



Seasonal Variations in Diet Choice of the Indian Flying Fox, *Pteropus medius*

Manjulendra Kumar and Vadamalai Elangovan

Department of Zoology, School of Life Sciences
Babasaheb Bhimrao Ambedkar University, Lucknow-226 025, India
E-mai: manjulendra725@gmail.com

Abstract: The seasonal diet choice of the Indian flying fox, *Pteropus medius*, was carried out in Lucknow, Uttar Pradesh, India, from March 2023 to February 2024. A total of 885 fecal samples (bolus and guano) were gathered from nine roost sites and analyzed. The analysis indicated that the diet predominantly consisted of six genera across five plant families, with *F. racemosa* and the Moraceae family being the most prevalent. Seasonal variations in dietary composition included the consumption of *M. alba*, *P. guajava*, and *N. cadamba*, while *F. racemosa* and *F. benjamina* which were abundant during the summer, monsoon, and post monsoon periods. Generalized Linear Model (GLM) utilizing a gamma distribution demonstrated that *P. guajava* and *F. racemosa* were the most frequently consumed species during the monsoon and summer seasons in the guano. The significant seasonal effects with increased consumption was observed during the monsoon and summer. The bolus analysis indicated a preference for *F. benjamina* and *M. indica*. These findings highlight the seasonal dietary adaptations of *P. medius*, emphasizing the essential role of specific plant species, particularly during the monsoon and summer seasons, in fulfilling its nutritional requirements.

Keywords: *P. medius*, Indian flying fox, *Ficus*, Diet analysis

The Indian flying fox, *Pteropus medius* (Temminck 1825), is a significant species within the order Chiroptera and the suborder Yinpterochiroptera (Lei and Dong 2016). It ranks among the largest bat species globally. This species is endemic to South Asia and plays crucial ecological roles, including pollination, seed dispersal, and nutrient cycling, impacting over 114 plant species (Aziz et al., 2021). The Indian flying fox is essential for sustaining ecosystem functionality, as it substantially contributes to various ecological processes such as pollination, seed dispersal, and nutrient cycling (Goveas et al., 2006, Kumar and Elangovan, 2019, Madala et al., 2022).

Despite their critical ecological significance, bats face numerous threats, including hunting and the culling of individuals, which are frequently perceived as pest species (Epstein et al., 2009). On a global scale, *P. medius* is classified as "Least Concern" on the IUCN red list of threatened species (Tsang 2020) and is afforded protection under Schedule II of the wildlife (protection) amendment act, 2021 in India, as well as by the convention on international trade in endangered species of wild fauna and flora (CITES: Appendix II). Bats, such as the Indian flying fox, exhibit distinctive feeding behaviors that set them apart from other mammalian species. Numerous studies have examined the dietary habits of various *Pteropus* species; however there is a paucity of research focusing on their dietary patterns within specific geographical contexts. In the Indian subcontinent, only a

limited number of investigations have been conducted regarding the diet of *P. medius* (Mahmood-Ul-Hassan et al., 2010, Javid et al., 2016, Ashwin and Jayakumar 2019, Tiwari et al., 2019, Basharat et al., 2021). The dietary preferences of *P. medius* are known to fluctuate in accordance with the seasonal availability of fruits (Stier and Mildenstein 2005). The present study concentrates on the region of Lucknow, Uttar Pradesh, which is characterized by a rich diversity of angiospermic flora, encompassing more than 1,263 plant species across 705 genera and 140 families. This assemblage includes 989 species of dicotyledons and 274 species of monocotyledons. The representation of monocotyledons is comparatively lower, with significant contributions from the Poaceae and Cyperaceae families. Specifically, out of the 274 monocotyledon species, 176 are classified within these two families, while the remaining 98 species are distributed among 23 additional families (Singh et al., 2020). The objective of this study was to investigate the seasonal dietary preferences of *P. medius* in Lucknow, Uttar Pradesh. These insights aim to support effective conservation strategies and ensure the long-term survival of this ecologically significant species.

