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DIETARY HABIT OF WESTERN HOOLOCK GIBBON (*HOOLOCK HOOLOCK* HARLAN, 1831) IN THE INNER LINE RESERVE FOREST OF SOUTHERN ASSAM, INDIA

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Abstract. This study investigates the dietary routines and feeding patterns of the western hoolock gibbon (*Hoolock hoolock*), a species facing extinction in the Inner Line Reserve Forest (ILRF) of Assam's Cachar district. The research, essential for effective primate conservation, focuses on a four-member gibbon group that resides in a small, isolated forest patch within the ILRF. Over a period of 12 days each month for a year (December 2011 to November 2012), with a total of 1,008 contact hours, observations reveal the diverse diet of the gibbon group. They allocate 34% of their annual activity budget to feeding, engaging in a varied diet that includes fruits (55.34%), leaves (24.28%), flowers (12.30%), seeds (5.18%), and minimal insect consumption (2.91%). Seasonal fluctuations in the consumption of plant parts are evident. The gibbon group displays extensive plant use, incorporating 56 species from 31 families. Moraceae (21.4%) dominates the diverse vegetation, which includes trees, figs, climbers, and woody lianas. Fruit consumption accounts for a significant portion (75%) of their diet, with *Artocarpus, Ficus, Dysoxylum*, and *Syzygium* species identified as preferred food sources. Although the gibbon group uses 56 species, the top 20 contribute approximately 75% to their overall feeding time. This study provides insights into the dietary preferences and plant choices of *Hoolock hoolock* in the ILRF. Understanding its activity budget, especially feeding time and dietary needs, is crucial for conservation, as it identifies essential food resources and seasonal dependencies. This knowledge can guide habitat management, restoration of preferred food species, and help mitigate habitat fragmentation impacts on the western hoolock gibbon.

INTRODUCTION

The western hoolock gibbon (*Hoolock hoolock* Harlan, 1831) is the only ape species native to India and one of the few gibbons found in the Indian subcontinent. Its distribution spans north-eastern India, Bangladesh, and western Myanmar, where it inhabits tropical and subtropical evergreen and semi-evergreen forests (Chetry et al. 2007; Brockelman and Geissmann 2008). Within India, the species is largely confined to forested regions south of the Brahmaputra River and east of the Dibang River, occurring across the states of Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, Nagaland, and Tripura (Choudhury 2008; Kumar et al. 2013). Over the past few decades, *H. hoolock* has suffered a sharp population decline – estimated at more than 90% in certain areas – primarily due to habitat destruction, fragmentation, and anthropogenic pressures such as hunting and shifting cultivation (Walker 2005; Brockelman and Geismann 2008; Borah et al. 2017). It is currently listed as globally endangered on the IUCN Red List.

Western hoolock gibbons are highly arboreal, diurnal primates with a primarily frugivorous diet, although they are known to consume a variety of plant parts including leaves, flowers, and seeds (Ahsan 1994; Islam and Feeroz 1992; Borah et al. 2017). Gibbons, being primarily frugivorous, depend heavily on the phenological cycles of forest vegetation, making them highly sensitive to environmental changes and forest degradation (Ahsan 1994; Hasan et al. 2005). Their dietary composition predominated by fruits, leaves, and flowers vary in response to seasonal fluctuations in food availability (Neha et al. 2020; Hasan et al. 2024). Ficus species (Moraceae), often referred to as keystone resources, play a critical role in sustaining these gibbons during periods of fruit scarcity (Muzaffar et al. 2007; Deb et al. 2014). Moreover, in response to habitat degradation and resource limitations, they have demonstrated dietary flexibility by consuming non-plant materials such as insects, soil, and bird eggs

(Deb et al. 2014; Neha et al. 2020) highlighting their adaptive foraging strategies.

Previous research across Bangladesh and northeast India has contributed to the understanding of the species' feeding ecology (Hasan et al. 2005; Neha et al. 2020), activity budgets (Borah et al. 2017), and habitat use (Hasan et al. 2007, 2024). However, most of these studies have focused on better-known habitats, leaving significant ecological gaps in lesser-studied regions. One such area is the Inner Line Reserve Forest (ILRF) of southern Assam, a key protected area for this species and an ecologically significant yet underexplored habitat at the intersection of fragmented forest corridors with respect to primate ecology and conservation.

