

Ecology and behavior of *Pteropus medius* Temminck, 1825 in the Indian Subcontinent: a review with insights for future directions

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Abstract

The Indian Flying Fox *Pteropus medius* Temminck, found across the Indian Subcontinent encompassing India, Sri Lanka, Nepal, Pakistan, Bhutan, Maldives, and Bangladesh, is a frugivorous bat species classified as Least Concern in the IUCN Red List of Threatened Species. While research on *P. medius* has spanned centuries, this review aims to provide a comprehensive overview of its ecology and behavior. A thorough examination of literature from 1997 to 2023 was conducted, utilizing various online scientific platforms such as Google Scholar, ResearchGate, Semantic Scholar, and PubMed. The findings reveal that *P. medius* predominantly roosts in trees of Fabaceae and Moraceae families. Due to their significant involvement in pollination and seed dispersal through their frugivorous activity, *P. medius* play a major role in the ecosystem and in conserving plant biodiversity. Their diet includes fruits mainly from family Moraceae, leaves from Fabaceae, flowers from Myrtaceae and nectar from Moraceae. The species exhibits both inter and intra-specific interactions with bats, bees, birds, and monkeys. Unfortunately, their population faces a decline attributed to various anthropogenic threats. To mitigate this decline, a deeper understanding of their fundamental ecology is imperative, and future studies should incorporate updated methodologies and tools.

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Introduction

Indian Flying Fox *Pteropus medius* Temminck, 1825, known by many names, was formerly widely known as *Pteropus giganteus*; its correct name is *Pteropus medius* (Mlíkovský, 2012). *Pteropus medius* is a frugivorous bat belonging to the family Pteropodidae (Old World Fruit Bats), categorized as Least Concern in IUCN Red Data List (Tsang, 2020). Five species of the genus *Pteropus* occur in the Indian Subcontinent, but *P. medius* is the only species found in mainland India. It is widely distributed in Indian Subcontinent including India, Sri Lanka, Nepal, Pakistan, Bhutan, Maldives, and Bangladesh. *Pteropus medius* on average, measures 152–183 mm in forearm length and 198–300 mm in

head-body length (Bates and Harrison, 1997). The pelage on the back is usually blackish-brown with a few paler hairs (Fig. 1). Leucism has been documented as a rare case (Amin et al., 2021).

They live in colonies which can vary from 10 individuals to a few thousand individuals (Chakravarthy and Yeshwanth, 2008; Krystufek, 2009; Ali, 2010; Gaikwad et al., 2012; Senthilkumar and Marimuthu, 2012; Bhatnagar, 2014; Talmale, 2014; Kumar and Kanaujia, 2015; Baskaran et al., 2016; Kumar et al., 2017a; Bhandarkar and Paliwal, 2017; Mushahid and Orus, 2018). The largest colony size recorded is from Sri Lanka with about 24,480 bats spreading over 20 hectares (Krystufek, 2009).



Figure 1: *Pteropus medius* (Indian Flying Fox) roosting in bamboo in Bengaluru, Karnataka, India. Photo Credit: Shraddha Kumari K

The main diet of Indian Flying Fox includes fruits, flowers, nectar, and tender leaves (Ashwin and Jayakumar, 2019). They play a vital role in the ecosystem through pollination and seed dispersal (Khan, 2001; Vendan and Kaleeswaram, 2011; Ali, 2014), and their bolus and excreta act as manure for plants (Goveas et al., 2006). Bats pollinate a variety of plants and are crucial as pollinators with some plants relying exclusively on them for pollination (Nathan et al., 2009). Until now, the only compendium on distribution, ecology, and behavior of *P. medius* is the book ‘Bats of the Indian Subcontinent’ (Bates and Harrison, 1997), now more than 25 years old. Hence this review is focused on gathering all the scientific articles published from 1997 until 2023 and compiling the data on *P. medius* with a statistical approach. This article gives a comprehensive view about the distribution, ecology, behavior, population dynamics and future perspective of studies regarding *P. medius*.

