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Diurnal Activity Profiles of Forest-inhabiting Indian Peafowl in Bornadi Wildlife Sanctuary, Assam, India

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Authors' contributions

This work was carried out in collaboration among all authors. Author AD collected the data. Authors PS and AB designed the study. Author AB performed the statistical analysis. All the authors wrote the manuscript and approved the final manuscript.

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ABSTRACT

A free-ranging flock of Indian Peafowl (*Pavo cristatus*) was studied to analyze their diurnal activity budget in Barnodi Wildlife Sanctuary, Assam, India. A total of 11,664 scan samples were collected over three consecutive years (2021-22 to 2023-24), covering all four distinct seasons. The study revealed that feeding was the predominant activity, impacting all other behaviors throughout the day. Bimodal peaks for feeding (up to 58% during the morning and 60% during the afternoon) and locomotion activities (up to 20% during the morning and 41% during the afternoon) while a mid-day peak for resting was observed. Additionally, mid-day peaks were noted for both preening and sand-basking behaviors. Display activity was more frequent during late morning and midday, further

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supporting its social function, which appeared to be balanced with resting time. However, the relatively consistent monitoring behavior suggested a typical approach to territory defense and predator safety. The findings also indicate that the random distribution of food resources influences the diurnal activity budget of forest-dwelling Indian Peafowl.

Keywords: Activity budget; Barnodi Wildlife Sanctuary; diurnal activity; Indian peafowl; Pavo cristatus; time budget.

1. INTRODUCTION

Time budgeting is a quantitative method used to analyze how animals allocate time to various activities (Struhsaker and Leland, 1979). The variation in time spent on these activities is influenced by factors such as individual physical condition, food availability, social structure, and environmental conditions (Clutton-Brock and Harvey, 1977), reflecting a species' adaptability to spatial and temporal changes. Numerous studies have examined activity budgeting, focusing on annual and seasonal variations across different species. However, the study of activity budgeting has certain limitations, as daily time allocation is often more crucial for meeting a species' immediate needs than seasonal or annual patterns. Diurnal activity profiles, which represent the daily cycle of time allocation, are shaped by physiological requirements and are influenced by factors such as weather and food resource availability in the habitat. As a result, understanding how time is allocated to various activities throughout the day is a valuable tool for studying how animals adapt to different habitats to optimize resource use for survival and reproduction (Defler, 1995).

Interestingly, studies on diurnal variation in time budgeting are quite scarce compared to those focusing on seasonal activity budgeting. Some research on diurnal activity budgeting has been conducted, correlating it with factors such as weather (Bernstein, 1972, 1975, 1980; Bernstein and Baker, 1988), temperature, and solar insolation (Chivers, 1968, 1977; Jarman and Jarman, 1973), light intensity (Farber and Ternes, 1969), pharmacological modifications (Ibuka, 1970), stress (Stroebel, 1969), and behavioral aspects like mother-infant relationships, separation, and sleep (Resenblum et al*.,* 1964). There have also been a few studies on diurnal feeding activity profiles (Robinson, 1984; Winkler, 1988; Passamani, 1998), including the effects of hunger (Resenblum et al., 1969) and digestive physiology and morphology (Leuthold, 1977), as well as on overall activity profiles (Bernstein, 1967; Martenson et al., 1977; Post, 1981; Altmann and Muruthi, 1988; Srivastava, 1989; Passamani, 1998).

The majority of the studies on activity budgeting were carried out on primates and large mammals. Some studies were also there on avian species like waterfowl and Coots (Christopher and Hill, 1988), Greater Flamingo (Kumar and Rana, 2021), Common Loon (Kirsch, 2022), Bee-eater (Ali and Asokan, 2015), Shelduck (Bensizerara and Chenchouni, 2019), Whooping Cranes (Vasseur et al., 2023), black-necked crane (Lhamo, 2021), White-breasted Kingfisher (Asokan and Ali, 2010) etc. However, the majority of the studies conducted on Indian Peafowl (*Pavo cristatus*) were either carried out on urban (Ojha, 2009; Dev, 2010; Harikrishnan et al*.,* 2010; Beauchamp, 2013; Mittal, 2015; Kaur and Kler, 2017; Senaratna et al*.,* 2019; Jain and Rana, 2023) or captive populations (Parveen et al*., 2018;* Miazi et al*., 2020;* Bhawna et al*.,* 2024; Das et al*.,* 2024) who partly depend on crops and/ or supplementary food. Hence, this paper aimed to cover the diurnal variation of activity budgeting of a free-ranging forest flock of Indian Peafowl in Brahmaputra valley which is identified as their easternmost distribution range.

2. STUDY AREA

The current study was conducted in Bornadi Wildlife Sanctuary, Assam, India, and spanned all four seasons. Located in the northern parts of Udalguri and Baksa districts, the sanctuary (26.7809°N, 91.7553°E) covers an area of 26.22 square kilometers. Nestled at the foothills of the Himalayas and sharing a border with Bhutan, it is situated about 30 km from Tangla town and 130 km (81 miles) from Guwahati (Fig. 1). The sanctuary takes its name from the Bornadi River, which runs along its western edge. Established in 1980, it serves as a protected area for wildlife.

