Feeding Strata Use by Tarai Gray Langurs (*Semnopithecus hector*) in Bardiya National Park, Nepal

By

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A thesis submitted in partial fulfillment of the requirements for the award of the degree of Masters 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

March 2023

DECLARATION

I hereby declare that the work presented in this thesis "**Feeding Strata Use by Tarai Gray Langurs (*Semnopithecus hector*) in Bardiya National Park, 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).

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Date: 9th March 2023

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RECOMMENDATION

This is to recommend that the thesis entitled "**Feeding Strata Use by Tarai Gray Langurs (*Semnopithecus hector*) in Bardiya National Park, Nepal**" has been carried out by Chanda Binadi for the partial fulfillment of Master's Degree of Science in Zoology with special paper Ecology and Environment. This is 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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LETTER OF APPROVAL

On the recommendation of supervisor Laxman Khanal, PhD this thesis submitted by Chanda Binadi entitled "**Feeding Strata Use by Tarai Gray Langurs (*Semnopithecus hector*) in Bardiya National Park, Nepal**" is approved for the examination and submitted to the Tribhuvan University in partial fulfillment of the requirements for Master's Degree of Science in Zoology with special paper Ecology.

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CERTIFICATE OF ACCEPTANCE

This thesis work submitted by Chanda Binadi entitled "**Feeding Strata Use by Tarai Gray Langurs (*Semnopithecus hector*) in Bardiya National Park, Nepal**" has been accepted 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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LIST OF ABBREVIATIONS

Abbreviated form	Details of abbreviations
DNPWC	Department of National Parks and Wildlife Conservation
BNP	Bardiya National Park
d.f.	Degree of freedom
N.	North
E.	East

LIST OF PHOTOGRAPHS

ABSTRACT

Tarai gray langurs (*Semnopithecus hector*) are the only colobine primates from Nepal Himalaya distributed primarily in dipterocarp forests of inner and outer Tarai. The activity budget, the time spent by an animal to different behaviors on a daily basis, is crucial in studies of species interaction with its resources and behavioral ecology. 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, feeding ecology and strata use by the langurs in lowland tropical forest of Bardiya National Park, Nepal. The data were collected from 08 to 28 February, 2022 in winter season and 05 to 25 August, 2022 in summer season recording 336 hours of behavioral data in two observational phases (morning 7.00–11.00 am; evening 2.00–6.00 pm). Daily activity budgets were recorded by focal animal sampling method and data on feeding ecology and strata use were recorded by scan sampling method. Langurs in Bardiya National Park invested majority of their diurnal time on feeding (42.32%), followed by resting (35.64%), allo-grooming (9.13%), moving (4.17%), Playing (3.77%) and vocalization (3.02%). Time spent by langurs in different activities differed significantly among the two observational phases of the days. Time invested by langurs in different activities varied in between the two seasons. Such difference was statistically significant for resting and allo-grooming. During field visit 40 species of food plants of langurs were noted. Langurs in Bardiya National Park spent majority of their diurnal time feeding on trees (69.66%), followed by shrubs (15.91%) and herbs (14.43%). Major food plants consumed by langurs in different seasons differed significantly for herbs, shrubs and trees. Langurs fed on variety of plant parts in Bardiya National Park. They spent majority of their time feeding on leaves (43.06%), followed by buds (13.47%), bark (13.47%), and fruits (12.93%). Plant parts consumed by langurs varied significantly in different seasons. Langurs in Bardiya National Park most frequently used above 12m stratum (70.87%), followed by ground (0–6 m) (15.17%) and middle stratum (6–12 m) (13.94%) on feeding. Findings of this research will be useful in proper management and conservation of langur species.

1. INTRODUCTION

1.1 General background

The activity budget of an animal is the time spent to different behaviors on a daily basis, and it is crucial in studies of species interaction with its resources and behavioral ecology (Rizzuto et al. 2017). 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 their life history features and animal adaptations to their environments (Bernstein 1968, Rodway 1998, Neha et al. 2021). To survive under the threat of habitat loss, exploitation and environmental degradation, the daily activity budget of an animal provides information on conservation and management efforts that can be carried out by considering the spatial and temporal distribution of available resources (McCain & King 2014). The method for recording daily activities was established by (Altman 1974) for studying animal behavior. The basic daily activities recorded are usually clustered into resting, feeding, moving, grooming, playing, vocalization, mating, fighting and others (Hambali et al. 2012, Ruslin et al. 2014, Siti-Kauthar et al. 2019).

Langurs (*Semnopithecus* spp.) is the only colobine primates from Nepal Himalaya distributed primarily in dipterocarp forests of inner and outer Tarai, occupy wide elevational and latitudinal distribution ranging from lowland forests to alpine zones (Khanal et al. 2018). In order to maximize their daily intake of required energy, nutrients and to thrive and survive in their available environments, primates specifically choose what to eat at any given time (Freeland & Janzen 1974, Leighton 1993, Stevenson 2004, Jildmalm et al. 2008, Jaman et al. 2010). To understand the basic biology of species, its ecological adaptation to the available environment, production dynamics, habitat requirements, pattern of sociality and vulnerability to extinction, it is important to know food and feeding ecology. Fluctuations in food availability, may not always directly measure to what extent the species are successful but by comparing the number of food items ingested across the season (Rahman et al. 2015). Food is the any fundamental need extremely important to all living organisms to survive in nature and sustain life as it provides nutrients for growth, maintenance and reproduction.

Langurs are ecologically flexible as they can survive in any type of climatic habitat and generalist feeders (feeds on any kind of food plants present around) yet selective in choice of

diet. They have been observed to be leaf eaters, fruit eaters, flower eaters, seed eaters, stem eaters, bud eaters, bark eaters in Bardiya National Park. All these food items provide species with essential elements like carbohydrates, proteins, fats, vitamins and minerals (Alarape et al. 2018). In spite of seasonal variation in their annual diet primates are categorized according to their main diet (Hill 1997). Langurs living in seasonal habitats feeds accordingly either they concentrate on specific food items available year round or they maintain their diet by feeding on various food plants available according to season (Hill 1997). Specific animal's food consumption depends on various factors such as size of the body, energetic or body requirements and physical strength that varies according to age sex class (Rahman et al. 2015).

Habitat differences and degradation leads an animal to behavioral flexibility, which help them thrive, survive, sustain their life and maintain an effective population size in different harsh habitats (Gordon et al. 2018, Galan-Acedo et al. 2019). Studies on behavioral responses by an animal to habitat differences and degradation are crucial that help to understand animal tolerance limit to habitat change and develop conservation and management strategies and tactics for endangered species (Ma et al. 2020). Differences in habitat structure and resource distribution can lead to strata use patterns for arboreal nonhuman primate (Campbell et al. 2005, Riley 2008, Mekonnen et al. 2018). Asian colobines are highly arboreal species, which are usually found residing on upper stratum and exhibit limited ground use due to their relatively small body size which makes them vulnerable to terrestrial predators (Borries et al. 2014). To facilitate life and movement within trees which are predominantly found in peripheral regions of forests canopies, they have evolved certain adaptations for forest living, such as long phalanges, powerful hind limbs and ischial callosities (Roy & Nagarajan 2018).

1.2 Research objectives

1.2.1 General objective

The general objective of this study was to document the diurnal activity budget, explore the feeding ecology and strata use of Tarai gray langurs (*Semnopithecus hector*) in Bardiya National Park, Bardiya, Nepal.

1.2.2 Specific objectives

The specific objectives of this study were:

1. To document the diurnal activity budget of langurs in Bardiya National Park.

2. To identify major food plants and parts consumed by langurs in Bardiya National Park.
3. To determine the strata use by langurs in Bardiya National Park.

1.3 Rationale of the study

Langurs are 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, feeding ecology and strata use are essential for comprehending the ecology, evolution and conservation of species. But no efforts are made to investigate it and very little information is available. Research on langurs in any aspects in Nepal is limited. Moreover, research on diurnal activity budget, feeding ecology and strata use can rarely be found. This research is needed to fulfill the knowledge gap regarding the diurnal activity budget, feeding ecology and strata use. Thus, this study provides information about daily activity budget, feeding ecology, major food plants, plant parts consumed and strata use by langurs which can be implicated for making further decision in the preservation and management of langurs and steps to be applied to minimize their potential threats.