Given its unique landscape, composed of interconnected forest patches and varying degrees of anthropogenic disturbance, the ILRF provides an important opportunity to explore how gibbons adapt to changing environments. In this context, the present study investigates the dietary habits of the western hoolock gibbon in the ILRF, with a focus on seasonal variation, food selection strategies, and behavioural adaptations. By filling a regional knowledge gap, the findings aim to inform evidence-based conservation efforts and contribute to a broader understanding of primate ecological resilience in fragmented landscapes. The study also seeks to support forest management and species conservation initiatives across northeast India.

MATERIALS AND METHODS

Study area

The study was conducted in the Inner Line Reserve Forest (ILRF), a significant protected area located in the Cachar district of southern Assam, India. The ILRF spans approximately 424 km², lying between 24°22' N to 25°8' N latitude and 92°24' E to 93°15' E longitude (Figure 1). This forest is bordered by Manipur to the east and Mizoram to the south, forming a crucial ecological corridor in the north-eastern region of India.

The ILRF is characterized by semi-evergreen and moist deciduous forests, with a diverse vegetation profile. Dominant tree species include *Artocarpus lakoocha, Dillenia indica, Careya arborea, Mangifera indica, and Syzygium cumini*. Evergreen trees such as *Ficus benghalensis, Garcinia cowa, and Pterospermum acerifolium* form a continuous canopy at the heights of 20–30 meters (Borah et al. 2016). The forest is situated at an elevation ranging between 50–300 meters above sea level. The region experiences a humid subtropical climate, with annual temperatures ranging from 6–8°C in winter to 35–38°C in summer. The average annual rainfall varies between 1,500 mm and 3,750 mm, and relative humidity remains high throughout the year, typically ranging from 70% to 85% (IMD).

This forest is home to a rich diversity of flora and fauna, including several endangered and vulnerable species.

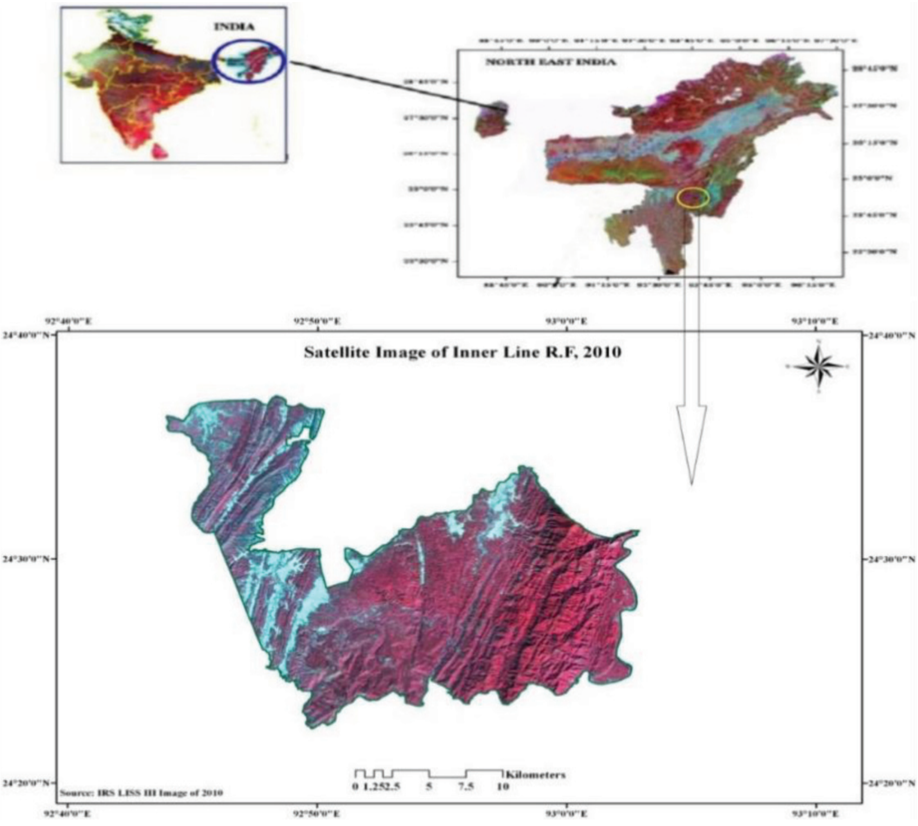

Figure1. Map showing the Inner Line Reserve Forest in northeast India.