Bornadi Wildlife Sanctuary is situated in the North East Brahmaputra Valley Biogeographic Province (9A) of the North East India Biogeographic Zone. The sanctuary encompasses a diverse range of fifty-one forest

types, including Tropical Wet Evergreen Forest, Tropical Semi-Evergreen Forest, Tropical Moist Deciduous Forest, Subtropical Broadleaf Hill Forest, Subtropical Pine Forest, Littoral and Swamp Forest, Grasslands, and Savannahs (Champion and Seth, 1968). The riverine dry deciduous forests in the sanctuary are largely in an early successional stage, gradually transitioning into moist deciduous forests as the distance from water sources increases, ultimately leading to semi-evergreen climax forests in the central part of the park.

The climate of Bornadi Wildlife Sanctuary is generally warm but highly humid for most of the year, with significant levels of precipitation. The area experiences four distinct seasons: pre-monsoon (PM), monsoon (M), retreating monsoon (RM), and winter (W) (Borthakur, 1986).

Bornadi Wildlife Sanctuary plays a crucial role in protecting several endangered species, including the Hispid hare and Pygmy hog. It is also home to a variety of other wildlife, such as capped langurs, porcupines, Indian gaurs, pangolins, tigers, Asiatic elephants, leopards, hornbills, swamp partridges, Bengal floricans, and many more. Additionally, over 200 bird species can be found within the sanctuary.

The forest fringe area surrounding the sanctuary is home to a diverse mix of ethnic and religious communities. The Bodos form the largest ethnic group, followed by Adivasi, Assamese, Bengali, and Nepali communities.

3. MATERIALS AND METHODS

The Scan Sampling method (Altmann, 1974) was determined to be the most appropriate technique after conducting several pilot projects, considering the forest's visibility and the study's objectives. A five-minute Scan Sampling protocol was implemented, resulting in a total of 11,664 scan samples collected over four distinct seasons: pre-monsoon (March-May), monsoon (June-September), retreating monsoon (October-November), and winter (December-February) (Borthakur, 1986). The flock was observed from dawn until dusk, with observations beginning half an hour before sunrise and continuing until half an hour after sunset. All major activities, including locomotion (travel), feeding, monitoring, resting, preening, sand bathing, reproductive behaviors, and other activities, were recorded.

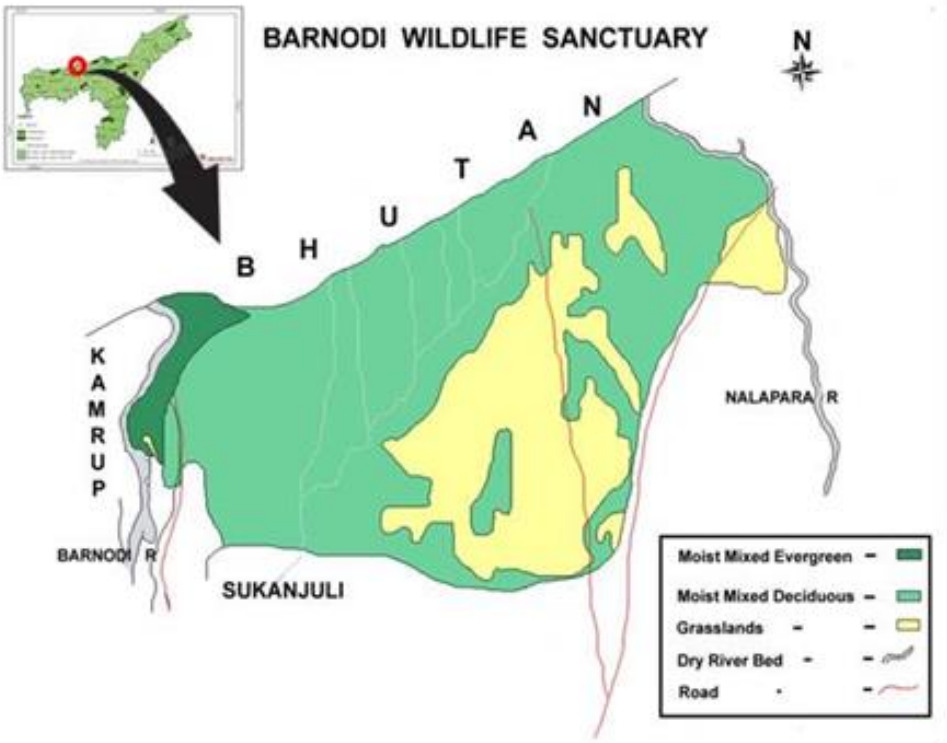

Fig. 1. Bornadi Wildlife Sanctuary, Assam
(Source: Assam Biodiversity Portal)

Activities representing less than 5% of the total observation time were grouped under the label "other activities," excluding reproductive and display behaviors. Infrequent behaviors, such as agonistic interactions and sexual behavior, were classified within the broader "other activities" category. The following specific cataloging was followed to record activities:

Locomotion: This refers to movements that exceed one body length, excluding those related to foraging. It encompasses all types of movement, including walking, running, flying/gliding, and jumping.

Feeding: This involves the intake of energy in the form of food, including foraging (the search for food), feeding, and drinking behavior.

Resting: This indicates a cessation of all known mechanical activities, which includes (a) resting behavior characterized by a motionless state with eyes open and (b) sleeping behavior identified by being motionless with eyes closed.

Monitoring: This describes solitary behavior in which an individual neither feeds, rests, sleeps, nor engages in social interactions, but instead looks around, observes, and remains vigilant for potential food sources.

