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Roost ecology, population size, behavioral patterns and morphometric analysis of Indian flying fox (*Pteropus medius*; Temminck, 1825) in the Goalpara District of Assam, India

JK. Talukdar*, AK. Haloi

Department of Zoology, Bhattadev University-Bajali, Pathsala, Assam, India

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Abstract

The present study was conducted at Krishnai Forest Range Office Campus (26°2' 0" North, 90°40' 0" East) situated at Goalpara district of Assam. Throughout the pre-monsoon season (March–May 2022), the survey location was periodically visited. The current study aims to identify the numerous roosting trees used by Indian flying foxes (*P. medius*), their diurnal behavioral pattern, and to assess the population size of the species together with their morphometric variations. A large mean colony size (5479 332.99) of *P. medius* bats was found in the study site, residing in a number of preferred roosting trees (n = 101). In April 2022, a population count of 5509 bats was recorded as the mean population size. However, the population count varies in March (5871) and May (5057). Population fluctuation was mainly due to inter-colony migration and other environmental factors. A very high population density of 4094.91 was recorded. Direct roost count method was used to estimate the population size following standard literature key (Bates and Harrison, 1997). Different times of the day were used to record the diurnal roosting habit patterns of the bats. The most frequent behavior was sleeping, which was followed by grooming, wing flapping, and wing spreading. Two of the few captured bats (n) were used to analyze the morphometric variances. The average body weight of the specimens that were caught was 699 ± 26.87g, and the average forearm length was 172.05 ± 2.616g. When compared to the caught (*P. medius*) bat species, the mean value of the morphometric measurements revealed a substantial variation. Roosting site selection depends on their abundance, risk of predation, availability and distribution of food resources and physical environment. An essential species for maintaining the ecosystem's equilibrium is the Indian flying fox. For the reforestation of the forest environment, it is regarded as a crucial method of seed dissemination and pollination. The study site was selected based on the very fact that earlier no prior study was carried out in this roosting site and proved to be a significant area sustaining bats for more than 30 years with approximately 80-85 % of the species (*P. medius*) roosts as year round.

* **Corresponding Author:** Jugal kishore Talukdar ✉ talukdarjk1893@gmail.com

Introduction

Bats are the unique group of sustained-flight mammals like birds belonging to the order Chiroptera (Adhikari *et al.,* 2010). Chiroptera (bats) account for one-fifth of mammalian species and are the second largest among 26 mammalian orders (Suga, 2009; Srinivasulu *et al.,* 2010). Traditionally, the order Chiroptera is divided into two distinct suborders Megachiroptera are Old World flying foxes distributed within a family of 01 and the Microchiroptera includes laryngeal echolocating bats and are distributed around 18 families (Mickleburgh *et al.,* 1992; Koopman, 1993; Hutson *et al.,* 2001, Simmons, 2005; Srinivasulu *et al.,* 2010, Saikia, 2019). However, using molecular and phylogenetic methods, scientists have proposed a new subdivision of Chiroptera, namely Yinpterochiroptera, which includes the megabat family Pteropodidae along with the Microbat families Rhinolophidae, Rhinopomatidae, and Megadermatidae, and Yangochiroptera including the remaining Microbat families (Teeling *et al.,* 2002). Bats are distributed worldwide and are more ecologically diverse than any other group of mammals (Handley *et al.,* 1996). They are widespread and have been recorded worldwide, with the exception of Antarctica and some oceanic islands (Mickleburgh *et al.*, 2002). More than 1,400 bat species are known worldwide, 190 species belong to the suborder Megachiroptera, which is distributed within a single family Pteropodidae (Bat Conservation International 2021; Talmale *et al.,* 2018).