MATERIAL AND METHODS

Study area: The present study was conducted at Lucknow, capital of Uttar Pradesh, is situated 123 meters above sea level. It is located between latitudes 26.30° and 27.10° North and longitudes 80.30° and 81.13° East.

Study sites: The nine roost sites of *P. medius* in Lucknow were selected for this study (Table 1). A cartographic representation of the study locations was created using QGIS software (version 3.36.0) (Fig. 1). According to the India meteorological department of Lucknow; the winter season spans December, January, and February, while March, April, and May constitute the summer season. The monsoon season occurs in June, July, August, and September. The post monsoon season includes October and November.

Field surveys and sample collections: Field surveys were conducted to gather fecal pellets from Indian flying foxes between March 2023 and February 2024. Sample collection was done during the morning hours, specifically from 8 AM to

12 PM, when the flying foxes were observed at their roosting locations. It has been documented that Indian flying foxes consume soft fruits, extracting juice and subsequently expelling the remnants, referred to as bolus, while the material excreted from the gastrointestinal tract is termed guano (Goveas et al., 2006). Fresh bolus and guano from *P. medius* were collected by placing old plastic sheets on the ground of diurnal roosting sites (Hodgkison et al., 2003). The samples were randomly selected from the overall population of flying foxes, following the methodology established by Parry-Jones and Augée (2001). The collected samples were then securely contained in sealed receptacles and transported to the laboratory for further analysis.

Diet analysis and species recognition: The samples were transferred into a 100 ml glass container, to which 50 ml of distilled water was subsequently added. The resulting mixture was agitated thoroughly to facilitate the separation of undigested food particles. The seeds and other components that were extricated from the bolus and guano were then enumerated and visually identified through comparison with reference seeds. This identification process was conducted utilizing a handheld magnifying glass and a stereomicroscope (RADICAL RSMr-3), in accordance with the methodology outlined by Hodgkison et al. (2003).

Data analysis: Generalized Linear Model (GLM) incorporating a gamma distribution and log link function was employed to examine the relationship between the frequency of plant species found in guano/bolus and seasonal variations. The dependent variable in this analysis was

Table 1. Geo-coordinates and elevations of roost sites of the *Pteropus medius*

Site name	Latitude (DD)	Longitude (DD)	Elevation (m)
Anora	26.7839	80.8564	145.58
Aishbagh	26.8417	80.9064	148.48
Basteya	27.0947	80.7608	140.33
CSIR- NBRI Banthara	26.6847	80.8375	146.3
Khurdai	26.7832	81.0481	142.64
Meenapur	26.6036	80.9222	147.63
Mohanlalganj	26.6831	80.9836	142.84
Natkur	26.7297	80.8692	145.34
Sohramau	26.7794	81.1364	142.8

(DD = Decimal Degree, m = Meter)