Preening: This includes the self-manipulation of feathers with the beak (preening) and also includes sand bathing (dusting behavior).

Others: Incidental behaviors that account for less than 5% of total activity time were grouped as "other activities". This category includes various behaviors related to excluding reproductive behaviors (courtship, display, copulation, nest building, oviposition, and incubation, etc.), aggression, play, and vocalization. Since animals spend very little time on these activities, they have not been categorized further.

Data analysis was done using SPSS ver. 20 and XLSTAT software. Chi-square and t-tests were used to find significant differences between diurnal activity patterns in different seasons assuming the samples are independent of each other. Additionally, the Pearson correlation was also computed to illustrate the association between different activities in different seasons and time scales.

4. RESULTS

4.1. Annual Variation

Due to the variation in sunrise and sunset times throughout the year, making comparisons based on specific timings was not feasible. Therefore, sunrise and sunset were used as the “prefix time scale” for comparing activities. The time allocated to various activities during the day is detailed below:

Feeding: The Indian Peafowl flock exhibited a bimodal peak in feeding activity throughout the day. Feeding commenced half an hour before sunrise and continued until half an hour after sunset. Approximately 40% of their total time spent on feeding occurred during the morning and evening, with feeding activity reaching up to 58% in the morning and 60% in the evening (Fig. 2). A significant variation in feeding at various time intervals was also observed during the morning ($t=18.398$, $p\leq0.05$) and afternoon hours ($t=10.593$, $p\leq0.05$) in the present study.

Locomotion: Locomotion consistently coincided with feeding activity throughout the day, making it the second most time-consuming activity after feeding. The flock spent approximately 20% of their total time engaged in locomotion, with a higher proportion (41%) occurring during the half-hour before sunrise and a lower percentage (12%) during midday. Locomotion activity of peafowl varies between the different times in the morning ($t=10.089$, $p\leq0.05$) and afternoon ($t=15.592$, $p\leq0.05$) as depicted by the t-test.

Resting: The flock exhibited significant variation in resting activity during the day, with a distinct peak at midday. They allocated only 0.5% of their total time to resting half an hour after sunrise, which gradually increased to 15% around midday before declining again to 3% in the evening. Ultimately, resting behavior peaked at 8% half an hour after sunset. Resting activity varied significantly only during morning hours ($t=2.730$, $p\leq0.05$) during the study period.

Monitoring: Monitoring activity remained relatively stable throughout the day, with a slight increase in the evening and half an hour after sunset, reaching 13%. There was also a significant difference in monitoring activity during the morning ($t=14.281$, $p\leq0.05$) and afternoon ($t=4.119$, $p\leq0.05$) of the peafowl in the present study.

Preening: Although the time dedicated to these activities was lower compared to feeding and resting, the study flock demonstrated a distinct peak in midday. Time spent on these activities varied from 0.2% to 34.6% throughout the day. The t-test illustrated a significant variation in the preening activity of peafowl both in the morning (t=5.844, p≤0.05) and afternoon (t=4.119, p≤0.05) in the present study.

Other Activities: Time spent on activities such as aggression and other behaviors was minimal, constituting only 3% during mid-day and decreasing further to just 0.6% in the evening. The other activities shown by the Indian peafowl also revealed a significant variation during the morning (t=6.063, p≤0.05) as well as in the afternoon (t=6.804, p≤0.05) as depicted in the present study.

There was a significant difference between the various activities ($\chi 2$=8.253E2, p≤0.05) of peafowl during morning hours in the present study. The present study revealed an association between various activities of the peafowl. There was a negative correlation between feeding and resting (r= -0.763, p≤0.05) whereas a positive correlation between preening and resting (r=0.915, p≤0.05) and between monitoring and other activities (r=0.756, p≤0.05) was observed during morning hours. Similarly, the various activities of peafowl revealed a significant difference ($\chi 2$=7.031E3, p≤0.05) during the afternoon time in the present study. Both positive and negative correlation between various activities of peafowl was observed during the afternoon hours. Feeding activities were negatively correlated with preening (r=-0.939, p≤0.05), monitoring (r=-0.760, p≤0.05), and resting (r=-0.924, p≤0.05). There was a positive correlation between resting and preening (r=0.937, p≤0.05) as well as with monitoring (r=0.794, p≤0.05) during the afternoon time.

4.2 Seasonal Variation

Though there is a marked inter-seasonal variation in activities throughout the daytime, it showed a similar trend in all seasons as in the annual variation.

Feeding: The study flock exhibited a bimodal peak in feeding activity, with one peak occurring in the morning and the other in the evening, regardless of the season. On average, the flock spent 45.18% (ranging from 16.5% to 67.9%) of their total time feeding during the pre-monsoon season, 38.23% (ranging from 8.8% to 65.3%) in the monsoon, 38.87% (ranging from 12.3% to 55.9%) in the retreating monsoon, and 38.38% (ranging from 21.7% to 55.1%) in winter. During the pre-monsoon, the highest peaks of feeding were 67.9% in the morning and 57.7% in the evening. However, the time spent feeding dropped to 19.3% during midday. In the monsoon season, the flock recorded its highest feeding activity at 65.3% in the morning and 59.2% in the evening. Although the feeding activity in the retreating monsoon and winter seasons did not exhibit a distinct bimodal pattern, it still showed notable variations, with 55.1% in the morning and 55.9% in the evening during the retreating monsoon, and 45.4% in the morning and 55.1% in the evening during winter. A significant variation in the feeding of Indian peafowl was also revealed by the t-test in pre-monsoon (t=10,105, p≤0.05), monsoon (t=9.031, p≤0.05), retreating monsoon (t=12.240, p≤0.05) and winter (t=13.731, p≤0.05) the present study.