2. LITERATURE REVIEW

2.1 Diurnal activity budget of primates

Non-human primates allocate the diurnal time for different activities based on the habitat they inhabit and availability of resources. Banded langur (*Presbytis fermoralis*) spent the major proportion of their time resting (43%). Banded langur spent 26% of their time feeding, 26% of their moving, 4% of their time on social activities and 1% on other activities (Najmuddin et al. 2020). In contrast to this study, another study has shown that spectacled Dusky leaf monkey (*Trachypithecus obscurus*) spent major proportion of their time feeding (40.81%), followed by resting (38.31%), moving (19.19%) and others (1.68%). Similarly, same study in Bangi campus of University Kebangsaan Malaysia, Selangor have shown that long tailed Macaques spent much longer time feeding (29.94%), moving (28.88%), resting (19.7%) and other activities (21.41%) (Ruslin et al. 2014). Another study in Kuala Selangor Nature park have shown that long tailed Macaques (*Macaca fascicularis*) spent most of their time moving (20.27%), followed by feeding (18.78%), being inactive (17.05%), grooming (10.84%), playing (10.50%), vocalization (10.36%), mating (7.42%) and the last is fighting (4.78%) (Hambali et al. 2012). Another study in Hatinh langurs (*Trachypithecus hatinhensis*) have shown that they spent most of their time resting (53.51%–56.96%), feeding (31.94%–16.83%), moving (5.63%–8.88%), Social activities (4.85%–6.85%), playing (3.43%–10.04%), foraging (0.54%–0.03%) and anti-predator (0.10%–0.42%) in both caged and semi-freed environments. Same study in Delacour's langurs (*Trachypithecus delacour*) have shown that they spent most of their time resting (51.10%–44.80%), feeding (34.54%–28.02%), moving (7.21%–11.36%), social activities (3.02%–13.49%), playing (3.88%–1.70%), foraging (0.56%–0.58%) and anti-predator (0.20%–0.04%) in both caged and semi-freed environment (Phan & Stevens 2012).

2.2 Feeding ecology of colobines

The study on northern plains sacred langurs (*Semnopithecus entellus*) have shown that they spent 60.2% (N=1094) of the total observation time feeding and consumed 54 different plant species of which 33 trees, 8 shrubs and 13 herbs. 37 plant species were consumed in rainy season, 49 in winter and 48 in summer season. Langurs fed on both natural and provisioned food available in their home range (Rahman et al. 2015). Another study on southern yellow-cheeked crested gibbons (*Nomascus gabriellae*) have shown that the diet of gibbon was

dominated by plant material and recorded 69 species of plants of which 43 trees, 19 vines, 7 epiphytes (Bach et al. 2017). Another study on phayre's Leaf Monkey (*Trachypithecus phayrei*) and Capped langurs (*Trachypithecus pileatus*) have shown that a total of 87 plant species including bamboo were recorded, 65 were woody plant species (81.13%), 5 species of bamboo (5.6%), 10 species of herbs (11.3%). Woody plant species were mainly tree species dominating the vegetation (Decemson et al. 2018). Another study on feeding of red langurs (*Presbytis rubicunda*) in Indonesia have shown that total of 65 plants species in 32 families of which there were 54 tree species, seven lianas species, three climbers and one epiphyte. Also, 7 fungi species and 2 invertebrate food items (Ehlers Smith et al. 2013). Another study in Mentawai Island langurs (*Presbytis potenziani*) have shown that langur species fed on a total of 42 plant species of which 48% fed on climbers/lianas/vines, 45% were trees and the remaining 7% were epiphytes, shrubs and other plant materials (Fuentes 1996). Another study in India have shown that a total of 52 plant species that belong to 30 families of which 90% of them were trees, 6% were climbers, 2% were aquatic plants and 2% were bamboo were fed upon by capped langurs (*Trachypithecus pileatus*) (Solanki et al. 2008).

2.3 Major plant parts consumed by langurs

Of the time spent on feeding by northern plains sacred langurs (*Semnopithecus entellus*) the greatest amount was spent on leaves (57.5%), followed by fruits (20.7%), buds (8.5%), flowers (3.9%) and bark (0.5%). Langurs also consumed provisioned food (8.7%) and non-plants food items including soil, water and fungi (1%) (Rahman et al. 2015). Another study on southern yellow-cheeked crested gibbons (*Nomascus gabriellae*) have shown that fruits were the most common food items eaten (43.3%), followed by leaves (38.4%), flowers (11.6%) and other plant parts (buds, petioles, shoots and roots) (6%). Insects and bird eggs contributed only 0.5% of the overall diet (Bach et al. 2017). Another study on black and white colobus (*Colobus guereza*) in the Kalinzu forest, Uganda have shown that the study groups fed highly on young leaves (87.0%), fruits (9.8%), including seeds (5.0%), both seeds and pulp of ripe fruits (4.5%), unripe fruits (0.3%), flowers (1.1%), bark (0.9%), soil (0.8%) and other foods (unspecified foods and mature leaves) (0.4%) (Matsuda et al. 2019). Similarly, study on capped langurs (*Trachypithecus pileatus*) have shown that the species spent most of their time feeding on leaves (68%), followed by flowers (16%) and fruits (16%) (Solanki et al. 2008). Similarly another study of the western hoolock gibbon (*Hoolock hoolock*) have shown that the major time spent was on feeding fruits (51.1%), young leaves (19.1%), followed by mature leaves

(15.7%), animal matter (9.7%) and others (flowers, flower buds and petioles) (<1%) (Borah et al. 2018).

2.4 Strata use by langurs

The study on Indo-Chinese gray langurs (*Trachypithecus crepusculus*) have shown that the study groups did not use strata evenly. They spent 97.1% of their time in trees, only 2.9% of their time on the ground. When in trees, they used the 11–15 m and 16–20 m strata more often than the <10 m and >20 m strata (Ma et al. 2020). Another study in Sulawesi Tonkean macaques (*Macaca tonkeana*) in two differently human altered habitat have shown that in minimally altered habitat 86% of the observation records were in the two upper forest strata levels, rarely being scored at lower levels whereas in highly altered habitat the group was scored across all levels (Riley 2008). The study on sympatric macaques in the limestone habitat of Nonggang, China has shown that Assamese macaque spent 67.3% of their time on ground whereas rhesus macaques spent only 3.1% of their time on ground. Similarly, Assamese macaques use 23.3% low stratum whereas Rhesus macaques use 38.4% low stratum. In the similar way, Assamese macaques use 7.6% lower middle stratum whereas Rhesus macaques use 39.3% lower middle stratum. Assamese macaques use 1.5% upper middle stratum whereas Rhesus macaques use 13.6% upper middle stratum. Assamese macaques use 0.3% upper stratum whereas Rhesus macaques use 5.7% upper stratum (Huang et al. 2015).

3. MATERIALS AND METHODS

3.1 Study area

This study was conducted in Bardiya National Park of Bardiya District (Figure 1) in western lowland Tarai of Nepal. It was established in 1988 as Royal Bardia National Park which lies in Lumbini province, Western Nepal. It is a protected area in Nepal covering an area of 968 km^2 and one of the most undisturbed National Parks in Nepal's Tarai, adjoining the eastern bank of the Karnali River and bisected by the Babai River. Its northern limits are demarcated by the crest of the Siwalik Hills. The Nepalgunj-Surkhet highway partly forms the southern boundary. The Bardiya National Park is located between 81°39'29" to 82°12'19" east longitude and 27°58'13" to 28°21'26" north latitude.

