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ROOSTING CHARACTERISTICS AND FEEDING ECOLOGY OF INDIAN FLYING FOX (PTEROPUS MEDIUS TEMMINCK, 1825): THE IMPORTANCE OF RESTRICTED URBAN GREEN SPACES IN CONSERVATION

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ABSTRACT: Present study investigated the roosting, diet and dietary composition, and conservation challenges of the Indian flying fox, *Pteropus medius* from April 2023 to March 2024. The study was based on monthly four to five days direct field observation walking through the trails laid over the study areas. The population was estimated by direct roost count methods (Kunz *et al.* 1996). A total of 1940 individual of bats from 45 colonies were recorded. The bats were roosted in well-branched tall trees above or near water bodies in the city's parks and gardens. Most roosts were permanent but varied insignificantly seasonally. Seventeen tree species of 11 families were used for roosting. The bats preferred well branched woody tall trees having a good crown to roost. Relationship between the bats abundance and diameter at breast height of the roosting trees ($r = 0.647$, $n = 44$, $p < 0.000$) and crown volume ($r = 0.466$, $n = 44$, $p = 0.0011$) were significant. Trees dbh explained 44% of the variation ($R^2 = 0.449$, $n = 41$, $p = 0.001$), while crown volume 22% ($R^2 = 0.217$, $p = 0.05$) in relation to the abundance of bats. *Pteropus feeding observation included on site (n = 112) and out site (n = 68) bouts.* They mostly fed on fruits (75.56%), followed by flowers (14.44%) and nectar (10%) respectively, while insect feeding observed occasionally. Feeding activities of the bats fluctuated significantly temporally ($x2 = 22.11$, $df = 6$, $p = 0.0011$). They fed on 15 plants species belonging to 11 families. *Neolamarckia cadamba*, *Polylthia longifolia*, *Putranjiva roxburghii, Ficus benghalensis*, *Ficus glomerata*, and *F. racemosa* were consumed round the year, even in the period of fall back. Habitat destruction, shrinkage and degradation of water bodies are the two major threats identified. The findings emphasize the importance of protecting the bats current roosting habitats and establishing enrichment plantation to improve their foraging areas and future long-term prospects for conservation of *Pteropus medius* in these areas.

Key words: *Pteropus medius***,** roosting, feeding, threats, and conservation.

INTRODUCTION

Fruit bats are key pollinators and seed dispersers maintaining over 114 tropical plants and sustaining ecosystem stability globally, (Fujita and

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Tuttle1991,Mickleburgh *et al.*1992, Kingston 2010, Kingston *et al.* 2003, Mickleburgh *et al.*1992). Despite their ecological importance, fruit bats populations are being declining nowadays, due to habitat loss caused by deforestation, agricultural expansion, and urbanization (Mickleburgh *et al.* 2002). If the situation continues at its current pace, nearly 24% of *Pteropodidae* species are projected to face extinction by the end of this century across Asian countries (Kingston 2010), which is very concerning for Bangladesh. As one of the world's most densely populated countries (168 million people; 1,260 people/km^2), it has lost almost 94% of its original forest cover to meet the needs of its growing population (Khan 2018, Azam 2022). The country may host between 31 and 112 bat species including seven fruit bats (*Pteropodidae*) (Hasan and Kingston 2022); however, early research reported between 31 and 38 species (Khan 2018, Sarker and Sarker 2005, Srinivasulu and Srinivasulu 2025, Molur *et al.*2002, IUCNBD 2015, IUCN 2022).

The Indian flying fox (*Pteropus medius*), the most widely distributed fruit bat in this country, has already lost more than 80% of its natural habitats (Khan 2001, Hassan *et al.* 2020). Yet, only 2–17% of the country's land is currently suitable for bats roosting (Hahn *et al.* 2013). In addition to the habitat destruction, hunting, negative cultural attitudes, and disease-related stigma (e.g., Nipah virus, COVID-19) further threatens bats survival in this area (Hassan *et al.* 2020, Epstein *et al.*2020, Nahar *et al.*2020, McKee 2021, Islam *et al.* 2021, Faus-Cotino *et al.* 2024). The Indian flying fox, while classified globally as least concern, appears to be declining locally. The roosting and feeding habits of the bats were well studied (Masood *et al.* 2024, Devi and Kumar 2024, Pandian and Suresh 2021, Schloesing *et al.* 2020, Tangavelou *et al.* 2013, Mahood-ul-Hasan 2010) throughout its range. However, one notes on *P. giganteus* roosts in north bengal found (Hasan *et al.* 2015); though bats diversity (Saha *et al.* 2017, Hasan and Kingston 2022., Khan 2015, Sarkar and Sarkar 2005), bats and Nipah virus transmission (Hassan *et al.* 2020), roosting links to Nipah virus epidemiology (Hahn *et al.* 2013, Epstein *et al.* 2020), seasonality of date palm sap feeding (Islam *et al.* 2021) and bush meat hunting (Nahar *et al.* 2020) were studied. No systematic studies have assessed population status, roosting ecology, and/ or feeding behavior of the bats (IUCN 2015). This is the first approach seeking to fill this gap by examining their roosting characteristics, feeding habits, and potential threats with the goal of informing strategies for its conservation in these urban ecosystems.