The mammalian fauna includes western hoolock gibbons (*Hoolock hoolock*), capped langurs (*Trachypithecus pileatus*), Phayre's langurs (*Trachypithecus phayrei*) thesus macaques (*Macaca mulatta*), Assamese macaques (*Macaca assamensis*) and pig-tailed macaque (*Macaca leonina)*. Other notable species found in the area include Himalayan serow (*Capricornis sumatraensis thar*), barking deer (*Muntiacus muntjak vaginalis*), jungle cat (*Felis chaus affinis*), common palm civet (*Paradoxurus hermaphroditus*), Indian pangolin (*Manis crassicaudata*), and golden jackal (*Canis aureus indicus*). Many of these species are listed under Schedule I and Schedule II of the Indian Wildlife (Protection) Act, 1972, and are also categorized as endangered or critically endangered on the IUCN Red List (Choudhury 2013).

Data collection and analysis

Collection of data

The study focused on observing the behaviour of a specific group of hoolock gibbons inhabiting a forest patch bordered by tea gardens and a nearby village settlement (24°42'14.84" N, 92°42'0.04" E). The group consisted of four individuals: an adult male, an adult female, a sub-adult male, and an infant (excluded from observations). Habituation to human presence began in October 2011 and was achieved within 21 days, enabling behavioural observations to commence. From December 2011 to November 2012, data were collected using the instantaneous scan sampling method (Altmann 1974) at 5-minute intervals from dawn to dusk (5 AM to 6 PM) for 12 days each month (3 days in a week, alternate-day sampling). This schedule resulted in 1,008 contact hours over 12 months, with an average daily observation of 7 ± 1.45 hours. The canopy height was categorized into six ranks [rank-1 (1–5 m), rank-2 (6–10 m), rank-3 (11–15 m), rank-4 (16–20 m), rank-5 (21–25 m), and rank-6 (greater than 25 m)], and the positions of gibbons on substrates were classified based on the distance from the trunk, ranging from near the trunk to the periphery of branches. Substrate thickness was also ranked from trunk to twigs. Feeding data included plant species and parts consumed, categorized into fruits, leaves, flowers, and seeds. Unidentified plant specimens were collected and subsequently identified at Assam University and the Botanical Survey of India, Shillong (Meghalaya).

Analysis of data

Behavioural data analysis involved calculating the proportions of diet and the percentage of time spent feeding using standard formula (Gupta and Kumar 1994) i.e. $T = (nf \times 100)/N$, where T represents the percentage of daytime spent feeding, nf signifies the number of records that included feeding, and N represents the total number of records for the day. Observations also accounted for seasonal (winter, pre-monsoon, monsoon, and post-monsoon) and diurnal (early morning, morning, noon, and afternoon) variations in activities.

Statistical analysis was conducted using Excel 2010 and XLSTAT Pro software. To examine variations in activity patterns across different age-sex groups and seasons, Mann-Whitney U tests and Kruskal-Wallis tests were applied. Specifically, the Kruskal-Wallis test was used to assess differences in the consumption of plant parts across seasons, with significance determined at the 95% confidence level.

RESULTS

Annual feeding activity

The western hoolock gibbon group exhibited distinct activity patterns, with feeding occupying the most substantial portion of their total activity time. Feeding accounted for 34% of the annual activity budget, exceeding other behaviours such as movement (24%), resting (22%), social activities (15%) and calling (5%).

Seasonal variation in feeding

A clear seasonal variation in feeding activity was observed. The gibbons allocated a highest percentage of their total activity time to feeding during winter (37%) and post-monsoon (36%), followed by pre-monsoon (32%), and the lowest during the monsoon season (29%). Statistical analysis confirmed significant variations in feeding activity across seasons ($H = 10.5$, $df = 3$, $p < 0.05$). The highest negative deviation in feeding activity was recorded during the monsoon season, suggesting a direct correlation between resource availability and feeding time (Figure 2).

Canopy height preferences during feeding

Gibbons predominantly utilized the middle canopy for feeding. The highest feeding activity was recorded at 21–25 m (37.26%), followed by 16–20 m (36.36%). Feeding activity was minimal above 25 m (7.73%) and negligible below 5 m (0.23%) (Figure 3). This preference reflects their arboreal lifestyle and dependency on mid-canopy fruiting trees.