There are 14 species of Pteropodidae in India and members of this family are colloquially known as flying foxes (Saikia *et al.,* 2018). The Indian fruit bat (*Pteropus medius*) is a species of fruit bat in the Pteropodidae family. The Indian flying fox is known locally as Pholkhowa Borbaduli (Frugivorous; large bat) in Assamese. *Pteropus medius* is a social species living in a large daytime roost and is one of the largest flying fox species of the subcontinent stretching from Bangladesh, China, India, Nepal, Pakistan to Sri Lanka (Khatun, 2014). Most fruit bats studied are moderately or strongly colonial (Rainey *et al.,* 1992). Perhaps some of them form colonies comprising a few hundred to millions of individuals (Nowak, 1999). Their good sense of smell and sight locate sources of ripe fruit. Flowering plants are a good and preferred food source and all fruit bat species feed only on nectar, flowers, pollen and fruit, which explains their limited tropical distribution. It is considered to be an essential means of seed dispersal and pollination for reforestation of the forest ecosystem (Ali, 2010).

Indian flying fox is one of the beneficial members of the animal community that acts as a key species to keep the ecosystem in balance. Despite their high utilitarian role, these bats are mistreated in India and are highly vulnerable to environmental nuisance. Many resting populations of the species have declined sharply in response to anthropogenic activity.

They are increasingly threatened locally by the hunt for meat and medicine, the felling of roosting trees for road construction and other development purposes have hit the Indian fruit bat population acutely (Bhandarkar *et al.,* 2018).

There is no official protection for Indian fruit bats or the other two species of fruit bats in India and indeed the Government of India's Wildlife Protection Act 1972 included them all in the schedule IV- Vermin (ENVIS, 2022). The species requires appropriate conservation measures to protect and continue its ecological role in restoring forests.

Although Northeast India has a rich diversity of bats, this mammalian species has been studied very little in the region. The north-eastern region of India has an exceptional wealth of mammals, including over 70 bat species, some of which have only recently been described or reported (Bates & Harrison 1997; Thong *et al.,* 2018). In Assam, there is very little published material on the Indian flying fox or the bat community as a whole (Sharma *et al.,* 2020).

A monograph by Bates & Harrison (1997) listed 28 bat species from Assam. The state's bat diversity is apparently not very high, comprising about 30 recorded species (Ali, 2022). A very limited information regarding the status of bat diversity in the state has found it mentioned in (Bates & Harrison

1997; Sinha, 1999; Ali *et al.,* 2010; Boro *et al.,* 2013; Boro & Saikia, 2015; Rahman *et al.,* 2017; Sharma *et al.,* 2020, Saikia *et al*., 2022; Ali, 2022). Considering the lack of comprehensive surveys and field studies documenting the diversity, distribution and status of the state's bat fauna, the reported species richness in the region would undoubtedly be an underestimate (Saikia *et al.,* 2018). This study was an initial effort in the area, a newly located roosting site, with the goal of identifying the various roosting trees used by Indian flying foxes (*P. medius*), their diurnal behavioural pattern, and to estimate the population size as well as their morphometric variations.

Materials and methods

Study area

The site selection for this study was done based on the presence of the species (*P. medius*) by personally investigating the place. Krishnai Forest Range office Campus covers a total area of 1.338 ha (10 Bigha in Assam). It is a prominent old spot for Indian flying fox nestled by the side of New NH17. This roosting site is located in Krishnai Guria Pt 1 village under the Matia circle of Goalpara district which is 30 km away from the district headquater Goalpara. The surveyed site was found dominated by roosting trees preferred by Indian flying fox (Table.1). The area's climate is ideal for a humid subtropical region with dry winters (Classification: Cwa). The district receives yearly temperatures of 27.55 °C and precipitation totals of 82.07 mm. The yearly rainfall ranges from 3805 mm to 149.8 inches (Climate-data.org, 2022). The districts holds a forest cover of 337 km² and it represents 18.48% of geographical area of Assam (Cencus of India, 2011). Google Maps provided the locational map (Fig. 1) of the surveyed roosting site.