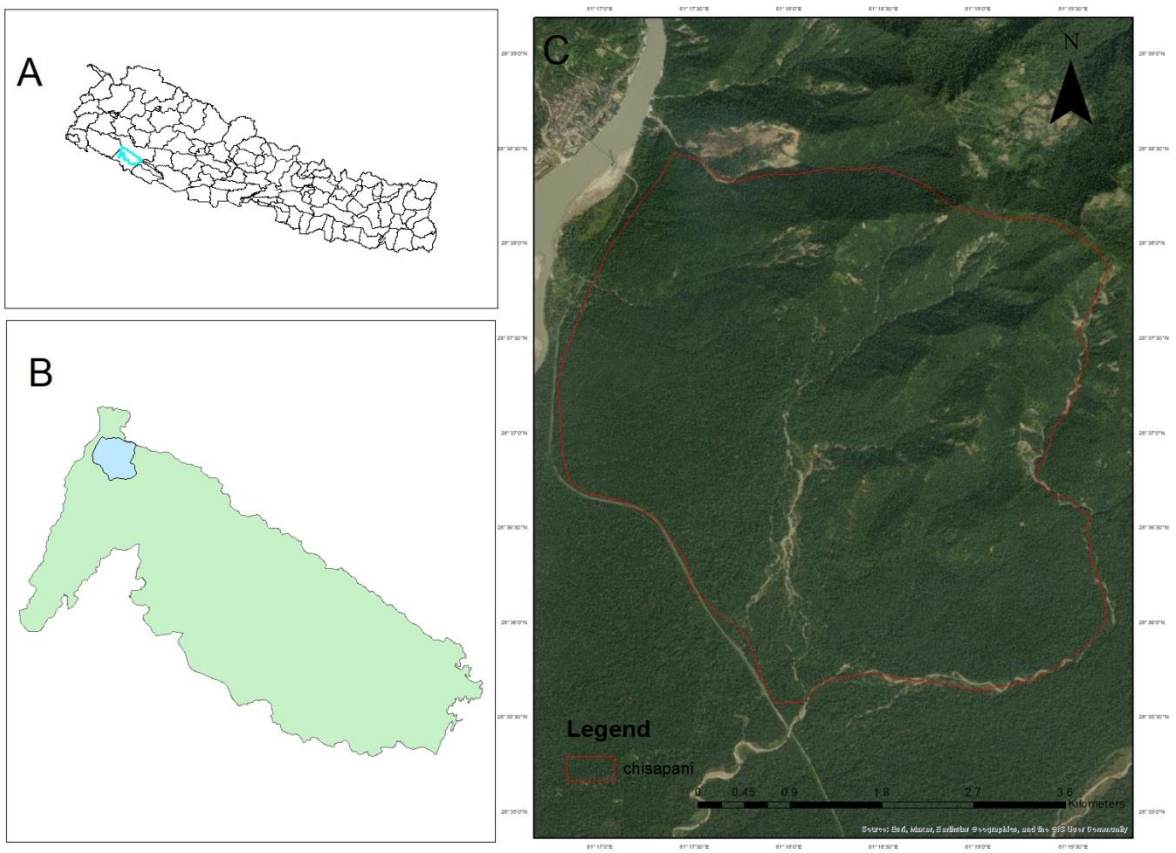


Figure 1. Map of the study area. A. Map of Nepal showing the Bardiya district. B. Map of Bardiya district showing Bardiya National Park. C. Map showing the area used by chisapani troop.

The park has been characterized by three distinct seasons, summer, winter and monsoon. From October to early April, the weather is dry. The days are characterized by hot warm weather and the nights are cool and pleasant. From April to June the temperature gradually rises up with a

peak temperature up to 45℃ in May. The hot sticky days give way to monsoon rains in July that lasts until September. The park offers a variety of flora and fauna species. The dominating vegetation in the park's forest is Sal (*Shorea robusta*) trees with a mixture of grassland, savannah and riverine forests. The wide range of vegetation types in forest and grassland provides suitable habitat to endangered animals such as Royal Bengal tiger (*Panthera tigris tigris*), Wild elephant (*Elephas maximus*), Greater one-horned rhinoceros (*Rhinoceros unicornis*), Swamp deer (*Cervus duvaucelii*) and Black buck (*Antilope cervicapre*). The other endangered species include Gharial (*Gavialis gangeticus*) and Marsh mugger crocodiles (*Crocodylus palustris*) and Gangetic dolphin (*Platanista gangetica*). Endangered birds found in the park are Bengal florican (*Houbaropsis bengalensis*), Lesser florican (*Sypheotides indicus*), White rumped vulture (*Gyps bangalensis*), Peafowl (*Pavo cristatus*) and Sarus crane (*Grus antigone*). More than 30 different mammals, over 407 species of birds and several species of snakes, lizard and fishes have been recorded in the park area (DNPWC 2018).

3.2 Materials used

Following materials were used during the study of behavioral sampling.

i. GPS
ii. Ethogram
iii. Binoculars
iv. Camera
v. Stop Watch

3.3 Focal group of Tarai gray langur

Various groups of langur were seen during the observation conducted in the study area but the Chisapani troop was selected for the study. The study group comprised 16 individuals of different age-sex categories (Table 1). The troop constituted 4 infants, 3 Juveniles, 2 sub adult males, 3 sub adult females, 2 adult males and 2 adult females. The langur individuals of the study group were identified using distinctive features of each individual including their faces, colorations, scars, body size, genital part, height.

Table 1. Age-sex categories of langurs used in the study

S.N.	Category	Description

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

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 five days during the February 2022. Additional information about the langur troops inhabiting the area was collected from the secondary sources and informal interviews with staffs of Bardiya National Park.

3.4.2 Behavioral data collection

Behavioral data for daily activity budget were recorded by using the focal animal sampling method (Altman 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 (Altman 1974). A total 42 days of field observations (21 days in winter and 21 days in summer) were conducted from 08 to 28 February 2022 in winter season and 05 to 25 August 2022 in summer season recording 336 hours of behavioral data (168 hours in winter and 168 hours in summer season). Field observations were divided into two periods: 1) morning (7.00 – 11.00 am) and 2) Evening (2.00 – 6.00 pm). The recorded activities were feeding, resting, moving, playing, grooming (auto-grooming and allo-grooming), vocalization and others (aggression, drinking, geophagy, lactating).

Table 2. An ethogram used to record behavioral data of Tarai gray langurs

S.N.	Behavior	Description
1.	Feeding	Eating or Chewing food
2.	Resting	Inactive whether standing, sitting or lying down
3.	Moving	Any mobile activity either walking, running, jumping or climbing.
4.	Playing	Any activity involving recreation, whether it be self-directed or involving others, entailing non aggressive interaction
5.	Grooming	Picking or manipulating fur or skin with hands

		(Auto-grooming: Self grooming); (Allo-grooming: grooming one another)
6.	Vocalization	Interaction with each other through sound
7.	Others	Other behavior includes: Aggression: Any aggressive behaviors, including chase, attack, teeth display; Drinking: The activity of having water or any other fluid; Geophagy: Licking the surface of the soil for mineral purpose; Lactating: Breast-feeding to the infant

3.4.3 Data collection on feeding ecology

The Scan Sampling Method (Altman 1974) was used to collect the data on feeding ecology. Study groups were observed from 7.00 to 11.00 am in the morning and 2.00 to 6.00 pm in the afternoon/evening. Scan sampling was carried out each after 10 minutes interval for observing feeding behavior in both winter and summer season for 42 days (21 days in winter from 08 to 28 February 2022 and 21 days in summer from 05 to 25 August 2022. For every feeding event recorded, the plants (trees, herbs, shrubs) and the plant parts (leaves, flowers, fruits, stem, seed, bark, buds) consumed was noted carefully.

3.4.4 Data collection on strata use

The Scan Sampling Method (Altman 1974) was used to collect the data on feeding ecology. Study groups were observed from 7.00 to 11.00 am in the morning and 2.00 to 6.00 pm in the afternoon/evening. Scan sampling was carried out at every 10 minutes interval for observing the strata use in summer season for 21 days from 05 to 25 August 2022. During each scan, we recorded the stratum use by the langurs dividing into three categories: i.e., Ground (0–6 m), Middle stratum (6–12 m), Above 12m stratum.

3.5 Data analysis

Normality of all the data were checked using Shapiro-Wilk test. In order to test the significance in difference in time spent in each of the behavioral activities among different seasons and at different observational phases t-test was employed. Similarly, to test the significance in difference in major food plants and plant parts consumed by langurs in different seasons chi-square test was performed. All statistical tests were carried out using R studio with significance level $p \leq 0.05$.

4. RESULTS

4.1 Total activity budget of Tarai gray langurs and at different time

Tarai gray langurs in Bardiya National Park invested majority of their diurnal time on feeding (42.32%), followed by resting (35.64%), allo-grooming (9.13%), moving (4.17%), playing (3.77%) and vocalization (3.02%) (Fig. 2). Auto-grooming and other behaviors like drinking, geophagy constituted a small proportion of their diurnal time.

The proportion of time spent in the different activities varied during the day. Feeding was the highest behavior shown by langurs in morning (7.00 to 11.00 am) which accounts for 41.05% of their time budget followed by resting (36.18%), allo-grooming (9.21%), moving (4.28%), playing (4.01%) and vocalization (3.13%). Langurs continued to spend more time feeding (41.58%) in the evening (2.00 to 6.00 pm) which is followed by resting (36.48%), allo-grooming (9.47%), moving (4.21%), playing (3.75%) and vocalization (3.03%). Time spent on feeding, resting and allo-grooming was higher in the evening than in the morning but the auto-grooming and vocalization was found to be higher in the morning than evening. They were seen playing more often in the morning than evening.