Substrate preferences during feeding

The gibbons displayed a distinct preference for smaller branches during feeding. Most of the feeding occurred on small branches near the periphery (41.32%), followed by twigs (28.99%). Feeding on medium branches (19.44%) was observed, while feeding on trunks or near trunks was minimal (4.69%) (Figure 4). These preferences indicate their adaptation to accessing fruits and young leaves in the outer canopy.

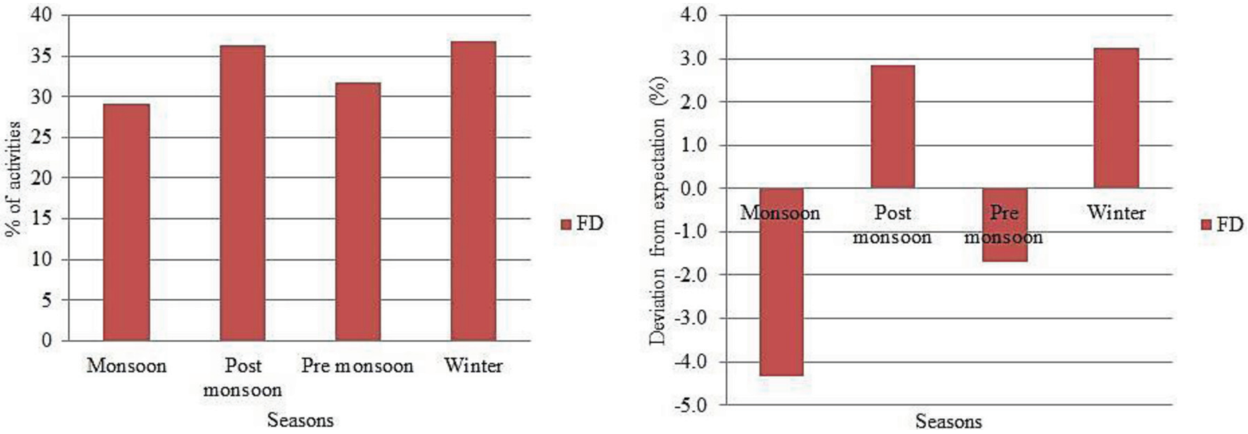

Figure 2. Seasonal variation of feeding activity (left) with deviation from the expectation (right) in the hoolock gibbon.

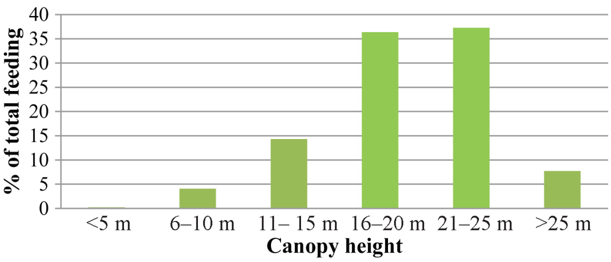

Figure 3. Canopy height used during feeding by the hoolock gibbon.

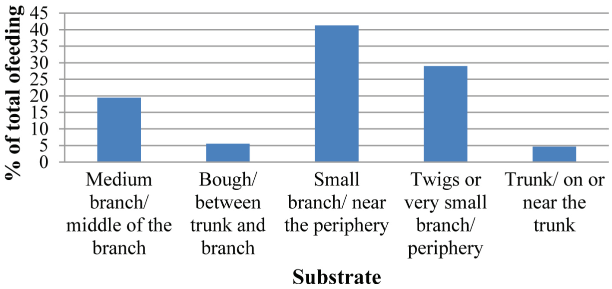

Figure 4. Thickness of branch substrates used during feeding by the hoolock gibbon.

Diurnal feeding patterns – annual

The hoolock gibbon group was observed to engage in feeding activities exclusively during daylight hours, with two distinct feeding peaks identified. The first peak occurred in the early morning between 5 AM and 9 AM, accounting for 45.75% of total feeding observations. A secondary, less pronounced peak was noted during the early afternoon, with feeding activity tapering off significantly after 3 PM. Feeding was infrequent during the midday period (12 PM–2 PM), recording the lowest activity at 6.83%.