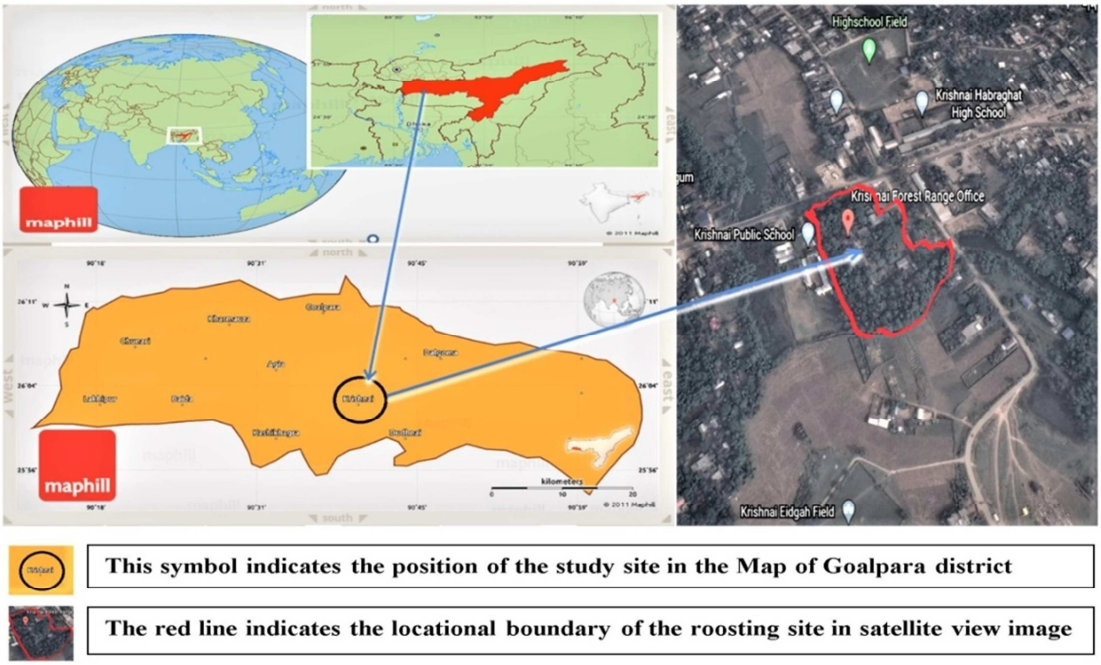

Fig. 1. Locational Map of the studied roost (26° 2' 0" North, 90° 40' 0" East).

Roosting site analysis

The survey site was periodically visited during the pre-monsoon period (March-May, 2022). Based on the available information from local residents, an opportunistic survey was conducted and the bat roost location was located. Roosting was surveyed by walking and identifying the number of roosting trees favored by the Indian fruit bat (*P. medius*) population. The method of direct roost census was used to estimate the population size of the colony (Expedition Field Techniques: Bats, 1999). Most observations were made with the naked eye. The number of bats roosting in an average tree was estimated and the total number of bats was calculated by counting the number of occupied trees. The roost name, surroundings, and threats were collected from

information gathered about the roost by the local people and forest officials.

Behavioural pattern study

The behavioral patterns of the bats were analyzed by observing the bats moving around the roost throughout the day. Different daily behavior patterns were observed and recorded at different times of the day. Their activity pattern shows that they are mainly active in the early morning and late evening. Table 3 highlights the detailed daily behavior pattern recorded from the roost.

The binoculars (Cason 8 x 40 HD) made it easier to observe the bats in the high treetops. Photos were taken with (Nikon D3500 with telephoto zoom lens/AF-P DX NIKKOR 70-300mm).

Morphometrics

To understand the morphology of the species (*P. medius*), a specimen was caught at its roost. The captured samples were anesthetized with chloroform. No species were harmed during morphometric identification and will be released immediately after morphometric analysis. External body measurements were recorded. The morphometric properties were then measured with a millimeter caliper (Zhart-0-300 mm) with an accuracy as close as possible to 0.01 mm. Each individual sample was measured and the measurements recorded for comparison to the relevant literature (Bates and Harrison, 1997). Table 3 shows the detailed acronyms of the morphometric measurements.