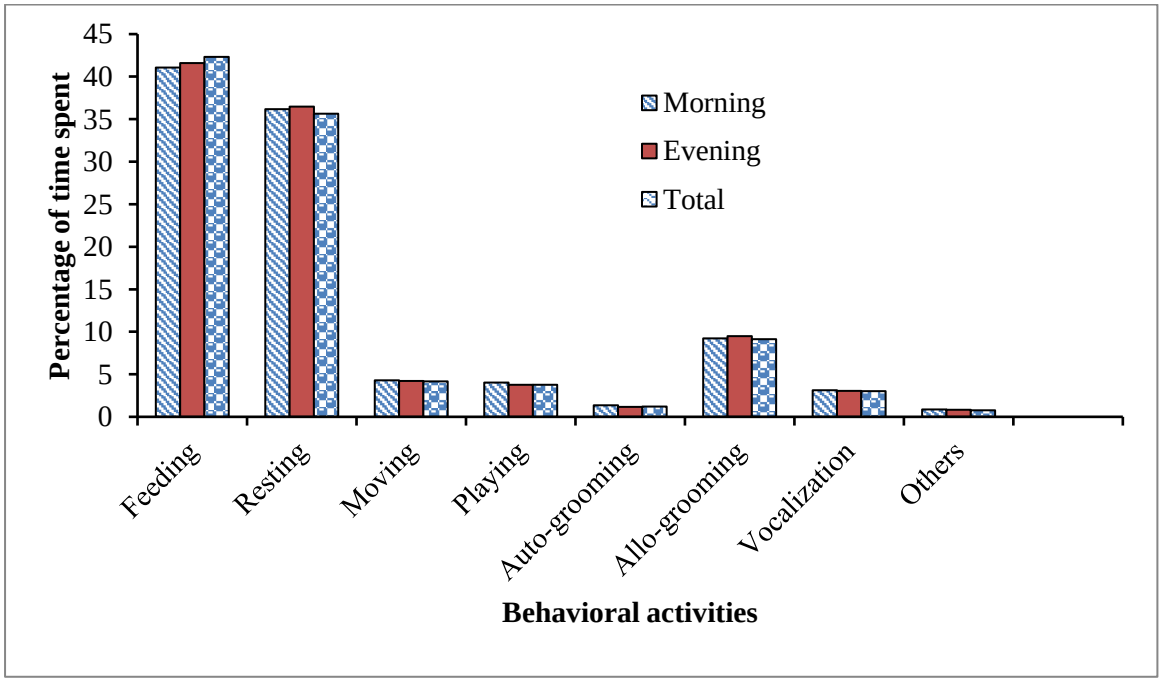


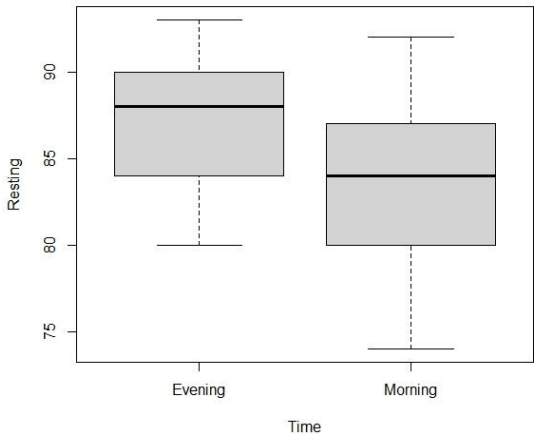
Figure 2. Total behavioral activities of the Tarai gray langurs and at different time

Time spent by langurs in different activities differed among the two observational phases. Such difference was statistically significant for resting, feeding and auto-grooming. However, the differences were not statistically significant for moving, playing, allo-grooming, vocalization and others during the different times of the day.

Table 3. Results of t-test testing the significance of variation in activity budget of Tarai gray langurs at different time

S.N	Behavioral category	t- value	P
1	Feeding	-2.8735	0.005203
2	Resting	4.1731	0.0000754
3	Moving	0.30681	0.7598
4	Playing	0.93197	0.3551
5	Auto-grooming	2.9498	0.004512
6	Allo-grooming	1.9816	0.05096
7	Vocalization	0.05928	0.9529
8	Others	0.13156	0.8957

A.



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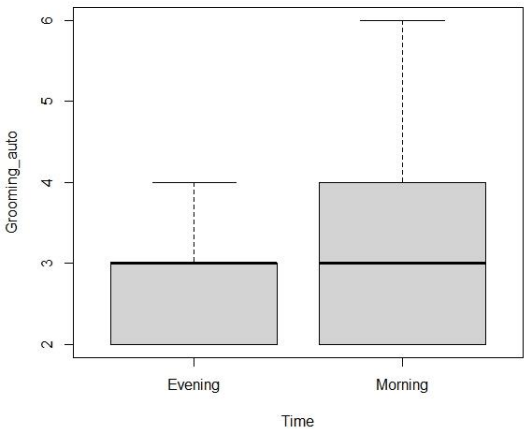

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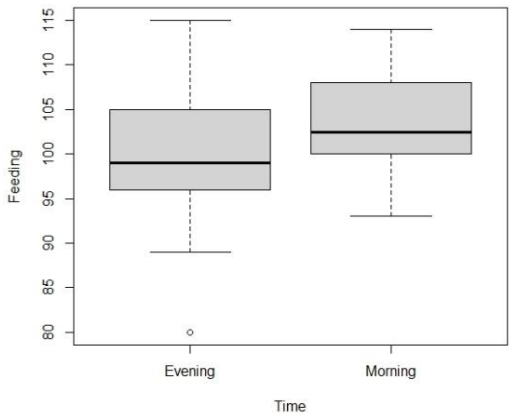

Figure 3. Box plots showing the differences in time invested by Tarai gray langurs on A. Resting B. Auto-grooming C. Feeding at different time period

4.1.1 Activity budget of Tarai gray langurs in different seasons

The proportion of time spent on various activities varied in different seasons. Feeding was the highest behavior shown by langurs in summer season which accounts for 43.78%, followed by resting (36.22%), allo-grooming (9.47%), playing (3.34%), moving (3.18%) and vocalization (2.77%). Langurs continued to spend more time feeding (40.94%), followed by resting (35.15%), allo-grooming (8.97%), moving (5.35%), Playing (4.37%) and vocalization (3.46%). In both the season, other activities like drinking, geophagy, aggression were least observed.

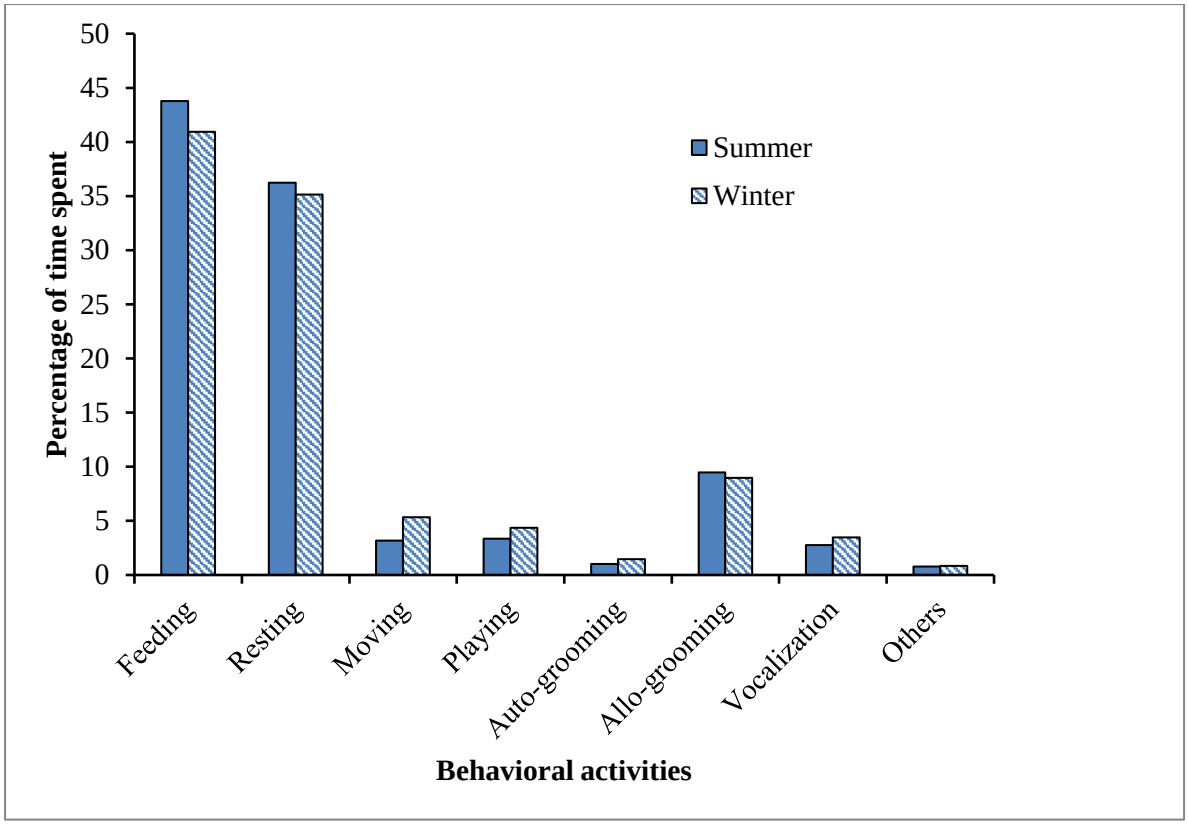

Figure 4. Behavioral activities of Tarai gray langurs in different seasons

Time invested by Tarai gray langurs in different activities varied in different seasons. Such difference was statistically significant for resting and allo-grooming. However, the differences were not statistically significant for feeding, moving, playing, auto-grooming, vocalization and others during the different seasons of the year.

