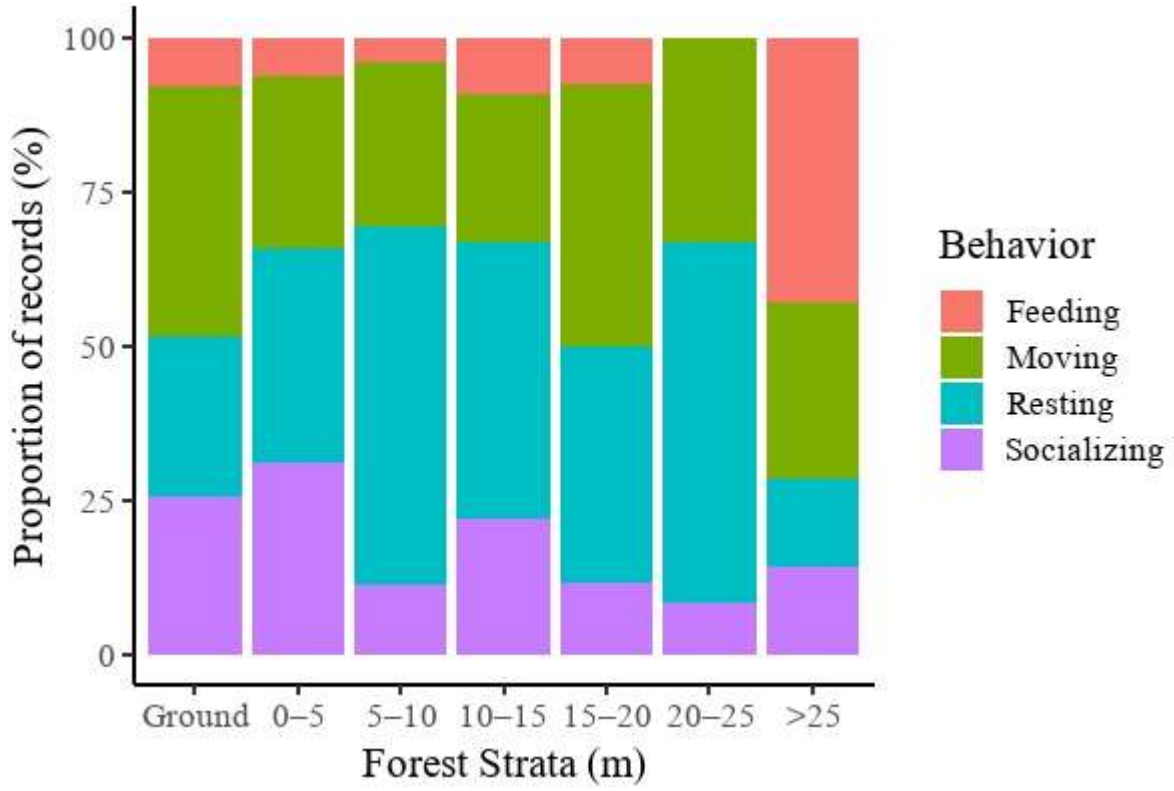


Figure 10. Strata use patterns of rhesus macaques in Nagarjun Forest of Shivapuri-Nagarjun National Park when engaged in different activities

4.2.3 Age-sex based difference on forest strata use

4.2.3.1 Interspecies comparison of forest strata for different age-sex group

Significant difference was seen in the forest strata use pattern by different age-sex group of the Assamese and rhesus macaques (Mann-Whitney U test, AM: $W = 114969$, $P < 0.05$; AF, $W = 18619$, $P < 0.05$, FI, $W = 27410$, $P < 0.05$; J, $W = 23045$, $P < 0.05$; I, $W = 5962.5$, $P < 0.05$). All age-sex group of Assamese macaques used 5-10 m more often than other forest strata. For rhesus, adult males, adult females and female with infants used forest floor significantly more than other strata. Juveniles of rhesus macaques used ground more followed by 0–10 m whereas infants of rhesus macaques were seen mostly below 5 m (**Figure 11**).

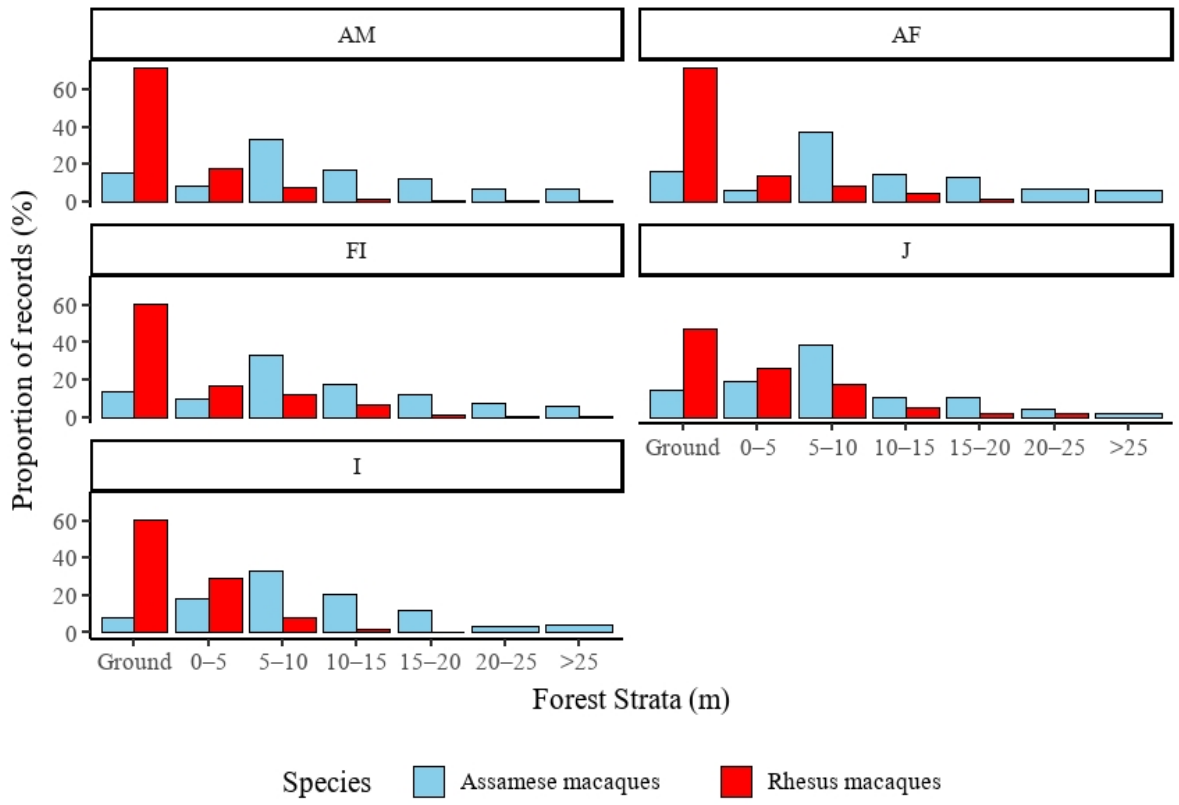


Figure 11. Comparison of the overall forest strata use by different age-sex group between Assamese and rhesus macaques

4.2.3.2 Interspecies comparison of forest strata for different behavior category

There was significant difference in the pattern in which the Assamese and rhesus macaques use the different forest strata for different activities (Mann-Whitney U test: Feeding, W = 24711, P <0.05; Moving, W = 115379, P < 0.05; Resting = 90416, P < 0.05; Socializing, W = 45495, P < 0.05). For feeding, both macaques use Forest floor more often than other strata. The second most used strata for feeding in the Assamese macaque is 5–10 m whereas for rhesus it is 0–5 m. While moving, Assamese macaques use 5–10 m more followed by 0–5 m and 10–20 m. Rhesus uses forest floor significantly more while travelling (**Figure 12**).