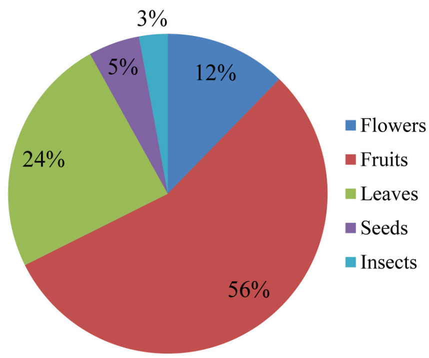

Figure 5. Annual dietary composition of the hoolock gibbon.

Annual dietary composition

Analysis of feeding activity data revealed the annual diet composition of the hoolock gibbon, encompassing fruits, leaves, flowers, seeds, and insects. Feeding data revealed that the gibbons' diet was predominantly frugivorous, consisting of fruits (55.34%), followed by leaves (24.28%), flowers (12.30%), seeds (5.18%), and the least feeding activity was observed on animal matter (insects), at 2.91% (Figure 5).

Table 1. Percentage time spent feeding on various plant parts by the hoolock gibbon.

Parts	% of plant parts eaten				
	Minimum		Maximum		Mean
	%	Month	%	Month	
Fruit	42.56	April	72.01	July	55.34
Leaves	14.68	November	30.47	April	24.28
Flowers	7.65	May	20.46	December	12.3
Seeds	0.25	November	11.01	March	5.18
Number of feeding bouts = 4114					

Monthly patterns in plant part consumption

The gibbon group's feeding behaviour demonstrated noticeable monthly patterns in the percentage of plant parts consumed. Throughout the year, the time spent feeding on fruits consistently exceeded other plant parts (refer to Table 1). Fruit consumption peaked in July (72.01%), whereas the lowest was recorded in April (42.56%). Leaf consumption was highest in April (30.47%), while flowers and seeds were predominantly consumed in December (20.46%) and March (11.01%), respectively. The lowest consumption of flowers and seeds was observed in May (7.65%) and September (0.25%), respectively (Figure 6).

Seasonal variation in plant part consumption

A significant seasonal variation in plant part consumption was observed (H = 12.5, df = 3, $p < 0.05$), indicating statistically meaningful differences in feeding patterns. Fruit consumption peaked during the post-monsoon (58.24%) and monsoon seasons, while it declined in pre-monsoon (31.76%) and winter (33.28%). Deviating from the average time spent on different plant parts, the study group exhibited the lowest fruit consumption in the pre-monsoon season, followed by winter. Leaf and flower consumption increased in winter (35.18% and 26.61%, respectively), whereas leaf consumption was lower in both the post-monsoon and winter seasons. Seed consumption peaked during the pre-monsoon season (15.07%). These variations highlight seasonal shifts in dietary preferences, likely influenced by resource availability (Figure 7).

Utilization of food plant species

The gibbons exhibited a diverse diet, utilizing 56 plant species as food sources, including trees, figs, climbers, and woody lianas. Among these, 21.4% belonged to the Moraceae family, followed by Anacardiaceae (8.9%), Euphorbiaceae (5.4%), Myrtaceae (3.6%), and others. Notably, Ficus species alone accounted for 60% of total fruit consumption, underscoring their significance as keystone resources. The majority of the plant species were used for a fruit-based diet (75%), followed by leaves (48.21%), flowers (28.57%), and seeds (23%). The gibbons showed a preference for specific food

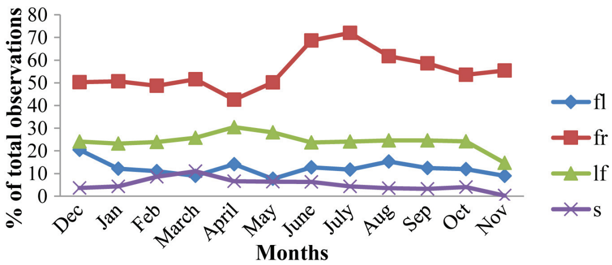

Figure 6. Monthly variation in time (%) spent feeding on various plant parts by the hoolock gibbon (fl – flowers, fr – fruits, lf – leaves, s – seeds).

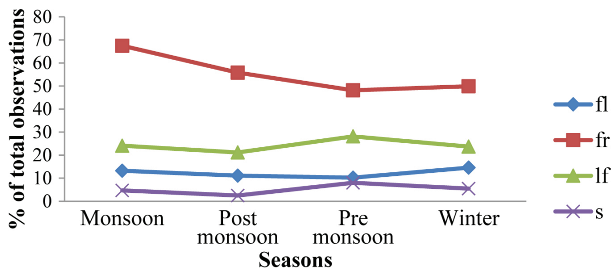

Figure 7. Seasonal variation in time (%) spent feeding on various plant parts by the hoolock gibbon (fl – flowers, fr – fruits, lf – leaves, s – seeds).