Table 4. Results of t-test testing the significance of variation in activity budget of langurs in different seasons

S.N	Behavioral category	t value	P value
1	Feeding	5.3374	<0.05
2	Resting	3.0591	0.00299
3	Moving	-13.168	>0.05
4	Playing	-5.258	>0.05
5	Auto-grooming	-4.6706	0.1049
6	Allo- grooming	2.0649	0.042261
7	Vocalization	-4.754	<0.05
8	Others	-1.0595	0.2925

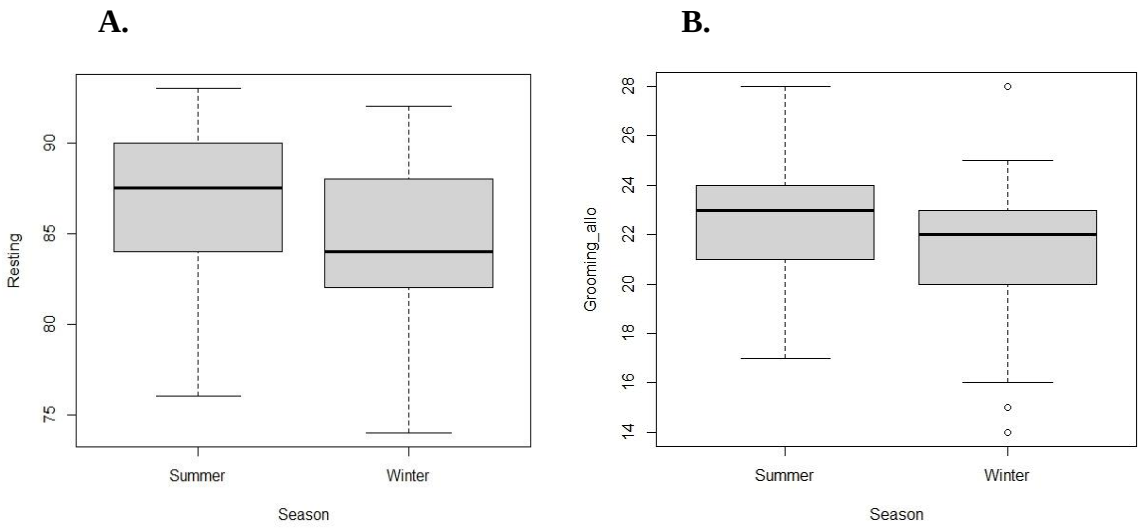

Figure 5. Box plots showing the differences in time invested by Tarai gray langurs on A. Resting B. Allo-grooming in different seasons

4.2 Feeding ecology of Tarai gray langurs in Bardiya National Park

During field visit 40 species of food plants of Tarai gray langurs were identified. In summer the langurs fed on 36 food plants and in winter on 32 food plants. Langurs utilized most of the Trees than Herbs and Shrubs.

4.2.1 Major food plants consumed by Tarai gray langurs

Tarai gray langurs in Bardiya National park spent most of their diurnal time feeding on trees (69.66%), followed by shrubs (15.91%) and then herbs (14.43%).

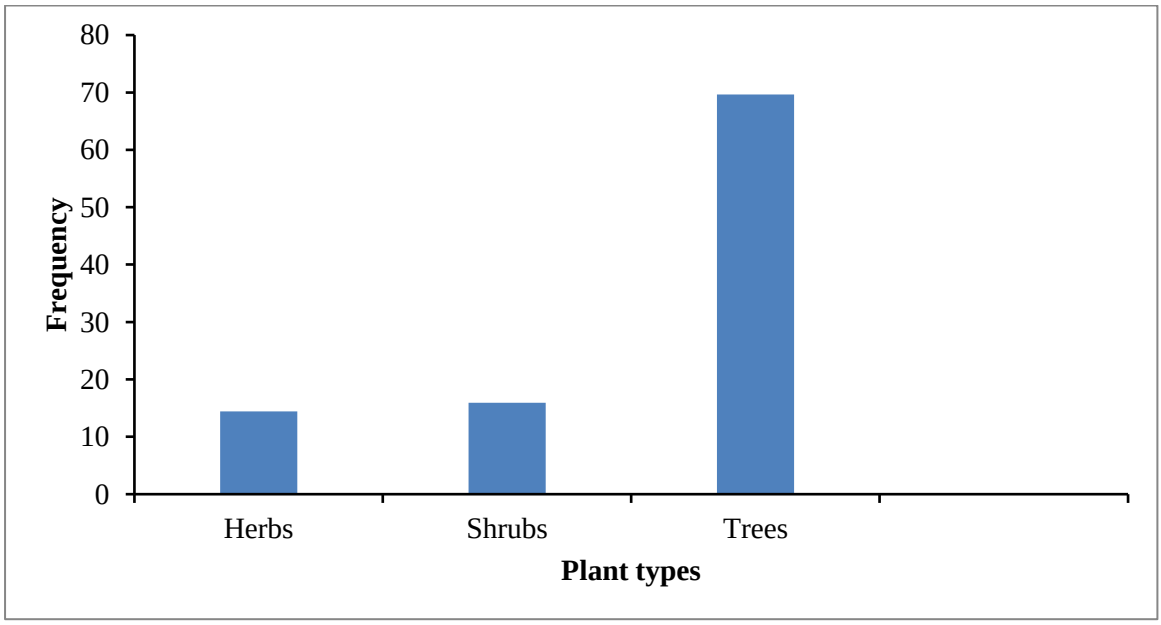

Figure 6. Major food plants consumed by Tarai gray langurs in total

4.2.2 Major food plants consumed by Tarai gray langurs in different seasons

In summer season, Tarai gray langurs spent most of their time feeding in trees (69.77%), followed by herbs (16.91%) and shrubs (13.32%). In winter season, langurs invested most of their time feeding trees (69.54%), followed by shrubs (18.88%) and herbs (11.66%). In both the season trees were the most fed plant species. Shrubs were consumed more frequently in winter than in summer.

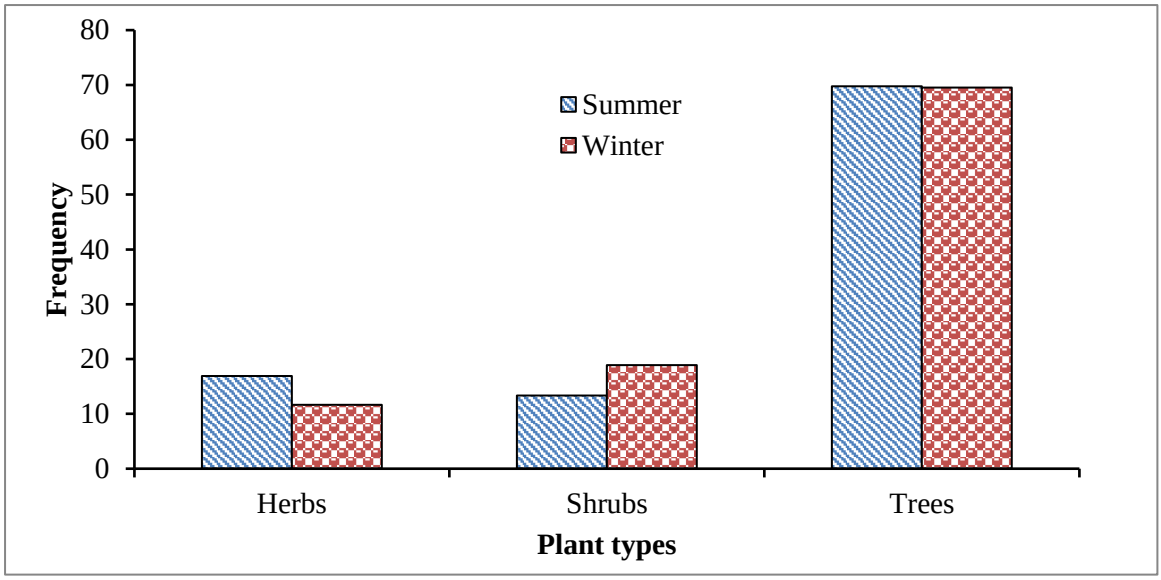

Figure 7. Major food plants consumed by Tarai gray langurs in different seasons

Major food plants consumed by Tarai gray langurs varied in different seasons. Such difference was statistically significant for herbs, shrubs and trees.

Table 5. Result of chi-square test testing the significance of variation in major food plants of langurs in different seasons

S.N.	Major food plants	Chi-square value	d.f.	p-value
1	Herbs	195.95	9	<0.001
2	Shrubs	162	7	<0.001
3	Trees	117.77	16	<0.001

4.2.3 Plant parts consumed by Tarai gray langurs

Tarai gray langurs fed on variety of plant parts in Bardiya National Park. They spent majority of their time feeding on leaves (43.06%), followed by bud (13.47%), bark (13.47%), fruits (12.93%), stem (8.97%), flowers (6.84%) and seed (2.01%). Some time they fed on rock materials and soil for obtaining minerals, occasionally they drank as well.