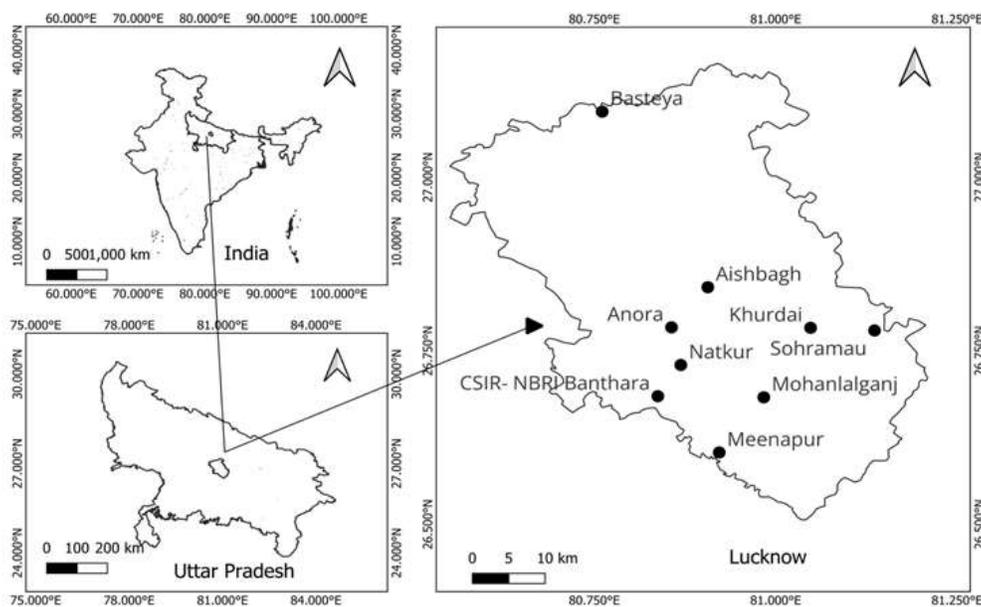


Fig. 1. Study area map of *Pteropus medius*

species frequency, while the independent variables included plant species and seasonal categories (winter, summer, monsoon and post-monsoon). The adequacy of the model fit was assessed through the deviance/df and Pearson chi-square/df ratios, with values approaching 1 indicating satisfactory fit. The Likelihood ratio Chi-Square test was utilized to evaluate improvements in the model, whereas the Wald Chi-Square test was used to analyze the effects of species and seasons. Parameter estimates B values (the regression coefficients from the GLM analysis, indicating the relative influence of each plant species on dietary frequency) and estimated marginal means were computed. All statistical analyses were conducted using SPSS (version 21). The data were expressed as frequency of occurrence for each plant species to determine the food preferences of *P. medius* (Mahmood-UI-Hassan et al., 2010).

$$\text{Frequency of occurrence} = \frac{\text{Number of samples in which particular plant source occurred}}{\text{Total number of samples analysed in a season}} \times 100$$

RESULTS AND DISCUSSION

An analysis of 885 fecal samples, encompassing both bolus and guano, indicated that *P. medius* engages in the consumption of plant materials from six genera across five distinct families. There were seasonal variations in dietary preferences, specifically; *Morus alba* from the Moraceae family was consumed at rates of 17.5 % during the summer and 3.13 % in the winter months. *Ficus racemosa* was consistently present throughout the year, with its consumption peaking during the monsoon season at 54.35%. Additionally, *Artocarpus lacucha* (4.61 %) was observed during the monsoon, while *Ficus benjamina*

(37.33%) was predominantly consumed in the post-monsoon period. *Neolamarckia cadamba*, belonging to the Rubiaceae family, was identified in both summer (13.33%) and winter (28.75%), whereas *Mangifera indica* (30%) from the Anacardiaceae family was also consumed in the summer. *Psidium guajava*, representing the Myrtaceae family (6.67 % in the monsoon and 4 % in the post-monsoon) and the *Tectona grandis* from the Lamiaceae family was observed in the post-monsoon (24%) season. Unidentified plant material was detected across all seasons, with a peak occurrence of 34.36 % in the monsoon period (Table 2).

The analysis of guano further illustrated the dietary flexibility of *P. medius*. The *Ficus religiosa* was consumed during the summer (13.33%), and winter (4.62%). *M. alba* exhibited peak consumption in the summer (30.67%) and winter (6.15%), while *F. racemosa* was present throughout the year, with the highest consumption in the monsoon (33%). *N. cadamba* was observed in winter (13.85%), and *P. guajava* was particularly dominant during the monsoon season (42%). Unidentified plant material was found in all the seasons with the highest proportion (49.23%) occurring in the winter (Table 3). *P. medius* exhibits significant dietary adaptability with *F. racemosa* serving a crucial role in its diet throughout the year.