Material and Methods

Literature survey

Data on *P. medius* concerning ecology, behavior, and threats were gathered using online scientific platforms such as Google Scholar, ResearchGate, Semantic Scholar, and PubMed. Only the publications between 1997–2023 were selected for review. Considering the taxonomic name change of the species, all literature using *P. giganteus* were taken into consideration. The keywords such as ‘Indian Flying Fox/*Pteropus giganteus*/*Pteropus medius*’, ‘Ecology’, ‘Roosting’, ‘Diet’, ‘Foraging’,

‘Feeding’, ‘Flight’, ‘Movement’, ‘Thermoregulation’, ‘Breeding’, ‘Reproduction’, ‘Mating’, ‘Population’, ‘Behavior’, ‘Distribution’, ‘Pollination’, ‘Threat’, ‘Sri Lanka’, ‘Nepal’, ‘Pakistan’, ‘Maldives’, ‘Bangladesh’ were used individually as well as in various combinations to get the best search results.

Data analysis

For the analysis of roosting tree preferences, all tree species have been manually noted down and compiled from each paper. For the dietary composition analysis, all the floral species specified in each paper have been considered. However, the proportions of dietary preference have not been considered due to limited references. For constructing the distribution map, locations of *Pteropus medius* provided in all the papers irrespective of their focus of study are considered. Google Earth Pro was used for getting geocoordinates for a few locations from literature in which it was not available. Geocoordinate data was used for mapping with the help of Google Earth Pro and ArcMap version.10.3. All graphs were plotted in R studio version 2024.04.1+748 (Posit Software, PBC).

Results

The literature survey identified 84 studies related to the distribution, ecology, behavior, threats, and population of *P. medius*. Most of the study locations belong to India (66), followed by Nepal (10), Sri Lanka (2), Pakistan (4), and Bangladesh (2) (Fig. 2). The number of studies showed low positive correlation with year of publications from 2000–2020, but, after 2020, there was a drastic decline in number of studies (Fig. 3).

Ecology and behavior

Habitat and roosting trees

Roosting is important because most of the life activities of *P. medius* takes place at the roosting site except for foraging. Though they seem to spend majority of the time resting in the roosting site, they also show other activities like self-grooming, allo-grooming, thermoregulation, communication, locomotion, swinging, yawning, flapping wings, sometimes flight, mating, and nursing (Ramakrishna et al., 2014; Ray, 2014; Manandhar et al., 2018; Roy et al., 2020; Prajapati et al., 2020; Talukdar and Haloi, 2023). Roosting tree selection and behaviors in roosts such as roost composition, roost size, thermoregulation, locomotion, and communication are seasonally variable (Chaturvedi and Singh, 2018; Mushahid and Orus, 2018; Roy et al., 2020). In addition, the daily frequency of each behavior can vary depending on the season (Manandhar et al., 2018).

Pteropus medius are generalised in their habitat selection and not restricted to a few species of trees or habitat type. They roost in varied places such as in or near villages, towns, near roads, orchards, agricultural fields, home garden, temple premises,

urban parks, factory campus; they also prefer areas nearby waterbody (Reginald et al., 2008; Bhatnagar, 2014; Talmale, 2014; Joshi et al., 2015; Kumar and Kanaujia, 2015; Jeyapraba, 2016; Bhandarkar and Paliwal, 2017; Mushahid and Orus, 2018; Ahmed et al., 2020; Khan et al., 2020; Prajapati et al., 2020), and in desert regions (Dookia and Tak, 2004). *P. medius* also show some migration which might be due to unfavorable weather or for feeding purposes (Koju and Chalise, 2011; Manandhar et al., 2018).