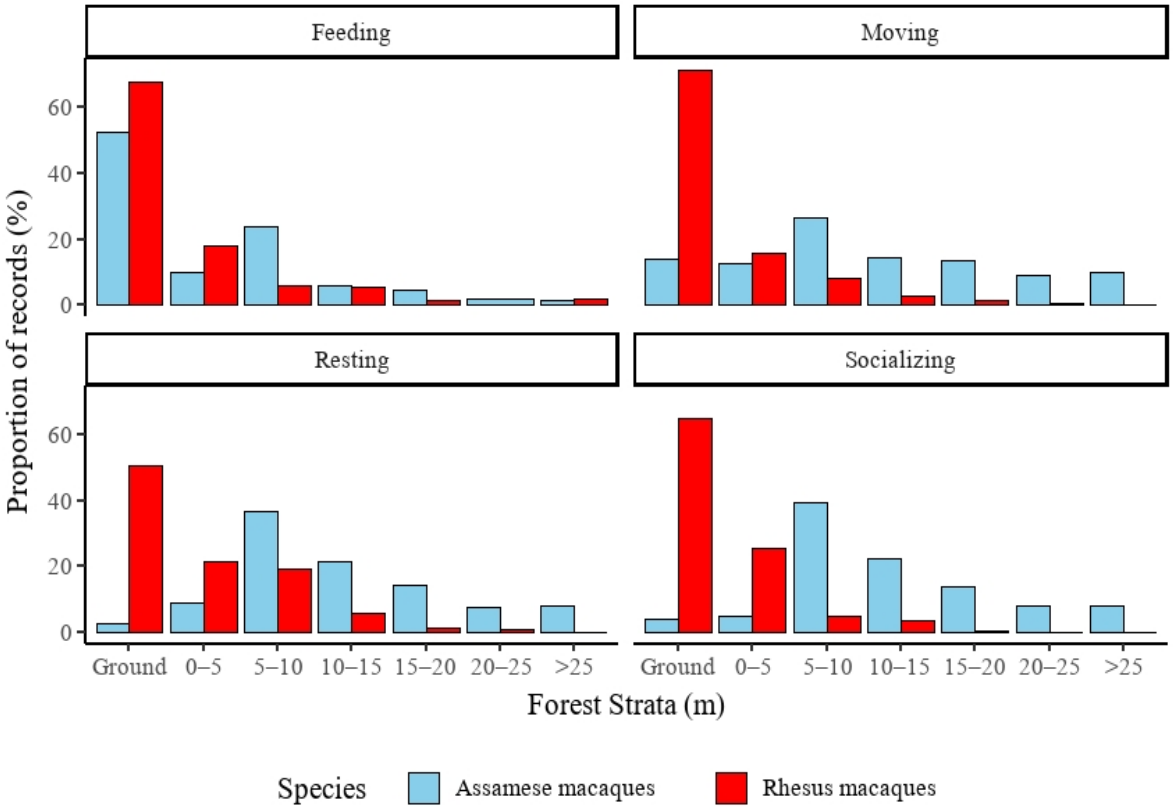


Figure 12. Comparison of the overall forest strata use between Assamese and rhesus macaques in different behavior category

Resting was done mostly in the strata 5–20 m by Assamese macaques whereas rhesus rested mostly below 10 m. Social activities by Assamese macaques were performed mostly above 5 m from ground and rhesus did most of the socializing below 5 m (**Figure 12**).

5 DISCUSSION

5.1 Activity budget of sympatric macaques

This study observed that both Assamese and rhesus macaques spend majority of diurnal time in socializing. They were also seen resting frequently. The frequency of aggression in Assamese macaques was significantly less than rhesus macaques and they travelled less distance than rhesus macaques. Assamese macaques were mostly found on tree whereas rhesus macaques were seen on the ground.

Assamese macaques were seen spending more time in feeding and socializing. This is as reported by Justa et al. (2019) that Assamese macaques more time feeding. Assamese macaques spending most of their time socializing was different from the report by Justa et al. (2019) who reported Assamese macaques spend most of the time feeding and less in socializing. Rhesus macaques spent most time in resting and socializing and less in moving and feeding. This is similar as reported by Justa et al. (2019). Another study however showed that rhesus spend most of their time in feeding and moving (Khatiwada et al. 2020). The difference in the higher feeding in Assamese macaques can be attributed to the availability of food near their resting area.

There was also significant differences in activity budget between males and female of the macaques. Males of Assamese macaques spend significantly more time in feeding and social interaction whereas males of rhesus macaques spend more time in socializing. Females of Assamese macaques spend more time in socializing and feeding whereas female of rhesus macaques spend more time in resting and socializing. Zhou et al. (2014) reported that males of Assamese macaques were seen spending more time in feeding whereas males of rhesus spend more time socializing as. The female Assamese macaques also spend significantly less time in resting than females of rhesus macaques.

The reason for more feeding in Assamese macaques than rhesus macaques can be attributed to frequent availability and access to food (Upadhayay et al. 2018). Assamese macaques were seen foraging mostly on the food scraps from the Army kitchen nearby. This availability of food may have also caused the Assamese macaques to change their habitat use pattern. Assamese macaques were not habituated to humans thus they only came to the ground floor while foraging and they spend a significant portion of their time in trees. Rhesus macaques were more habituated and came in direct contact with the human beings more than the

Assamese macaques. Since, rhesus macaques were in direct contact with human beings, they had to move more frequently than the Assamese macaques to go near the human for the food (Upadhayay et al. 2018). Assamese macaques already have move in smaller range area than rhesus macaques (Khatiwada et al. 2020). As the food is readily available for the Assamese macaques near their resting ground, these Assamese macaques moved less distance than rhesus macaques.

Moving was seen less frequent in Assamese macaques than rhesus macaques. This was perhaps due to Assamese macaques being dependent on fewer food items than rhesus macaques as suggested by Khatiwada et al. (2020), which makes rhesus macaques more prone to wandering due to opportunistic feeding and are more exploratory than Assamese macaques.

5.2 Forest strata use by sympatric macaques

The results of this study showed that Assamese and rhesus macaques utilize different habitats, perform different activities, and these utilizations vary in different age-sex group.

It was found that Assamese macaques spend more time in arboreal habitats. Assamese macaques spent 88.4% of their time was in different arboreal strata. This is different from the report of Zhou et al. (2014) and Chen et al. (2019) where it was found that Assamese macaques used ground level more frequently than the other strata. Assamese macaques spend majority of their time on the ground for feeding purpose. Assamese macaques descended to the ground when searching for food. As the study group was semi-provisioned on the food scraps from the nearby Army barracks, the number of trips to the ground for food was significantly higher (**Annex 1**). This caused Assamese macaques to use the forest floor more often during feeding (52.2%). This is similar as reported by Huang et al. (2015)

Assamese macaques also used higher strata (5–10 m) for feeding natural food such as tree leaves, flower and seeds and they also ate and chewed the already foraged feed in 5–10 m which is similar as reported by Justa et al. (2019) who found that Assamese macaques feed on ground and middle canopy (3–6m) more. Assamese macaques also travel 85.8% of times in the trees and 14.2% on the ground. Assamese macaques are adapted to arboreal locomotion as they exhibited a gait using the hands in a palmigrade posture and frequently flexing the fingers at varying degrees which is not optimized for terrestrial locomotion (Hirasaki et al. 2019).