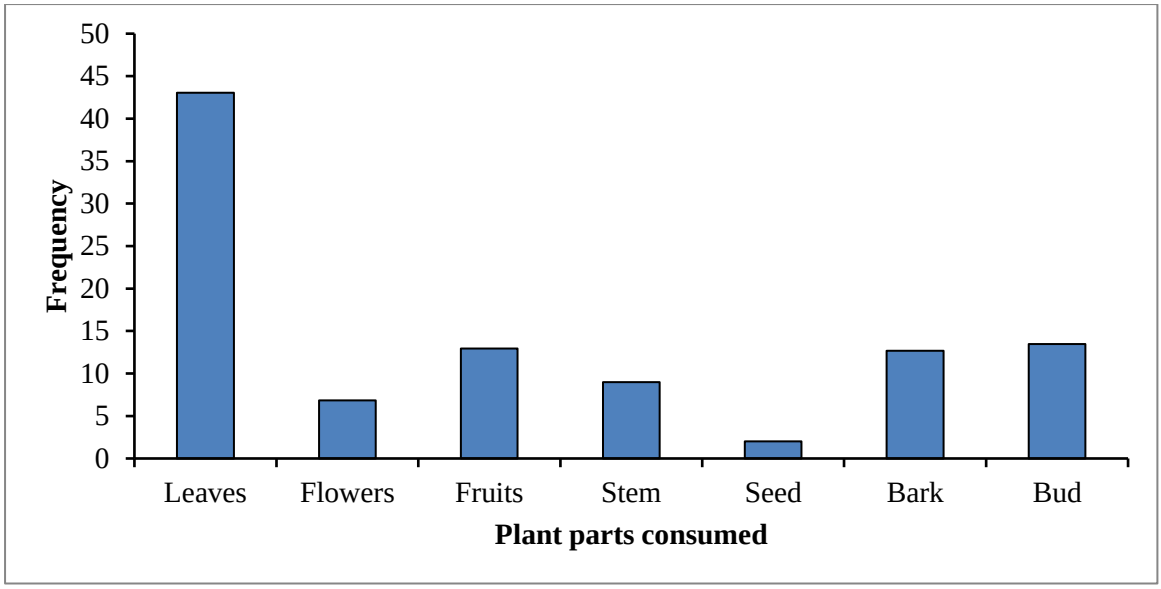

Figure 8. Plant parts consumed by Tarai gray langurs in total

4.2.4 Plant parts consumed by Tarai gray langurs in different seasons

Tarai gray langurs invested their majority of time feeding on leaves (66.88%), followed by fruits (14.90%), flowers (7.05%), bud (4.18%), stem (3.36%), bark (2.55%) and finally rarely on seed (1.23%) in summer season. In contrast to this, in winter season they fed frequently on bark (24.12%), followed by bud (23.88%), leaves (16.39%), stem (15.36%), fruits (10.72%), flowers (6.62%) and then on seed (2.88%).

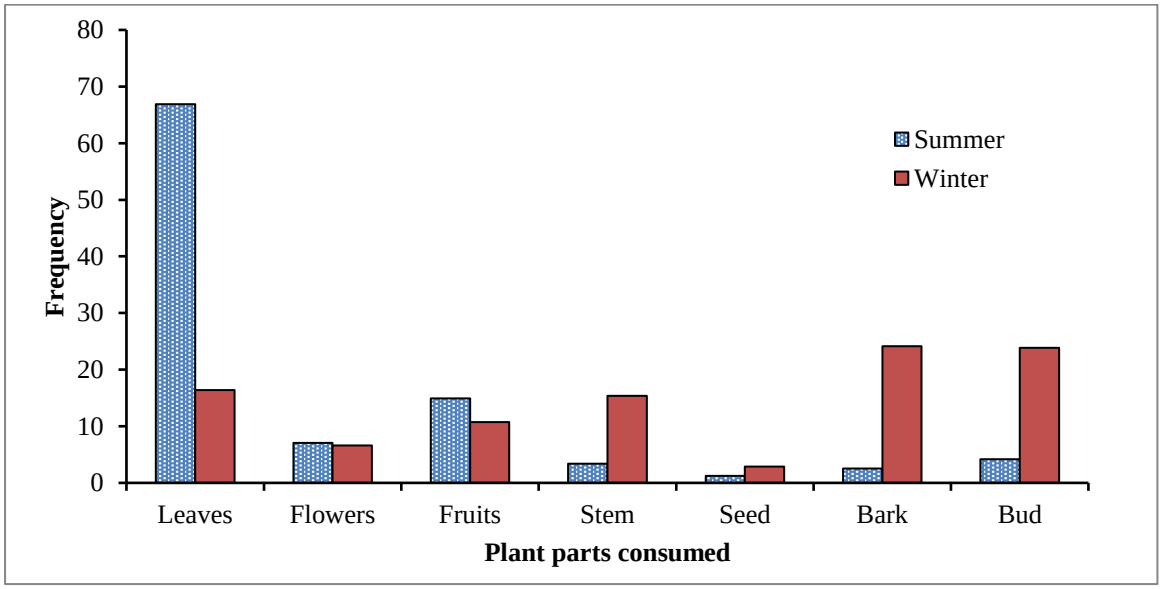

Figure 9. Plant parts consumed by Tarai gray langurs in different seasons

Plant parts consumed by langurs varied in different seasons. Such difference was statistically significant for leaves, flowers, fruits, stem, seed, bark, bud.

Table 6. Results of chi square test testing the significance of plant parts consumed by Tarai gray langurs in different seasons

S.N.	Plant parts consumed	Chi square value	d.f	P value
1	Leaves	1530.7	15	0.001
2	Flowers	176.5	5	0.001
3	Fruits	237.1	6	0.001
4	Stem	444.12	7	0.001
5	Seed	48.65	3	0.001
6	Bark	875.01	10	0.001
7	Bud	762.57	9	0.001

4.3 Strata use by Tarai gray langurs in Bardiya National Park

Strata use by Tarai gray langurs was divided into three categories: a) Ground (0–6)m, b) Middle stratum (6–12)m and c) Above 12m. Langurs in Bardiya National Park most frequently uses above 12m stratum (70.87%), followed by ground (0–6)m (15.17%) and middle stratum (6–12)m (13.94%).