Table 2. Top 20 food plant species used by the hoolock gibbon with relative frequency of occurrence, feeding frequency, and plant parts consumed (fl – flowers, fr – fruits, lf – leaves, s – seeds).

Sl. No.	English Vernacular Name	Scientific Name	Family	Feeding Frequency (%)	Relative Frequency of Availability (%)	Fr	Lf	Fl	S
1	Kadamba tree / burflower tree	*Anthocephalus cadamba* Miq.	Rubiaceae	3.24	2.27	+	+	–	–
2	Chaplash / small jackfruit	*Artocarpus chama* Buch- Ham.	Moraceae	3.49	1.52	+	+	+	+
3	Monkey Jack / Lakoocha	*Artocarpus lakoocha* Roxb.	Moraceae	4.3	1.52	+	–	+	+
4	Indian chestnut	*Castonopsis indica* DC.	Fagaceae	2.11	3.03	+	–	+	+
5	Roxburgh's star apple	*Chrysophyllum roxburghii* G.Don	Sapotaceae	2.65	1.52	+	–	–	–
6	Indian white cedar	*Dysoxylum gobora* Miq.	Meliaceae	3.1	0.76	+	+	–	–
7	Roxburgh fig / elephant ear fig	*Ficus auriculata* Lour.	Moraceae	6.2	3.03	+	+	–	–
8	Banyan tree	*Ficus benghalensis* L.	Moraceae	3.9	1.76	+	+	–	–
9	Weeping fig	*Ficus benjamina* L.	Moraceae	6.45	0.76	+	+	–	–
10	Variable-leaf fig	*Ficus heterophylla* L. f. Supl.	Moraceae	4.05	1.52	+	+	–	–
11	Cluster fig / Indian fig	*Ficus racemosa* Vahl.	Moraceae	5.27	2.27	+	+	–	–
12	Sacred fig / peepal tree	*Ficus religiosa* L.	Moraceae	2.57	0.76	+	+	–	–
13	Cowa / Assam garcinia	*Garcinia cowa* Roxb.	Clusiaceae	3.49	1.52	+	+	–	–
14	Gmelina / white teak	*Gmelina arborea* Roxb.	Verbenaceae	4.1	3.79	+	+	+	–
15	Wild jamun / bush cherry	*Syzygium fruticosum* DC.	Myrtaceae	4.01	4.55	+	–	+	+
16	Wild mango / hog plum	*Spondias pinnata* Kurz.	Anacardiaceae	3.15	0.76	+	+	–	–
17	Java plum / black plum (jamun)	*Syzygium cumini* L.	Myrtaceae	5.32	4.55	+	–	+	+
18	Beleric myrobalan / baheda	*Terminalia belerica* Roxb.	Combretaceae	2.66	0.76	+	+	–	+
19	Chebulic myrobalan / haritaki	*Terminalia chebula* Retz.	Combretaceae	1.81	0.76	+	–	–	+
20	Chaulmoogra tree	*Hydnocarpus kurzii* Warb.	Flacourtiaceae	3.22	1.52	+	–	–	–

Key: Fr = fruit, Lf = leaf, Fl = flower, S = seed '+' = used, '–' = not used.

plants, including *Artocarpus, Ficus, Dysoxylum,* and *Syzygium* species.

Despite consuming a variety of plant species, the top 20 species contributed approximately 75% of total feeding time, highlighting the selective nature of their diet (Table 2). These predominant species primarily belonged to the Moraceae, Myrtaceae, Anacardiaceae, Meliaceae, and Flacourtiaceae families, with Ficus species being a major dietary component irrespective of availability. These findings provide crucial insights into the dietary preferences and ecological adaptations of the western hoolock gibbon, emphasizing the need for conservation efforts focused on preserving key fruiting tree species to support their survival.