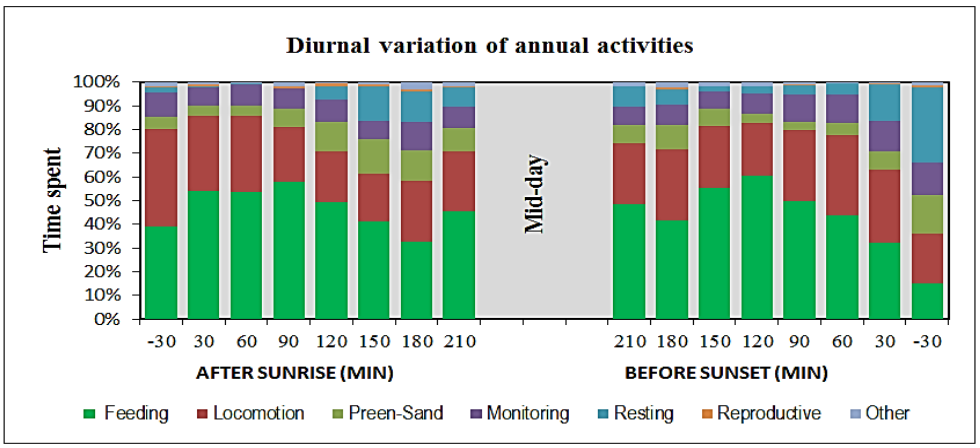

Fig. 2. Diurnal variation of activity budgeting

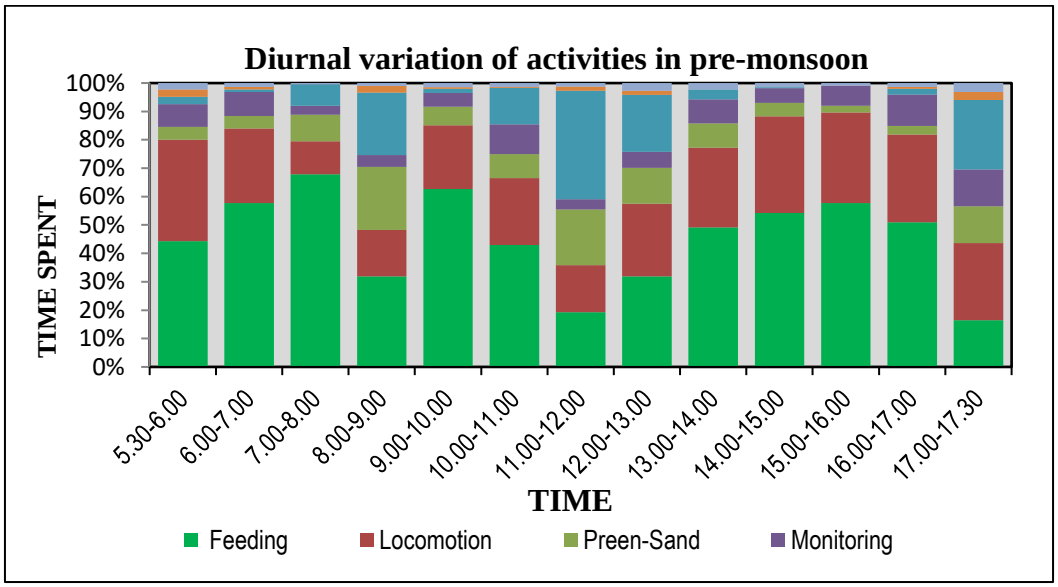

Fig. 3. Diurnal variation of activity profile in pre-monsoon

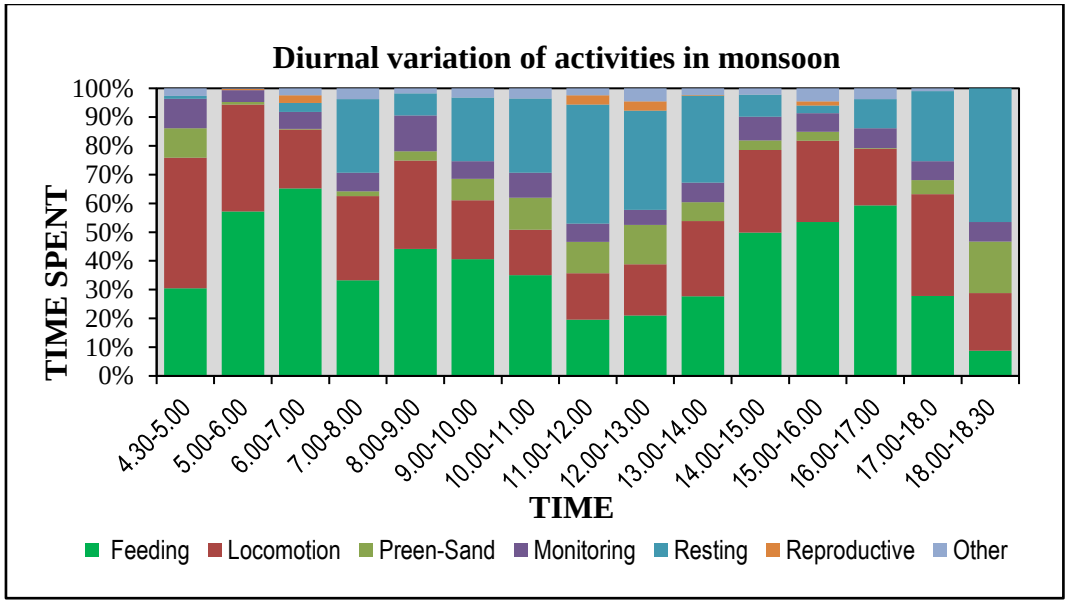

Fig. 4. Diurnal variation of activity profile in monsoon

Locomotion: Locomotion activity also exhibited a distinct bimodal peak across all seasons, as it is closely linked to feeding behavior. The study flock devoted an average of 25.38% (ranging from 11.7% to 35.7%) of their time to locomotion in the pre-monsoon season, 26.11% (ranging from 15.8% to 45.5%) in the monsoon, 23.79% (ranging from 8.9% to 38.3%) during the retreating monsoon and 26.83% (ranging from 15.8% to 46.6%) in winter. Locomotion activity peaked half an hour before sunrise in each respective season, while it decreased during midday. The t-test also revealed a significant difference in locomotion during pre-monsoon ($t=12.731$, $p\leq0.05$), monsoon ($t=11.697$, $p\leq0.05$), retreating monsoon ($t=10.852$, $p\leq0.05$) and winter ($t=11.882$, $p\leq0.05$) of the Indian peafowl in the present study.

Resting: Similar to annual variation, resting activity displayed a distinct mid-day peak across all seasons. On average, the flock spent 10.45% (ranging from 0% to 38.2%) of their total time resting during the pre-monsoon season, 18.87% (ranging from 0% to 46.4%) in the monsoon, 11.98% (ranging from 0.2% to 44.1%) in the

retreating monsoon, and 7.22% (ranging from 0% to 14.3%) in winter. The t-test also illustrated a significant difference in the resting activity of the peafowl during pre-monsoon (t=3.102, p≤0.05), monsoon (t=4.769, p≤0.05), retreating monsoon (t=3.497, p≤0.05) and winter (t=4.174, p≤0.05) in the present study.

Monitoring: The time allocated to monitoring activity remained relatively consistent throughout the day in each season. The flock dedicated an average of 7.17% (ranging from 3.2% to 13%) of their total daily time to monitoring in the pre-monsoon season, 7.16% (ranging from 4.2% to 12.5%) in the monsoon, 12.16% (ranging from 6.5% to 17.5%) during the retreating monsoon, and 12.58% (ranging from 9% to 25%) in winter. The monitoring activity of the Indian peafowl depicted a statistical variation during pre-monsoon (t=8.429, p≤0.05), monsoon (t=13.622, p≤0.05), retreating monsoon (t=13.406, p≤0.05) and winter (t=9.554, p≤0.05) in the present study.