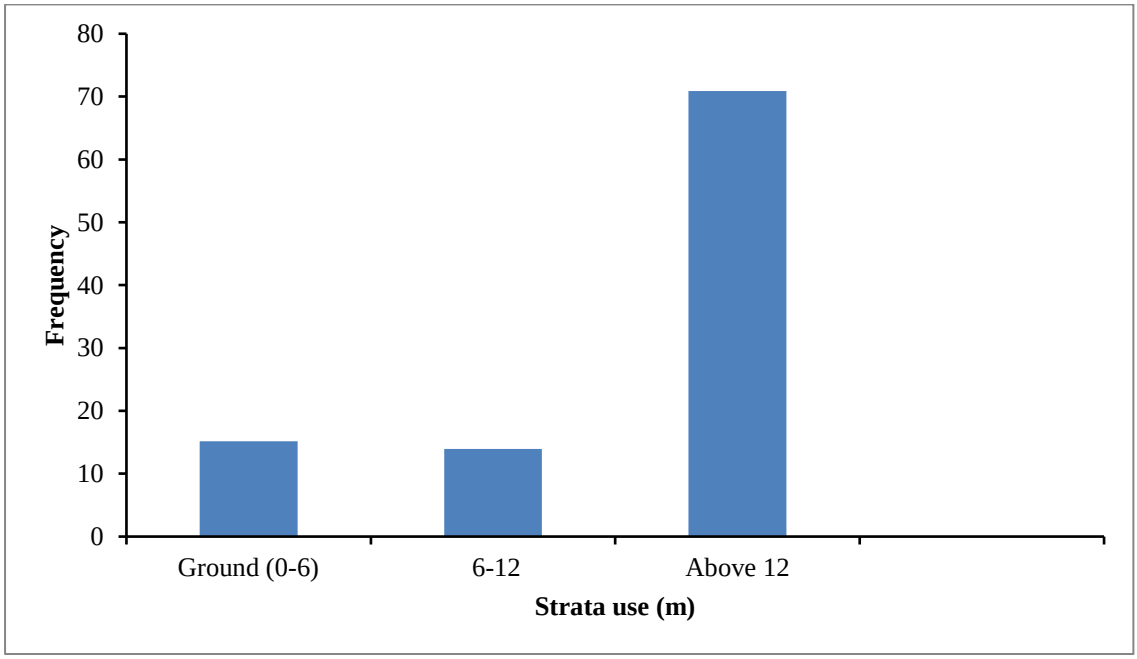

Figure 10. Strata use by Tarai gray langurs in Bardiya National Park

5. DISCUSSION

5.1 Diurnal activity budget of primates

Results of this study revealed that most frequently observed daily activity was feeding. Similar results were reported by other studies that showed spectacled Dusky leaf monkey (*Trachypithecus obscurus*) spent majority of their diurnal time on feeding compared to other activities (Ruslin et al. 2014). The most likely reason for our result was due to the absence of any disturbance factors they continuously fed during morning and evening. Plants were readily accessible in the forest which causes langurs to feed rather than searching for their own foods, thereby increasing the amount of time feeding. This was consistent with prior research that found long tailed Macaques spent less time moving and searching and more time feeding (Ruslin et al. 2014).This result is because the langurs are diurnal animal and are active during the day time in feeding in their territory (Hambali et al. 2012). Langurs fed primarily on trees and different parts of trees like leaves, buds and fruits. The second highest activity in our study was resting which is supported by Ruslin et al. (2014). Since, the langurs have tripartite stomach and herbivory diet, the fermentation and digestion of plant materials like leaves, flowers, fruits, seed, bark and so on in such stomach lasts for about 40 hours of particle mean retention time that is hypothesized to be associated with long resting time in them (Nijboer 2006, van Nijboer et al. 2007, Long et al. 2010). However, contrast to this (Dasilva 1993) argued that resting time is associated with the weather condition around rather than the food intake by an species. There are several other factors that are related to resting time and development of optimal foraging strategy such as on top of the factors listed gut size, food passage rate, home range area and the cost of locomotion (Garber 1987). 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). Langurs usually engaged in grooming one another (allo- grooming) after resting. Mothers are usually found grooming their young. The majority of the time grooming took place between females. Fourth highest activity was moving. Moving activities shown by species are affected by multiple factors of an species such as digestive physiology, ranging area, disturbance, threats, food abundance, weather and population dynamics (Najmuddin et al. 2020).

Playing behavior is the fifth highest behavior that has been observed during the observation period. This behavior is often done by the infant and juvenile categories that may form a social competition. Since, juveniles are in their active age period playing behavior may help them to learn on social behaviors and develop friendly relations with infants. To keep their children from attacks by predators, any physical injury during the play and also to teach them to live in their society, the mother of langurs appears to be always monitoring their infant and sometimes play with them and keeps roaming around. Vocalization behavior becomes the sixth behavior that has been observed at the study location. Langurs often produce vocal while playing and are also found to produce vocal warnings to inform members of the group that there are predators around. Member of the group who heard the vocal warning will immediately climb to higher stratum from ground to escape from the predators and be safe in their area. This study was supported by Hambali et al. (2012).

5.1.1 Activity budget of langurs at different observational phases

We found the significant difference between behaviors at different observational phases. The percentage of time langurs spent in different activities varied during the day. The most frequent activity that took place during the morning and evening was feeding. This is because of availability of food easily in the forest and are active during the day time and feed voraciously on various plant parts. Langurs spent little bit more time feeding during evening than morning. Second highest activity was resting at both observational times. This is because as the heat rises they need to balance their body temperature. Third highest activity was allo-grooming in both observational time period. This is because after feeding they rest and during resting mothers are usually found grooming their young so that they feel comfortable. Fourth highest activity was moving this is because after feeding completely they move to find predator free areas for resting (Hambali et al. 2012). Playing among the infants and juvenile was the activity observed after moving. This is because to develop social interaction among themselves and well communication as well. Vocalization was also seen frequently during playing and passing warning signals of predators among them.

5.1.2 Activity budget of langurs in different seasons

We found the significant difference between behaviors in different seasons. The most frequent behavior was feeding in both seasons. Langurs invest more time feeding in summer than in winter season. This is because of readily accessibility of food plants in summer than in winter. Second highest behavior was resting. In summer due to high temperature in day time they avoid

sun and find shady places to rest. Third highest behavior was grooming one another (allo-grooming). Allo-rooming was found to be higher in summer than in winter. This is because in summer they spend more time resting compared to winter thus during the time mother start grooming to their baby. In winter playing was higher than in summer. This is because less number of food plants available in winter compared to summer decreasing feeding time and increasing time for other activities. Moving was found to be higher in winter than in summer season. This is because of scarce food availability in winter they move around in search of food than in summer. Vocalization was found tom be higher in winter than in summer. This is because in winter they play more often producing vocal during the play.

5.2 Feeding ecology of langurs

Results of this study revealed that the most frequently fed food plants were trees. Similar results were reported by other studies that showed red langurs spent majority of time feeding on trees (Ehlers Smith et al. 2013). Trees were the dominating category of plant species in the study area and also the langurs mainly use upper strata to avoid predators and spend majority of their time on trees. Langurs almost fed on 40 different plant species during the course of study period. The second most fed food plants were shrubs. This is because shrubs species were readily available in the study area. Different shrubs species serve the langurs with fruits, flowers and leaves. Langurs are primarily folivorous, spent most of their time feeding leaves that contain higher amount of protein required by their body for growth and development. The third most fed food plants were herbs. Herbs include Cogon grass, bermuda, holy basil and other species.

5.2.1 Major food plants of langurs in different seasons

Results of our study revealed that the major food plants of langurs in the study area were trees in both the seasons. In summer, trees were fed in more amount than in winter. This is because of plenty of rainfall in summer that gives rise to numerous plant species to grow, leaves, flowers, fruits and buds were easily available. In winter the leaves of the trees were fallen and rarely the plants with fruits, leaves and flowers were available. The second highest fed plant species were herbs in summer than in winter. This is because of presence of higher amount of grasses in summer than in winter. Shrubs were least fed plant species in summer because shrubs plant species were available scarcely and second highest fed plant species in winter. Major food plants consumed by langurs varied in different seasons. Such difference was statistically

significant for herbs, shrubs and trees. There was significant difference in feeding in herbs, shrubs and trees in both seasons.

5.2.2 Plant parts consumed by langurs

Our study revealed that various plant parts were fed by the langurs like leaves, flowers, fruits, stem, seeds, bark and buds. Among this all category, leaves were the most fed plant parts in the study area. This is because the langurs are the primarily folivorous mainly relying on leaves for food as the leaves are the highest source of protein for growth and development. Our study is supported by Rahman et al. (2015). The second most fed plant parts were the buds due to the greater availability. The third most fed plant parts were bark as in winter leaves were rarely available, they fed on bark. Fourth most fed plant parts are fruits. This is because the forest does not contain higher number of fruiting plants, even if some plants are present they does not contain higher number of fruits at the time of study. Stem was the fifth highest plant parts fed during the course of time when not enough leaves were present. The sixth most fed plant parts were flowers and lastly, they fed occasionally on seeds when every other food plant parts were rarely present.

5.2.3 Plant parts consumed in different seasons

Plant parts consumed by langurs varied in different seasons. Such difference was statistically significant for leaves, flowers, fruits, stem, seeds, bark and buds. In summer, langurs primarily fed on leaves as leaves were readily available followed by fruits, flowers, buds, stem, bark and seeds. The feeding ecology of langurs depend on phenological stages of their food plants species. In contrast to this, in winter season langurs fed frequently on bark as young leaves were not available readily and maximum plants shade their leaves and some leaves are wilted. The second most fed plant parts were buds as many plants contain buds in them. Leaves were third most fed plant parts, followed by stem, fruits, flowers and seeds. In both the season langurs fed least on seeds because they were rarely available. Thus, there was variation in feeding the parts of plants in both seasons.

5.3 Strata use by Tarai gray langurs

Strata were divided into three categories in our study. The results of our study revealed that langurs spent their maximum time on above 12m stratum which is likely a response to the specific forest structure of the study area. The study is supported by Ma et al. (2020). This is because spending more time on above 12m stratum save them from terrestrial predator's attack.

The second most use stratum was ground and then (6-12m) strata. Upper forest stratum levels, were also used by macaques (*Macaca tonkeana*) in two differently human altered habitat , rarely being scored at lower levels (Riley 2008). Contrast to our study, another study on strata use have shown that Assamese macaques spent most of their time on ground which provides more stable support than trees and least time on upper stratum whereas Rhesus macaques spent most of their time on lower middle stratum whereas least time on ground. This is because they search for fruits and other foods for them in plants (Huang et al. 2015). Another study on Tibetan macaques have shown that Tibetan macaques use most frequently ground substrate and spent least time on upper forest stratum. This is because of their high body mass that makes them imbalance in upper stratum and more stable in ground substrate (Li et al. 2022).

6. CONCLUSION AND RECOMMENDATION

6.1 Conclusions

Feeding, resting, allo-grooming, moving and playing were the most common daily activities of langurs in Bardiya National Park. The activity budget of langurs varied in different seasons. In summer they spent more time on feeding than in winter. Similarly, significant difference was found in daily activity budget of langurs at different time periods of the day. Feeding was the most time invested activity of the langurs on each day. They fed on 40 different plant species during the course of study. Primarily they fed on trees followed by shrubs and then herbs. They fed on various parts of the plant species. The most fed plant parts are leaves in both the seasons. Second most fed plant parts were buds, followed by fruits, bark and stem. Similarly, significant difference was found in feeding various plant parts in different seasons. Langurs spent most of their time on upper strata (12-18) m, followed by ground and then middle layer (6-12) m.