Resting is a behavioral state with high-security requirements (Fruth & McGrew 1998) and even larger primates sleep on bare branches (Fruth & McGrew 1998, Anderson 2000). These

primates perform most of the activities on ground. Assamese macaques also predominantly rested in 5–15 m strata (59.11%) likely to avoid the potential, or perceived, risk of predation by terrestrial predators. Assamese macaques tend to move lot less than other macaques and they spend most of their time resting. Most of the social activities were also performed on 5–15 m. A previous study however found that Assamese macaques travelled, rested and performed social activities in ground (Huang et al. 2015).

This study showed that rhesus macaques spend 62.78% of their time in ground layer which is different from previously reported that rhesus predominantly use trees (Zhou et al. 2014). Rhesus macaques also used ground floor for majority of feeding, moving, and resting and for social activities which is similar to report of Justa et al. (2019) who found rhesus tended to feed on the ground. Previous study on Nonggang, China however showed that rhesus macaques used forest layer between 0–10 m for feeding, moving, resting and for social activities (Zhou et al. 2014). The variation in the strata use pattern in these two group of Assamese and rhesus macaques could be because of the feeding habit and the terrain use. In the study of Huang et al. (2015), the rhesus macaques were found on the hillsides because of their preference of fruits, which was abundantly found in hillsides whereas Assamese macaques which preferred *Indocalamus calcicolus* which was found in cliffs and hilltops (Zhou et al. 2011).

The reason for higher use of arboreal strata by Assamese macaques and ground floor by rhesus macaques can also be explained by the pattern of their movement. In the study, it was found that Assamese macaques use walking and climbing more often as a mode of locomotion whereas rhesus macaques walked significantly more (**Annex 4**). Assamese macaques moved vertically more often, whereas rhesus macaques tended to move horizontally which may have caused Assamese macaques to be arboreal, whereas the rhesus macaques were terrestrial (Khatiwada et al. 2020). The other vertical habitat use has been reported in Indo-Chinese gray langurs (*Trachypithecus crepusculus*), Golden Snub-Nosed Monkey (*Rhinopithecus roxellana)* (Zhu et al. 2015, Justa et al. 2019, Ma et al. 2020).

On the overall use of the forest strata by different age group, there was significant difference in all five age-sex group. The pattern in which each age sex group use the strata for different behavior was also significantly different. Adults of Assamese macaques and juvenile were seen feeding mostly in ground strata which was followed by 5–10 m forest level. However infants of Assamese macaques were fed mostly in 5–10 m level which was mostly through lactating. Adults and infants of rhesus macaques were seen feeding mostly in ground whereas juvenile

were seen using strata below 5 m more for feeding (**Annex 5**). The shift in the forest strata use while feeding by Assamese macaques may have been influenced due to human involvement as suggested by Siemers (2000) where he reported that primates changed their habitat use because of the food supplemented by humans. In this case, the food discards by human is the easily available food option for the Assamese macaques which may have shifted their forest utilization while feeding.

Adults of Assamese macaques travelled mostly above 5 m from the ground whereas juvenile travelled mostly between 0–10 m levels. Infants also travelled mostly above 5 m strata which was likely due to them accompanying their mother. Travelling of adult rhesus macaques occurred significantly in ground floor whereas Juvenile and infants both used ground and up to 5 m significantly more while travelling (**Annex 6**).

Adults and infants of Assamese macaques rested mostly above 5 m. Juveniles of Assamese macaques were seen resting mostly in 0–10 m range of forest strata. Adults male and female of rhesus macaques rested mostly in ground strata. Female with infants, juvenile and infants however rested mostly up to 10 m (**Annex 7**). Most of the socialization for all group of Assamese macaques occurred above 5 m. In rhesus macaques, adults socialized more on the ground whereas juvenile and infants were seen socializing in different strata below 10 m which was through playing (**Annex 8**).

Overall strata use pattern in adults, juvenile and infants of Assamese macaques did not vary significantly. In rhesus macaques, juvenile used arboreal substrate more than adults and infants (**Figure 11**). According to Li et al. (2022), juvenile macaques use arboreal substrate more while adult macaques use terrestrial and larger substrate. This could be also due to body size constraints (Grueter et al. 2013). Adult males of rhesus grow larger in size and become muscular which makes arboreal movement challenging for them.

The distinct vertical stratification in the habitat use by these macaques could be a mechanism to reduce interspecific competition (Ganzhorn 1989, Hadi et al. 2011). Assamese macaques spend most of the time in tree canopy which can be explained by Fleagle & Mittermeier (1980), who suggested that larger primates climb trees more often than smaller primates. Predation pressure from predators like leopards, which most likely prey on monkey on ground during the day, may also have pushed the macaques to occupy different habitats (Shrestha & Thapa 2016).

The dietary differences of these sympatric macaques also play role in the vertical stratification. Assamese macaques feed on tree foliage, climbers and vines (Khatiwada et al. 2020) which has caused them to spend time more in the middle canopy (Justa et al. 2019). In contrast, rhesus macaques depends largely on shrubs, herbs, grass and agricultural crops, therefore spent a majority of their time feeding at the ground level (Justa et al. 2019, Khatiwada et al. 2020). Rhesus macaques are also opportunistic feeders and they have broad range of food items, which has made rhesus utilize alternate food items in the absence of preferred food (Marshall & Wrangham 2007). Thus, they have travel huge ranging distance.

The instances of resource sharing is high among sympatric primates (Cords 1986, Chapman & Pavelka 2004). In sympatric Assamese and rhesus macaques, there are some dietary overlap as reported by Zhou et al. (2014) and Khatiwada et al. (2020). This may have reflected on the difference in the habitat use. Assamese and rhesus macaques exhibit different socioecological behavior such as different population density and group size, likely to reduce resource sharing and to decrease the degree of conflict (Chapman & Pavelka 2004). For example, rhesus macaques covers large distance while travelling likely to secure more food for their large group. The variation in habitat use and behavior of the macaques enable them to coexist through resource partitioning (Khatiwada et al. 2020).

6 CONCLUSION AND RECOMMENDATION

6.1 Conclusion

This study found that males of Assamese macaques spend significantly more time in feeding whereas males of rhesus macaques spend more time in moving, resting and socializing. Females of Assamese macaques also spend more time in feeding whereas females of rhesus macaques spend more time in other activities. The female Assamese macaques also spend significantly less time in resting than females of rhesus macaques. It was also found that Assamese macaques were mostly arboreal whereas rhesus macaques were mostly terrestrial. Assamese macaques do most of the activities in trees and only using ground floor for food foraging. The studied troop of Assamese macaques mostly depend on the food scraps of human. Rhesus macaques were seen mostly on ground and they perform all the activities mostly on ground. Age and sex also played role in strata use of macaques. Adults of rhesus were seen using forest floor significantly more than juvenile. Adult males and females of rhesus macaques use forest floor for sleeping whereas female with infants, juvenile and infants used trees up to 10 m for resting. Socialization of juvenile and infants also extended to 10 m which was primarily due to playing among other juveniles and infants. The study shows that there is significant niche partitioning among Assamese and rhesus macaques. This difference in the forest use can be linked with the morphology, food preference, behavior and the influence of the external factors such as humans.

6.2 Recommendation

During the study period, it was observed that Assamese macaques and rhesus macaques often forage in the trash discarded from the Army barrack and park visitors in the Balaju Garden. Due to this, it can be estimated that these macaques get habituated to humans. Rhesus macaques are already habituated to human. This may cause the macaques to encroach in human settlement. There is prospect of studying variation in the strata use by these macaques in the semi-provisioned group of macaques and the true wild troop of macaques.

7 REFERENCES

Altmann, J. 1974. Observational study of behavior: sampling methods. Behaviour **49**(3):227–267. https://doi.org/10.1163/156853974x00534.

Anderson, J. R. 2000. Sleep-related behavioural adaptations in free-ranging anthropoid primates. Sleep Medicine Review **4**(4):355–373. https://doi.org/10.1053/smrv.2000.0105.