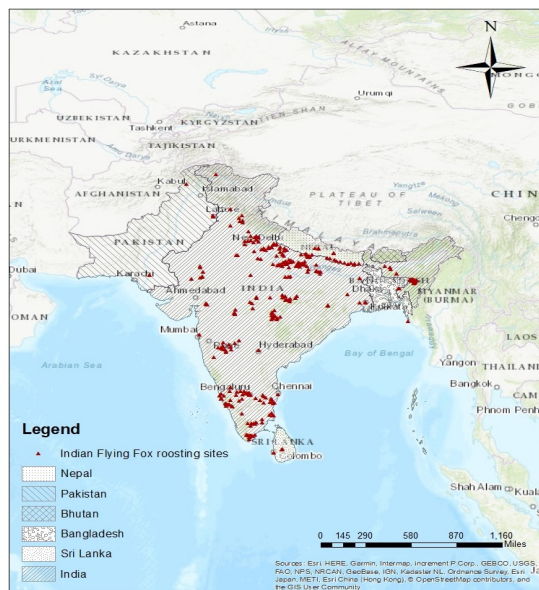


Figure 2: Geographic distribution of published studies on *Pteropus medius* across the Indian Subcontinent: Map shows its distribution in Nepal, Pakistan, Bhutan, Bangladesh, Sri Lanka, and India. Country boundaries were downloaded from <https://public.opendatasoft.com/explore/dataset/world-administrative-boundaries/export/>.

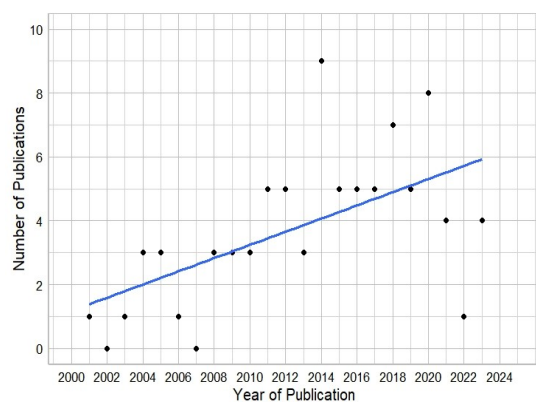


Figure 3: Number of published studies on *Pteropus medius* from the Indian Subcontinent per year, showing temporal trends in research effort over the years 2000–2023.

Pteropus medius were observed to roost in 143 trees species belonging to 37 families. The most common

roosting trees were in Fabaceae, followed by Moraceae and Myrtaceae (Fig. 4). *P. medius* roost in large trees of varied species which are influenced by the tree characteristics such as height, diameter at breast height (Khatun and Ali, 2016; Madala et al., 2022), canopy (Khatun and Ali, 2016; Kumar and Elangovan, 2019; Kumar et al., 2017a), and crown spread (Madala et al., 2022). They also roost in the trees with overlapping canopies (Bhatnagar, 2014).

Inter and intra-specific interaction

Pteropus medius face interspecific competition for space: Crows (*Corvus splendens*) were found to interact with *P. medius* for space use by chasing the juveniles of *P. medius* (Joshi et al., 2015; Pandian and Suresh, 2021) and crows attack old and isolated individuals (Koju and Chalise, 2010). There is also evidence that *P. medius* interact with Bonnet macaque *Macaca radiata* (É. Geoffroy, 1812) (Pandian and Suresh, 2021): These bats were observed to show escape behavior when Bonnet macaque tried to pluck fruits from a roosting tree; in one instance, a Bonnet Macaque was observed attacking a roosting *P. medius* individual that tried to prevent it from having fruits. Also, *P. medius* colony was raided by Bengal Sacred Langur *Semnopithecus entellus* (Dufresne, 1797) (Mallick et al., 2023). However, sometimes there is no conflict between bats, bees, birds, and monkeys (Suthari and Raju, 2012). Additionally, these bats show inter-specific aggressiveness while foraging. It shows inter-specific interaction with Short-nosed Fruit bat *Cynopterus sphinx* (Vahl, 1797) (Nathan et al., 2005; Nathan et al., 2009) and when they share their foraging tree with *C. sphinx*, there was spatial partition between them (Singaravelan and Marimuthu, 2004).

Thermoregulation

During summer, bats spend most of the time grooming, flapping their wings and fanning (Mathur et al., 2011; Ray, 2014; Mushahid and Orus, 2018). During winter, they spend more time resting and closing their wings while roosting (Ray, 2014; Mushahid and Orus, 2018). During rains, Indian Flying Foxes cover their head and body by wrapping with the help of patagia; after rains, they remove all water adhering to their body by grooming, scratching, and licking (Baskaran et al., 2016; Pandian and Suresh, 2021).