Statistics: Using a Generalized Linear Model (GLM) with a gamma distribution and log link function, the bolus analysis showed a strong model fit, with a deviance/df ratio of 0.395 and an Akaike Information Criterion (AIC) of 145.927. The Wald Chi-Square test for plant species was highly significant ($\chi^2 = 93.323$), indicating that species like *F. benjamina* (B = 2.228), *M. indica* (B = 2.316), and *F. racemosa* (B = 2.140) were frequently consumed, with *F. benjamina* having the highest mean frequency (35.94). Although the effect of

Table 2. Seasonal frequency of occurrence of plant species in the bolus of *P. medius*

Family	Plant name	Common name	Summer	Monsoon	Post-monsoon	Winter
Moraceae	<i>Ficus religiosa</i>	Sacred Fig	+ (14.17)	-	-	+ (7.5)
	<i>Morus alba</i>	Mulberry	+(17.5)	-	-	+ (3.13)
	<i>Ficus racemosa</i>	Cluster Fig	+(16.67)	+ (54.35)	+ (18.67)	+(48.12)
	<i>Ficus bengalensis</i>	Banyan Tree	+(4.17)	-	-	-
	<i>Artocarpus lacucha</i>	Monkey Jack	-	+ (4.61)	-	-
	<i>Ficus benjamina</i>	Weeping Fig	-	-	+ (37.33)	-
Rubiaceae	<i>Neolamarckia cadamba</i>	Kadamba Tree	+(13.33)	-	-	+(28.75)
Anacardiaceae	<i>Mangifera indica</i>	Mango Tree	+(30.00)	-	-	-
Myrtaceae	<i>Psidium guajava</i>	Guava Tree	-	+ (6.67)	+ (4.00)	-
Lamiaceae	<i>Tectona grandis</i>	Teak Tree	-	-	+ (24.00)	-
	Unidentified	-	+ (4.16)	+ (34.36)	+ (16.00)	+ (12.5)

Summer = March to May; Monsoon = June to September; Post-monsoon = October and November; Winter = December to February. Presence [+], Absence [-], Frequency of occurrence of plant species given in parenthesis

Table 3. Seasonal frequency of occurrence of plant species in the guano of *P. medius*

Family	Plant name	Common name	Summer	Monsoon	Post-monsoon	Winter
Moraceae	<i>Ficus religiosa</i>	Sacred Fig	+ (13.33)	-	-	+ (4.62)
	<i>Morus alba</i>	Mulberry	+ (30.67)	-	-	+ (6.15)
	<i>Ficus racemosa</i>	Cluster Fig	+ (21.33)	+ (33.00)	+ (27.70)	+(26.15)
	<i>Ficus bengalensis</i>	Banyan Tree	+ (10.67)	-	-	-
	<i>Ficus benjamina</i>	Weeping Fig	-	-	+ (26.15)	-
Rubiaceae	<i>Neolamarckia cadamba</i>	Kadamba Tree	+ (17.33)	-	-	+(13.85)
Myrtaceae	<i>Psidium guajava</i>	Guava Tree	-	+ (42.00)	-	-
	Unidentified	-	+ (6.67)	+ (25.00)	+ (46.15)	+ (49.23)

See table 2 for details

seasons on the bolus frequency was not statistically significant, descriptive statistics suggested trends highest mean frequency with the monsoon season (20.90). Seasonal trends in diet were less pronounced in the bolus, some seasonal variation in plant availability may still influence the composition of the bolus. The diet of *P. medius* is significantly influenced by plant species, with species like *P. guajava*, *F. racemosa*, *F. benjamina* and *M. indica* playing key roles.

In contrast, the guano analysis, the model fit was adequate, with a Pearson chi-square/df ratio of 0.155 and a Pearson chi-square/df ratio of 0.142. The Wald Chi-Square test revealed that both plant species ($\chi^2 = 191.647$) and seasons ($\chi^2 = 17.159$) had significant effects on the frequency of plant species in the guano of *P. medius*. Specifically, *P. guajava* (B = 2.282) and *F. racemosa* (B = 2.136) were in significantly higher frequencies, with *P. guajava* showing the highest mean frequency (32.33). Seasonal effects were also highly significant, with monsoon (B = 0.603) and summer (B = 0.582) showing higher frequencies compared to winter, and monsoon exhibiting the highest mean frequency (17.34). This suggests a clear seasonal shift in plant consumption, with certain species like *P. guajava* and *F. racemosa* being more prevalent during monsoon and summer. Parry-Jones and Augee (2001) also reported that fruits in the droppings of bats occurred in low quantity in winter season as compare to summer season.