Bitty, E. A. and McGraw, W. S. 2007. Locomotion and habitat use of Stampflii's putty-nosed monkey (*Cercopithecus nictitans stampflii*) in the Tai National Park, Ivory Coast. American Journal of Primatology **134**(3):383–391. https://doi.org/10.1002/ajpa.20679.

Boonratana, R., Chalise, M., Htun, S. and Timmins, R. J. 2020. *Macaca assamensis*. The IUCN Red List of Threatened Species 2020: e.T12549A17950189. https://doi.org/https://dx.doi.org/10.2305/IUCN.UK.2020-2.RLTS.T12549A17950189.en.

Chalise, M. K. 2013. Fragmented primate population of Nepal. In: (Eds) Primates in fragments. Springer. pp 329–356.

Chalise, M. K., Bhattarai, G. P. and Pandey, B. 2015. Ecology and behavior of Assamese monkeys in Shivapuri Nagarjun National Park, Nepal. Journal of Natural History Museum **27**:12–24. https://doi.org/10.3126/jnhm.v27i0.14149.

Chapman, C. A., Bicca-Marques, J. C., Dunham, A. E., Fan, P., Fashing, P. J., Gogarten, J. F., et al. 2020. Primates can be a rallying symbol to promote tropical forest restoration. Folia Primatologica **91**(6):669–687.

Chapman, C. A. and Pavelka, M. S. M. 2004. Group size in folivorous primates: ecological constraints and the possible influence of social factors. Primates **46**:1–9. https://doi.org/10.1007/s10329-004-0093-9.

Chen-Kraus, C., Raharinoro, N. A., Randrianirinarisoa, M. A., Anderson, D. J., Lawler, R. R., Watts, D. P., et al. 2022. Human-Lemur coexistence in a multiple-use landscape. Frontiers in Ecology and Evolution **10**. https://doi.org/10.3389/fevo.2022.779861.

Chen, T., Huang, Z., Huang, C.-m., Wei, H. and Zhou, Q. 2019. Positional behaviours of François' langur (*Trachypithecus francoisi*) in the Limestone Forest of Nonggang, Guangxi, South-West China. Folia Primatologica **91**(3):170–187. https://doi.org/10.1159/000502503.

Cords, M. 1986. Interspecific and intraspecific variation in diet of two forest guenons, *Cercopithecus ascanius* and *C. mitis*. Journal of Animal Ecology **55**(3):811–827. https://doi.org/10.2307/4418.

DNPWC 2019. Shivapuri Nagarjun National Park, Brochure, Kathmandu. Department of National Park and Wildlife Conservation.

Fleagle, J. 2013. *Primate adaptation and evolution*. Academic press. p 1–423.

Fleagle, J. G. and Mittermeier, R. A. 1980. Locomotor behavior, body size, and comparative ecology of seven Surinam monkeys. American Journal of Physical Anthropology **52**(3):301–314. https://doi.org/https://doi.org/10.1002/ajpa.1330520302.

Fruth, B. and McGrew, W. 1998. Resting and nesting in primates: Behavioral ecology of inactivity. American Journal of Primatology **46**:3–5. https://doi.org/10.1002/(SICI)1098-2345(1998)46:1<3::AID-AJP2>3.0.CO;2-#.

Ganzhorn, J. U. 1989. Niche separation of seven lemur species in the eastern rainforest of Madagascar. Oecologia **79**(2):279–286. https://doi.org/10.1007/BF00388489.

Gause, G. 1934. *The struggle for existence*. Baltimore, Maryland, Williams and Wilkins. p 163.

Ghimire, K. and Chalise, M. K. 2021. Activity pattern and habitat association of Assamese macaques *Macaca assamensis* McClelland, 1840 in Shivapuri Nagarjun National Park, Nepal. Nepalese Journal of Zoology **5**(2):51–61. https://doi.org/10.3126/njz.v5i2.42032.

Grueter, C. C., Li, D., Ren, B. and Li, M. 2013. Substrate use and postural behavior in free-ranging snub-nosed monkeys (*Rhinopithecus bieti*) in Yunnan. Integrative Zoology **8**(4):335–345. https://doi.org/10.1111/1749-4877.12023.

Hadi, S., Ziegler, T., Waltert, M., Syamsuri, F., Mühlenberg, M. and Hodges, J. K. 2011. Habitat use and trophic niche overlap of two sympatric colobines, *Presbytis potenziani* and *Simias concolor*, on Siberut island, Indonesia. International Journal of Primatology **33**(1):218–232. https://doi.org/10.1007/s10764-011-9567-y.

Hirasaki, E., Malaivijitnond, S. and Hamada, Y. 2019. Locomotor kinematics of two semi-wild macaque species (*Macaca assamensis* and *Macaca arctoides*) in Thailand. Folia Primatologica **90**(3):162–178. https://doi.org/10.1159/000496024.

Huang, Z., Huang, C., Wei, H., Tang, H., Krzton, A., Ma, G., et al. 2015. Factors Influencing Positional Behavior and Habitat Use of Sympatric Macaques in the Limestone Habitat of Nonggang, China. International Journal of Primatology **36**(1):95–112. https://doi.org/10.1007/s10764-015-9813-9.

Justa, P., Kumar, R. S., Talukdar, G. and Sinha, A. 2019. Sharing from the same bowl: resource partitioning between sympatric macaque species in the western Himalaya, India. International Journal of Primatology **40**:356–373. https://doi.org/10.1007/s10764-019-00092-z.

Kanai, H. and Shakya, P. R. 1970. Vegetation survey of Nagarjun forest. In DMP (1973) Bulletin of the Department of Medicinal Plants. No. 4 - Flora of Nagarjun: iii-vi, 1-93 and I-XIX.

Khatiwada, S., Paudel, P. K., Chalise, M. K. and Ogawa, H. 2020. Comparative ecological and behavioral study of *Macaca assamensis* and *M. mulatta* in Shivapuri Nagarjun National Park, Nepal. Primates **61**(4):603–621. https://doi.org/10.1007/s10329-020-00810-9.

Li, P. H., Li, W. B., Li, B. W., Li, Y. D., Wang, X. and Li, J. H. 2022. Positional behavior and substrate use in wild Tibetan macaques. Animals **12**(6). https://doi.org/10.3390/ani12060767.

Liu, F., Li, Y., Zhang, K., Liang, J., Nong, D. and Huang, Z. 2022. Habitat use of the white-headed langurs in limestone forest of Southwest Guangxi, China: Seasonality and group size effects. Ecology and Evolution **12**(7). https://doi.org/10.1002/ece3.9068.

Ma, C., Xiong, W. G., Yang, L., Zhang, L., Tomlin, P. R., Chen, W., et al. 2020. Living in forests: strata use by Indo-Chinese gray langurs (*Trachypithecus crepusculus*) and the effect of forest cover on *Trachypithecus* terrestriality. Zoological Research **41**(4):373–380. https://doi.org/10.24272/j.issn.2095-8137.2020.047.

Marshall, A. and Wrangham, R. 2007. Evolutionary Consequences of Fallback Foods. International Journal of Primatology **28**:1219–1235. https://doi.org/10.1007/s10764-007-9218-5.

McGraw, W. S. and Bshary, R. 2002. Association of terrestrial mangabeys (*Cercocebus atys*) with arboreal monkeys: experimental evidence for the effects of reduced ground predator pressure on habitat use. International Journal of Primatology **23**:311–325. https://doi.org/10.1023/A:1013883528244.

Mekonnen, A., Fashing, P. J., Sargis, E. J., Venkataraman, V. V., Bekele, A., Hernandez-Aguilar, R. A., et al. 2018. Flexibility in positional behavior, strata use, and substrate utilization among Bale monkeys (*Chlorocebus djamdjamensis*) in response to habitat fragmentation and degradation. American Journal of Primatology **80**(5):e22760. https://doi.org/10.1002/ajp.22760.