There are seasonal shifts in *P. medius* roosting tree selection. They choose denser canopies during summer to avoid direct sunlight. During summer *P. medius* were found to move from the top branches of roosting trees to the midcanopy of trees where the canopy is dense (Pandian and Suresh, 2021). They were also recorded moving from winter roosting site consisting of naked tree branches to underneath the thick foliage in the summer (Gulraiz et al., 2015; Mushahid and Orus, 2018). In addition, they moved to other tree species with dense canopies for roosting in summer (Vyas and Upadhyay, 2014).

Movement and migration

Pteropus medius initiate their flight after sunset (Murugavel et al., 2021a) and their emergence is influenced by sunset time, day length, temperature (Kumar et al., 2019), season (Mathur et al., 2011), light intensity, and moon phases (Sudhakaran et al., 2012). They emerge earlier in highly light-polluted areas (Murugavel et al., 2023b). *P. medius* fly around the roosting area after emerging in the evening before they diverge and fly for foraging (Chakravarthy et al., 2009; Pandian and Suresh, 2021). After returning to the roosting site from the foraging area the bats spend one to two hours in clustering and settling, after which the activity reduces. Following these behaviors, they spend time grooming and engaged in other activities (Ray, 2014). Also, one study showed *P. medius* travels more than 40 km in a single night (Murugavel et al., 2023a). Although foraging trips usually lasts for one night occasionally an individual can travel more than 70 km and lasts for three days (McEvoy et al., 2021). However, time of flight and distance covered per night do not vary much (Murugavel et al., 2021b). In addition, these bats also showed fluctuations in their population size across seasons in particular roosting sites, suggesting local migration (Mishra et al., 2020).

Foraging and diet composition

Foraging activity: *P. medius* are canopy feeders, feeding on fruits and flowers of trees than herbs (Tiwari et al., 2019), consuming both wild fruits and commercial fruits (Raghuram et al., 2011). They feed voraciously throughout the night, feeding on mid-crown to top regions of fruiting trees; and the moon phase generally does not affect their foraging activity (Sudhakaran and Doss, 2012). But the peak active foraging time varies depending on the geographical region, season, and food availability (Nathan et al., 2005; Nathan et al., 2009; Mahandran et al., 2018).

Feeding location: Indian Flying Foxes usually feed *in-situ* (Mahandran et al., 2018). Also, feeding location can vary depending on the size of the fruit: small fruits and flowers are eaten *in situ* and the larger fruits are carried to other places (Prasad et al., 2014). Adults rarely feed on fruits at roosting sites;

subadults prefer to feed on nearby accessible fruits at roosting sites such as mango, guava, and banana (Kumar and Kanaujia, 2015). They are recorded to travel a few kilometers for foraging (Gaikwad et al., 2012). When mother bats fly for foraging, pups are left at roosting site; mother bat forages nearby and visit the roost early (Chakravarthy et al., 2009). Sometimes, mothers also carry their pup while foraging (Mahandran et al., 2018).

Dietary preferences: The Indian Flying Fox mainly feeds on fruits, flowers, nectar, leaves including tender twigs depending on the availability of food source. The bat can feed on both native and exotic plants. Although its primary food plants are trees, and they provide most of its food, bats also feed on herbs and climbers (Ashwin and Jayakumar, 2019). They orient more on the cultivated plants compared to the wild plants, and ripe fruits over unripe fruits. Bats prefer seasonal plant species (fruiting only in particular season) over perennial plant species (fruiting throughout seasons) for their diet (Ashwin and Jayakumar, 2019). *P. medius* drink water by surface diving (Chakravarthy et al., 2009). They also exhibit a wide range of diet compositions. A total of 151 species of plants were documented as part of their diet. The most important component of diet appears to be fruits (58.28%), followed by flowers (29.80%), leaves and nectar is the least commonly exploited (5.96% each).

Pteropus medius was documented to feed on fruits of 88 plant species belonging to 29 families. Most fruits consumed were from the Moraceae (21.29%), followed by Musaceae (6.82%) (Fig. 5A). Bats fed on flowers of 45 plant species belonging to 25 families. They consumed flowers of Myrtaceae (15.56%), followed by Musaceae (13.33%) (Fig. 5B). Bats also fed on leaves of 9 plant species belonging to 4 families; Fabaceae and Moraceae (33.33% each) represented the highest component, followed by Myrtaceae and Sapotaceae (22.22% each) (Fig. 5C).