Preening: Although the time dedicated to preening and sand basking activities was lower compared to feeding and locomotion, these activities still exhibited a distinct peak at midday. The study flock spent an average of 9.18% (ranging from 2.4% to 22.3%) of their time on these activities during the pre-monsoon season, 6.36% (ranging from 0.2% to 17.9%) in the monsoon, 12.04% (ranging from 4% to 24.8%) in the retreating monsoon, and 13.11% (ranging from 1.8% to 34.6%) in winter. The preening activity of peafowl also differed significantly during pre-monsoon (t=5.332, p≤0.05), monsoon (t=4.578, p≤0.05), retreating monsoon (t=7.390, p≤0.05), and winter (t=4.734, p≤0.05) as observed in the present study.

Other Activities: The time allocated to other activities (reproduction, aggression, etc.) was minimal throughout the day across all seasons. There was a significant variation among other activities of the peafowl during pre-monsoon (t=6.009, p≤0.05), monsoon (t=5.974, p≤0.05), retreating monsoon (t=4.360, p≤0.05) and winter (t=9.367, p≤0.05) in the present study.

Correlation among Various Diurnal Activities: There was a significant variation among various activities ($\chi 2$=9.889E2, p≤0.05) of peafowl in the pre-monsoon season as illustrated in the present study (Fig. 7). Different activities of the peafowl exhibited both positive and negative associations among themselves during pre-monsoon season. The feeding activity was significantly negatively correlated with preening (r=-0.716, p≤0.05), resting (r=-0.869, p≤0.05), and other activities (r=-0.747, p≤0.05). Further, the locomotion activity of peafowl was significantly negatively correlated with preening (r=-0.681, p≤0.05). Additionally, preening activity was significantly positively correlated with resting activity (r=0.886, p≤0.05).