Oviedo, L., Fernández, M., Herra-Miranda, D., Pacheco-Polanco, J. D., Hernández-Camacho, C. J. and Aurioles-Gamboa, D. 2018. Habitat partitioning mediates the coexistence of

sympatric dolphins in a tropical fjord-like embayment. Journal of Mammalogy **99**(3):554–564. https://doi.org/10.1093/jmammal/gyy021.

Pandey, B. P. and Chalise, M. K. 2015. General ecology and time budgeting for Assamese monkey (*Macaca assamensis*) in Shivapuri Nagarjun National Park, Nepal. Biodiversity Conservation Efforts in Nepal (Special issue, DNPWC-2072):57–73.

Peres, C. A. 1994. Primate responses to phenological changes in an Amazonian terra firme forest. Biotropica **26**(1):98–112. https://doi.org/10.2307/2389114.

Pianka, E. R. 1981. *Competition and niche theory*. Blackwell Scientific Publications, Oxford. p 167–196.

Pontes, A. R. M. 1997. Habitat partitioning among primates in Maracá island, Roraima, northern Brazilian Amazonia. International Journal of Primatology **18**(2):131–157. https://doi.org/https://doi.org/10.1023/A:1026364417523.

Riley, E. P., Shaffer, C. A., Trinidad, J. S., Morrow, K. S., Sagnotti, C., Carosi, M., et al. 2021. Roadside monkeys: anthropogenic effects on moor macaque (*Macaca maura*) ranging behavior in Bantimurung Bulusaraung National Park, Sulawesi, Indonesia. Primates **62**(3):477–489. https://doi.org/10.1007/s10329-021-00899-6.

Rodman, P. S. 1991. Structural differentiation of microhabitats of sympatric *Macaca fascicularis* and *M. nemestrina* in East Kalimantan, Indonesia. International Journal of Primatology **12**:357–375.

Schreier, B., Harcourt, A., Coppeto, S. and Somi, M. 2009. Interspecific Competition and Niche Separation in Primates: A Global Analysis. Biotropica **41**:283–291. https://doi.org/10.1111/j.1744-7429.2008.00486.x.

Shrestha, P. M. and Thapa, T. B. 2016. Diet composition of leopard (*Panthera pardus*) in Shivapuri-Nagarjun National Park, Nepal. Journal of Ecosystem & Ecography **6**(1):66.

Siemers, B. M. 2000. Seasonal variation in food resource and forest strata use by brown capuchin monkeys (*Cebus apella*) in a disturbed forest fragment. Folia Primatologica **71**(3):181–184.

Singh, M., Kumar, A. and Kumara, H. 2020. *Macaca mulatta*. IUCN Red List of Threatened Species:e. T12554A17950825. https://doi.org/10.2305/IUCN.UK.2020-2.RLTS.T12554A17950825.en.

SNNP 2017. Shivapuri Nagarjun National Park and buffer zone management plan Fiscal Year 074/075-078/079 (2017/018-2021/022)

Upadhayay, P., Khanal, L., Ogawa, H. and Chalise, M. K. 2018. Behavioral asymmetries among Mother-Infant Dyads of Syntopic Macaques (*Macaca assamensis* and *M.*

mulatta) in Shivapuri-Nagarjun National Park, Nepal. Journal of Ecology & Natural Resources **2**(5). https://doi.org/10.23880/jenr-16000142.

Wallace, R. B. 2008. Factors influencing spider monkey habitat use and ranging patterns. In: (Eds) Spider Monkeys: Behavior, Ecology and Evolution of the Genus *Ateles*. Cambridge University Press. pp 138–154.

Xiang, Z., Huo, S., Xiao, W., Quan, R. and Grueter, C. C. 2009. Terrestrial behavior and use of forest strata in a group of black-and-white snub-nosed monkeys *Rhinopithecus bieti* at Xiaochangdu, Tibet. Current Zoology **55**(3):180–187. https://doi.org/https://doi.org/10.1093/czoolo/55.3.180.

Youlatos, D. 1999. Comparative locomotion of six sympatric primates in Ecuador. Annales des Sciences Naturelles **20**(4):161–168. https://doi.org/https://doi.org/10.1016/S0003-4339(00)88884-X.

Zhou, Q., Wei, H., Huang, Z. and Huang, C. 2011. Diet of the Assamese macaque *Macaca assamensis* in limestone habitats of Nonggang, China. Current Zoology **57**(1):18-25. https://doi.org/10.1093/czoolo/57.1.18.

Zhou, Q., Wei, H., Tang, H., Huang, Z., Krzton, A. and Huang, C. 2014. Niche separation of sympatric macaques, *Macaca assamensis* and *M. mulatta*, in limestone habitats of Nonggang, China. Primates **55**(1):125–137. https://doi.org/10.1007/s10329-013-0385-z.

Zhu, W. W., Garber, P. A., Bezanson, M., Qi, X. G. and Li, B. G. 2015. Age- and sex-based patterns of positional behavior and substrate utilization in the golden snub-nosed monkey (*Rhinopithecus roxellana*). American Journal of Primatology **77**(1):98–108. https://doi.org/10.1002/ajp.22314.

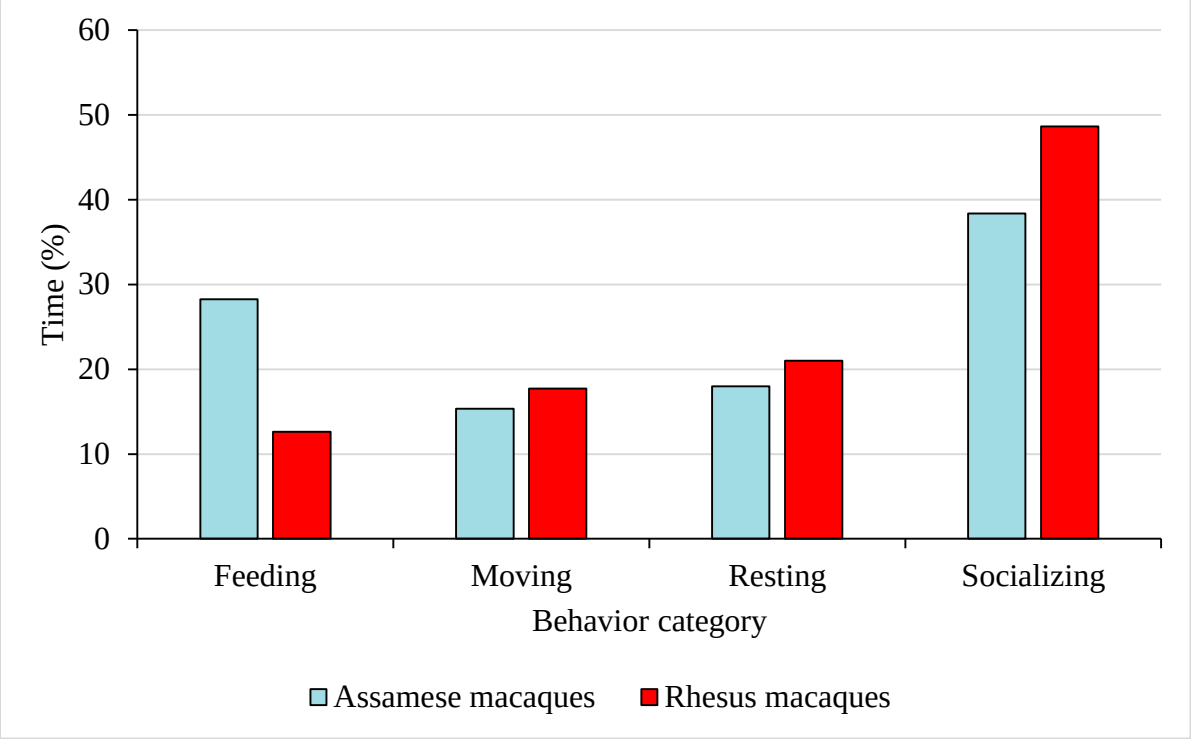
ANNEX

Annex 1. Descriptive summary on Strata use patterns of *M. assamensis* in Nagarjun Forest of Shivapuri-Nagarjun National Park when engaged in different activities