Only 9 species and three families of plants were documented as nectar sources for *P. medius*; among these, Musaceae is known to contribute highest (77.78%) and the remaining two families, Fabaceae and Malvaceae share equally (11.11% each) (Fig. 5D).

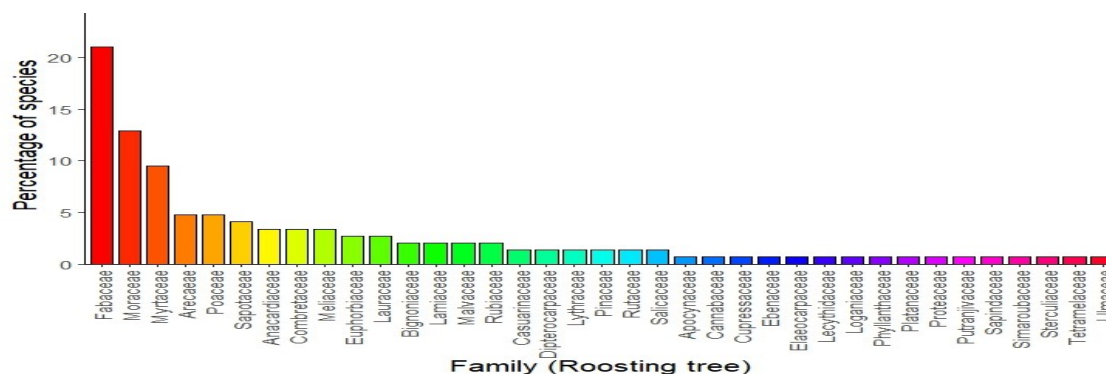


Figure 4: Roosting tree used by *Pteropus medius*: Graph shows trees preferred by bats for roosting. Preference is shown by the roosting tree families (X-axis) and percentage of species found in each family (Y-axis).

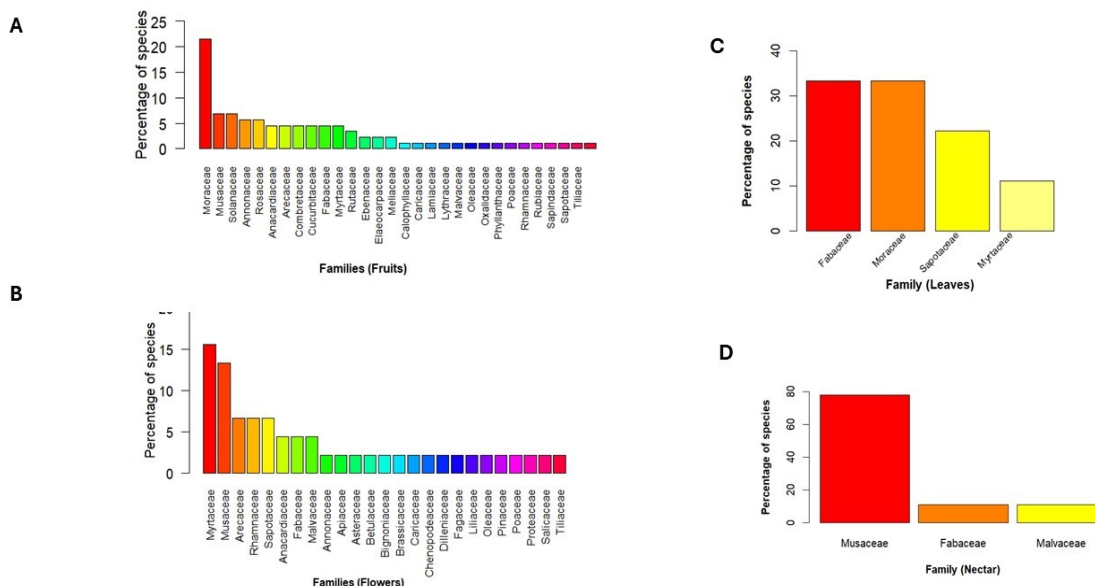


Figure 5: Plant families on which *Pteropus medius* feed: (A) fruits, (B) flowers, (C) leaves, and (D) nectar.