Statistical Calculation

The mean of two samples and the standard deviation are calculated. The standard deviation is a statistical measure of the diversity or variability in a data set. A low standard deviation indicates that data points are generally close to the mean or average. A high standard deviation indicates greater variability in the data points, or greater deviation from the mean. For a number of n samples (Table 1) the mean or average value for the measurement range is first calculated and later the standard deviation is calculated using an online software tool (calculator.net).

Result and discussion

The detailed survey period at the localized roost (25.9843224 N, & 90.7862606 E) reveals a large colony of *Pteropus medius* species. Within the roost, 157 trees were examined for the presence of bats, of which 64.33% (n = 101) were active roosting trees favored by the species (*P. medius*) and 35.66% (n = 56) were non-sleeping trees. Roosing trees were taller (max = average 25 m), had large diameter (max = average 73.5 cm), and were more likely to be tall canopies. Among the 12 species of roosting trees identified, *Tectona grandis* (50.49%) is found as a maximum in and least for *Phoenix sylvestris* and *Delonix regia* (1.98%). A detailed assessment of roost tree selection by *P. medius* in the study area is presented in Table 1.

An oversized colony size of bats with an average population (5479±332.99) was identified at the study site inhabiting a number of preferred roosting trees (n=101). The bat colony consists of adults and sub-adults. Different population sizes resulted from different survey plans. With 5871 individuals, the bat population is highest in (March, 2022) and with 5057 bat populations it gradually decreases over the course of (May, 2022). The mean population size was recorded in (April, 2022) with a population size of 5509 bats. This monthly variation in population size was mainly due to inter-colonial migration and other environmental factors. A very high population density of 4094.91 is recorded in the studied area. A high population density of bats was recorded in *Tectona grandis* (3315 individual bats), followed by 910 individuals in *Shorea robusta* (locally referred to as Shal) and least in *Phoenix sylvestris* (locally referred to as khejur), inhabiting 19 individual bats (Fig.2).

The observed pattern of behavior at different times of the day shows that wing spreading began at sunrise and continued when it was hot in the afternoon. However, the behavior was common in the morning hour. The Indian flying fox has been found to be involved in early morning grooming to rid its body of ectoparasites after its arrival for foraging. They are nocturnal and spend most of the day sleeping. Sleep frequency changed significantly throughout the day.

Table 1. *Pteropus medius* roost tree selection (Preferred & avoided tree species) at the studied site.

Common Name	Botanical Name	Family	No. of Individual roost trees (n)	Roosting tree Preferred by Indian flying fox.
Raintree	*Samanea saman*	Fabaceae	2	Preferred
Eucalyptus	*Eucalyptus maculate*	Myrtaceae	5	Avoided
Teak	*Tectona grandis*	Lamiaceae	51	Preferred
Gajari	*Shorea robusta*	Dipterocarpaceae	14	Preferred
Mango	*Mangifera indica*	Anacardiaceae	7	Preferred
Jack fruit	*Artocarpus heterophyllus*	Moraceae	4	Preferred
Kadam	*Neolamarckiacadamba*	Rubiaceae	5	Preferred
Cotton silk	*Ceiba pentandra*	Malvaceae	4	Preferred
Beechwood	*Gmelina arborea*	Lamiaceae	5	Preferred
Neem	*Azadirachta indica*	Meliaceae	3	Preferred
Banana	*Musa paradisiaca*	Musaceae	19	Avoided
Date palm	*Phoenix sylvestris*	Arecaceae	2	Preferred
Betel nut	*Areca catechu*	Arecaceae	27	Avoided
Elephant Apple	*Dillenia indica*	Dilleniaceae	3	Preferred
Royal poinciana	*Delonix regia*	Fabaceae	2	Preferred
Jujube	*Zizyphus jujuba*	Rhamnaceae	4	Avoided
			n=157	

*Total roosting trees (n=157), preferred roosting trees (n=101), avoided roosting trees (n= 56).