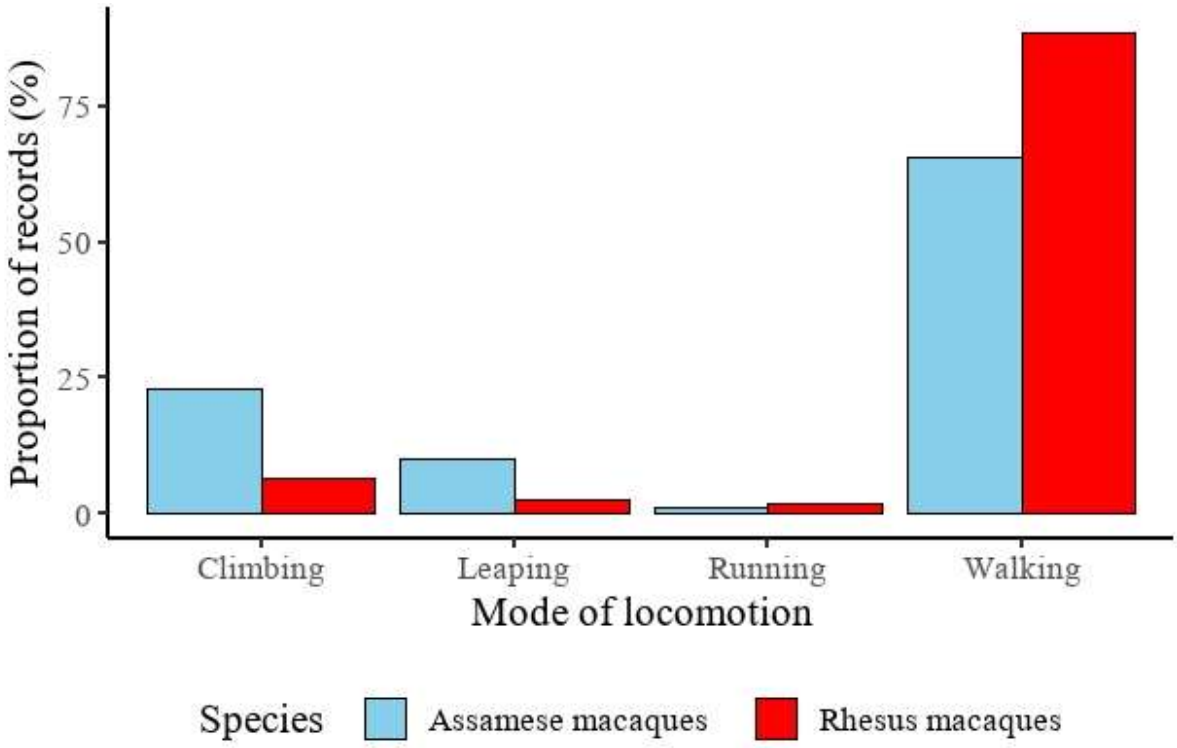
	Ground	**0–5 m**	**5–10 m**	**10–15 m**	**15–20m**	**20–25m**	**>25m**
Feeding							
Overall	52.20	10.00	23.90	6.10	4.39	1.95	1.46
Adult Males	53.53	12.94	18.82	4.71	5.88	2.35	1.76
Adult Females	63.39	5.36	22.32	4.46	2.68	-	1.79
Female with Infants	38.71	16.13	29.03	6.45	6.45	-	3.23
Juveniles	56.52	10.87	17.39	10.87	2.17	2.17	-
Infants	13.33	6.67	60.00	13.33	6.67	-	-
Moving							
Overall	14.02	12.65	26.40	14.39	13.57	8.89	10.08
Adult Males	19.41	7.13	29.73	14.00	12.29	8.11	9.34
Adult Females	14.69	11.89	25.17	12.59	16.78	10.49	8.39
Female with Infants	23.88	13.43	25.37	8.96	10.45	8.96	8.96
Juveniles	16.67	26.19	28.57	5.95	11.90	6.55	4.17
Infants	7.27	32.73	36.36	16.36	3.64	1.82	1.82
Resting							
Overall	2.76	9.03	36.79	21.58	14.45	7.51	7.89
Adult Males	2.89	9.74	37.63	23.16	14.47	6.84	5.26
Adult Females	4.32	7.41	41.98	22.22	12.96	5.56	5.56
Female with Infants	4.81	11.54	35.58	17.31	12.50	9.62	8.65
Juveniles	1.72	31.03	56.90	3.45	1.72	3.45	1.72
Infants	2.86	14.29	31.43	22.86	20.00	5.71	2.86
Socializing							
Overall	3.93	4.93	39.18	22.17	13.78	8.16	7.85
Adult Males	4.41	6.47	39.12	20.29	13.24	8.82	7.65
Adult Females	3.64	2.43	47.77	16.19	14.98	8.10	6.88
Female with Infants	6.67	2.67	40.00	30.67	14.67	5.33	-
Juveniles	3.62	8.70	50.00	20.29	15.22	2.17	-
Infants	10.10	14.14	27.27	23.23	14.14	4.04	7.07

Annex 2. Descriptive summary of strata use patterns of *M. mulatta* in Nagarjun Forest of Shivapuri-Nagarjun National Park when engaged in different activities