Reproduction

Breeding season: There is no concrete data providing details on the breeding or reproduction of Indian Flying Foxes. In Uttara Pradesh, the breeding season extends from March to September (Mathur et al., 2011; Kumar and Kanaujia, 2015). In Tamil Nadu, breeding was observed during July to January with maximum copulation during October–November (Maruthupandian and Marimuthu, 2013; Pandian and Suresh, 2021). In Karnataka, breeding was observed during February–April and in December (Chakravarthy and Girish, 2003; Chakravarthy et al., 2009), and in Gujarat pups were recorded during April–May (Vyas and Upadhyay, 2014).

Courtship behavior: Males of the species show courtship behavior before copulation (Baki et al., 2015). Mating approaches by male includes stretching and fanning the wings, sniffing the female (Kumar and Kanaujia, 2015), biting the neck of females, and wrapping them with their wings, touching females with stretched wings, pulling the females, snuffling the vaginal region, licking the face and scruff (Mathur et al., 2011; Baki et al., 2015). Females initially tend to ignore the males’ approach, scream (Mathur et al., 2011) and change their position (Maruthupandian and Marimuthu, 2013; Kumar and Kanaujia, 2015). But when the female stops moving away from the male, it allows the male to enact cunnilingus behavior, which increases the copulation duration (Maruthupandian and Marimuthu, 2013). The copulation lasts around 10–90 seconds (Mathur et al., 2011; Maruthupandian and Marimuthu, 2013; Kumar and Kanaujia, 2015) and maximum copulation occurs under dim-sunlight rather than under bright sunlight (Kumar and Kanaujia, 2015). Mounting

can be of two modes: (a) Ventral and (b) Dorsal (Kumar et al., 2017b). Oral sex is also known to occur in *P. medius* (Kumar and Kanaujia, 2015). Additionally, Indian Flying Foxes have been observed engaging in the rare behavior of homosexual (male–male) fellatio (Sundar and Kittur, 2020).

Parental care: A study from Odisha documented that females deliver young ones during April–June and the period of gestation is approximately 145–160 days. Most of the females hold young ones through their patagium by wrapping it around them when hanging on trees as well as during flying and carrying them, while pups hold on to the ventral side of the mother firmly. The pups are usually taken care of by the mother for 3–4 weeks. Parental care is only by females. Between the mother and the pup tactile communication exists. Weaning happens for 5 months. Young ones are capable of flight at 11 weeks and mature by 1.5 years (Rao, 2017).

Population dynamics

Populations of *Pteropus medius* are under significant threats from various factors such as habitat destruction, electrocution, and hunting for various purposes. Consequently, numerous studies have documented a noticeable decline in their population as elaborated below: Population trends were documented over a period in different studies either observed by authors themselves or by information through local people. A decline in population from 6370 individuals to 5033 (21%) in two years - from 2013 to 2015 - was recorded in Cachar district of Assam (Rahman and Choudhury, 2017). In Dhubri district of Assam from 2001 to 2010, the population was recorded to decrease from 547 to 287 (47%) over a period of 10 years. In Uppinangadi of Karnataka,

population of the species was observed to decline from 4000 individuals to 2500 (38%) from 1994 to 1999 (Chakravarthy and Girish, 2003). On the other hand, at the roosting site of the Itiadh Dam of Maharashtra, the population size was observed to increase from 410 in 2010 to 692 individuals in 2014 (Bhandarkar and Paliwal, 2014).

Indian Flying Foxes are also known to change or shift their roost when roosting trees are cut down: A colony of the species about 75 years old in Tumakuru of Karnataka was recorded to change its roosting trees two times when the roosting trees were cut down. The final or third roosting trees selected by the individuals of bat belong to private land and fortunately landowners protect these bats. But there are hunters coming from far places to hunt bats for meat and medicinal purposes. Also hunting contributes to 30% of bat decline in Karnataka (Chakravarthy et al., 2009). Similar observation was noticed in Tamil Nadu, where villagers worship roosting tree species. Some villagers even stopped using crackers during festivals (Pandian and Suresh, 2021) as they noticed the decrease in population in six decades. Information from the villagers from Tumakuru region of Karnataka says that population of *P. medius* is increasing at a few sites and decreasing at others (Chakravarthy et al., 2009). The population fluctuation throughout the year and higher population during the fruiting season (Prajapati et al., 2020) indicate that the species uses seasonal migration for feeding purposes.