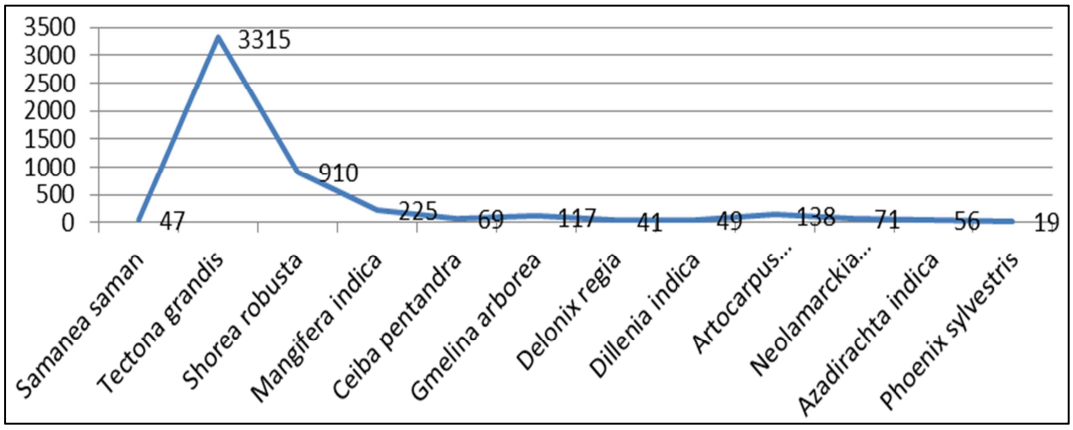

Fig 2. Average number of bat population inhabiting according to preferred roosting trees.

It has been found that sleep duration is highest during the early morning hours and decreases as the day progresses. They are observed to become very active in the evening hours (onset of sunset) and leave the roost with high pitched screeching noises. The very rarely observed activities were mating and fighting (Table 2). They fly together to feed at various local feeding grounds in the late evening and generally return in the morning hours of the next day. Foraging activity appeared to continue passively, with some of the trees being completely defoliated due to their foraging activity (Gulshan, 2020).

Table 2. Diurnal Behavioral activities of *P.medius* Sighted in the roosting site

SL	Observed Behavioural patterns	Day time	Frequency	Description
1	sleep	Early morning	Frequently	wings wrapped around body with eyes closed
2	Groom	Morning	Frequently	Licking and scratching of body
3	Wing spread	All day time	Frequently	Wings wide open
4	Wing Flap	Afternoon	Frequently	Fanning body with wing
5	Movement in tree	All day time	Moderately	Climbing along branch or trunk
6	Nursing/ Maternal behaviour	All day time	Moderately	Juvenile attached
7	Mating	Morning	Rarely	Males licking and/or copulating with female
8	Flight	Morning & Late evening	Frequently	Within tree or out of and into tree
9	Fight	Any time of day	Rarely	Fighting between individual
10.	Foraging	Late evening	Frequently	Leaving roost in search of food.

Morphologically, the Indian flying fox is so named because of its unique, fox-like appearance: reddish-brown fur, characteristically long snout, and large eyes.

The ear was long, pointed black, and the length of the fingers was noted with an invisible tail (Fig. 8). Wings were found comparatively heavy and large. The fur of the back was black, the mantle was pale tawny, and the underside was buffy brown. Thumbs have been observed in this species in the study area to be attached to trees, and the same view has been taken by Bennet (1993) that the pendulous postures of Megachiroptera are attached by one or both feet, facilitated by a locking mechanism (Fig.5).The detailed analysis of the morphometric variation (n = 2) of the individual catch samples are indicated in table 3.