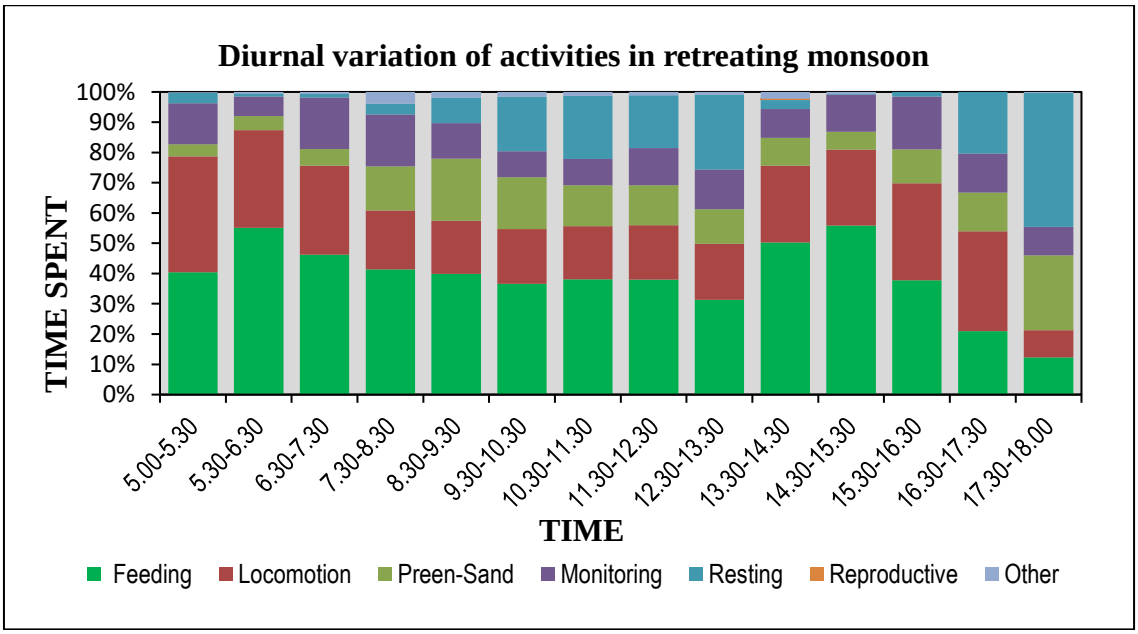

Fig. 5. Diurnal variation of activity profile in retreating monsoon

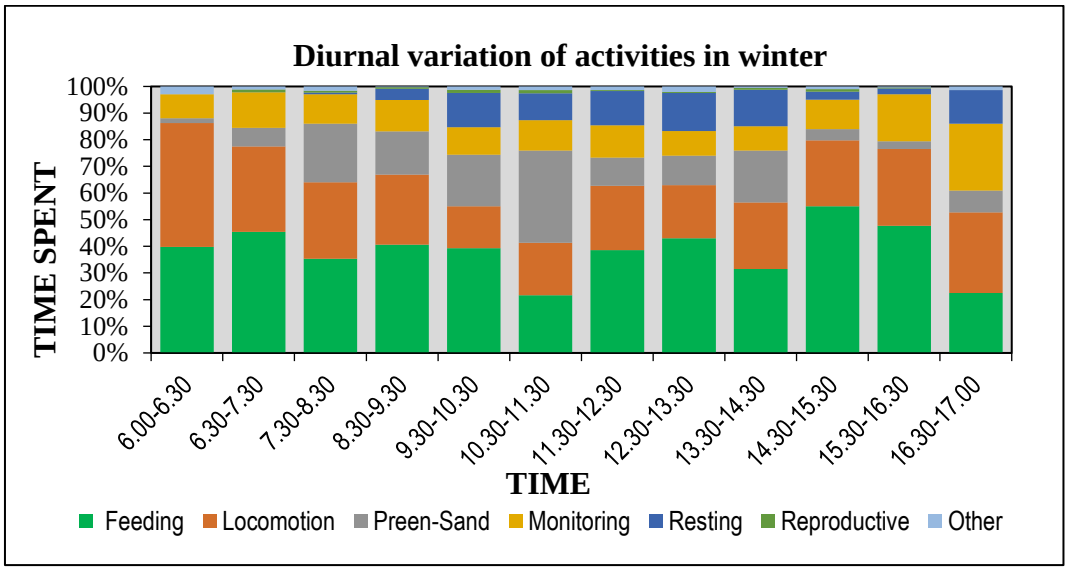

Fig. 6. Diurnal variation of activity profile in winter

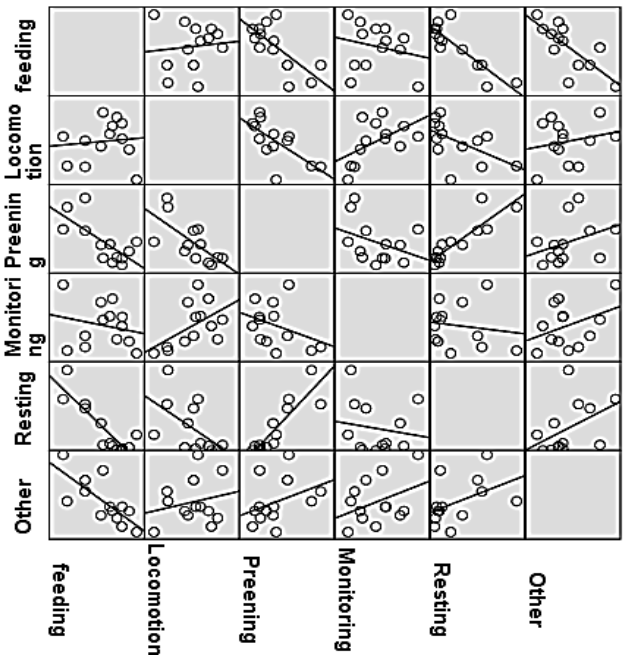

Fig. 7. Correlation among different activities during pre-monsoon

The various activities ($\chi 2=8.372E2$, $p\leq0.05$) of peafowl also differed significantly during monsoon in the present study (Fig. 8). The various activities of peafowl also illustrated both positive and negative correlations among themselves. There was a significant negative correlation between feeding with preening ($r=-0.858$, $p\leq0.05$) and resting ($r=-0.853$, $p\leq0.05$). Additionally, a significant negative correlation was also observed between locomotion and resting activity ($r=-0.576$, $p\leq0.05$). Further, preening and resting ($r=0.729$, $p\leq0.05$) were positively and significantly correlated with each other during monsoon in the present study.

There was also a significant difference among various activities ($\chi 2=7.015E2$, $p\leq0.05$) of peafowl during retreating monsoon in the present study (Fig. 9). Both positive and negative correlation among various activities of peafowl was exhibited in the present study. Feeding was negatively and significantly correlated with

preening (r=-0.704, p≤0.05) and resting (r=-0.864, p≤0.05). Locomotion was also negatively and significantly correlated with preening (r=-0.810, p≤0.05) and resting (r=-0.680, p≤0.05) whereas preening was positively and significantly correlated with resting (r=0.723, p≤0.05) during retreating monsoon in the present study.

There was a significant variation among all the activities ($\chi 2$=6.613E2, p≤0.05) of the peafowl in the present study during the winter season (Fig. 10). The various activities of peafowl correlated with each other positively and negatively. However, a significant negative correlation only was found among feeding and preening (r=-0.636, p≤0.05) as well as between locomotion and resting (r=-0.648, p≤0.05) during winter in the present study.