Threats

Habitat degradation: This is the principal reason for the population decline of *P. medius*. Felling trees for renovation and construction (Khan, 2001; Ali, 2010; Jha, 2013; Katuwal et al., 2019), constructing

buildings near roosting trees can cause the entire colony can disappear within a few months (Sharma et al., 2018), and highway development and other development also adversely affects their population (Srinivasulu and Srinivasulu, 2004). Habitat destruction also leads to food scarcity (Manandhar et al., 2018). However, the bats tolerate low level of human disturbance for roosting (Sharma et al., 2018).

Electrocution: Death from electrocution (Fig. 6) is one of the common threats to *P. medius* in both urban and rural areas (Talmale, 2014; Kumar and Kanaujia, 2015; Neupane et al., 2016; Prasad, 2020). Mushahid and Orus (2018) recorded 3–4 bats dying per week from electrocution. Also, Jeyaprabha (2016) documented *P. medius* death due to electrocution near foraging trees such as Banyan and Neem.

Direct interventions: Indian Flying Fox are hunted for various purposes such as bushmeat (Sharma et al., 2005; Thapa, 2008; Ali, 2010; Jeyaprabha, 2016), medicine, leather, and institutional specimens (Ali, 2010; Kumar and Kanaujia, 2015; Katuwal et al., 2019). They are also considered as a bad omen and crop damagers (Jha, 2013) which are other major threats to them. People hunt the species for medicine purpose (Sharma et al., 2005; Pandian and Suresh, 2021) such as asthma, (Chellappandian et al., 2014; Jeyaprabha, 2016), backaches, chronic pains, and menstrual problems (Jeyaprabha, 2016). Though there was an outbreak of Nipha virus in Kerala, local people continued to consume bat bushmeat (Murugan et al., 2020). People living close to the bat roosting sites tend to eradicate bats because of the continuous noise, guano smells, and guano markings on building walls. People use loud noises, firecrackers (Kumar and Kanaujia, 2015; Bhandarkar and Paliwal, 2018), and set smoke under the canopy to discourage bats from roosting (Vyas and Upadhyay, 2014).



Figure 6: A *Pteropus medius* found hanging dead on an electric wire after electrocution in Sirsi, Karnataka, India. Photo Credit: Shraddha Kumari K.

Discussion

Although we have a fair knowledge on a few ecological aspects of *Pteropus medius*, we lag in understanding their complete ecology such as habitat requirement, range of flight, foraging bouts, reproduction, colony structure, permanent and temporary roosting behavior, and migratory behavior. This review presents a detailed picture on the geographical distribution of *P. medius*, type of roosting trees preferred, habitat selected for roosting, dietary composition including types of fruits, leaves, and flowers consumed, foraging behavior, different types of activities shown in roosting sites, their interaction with other organisms, roost sharing and territory behavior, breeding season and courtship behavior, threats by anthropogenic activities, and future perspectives in ecological research.

From 1997–2023 there has been limited advancement in the methodologies used to address most research questions on the ecology and behavior of *P. medius*. However, a recent study by Murugavel et al. (2023a) demonstrates a significant step forward, by employing GPS tagging to investigate home range of *P. medius*. The relatively lower number of studies on the species compared to other mammals can be attributed to several challenges to study it – its nocturnal activity, ability to travel longer distances by flight, roosting in large and tall trees and other distinguishing characteristics. It might also be the case that people might show reduced interest in this species considering its wide distribution, many researchers focusing more on rare and little-known species (Krystufek, 2005).

From the current review, it is also evident that *P. medius* prefers native tree species over exotic species, where about 66% of roosting trees are native and about 33% are exotic, which is in line with the study of Madala et al. (2022). Also, local perceptions and cultural beliefs play significant role in the conservation of this species. As documented by Saikia et al. (2011) that people in Himachal Pradesh live in harmony with *P. medius* although they cause considerable damage to crops, showing people's attitude and role in conservation of the species. Additionally, a study shows that this species is not typically considered as a pest, and that most of their food comes from plants other than crops (Mahmood-Ul-Hassan et al., 2010). It is very important to notice that sacred groves play crucial roles in conservation of Indian Flying Fox, where people worship bats as sacred animals (Tangavelou et al., 2013).