6.2 Recommendations

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 langurs. Microscopic studies on major food plants and plant parts consumed would be more appropriate for exploring their feeding ecology. Furthermore, proper management and conservation plans would be effective for the welfare of the langurs in Bardiya National Park.

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8. ANNEX

Table 7. The name of plants and different parts of plant utilized by the langur population in two different seasons

S.N	Local Name	Scientific Name	Family	Type	Plant parts
1.	Simal	*Bombax ceiba*	Malvaceae	Tree	Flowers
2.	Khair	*Senegalia catechu*	Fabaceae	Tree	Leaves
3.	Ruhinu	*Ceiba pantandra*	Malvaceae	Tree	Stem
4.	Sal	*Shorea robusta*	Dipterocarpaceae	Tree	Stem
5.	Mottelo				
6.	Amala	*Phyllanthus emblica*	Phyllanthaceae	Tree	Stem
7.	Ambha	*Psidium guajava*	Myrtaceae	Tree	Fruits
8.	Jamun	*Syzygium cumini*	Myrtaceae	Tree	Bark
9.	Haldu	*Haldina cordifolia*	Rubiaceae	Tree	Bark
10.	Kusum	*Schleichera oleosa*	Sapindaceae	Tree	Stem
11.	Hade bayer	*Zizyphus incurva*	Rhamnaceae	Shrub	Leaves
12.	kash	*Saccharum spontaneum*	Poaceae	Herb	Leaves
13.	Babiyo	*Eulaliopsis binata*	Poaceae	Herb	Leaves
14.	Jungali bihin	*Solanum nigram*	Solanaceae	Herb	Stem
15.	Saj	*Terminalia elliptica*	Combretaceae	Tree	Bud
16.	Malu (tata)	*Phanera vahlii*	Fabaceae	Tree	Bud
17.	Pipal	*Ficus religiosa*	Moraceae	Tree	Stem
18.	Datiwan	*Achyranthus aspera*	Amaranthaceae	Shrub	Stem
19.	Bhang/ ganja	*Canabis sativa*	Cannabinaceae	Herb	Leaves
20.	Tejpat	*Cinnamomum tamala*	Lauraceae	Tree	Leaves
21.	Kimbu	*Morus macoroura*	Moraceae	Tree	Stem
22.	Mayal	*Pyrus pashila*	Rosaceae	Tree	Stem
23.	Tulsi	*Ocimum tenuiflorum*	Lamiaceae	Herb	Seed
24.	Dubo	*Cynodon dactylon*	Gramineae	Herb	Leaves
25.	Koiral	*Bauhinia variegata*	Fabaceae	Tree	Leaves, stem
26.	Faledo	*Erythrina indica*	Fabaceae	Tree	Bud
27.	Katush	*Castanopsis indica*	Fagaceae	Tree	Leaves
28.	Bhimal	*Grewia optiva*	Malvaceae	Tree	Leaves

29.	Siru grass	*Imperata cirillo*	Poaceae	Herbs	Leaves
30.	Timilo	*Ficus racemosa*	Moraceae	Tree	Fruits
31.	Imili	*Tamarindus indica*	Euphorbiceae	Shrubs	Fruits
32.	Rukh katahar	*Atrocarpus heterophyllus*	Moracae	Tree	leaves
33.	Parijat	*Nyctanthus arbutristis*	Oleaceae	Shrubs	Flower
34.	Kagati	*Citrus species*	Rutaceae	Shrubs	Leaves
35.	Bel	*Aegle marmellos*	Rutaceae	Tree	Fruits
36.	kera	*Musa paradisica*	Musaceae	Shrubs	Fruits
37.	Dalchini	*Cinnamomum zylanicum*	Lauraceae	Shrubs	Bark
38.	Thulo Ashare	*Largerstromia regime*	Lythraceae	Tree	Leaves
39.	Bans	*Bambusa species*	Graminaceae	Tree	Leaves
40.	Bedu	*Ficus palmata*	Moraceae	Tree	Fruits

9. PHOTO PLATES

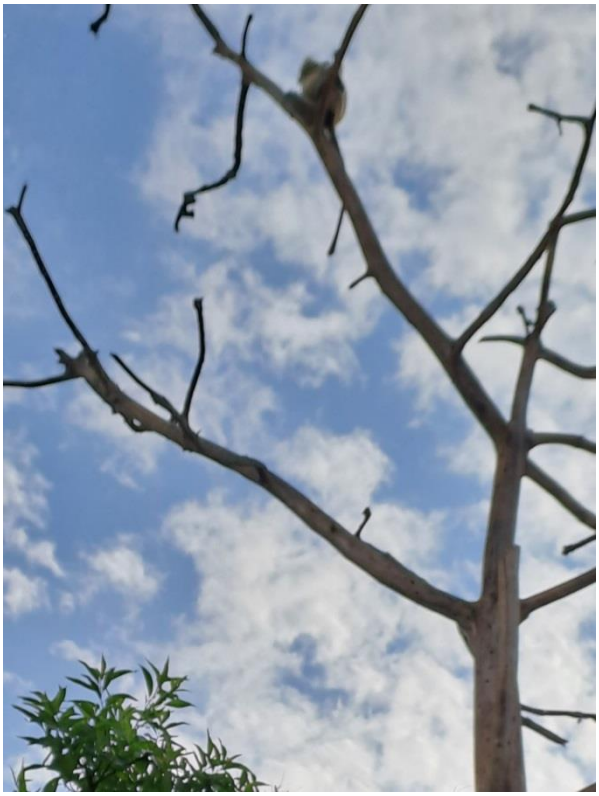

Photo 1. Adult male resting on tree

Photo 2. Adult female feeding on shrubs

Photo 3. Adult male feeding on bark

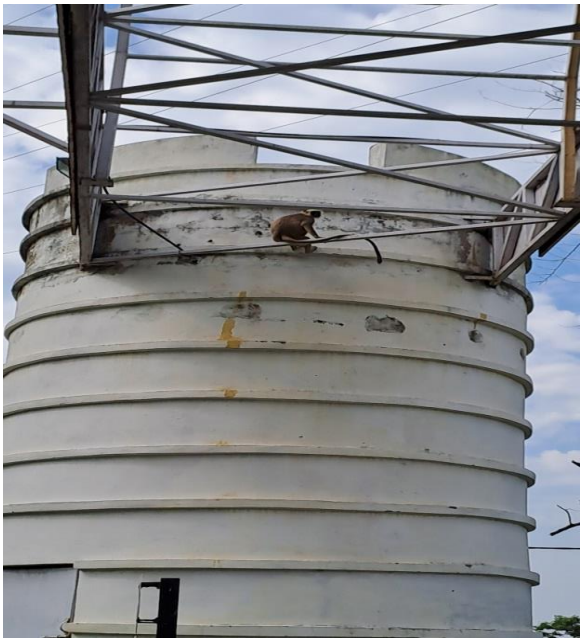

Photo 4. Juvenile male licking the surface of constructed structure for obtaining mineral

Photo 5. Adult female grooming her infant

Photo 6. Adult male feeding on herbs

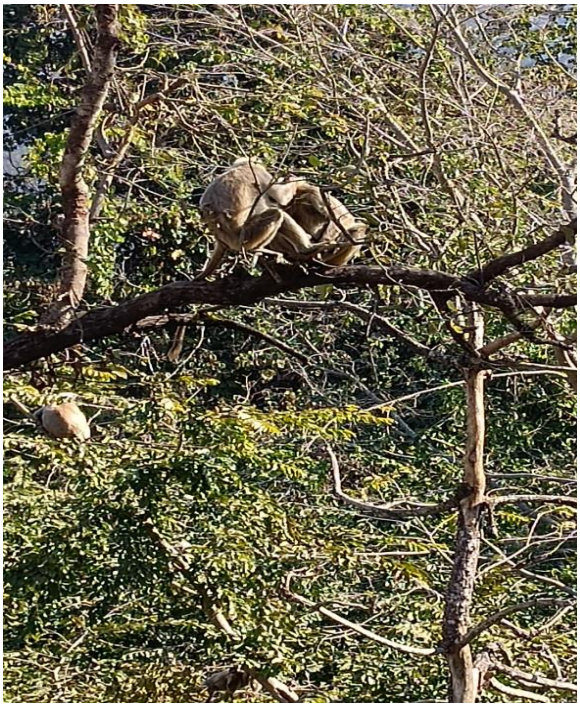

Photo 7. Juveniles grooming each other

Photo 8. Langurs in alert posture against perceived threat

Photo 9. Juvenile crossing the road to access for water

Photo 10. Langurs using ground stratum

Photo 11. Observer taking help from the park staffs for identification of food plants of langurs

Photo 12. Observer taking the GPS points of the study area