5. DISCUSSION

For survival, a species primarily requires food, which is one of the most critical factors influencing daily activities based on the resources available in their habitat. The quantity of food and its energy content needed by a species, along with the effort involved in gathering sufficient food, significantly impact their activity levels and time allocation across various daily activities (Kushlan, 1978). Consequently, individuals tend to prioritize feeding activities in the morning due to hunger, leading to increased time spent on feeding during these hours, which gradually declines as the day progresses (Kaur and Kler, 2017; Choudhary et al., 2021). A similar pattern has been observed in various other avian species (Soni et al., 2010; Rameshchandra, 2014; Shao et al., 2015; Kumar and Rana, 2021). For some avian species, such as the Black-headed Ibis and Red-naped Ibis, feeding activity peaks during both morning and evening hours (Espino-Barros and Baldassarre, 1989). A similar trend has been recorded in primates (e.g., Hanuman langurs: Srivastava, 1989; Pig-tailed macaques: Bernstein, 1972), where a bimodal peak in feeding activity is typical for most diurnal primate species. The physiological need for energy drives increased time spent feeding in the morning and evening. However, the extent of each feeding peak is influenced by habitat quality. The distribution of food resources also affects the time spent on feeding activities in primates (Oates, 1987). In forest environments, food is often distributed randomly (Sarkar, 2000), leading to longer foraging times and an extended feeding curve. This phenomenon does not apply to captive or urban populations, where food resources are clustered (Sarkar, 2014). Consequently, Indian Peafowl living in urban or captive conditions spend less time feeding compared to those in the wild (Miazi et al., 2020; Das et al., 2024).