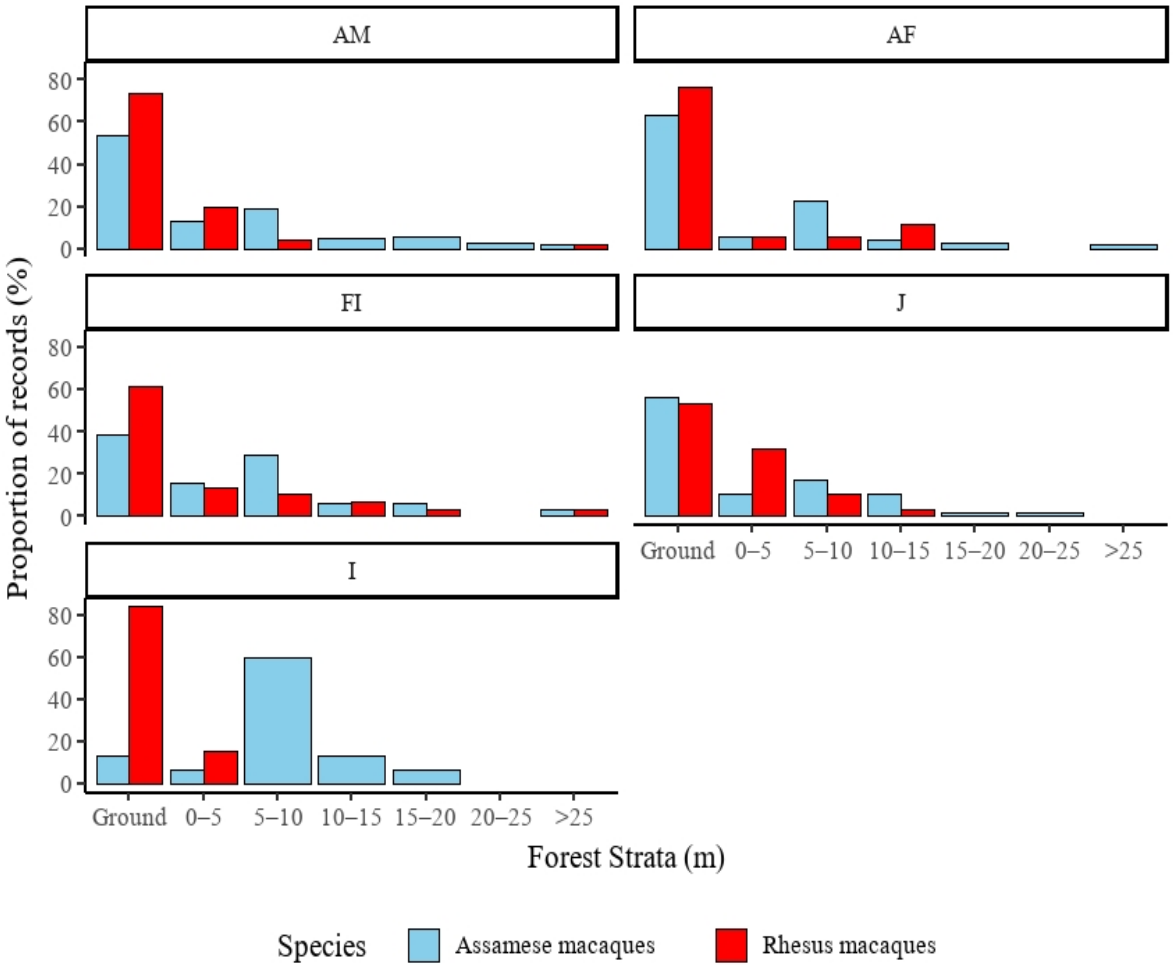
	Ground	**0–5 m**	**5–10 m**	**10–15 m**	**15–20 m**	**20–25 m**	**>25 m**
Feeding							
Overall	67.55	17.88	5.96	5.30	1.32	0.00	1.99
Adult Males	73.91	19.57	4.35	-	-	2.17	
Adult Females	76.47	5.88	5.88	11.76	-	-	-
Female with Infants	62.07	13.79	10.34	6.90	3.45	3.45	-
Juveniles	53.57	32.14	10.71	3.57	-	-	-
Infants	84.21	15.79	-	-	-	-	-
Moving							
Overall	71.18	15.70	7.98	2.84	1.49	0.54	0.27
Adult Males	79.37	12.94	3.85	1.75	1.75	0.35	-
Adult Females	75.93	12.96	7.41	3.70	-	-	-
Female with Infants	76.00	13.14	4.00	4.57	0.57	0.57	1.14
Juveniles	50.94	24.53	16.04	4.72	1.89	1.89	-
Infants	67.65	25.00	7.35	-	-	-	-
Resting							
Overall	50.60	21.56	19.31	5.84	1.50	1.05	0.15
Adult Males	58.24	23.08	15.38	1.1	0.55	1.65	-
Adult Females	64.91	15.79	15.79	3.51	-	-	-
Female with Infants	47.26	18.14	21.94	8.86	2.11	1.27	0.42
Juveniles	30	16.67	36.67	6.67	6.67	3.33	-
Infants	55.17	24.14	15.52	3.45	1.72	-	-
Socializing							
Overall	64.90	25.49	4.90	3.73	0.59	0.20	0.20
Adult Males	74.42	18.60	6.20	-	-	-	0.78
Adult Females	73.47	16.33	2.04	4.08	4.08	-	-
Female with Infants	65.38	23.08	3.85	6.41	1.28	-	-
Juveniles	48.08	30.77	13.46	5.77	-	1.92	-
Infants	55.24	37.14	5.71	1.90	-	-	-



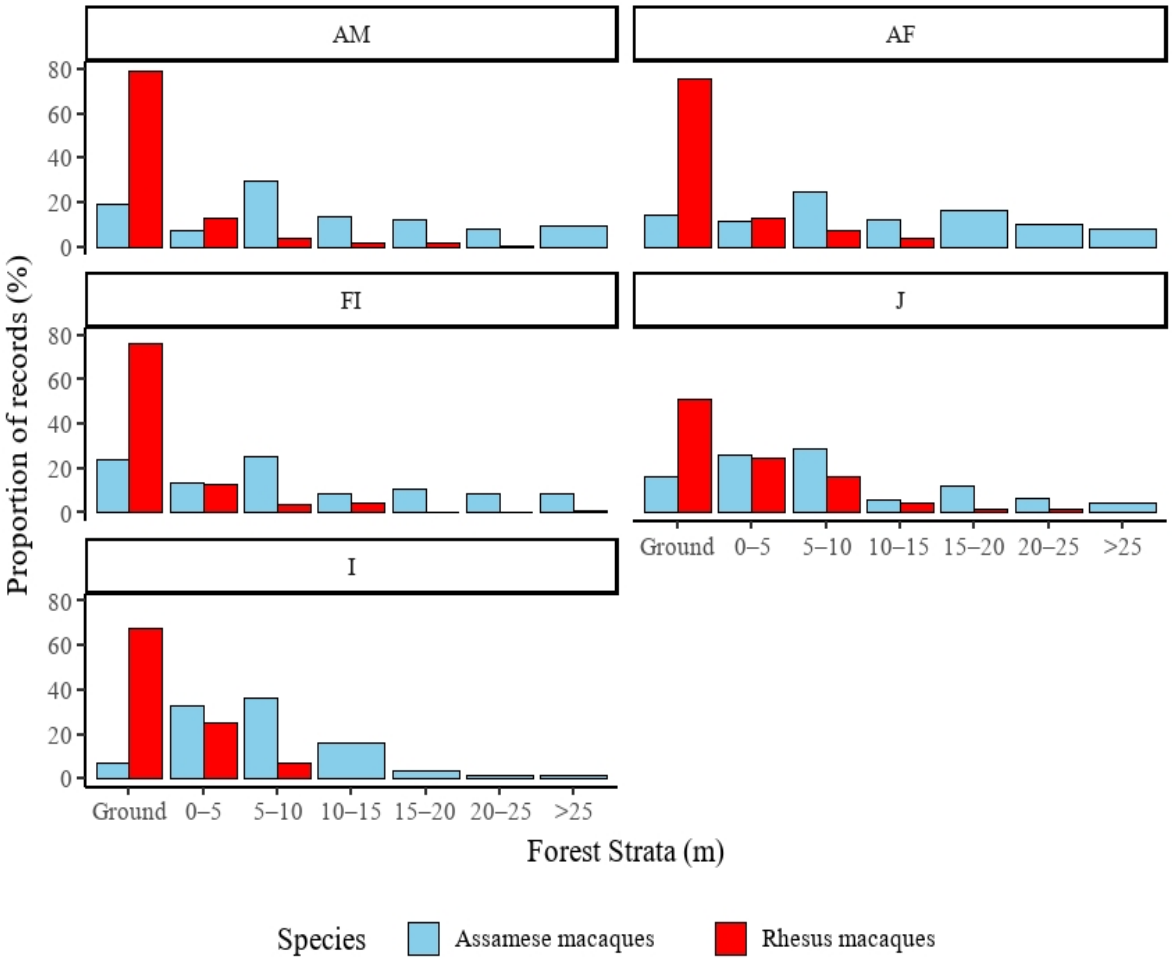
Annex 3. Overall activity budget of Assamese and rhesus macaques