The comparison of bolus and guano analyses underscores dietary flexibility of *P. medius*. The consistent presence of *F. racemosa* and other moraceae members highlights their ecological significance for bat populations and forest regeneration, as noted by Basharat et al. (2021). Schmelitschek et al. (2009) mentioned the major dietary part of these bats are *Ficus spp.* belonging to the family moraceae. The dominance of the moraceae family, particularly *Ficus spp.* is consistent with Gulraiz et al. (2016) and Javid et al. (2016) and also known to form a core component of diet of fruit bat due to their nutritional richness and year-round availability (Wendeln et al., 2000, Epstein et

al., 2009, Aung and Htay 2019). The consumption of *T. grandis* may indicate a response to specific nutritional needs during post- monsoon; although it is uncommon in the diet of *P. medius* and highlights opportunistic feeding behaviour. The inclusion of multiple plant families, such as Rubiaceae, Myrtaceae, Anacardiaceae and Lamiaceae suggests a strategy to mitigate competition and optimize nutrient intake (Sudhakaran and Doss 2012). This nutritional flexibility is essential for their survival, particularly in regions where the availability of fruit fluctuates throughout the year (Ashwin and Jayakumar 2019; Tiwari et al., 2019).

CONCLUSIONS

The study presents a comprehensive analysis of the evolving dietary preferences of *P. medius* in Lucknow, India. It underscores the significance of specific plant families, particularly Moraceae, in their diet. *F. racemosa* emerges as a crucial and reliable food source for *P. medius*, evidenced by its consistent consumption throughout the year. The inclusion of *P. guajava*, *N. cadamba*, and *M. alba* in their diet illustrates the species' adaptability to variations in resource availability. The dietary habits of *P. medius* are significantly influenced by seasonal changes in food availability. The study highlights the importance of conserving a diverse array of plant species to support fruit bats, thereby enhancing our understanding of the ecological role of *P. medius*. Future research should aim to extend the geographical scope of dietary analyses to comprise various regions within India and examine the influence of vegetation composition and local environmental factors on dietary preferences. Long-term monitoring of feeding behaviour, particularly in relation to habitat changes and climate change, is essential for understanding dietary impacts on *P. medius* populations. Moreover, genetic analysis of bolus and guano samples could provide more detailed insights into the food ecology of *P. medius*, including identifying less conspicuous or degraded plant species in their diet.

ACKNOWLEDGEMENTS

Authors would like to express gratitude to the director of National Botanical Research Institute (CSIR-NBRI), Lucknow for granting permission to collect samples at their Banthara research station.