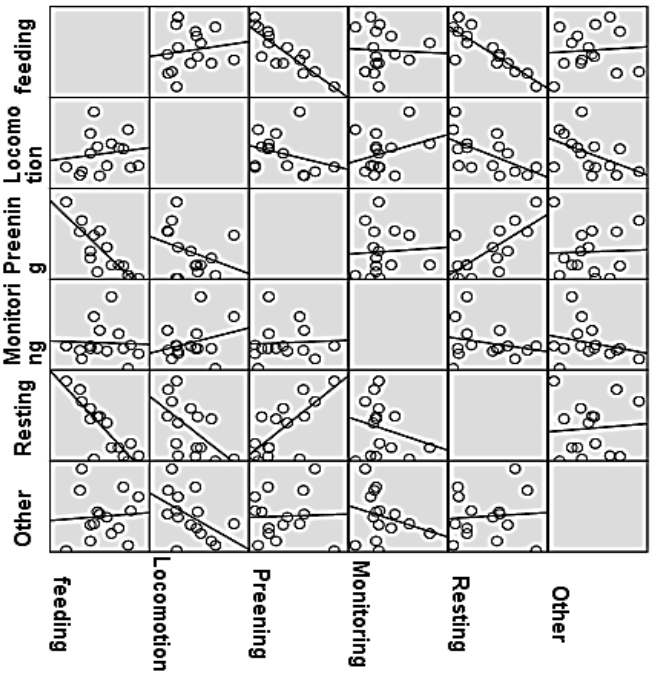

Fig. 8. Correlation among different activities during monsoon

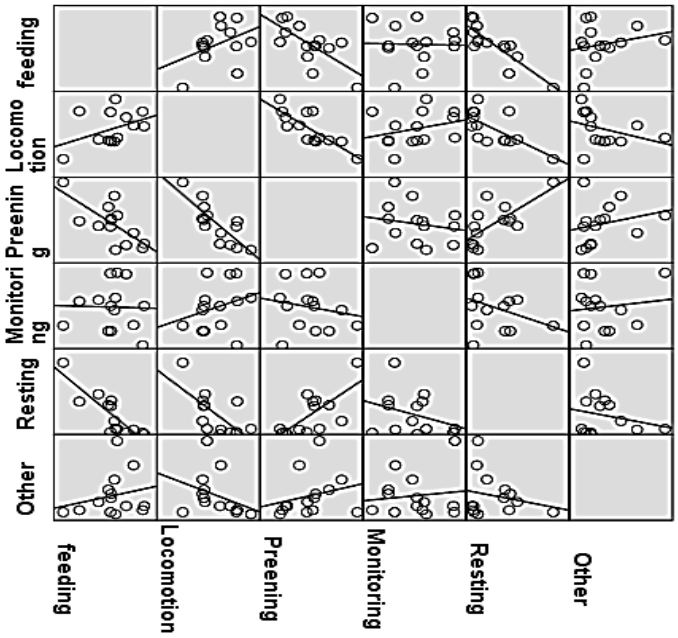

Fig. 9. Correlation among different activities during retreating monsoon

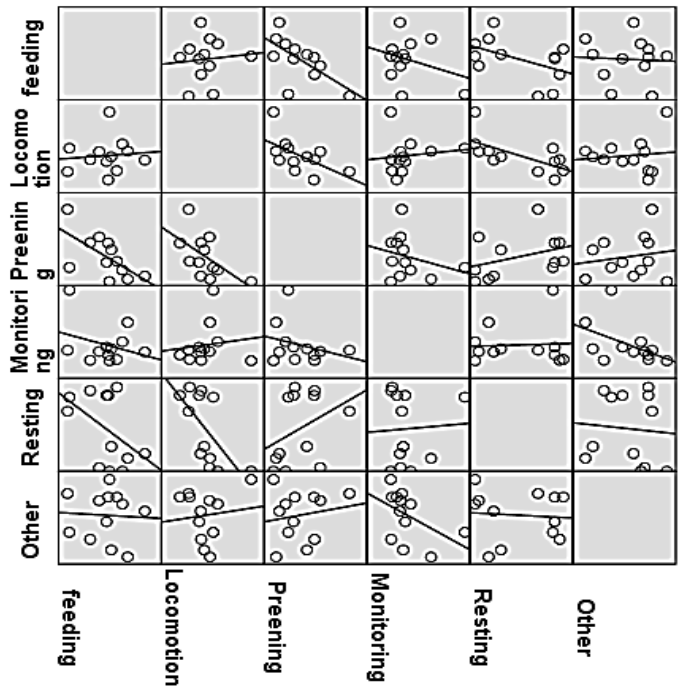

Fig. 10. Correlation among different activities during winter

Indian Peafowl typically move from their roosting sites to feeding areas in the morning and return in the evening. During foraging, they regularly transition from one feeding site to another in search of food, which increases locomotion activity. Therefore, feeding activity is closely linked with locomotion, resulting in a bimodal curve for locomotion that mirrors that of feeding activity. In degraded habitats, individuals may need to travel greater distances to find food, resulting in heightened locomotion activity. In such cases, the feeding curve may extend more than in undisturbed habitats.

Increased locomotion and feeding activities result in higher energy expenditure. To balance energy loss with energy gain, Indian Peafowl individuals need to allocate more time to resting activities. Consequently, the entire flock tends to rest during the mid-day hours (Kaur and Kler, 2017; Chaudhary et al*.,* 2021) after extensive feeding and locomotion. The amount of time spent resting is positively correlated with the duration of both feeding and locomotion activities.

Hypothetically, the time spent on monitoring activity should remain relatively constant since the risks from predators and the need for territory defense do not fluctuate significantly throughout the day. This study's findings align with the consensus that time spent on monitoring activities remains fairly static during the day. As a result, no distinct diurnal peak for monitoring activity was observed during the study period.

The time dedicated to preening was minimal compared to other activities and was typically noted in the early morning and late evening hours. Previous research on Indian Peafowl has reported similar findings (Khera and Kalsi, 1986; Ramachandran, 1998; Martinez, 2000; Muzaffar, 2004; Ali et al*.,* 2010a,b; Asokan et al*.,* 2010). In contrast, sand basking activities were more commonly observed during mid-day and early evening hours.

Regarding reproductive behavior, peacocks engage in dancing and displaying to attract peahens for copulation, which occurs more frequently in the morning and decreases in the afternoon during the monsoon season (Sharma, 1972; Johnsingh and Murali, 1978; Yasmin, 1995). Overall, the time allocated to breeding and display activities is significantly less compared to other activities. Following this, peahens initiate incubation, which lasts for an extended period.

6. CONCLUSION

The investigation into the diurnal activity patterns of Indian Peafowl flocks in the Brahmaputra Valley reveals that the availability of food resources significantly impacts these activity profiles. The random distribution of food within the forest leads to a pronounced peak in feeding and locomotion activities during the morning, followed by a mid-day peak in resting. This is then succeeded by additional peaks for both feeding and locomotion activities in the evening. In contrast, there was no distinct peak observed for monitoring activity, as the efforts related to territory defense and predator awareness remained consistent throughout the day. Thus, the availability of food resources shapes the diurnal activity profiles of free-ranging Indian Peafowl.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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