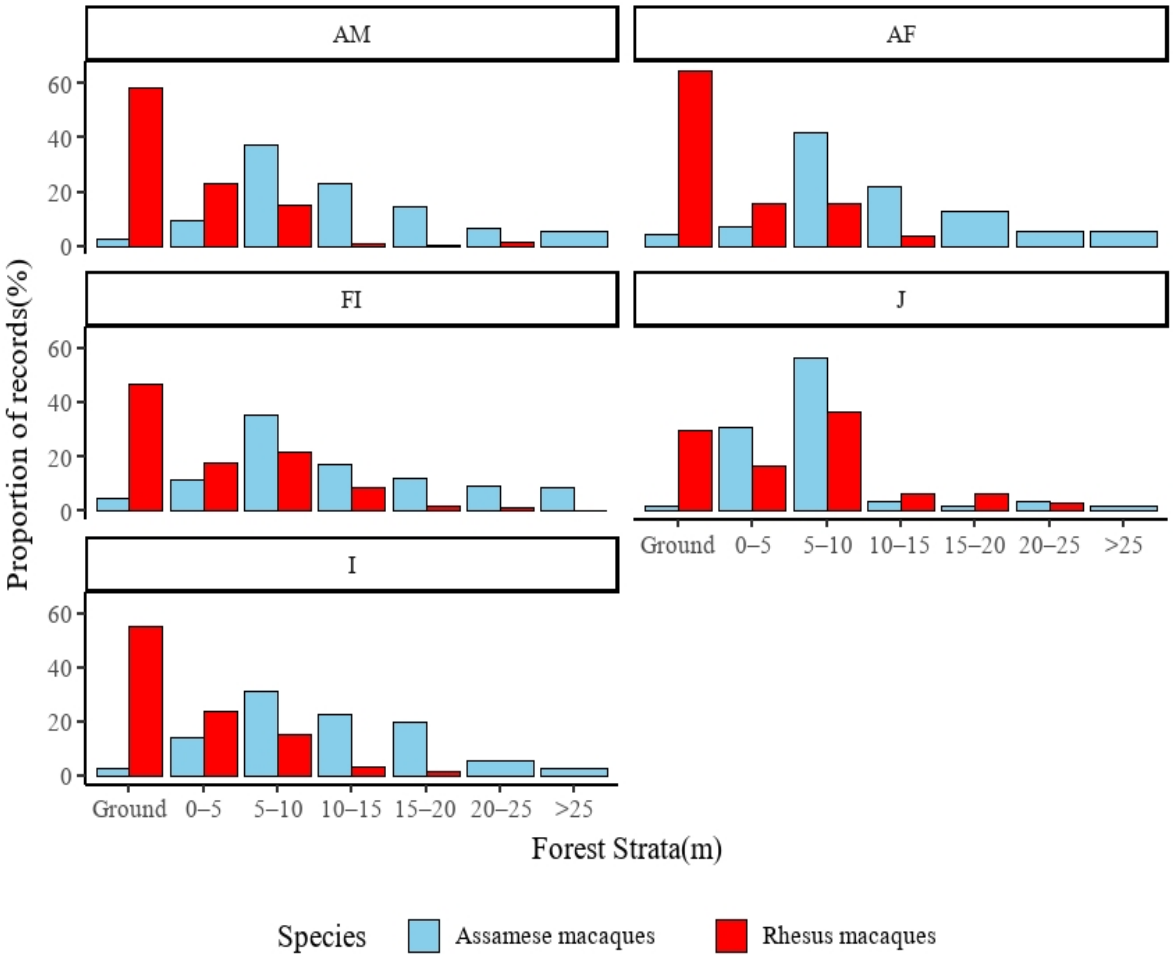
Annex 4. Comparative mode of locomotion of Assamese and rhesus macaques



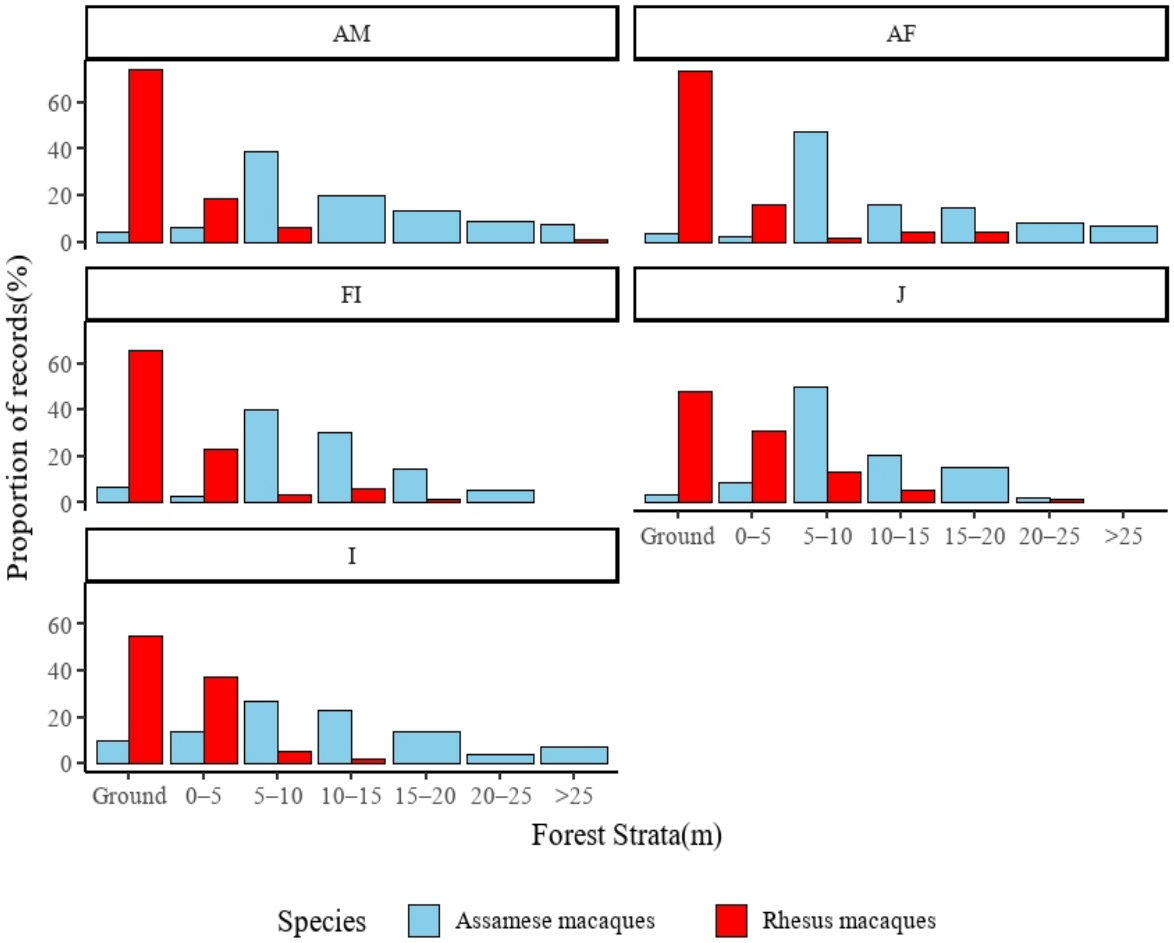
Annex 5. Comparison of different age-sex group of Assamese and rhesus macaques while feeding



Annex 6. Comparison of different age-sex group of Assamese and rhesus macaques while moving



Annex 7. Comparison of different age-sex group of Assamese and rhesus macaques while resting



Annex 8. Comparison of different age-sex group of Assamese and rhesus macaques while socializing

PHOTOGRAPHS

Photograph 1. Assamese male macaques foraging near the garbage

Photograph 2. Assamese macaques grooming on tree

Photograph 3. An adult male of Assamese macaque resting

Photograph 4. Females of Assamese macaques foraging on human trash

Photograph 5. Rhesus macaques eating foods supplemented by humans

Photograph 6. Rhesus male and female resting

Photograph 7. A group of rhesus macaque running inside Nagarjun Forest

Photograph 8. A group of rhesus macaques resting inside the forest