Several research gaps are identified in this review, offering meaningful directions for future ecological research on *Pteropus medius* as discussed below:

Since this review revealed that many individuals of *P. medius* roost close to human settlements, studies are required concerning behavioral changes such as any shifts towards urban centers and if present, the

factors influencing such behavior (Tait et al., 2014; Scheelings and Frith, 2015), stress level to heat and effects of temperature (Welbergen et al., 2008; Snoyman and Brown, 2011; Snoyman et al., 2012). Non-invasive methods such as guano-based cortisol metabolite analysis can be used to understand the level of stress bats are undergoing due to human activities and environmental factors (Kelm et al., 2016). The relationship between different environmental aspects such as change in landscape for agriculture purposes, buildings, alteration in temperature due to human activities can be studied by understanding the bat's behavior towards each environmental parameter. Also, since bats can serve as reservoirs or vectors for zoonotic diseases, understanding bat habitat preference and resource requirements is a key requisite for developing preventive measures for such diseases (Hahn et al., 2014).

A detailed understanding of bat distribution, habitat use, natural resources required for survival, dietary needs, and population size are fundamental to developing conservation plans and reducing or avoiding risks of potential risks from this species. Saikia et al. (2018) noted that documentation of bat caves and threats on *P. medius* is vital for its conservation, but it is equally important to document roosting trees for *P. medius*.

Methods used until now for the dietary analysis of *P. medius* are the conventional such as collection of fruits, seeds, and leaves consumed by them (Prasad et al., 2014; Ashwin and Jaykumar, 2019). Also, advanced tools can be adapted in the analysis of food plants or dietary composition of the species using non-invasive, less time consuming, and more precise tools i.e. DNA metabarcoding using eDNA sample from the guano. This tool was successful enough to identify food plants of frugivore and nectarivore bats including some congeneric species of *P. medius* (Hayward, 2013; Aziz et al., 2017; Lim et al., 2018a, b; Bell et al., 2021; Boardman, 2021; Bradford et al., 2022). Additionally, more focused studies on fecal and bolus samples across regions can help identify key dietary plants, aiding reforestation or the reintroduction of preferred tree species for foraging (Majumdar et al., 2016).

Studies regarding the Indian Flying Fox and human conflicts are underexplored. Hence strategic foresight should focus on the cause for any human-bat conflicts, such as bat strikes in aircraft (Pearson and Clarke, 2018), and counting bat deaths caused by windmills via direct observations, carcass counts (Zimmerling and Francis, 2016), videography (Cryan et al., 2014), or by GPS tracking (Roeleke et al., 2016). Future studies should focus on the bat population pattern on the native and invasive species of roosting trees and diet resources to understand any significant pattern by the individuals in choosing roosting site. Population studies can be aided with direct count for small camps; tools such as State-Space Models for bigger camps (Sugita et al., 2009; Westcott et al., 2018). This will help in planning

conservation actions such as maintaining around 150 m distance between bat roosting sites and human activities (Van der Aa et al., 2006), monitoring light levels (Murugavel et al., 2023b), reducing noise pollution (Pearson and Clarke, 2018), and avoiding over-pruning in urban areas (Wu et al., 2022).

Conclusion

Since the local perception offers valuable insights and help in conservation (Deshpande and Kelkar, 2015), efforts to educate people living close to the bat roosts can mitigate threats to bats from various causes such as colony destruction for bushmeat, medicine, etc. Conservation of *P. medius* means protection and restoration of their habitat for roosting and the habitat required for their food plants, and the flight paths needed to reach fruiting trees from their roosting trees. It is also crucial to conserve the existing native tree species which are preferred roosting sites for *P. medius*. To achieve this, it is mandatory to understand their habitat and ecology initially, for which the data compiled in the current review would help.

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Author contributions

Conceptualization, data analysis, and original draft were by SKK; and review and editing were by VKN and SKK.

Conflict of interest

The authors declare that there are no conflicting issues related to this review article.

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