REFERENCES

- Ashwin CP and Jayakumar S 2019. Diet of Indian flying fox *Pteropus giganteus* (Brunnich 1782) in selected districts of Kerala and Tamil Nadu, India. *Journal of Science, Transitions and Technology* **13**(1): 31-36.
- Aung MM and Htay TT 2019. Dietary analysis of the Indian Flying Fox *Pteropus giganteus* (Brunnich 1782) (Chiroptera: Pteropodidae) in Myanmar through the analysis of faecal and chewed remnants. *Journal of Threatened Taxa* **11**(8): 13977-13983.
- Aziz SA, McConkey KR, Tanalgo K, Sritongchuay T, Low MR, Yong JY and Racey PA 2021. The critical importance of Old World fruit bats for healthy ecosystems and economies. *Frontiers in Ecology and Evolution* **9**: 641411.
- Banack SA 1998. Diet selection and resource use by flying foxes (*Pteropus*). *Ecology* **79**(6): 1949-1967.
- Basharat T, Akrim F, Mahmood T, Rafique A, Qasim S, Shah AH and Munawar N 2021. Diet composition of flying foxes in district Kotli, Azad Jammu and Kashmir, Pakistan. *International Journal of Biosciences* **19**(2): 1-11.
- Epstein JH, Field HE, Luby S, Pulliam JR and Daszak P 2006. Nipah virus: impact, origins and causes of emergence. *Current Infectious Disease Reports* **8**(1): 59-65.
- Gulraiz T, Javid A, Mahmood-Ul-Hassan M, Hussain S, Azmat H and Daud S 2016. Role of Indian flying fox *Pteropus giganteus* Brunnich, 1782 (Chiroptera: Pteropodidae) as a seed disperser in urban areas of Lahore, Pakistan. *Turkish Journal of Zoology* **40**(3): 417-422.
- Goveas SW, Miranda EC, Seena S and Sridhar KR 2006. Observations on guano and bolus of Indian flying fox, *Pteropus giganteus*. *Current Science* **90**(2): 160-162.
- Hodgkison R, Balding ST, Zubaid A and Kunz TH 2003. Fruit bats (Chiroptera: Pteropodidae) as seed dispersers and pollinators in a lowland Malaysian rain forest. *Biotropica* **35**(4): 491-502.
- Kumar R and Elangovan V 2019. Effect of tree characteristics on roost selection of the Indian flying fox, *Pteropus giganteus*. *Journal of Bat Research and Conservation* **12**(1): 100-106.
- Lei M and Dong D 2016. Phylogenomic analyses of bat subordinal relationships based on transcriptome data. *Scientific Reports* **6**(1): 27726.
- Madala MF, Guna C, Pradeepan A and Chalil AK 2022. Roost tree characteristics of *Pteropus medius* (Chiroptera: Pteropodidae) in the midland laterite hillocks of northern Kerala, India. *Journal of Asia-Pacific Biodiversity* **15**(4): 465-472.
- Mahmood-Ul-Hassan M, Gulraiz TL, Rana SA and Javid A 2010. The diet of Indian flying foxes (*Pteropus giganteus*) in urban habitats of Pakistan. *Acta Chiropterologica* **12**(2): 341-347.
- Parry - Jones KA and Augee ML 2001. Factors affecting the occupation of a colony site in Sydney, New South Wales by the Grey headed Flying Fox *Pteropus poliocephalus* (Pteropodidae). *Austral Ecology* **26**(1): 47-55.
- Richards GC 1995. A review of ecological interactions of fruit bats in Australian ecosystems. *Symposium of the Zoological Society of London* **67**: 79-96.
- Schmelitschek E, French K and Parry-Jones K 2009. Fruit availability and utilisation by grey headed flying foxes (*Pteropus poliocephalus*) in a human-modified environment on the south coast of New South Wales, Australia. *Wildlife Research* **36** (7): 592-600.
- Shilton LA, Altringham JD, Compton SG and Whittaker RJ 1999. Old World fruit bats can be long-distance seed dispersers through extended retention of viable seeds in the gut. *Proceedings of the Royal Society of London Series B: Biological Sciences* **266**(1416): 219-223.
- Singh BP, Krishna A, Singh SC and Kumar S 2020. Angiospermic biodiversity of Lucknow areas of Uttar Pradesh, India. *Current Journal of Applied Science and Technology* **39**(13): 101-109.
- Stier SC and Mildenstein TL 2005. Dietary habits of the world's largest bats: the Philippine flying foxes, *Acerodon jubatus* and *Pteropus vampyrus lanensis*. *Journal of Mammalogy* **86**(4): 719-728.
- Sudhakaran M and Doss PS 2012. Food and foraging preferences of three pteropodid bats in southern India. *Journal of Threatened Taxa* **4**(1): 2295-2303.
- Tiwari N, Koju NP, Acharya PR and Dhamala MK 2019. Diet composition of Indian flying fox (*Pteropus giganteus*) in Kathmandu Valley. *Nepal Journal of Environmental Science* **7**: 25-30.
- Tsang SM 2020. *Pteropus giganteus* (errata version published in 2021). *The IUCN Red List of Threatened Species* 2020: e.T18725A194134899. Accessed on 11 September 2024.
- Van der Pijl L 1957. The dispersal of plants by bats (*Chiropterochory*). *Acta Botanica Neerlandica* **6**(3): 291-315.
- Wendeln MC, Runkle JR and Kalko EK 2000. Nutritional values of 14 fig species and bat feeding preferences in Panama. *Biotropica* **32**(3): 489-501.