DISCUSSION

The present study reveals significant seasonal variation in the dietary composition and foraging behaviour of the western hoolock gibbon in the Inner Line Reserve Forest (ILRF), southern Assam. Feeding accounted for 34% of the gibbon's activity budget annually, with fruits being the predominant dietary component (55.34%), followed by leaves (24.28%), flowers (12.30%), seeds (5.18%), and insects (2.91%). Fruit consumption was the highest during the monsoon season, aligning with findings from other studies in northeast India and Bangladesh (Ahsan 1994; Borah et al. 2017), and the lowest in the pre-monsoon season, where reliance on leaves and flowers increased. This pattern supports the concept that resource availability plays a pivotal role in shaping gibbon feeding strategies (Muzaffar et al. 2007; Islam and Feeroz 1992; Neha et al. 2020).

Unlike earlier studies that generalized seasonal patterns across regions, this study provides a nuanced perspective by situating the feeding ecology within the context of fragmented habitats in the ILRF. Compared to other documented populations utilizing over 70 plant species (Neha et al. 2020), the gibbons in our study relied on only 56 species, potentially reflecting habitat degradation and selective pressure. The gibbons in ILRF utilized these plant species across multiple families, with a dominant representation of Moraceae, Anacardiaceae, Myrtaceae, and Euphorbiaceae. This reflects patterns observed in other tropical forest fragments where these plant families form the core of gibbon diets (Hasan et al. 2007; Kumar et al. 2013). Habitat degradation and biotic disturbances, particularly shifting cultivation, reduce plant species diversity and alters the availability of key resources. The concentration of feeding time on 20 food plant species indicates a selective feeding strategy, likely based on palatability, nutritional content, and predictability of fruiting phenology (Borah et al. 2017). The predominance of a few selected food species in the diet, particularly *Ficus* species, from the Moraceae family were the most heavily consumed, reinforcing their status as keystone resources in tropical forest ecosystems (McConkey et al. 2003; O'Brien et al. 2003; Deb et al. 2014). This dependency underscores the need to conserve specific plant taxa crucial to the species' survival.

The study also reveals distinct canopy use and substrate preferences. Gibbons predominantly foraged between 16–25 m, favouring peripheral branches, consistent with their suspensory locomotion and arboreal foraging style (Gittins 1982; Ahsan 1994). This vertical stratification helps reduce interspecific competition with sympatric species like *Macaca mulatta* and *Trachypithecus pileatus* (Feeroz 2000). Similar canopy-related shifts in gibbon behaviour were observed by Hasan et al. (2007) in Lawachara National Park and supported by recent work in Assam's fragmented landscapes (Mishra and Saudagar 2024).

Diurnal feeding patterns observed in this study reveal two distinct feeding peaks, one in the early morning between 5–9 AM, and another less pronounced peak during the early afternoon, with tapering off significantly after 3 PM. Feeding was infrequent during the midday period (12–2 PM). This bimodal pattern of feeding likely reflects a thermoregulatory strategy, avoiding midday heat stress, and has been similarly observed in other primate populations (Tilson 1979; Islam and Feeroz 1992; Hasan et al. 2024). The midday declines in feeding activity may be attributed to increased ambient temperatures and reduced food-searching efforts during peak heat hours.

Our findings reinforce the hypothesis that food resource distribution strongly affects activity budgets. In resource-scarce environments, gibbons appear to invest more time in feeding and locomotion and less in resting and social interactions. These adaptive responses mirror those reported in other frugivorous primates exposed to habitat fragmentation and declining food availability (Gittins 1982; McConkey et al. 2003). Recent dietary studies in similar fragmented habitats have reported parallel adaptations in activity budgets and foraging effort (Chetry et al. 2007; Mishra and Saudagar 2024). This behavioural adaptation mirrors patterns observed in forest-dwelling primates with limited resource availability (Gittins 1982; O'Brien et al. 2003). A relatively high percentage of time spent on feeding in this study suggests that habitat fragmentation may be exerting additional foraging pressures on the gibbon group. Recent studies (Mishra and Saudagar 2024) have also documented similar activity budget adaptations in gibbons inhabiting human-modified landscapes, further supporting this trend.

In conclusion, this study provides valuable insights into the dietary habits and foraging strategies of the western hoolock gibbon in the Inner Line Reserve Forest. A strong seasonal dependency on fruiting trees highlights the importance of habitat conservation and restoration efforts, particularly the protection of keystone species such as *Ficus* spp. Further research is needed to assess the long-term impacts of habitat fragmentation and climate variability on gibbon foraging ecology, which will be crucial for developing effective conservation strategies.

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