Table 3. Morphometric variation (external measurements) of *P. medius*

Morphological parameters	Attributes of meaurements	Measurements in (mm)		Mean ± S.D (n=2)
		Male	Female	
Head body length	(HB)	256.2	258.0	257.1±1.272
Tail Length	(T)	Absent	Absent	----------
Tibia length	(TIB)	87.4	85.2	86.3±1.555
Length of Femur	(F)	67.2	68.6	67.9±0.98
Hind Foot Length	(HF)	42.5	47.9	45.2±3.818
Length of Humerus	(H)	102.3	103.9	103.1±1.131
Forearm length	(FA)	170.2	173.9	172.05±2.616
Ear length	(EL)	32.5	35.2	33.85±1.909
Ear Wide	(EW)	17.1	18.5	17.8±0.989
Tragus	(TR)	NA	NA	--------
Thumb	D.1	45.1	46.5	45.8±0.989
2nd Finger	D.2	115. 4	118.2	116.8±1.979
3rd Finger	D.3	128.5	130.7	129.6±1.555
4th Finger	D.4	185.7	188.9	187.3±2.262
5th Finger	D.5	232.5	235.1	233.8±1.838
Wing Span	(WSP)	920	985	952.5±45.961
Weight	(W)	680 g	718 g	699±26.870
Sex	M / F	Male	Female	----------

*Mean and S.D (Standard deviation) is calculated for 'n' number of captured specimen.

P. medius has a well-rounded skull that makes it easy to hang like a pendant from its roost for easy take-off during flight. Male weight (680g) was comparatively lower than female weight (718 g) with a mean of 69926.870 (S.D). The tail was absent from both the individual and the forearm (FA) length is recorded as 172.052.616 (S.D), head body length (257.11.272) and other acronyms of the morphometric measurements are presented in Table 3. The acronyms of the study's recorded measurements are broadly compared to other species and the result is similar (Simmons, 2005; Ali 2010; Khan *et al.,* 2019).

The Indian flying fox (*Pteropus medius,* formerly *Pteropus giganteus*), also known as the greater Indian fruit bat, is a species of flying fox native to the Indian subcontinent. This species is frequently viewed as vermin due to its destructive tendencies towards fruit farms, although the advantages of its pollination and seed dissemination frequently outweigh the disadvantages of its fruit consumption. These species consume a variety of fruits and flowers, serving as vital seed dispersers for many plants, which benefits the environment throughout their geographic range (Animalia, 2023).

Fig. 3. Grooming Behaviour.

Fig. 4. Foraging flight.

Fig. 5. Resting position.

Fig.6. Inter colony Migration.

Fig. 7. Bat population in Roosting trees.

Fig. 8. *Pteropus medius* (Male) with large eyes, absent tail and distinct penis.

Conclusion

The Goalpara District's ecological diversity provides habitat for many different bat species. The research region has not been directly impacted by humans, and as a result, a large population of *P. medius* has lived there for the past 30 years. They prefer to dwell near to people because they have adapted to the surroundings. Indian flying fox species are essential pollinators and seed dispersers for the ecosystem's regeneration. In order to preserve the species and maintain the provision of ecosystem services, it is therefore of utmost importance to keep the roost free from human intrusion.

In order to ensure that bats are adequately protected, the current study strongly suggests revising the legal context of state wildlife protection laws. The protection of the environment as a whole, as well as the conservation of species, should be a priority for state governments and non-governmental groups. It can be said that the area under study provides a good habitat for species conservation and, with the help of the state government's environment and forest department, could soon be designated a bat park or bat centre. This will raise the required awareness and make it possible for future generations to fully appreciate its significance and the necessity for conservation.

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Declaration

This material is the authors' own original work and both the authors have declared that this manuscript hasn't submitted to other journal or anywhere for consideration or publication at the same time. The paper reflects the authors' own research and analysis in a truthful and complete manner. Therefore, the authors have been personally and actively involved in substantial work leading to the paper, and will take public responsibility for its content.

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