MATERIAL AND METHODS

Study area: The fieldwork was carried out at four selected green patches in Dhaka: Ramna Park, Dhanmondi Lake, National Botanical Garden and

Baldha Garden from April 2023 to March 2024. Ramna park is an area of 27.72 ha including 3.55 ha lakes administered by public works department (Figure 1). The lake and a narrow channel flow through the park area is an endowment providing scenic beauty and maintain a good temperature and humidity of the park. Moreover, the Hare Road—one of the most beautiful roads runs in this city. This road seems to give off a miraculous calm amid the city's constant exhaustion. Also, a line of century-old growth trees spread over gentle, shaded serenity to the Ramna Park, where the city people especially enjoy their morning and evening walk round the year supports a good number of bats. The bats in the park roost above the channel of the well branched tall trees, therefore, droppings were departed in the water and feces do not soiled the park (Figure 2). The park supported 192 plant species including flowering (71species), fruiting (36species), medicinal (33species) and forestry (41 species) and ornamental (11 species) plants (Pasha *et al.* 2021). ii) Dhanmondi Lake, a prominent water body covers an area of 34.64 ha, comprising 36% land area and 64% water bodies. The lake is evidently flowing into the Buriganga River (Figure 3). It is surrounded by old growth trees, shrubs and understory bushes. There are walkways where the city people enjoy walking and gathering daily round the year. It serves as a reservoir of rain water and maintains a stable water body over the year. iii) Bangladesh National Botanical Garden, the largest plant conservation center with an area of around 84.98 ha. It lies between Bangladesh National Zoo and National Herbarium. A large pond and two lakes go over the zoo which attracts huge resident and migratory birds throughout the year as well as the bats residing in both the zoo and the garden (Figure 4). The garden comprises a total of about 56,000 individual trees, herbs, shrubs, and flowering and fruiting plants. Moreover, the area supports a huge collection of aquatic, rare, and exotic plant species ensures mosaic habitats in the garden area. iv) Baldha Garden is a botanical garden covers an area of 1.27 ha. It is situated in the Wari area of old Dhaka city administrative part of the National Botanical Garden operated by the department of forestry. This garden supported a total of 672 plant species attracting wildlife (Satu *et al.* 2019) (Figure1).

Roosting Characteristics: Monthly four days fieldwork were employed at the four study sites through direct roost count methods between April 2023 and March 2024. If any unavoidable circumstances arose and we could not visit one of the four stations in a month we employed more one day for fieldwork for the missed station. Data were collected in two phases: i) at the very early morning (dawning) to 11 am ii) at afternoon 4 pm to night until 10 pm. A total of 50 days fieldworks were conduct done during the study period. We used walking with average speed 2.1 km/h along the trails laid over the study sites. We took notes on the number of bats individuals in a single roost, and roosting habitats

characteristics, e.g., tree species and abundance, trees dbh, tree height, crown length, and crown height of the roosting trees by Franceschi *et al.* (2022). When bats were aggregated in multiple trees at a single site considered as dispersed roost and single aggregation in a single tree in a single site as single roost. The number of *P. medius* on each roosting tree was counted through direct roost count method following Kunz *et al.* (1996). The counting of bats was done mostly by naked eye and a binocular (Tasco 7 X 50 mm). The number of bats counted on each roost was recorded by taking a consensus of the observers to avoid bias.

Diet and dietary composition: We observed *P. medius* commuted leaving the roost for foraging at the crepuscular time. Foraging activities included: (i) commuting long-distance flights: flights from roost site to long-distance (ii) short-distance foraging movements: flights between roost sites to the adjacent short distance i.e., eyesight distance iii) stationary bouts: foraging flights in the

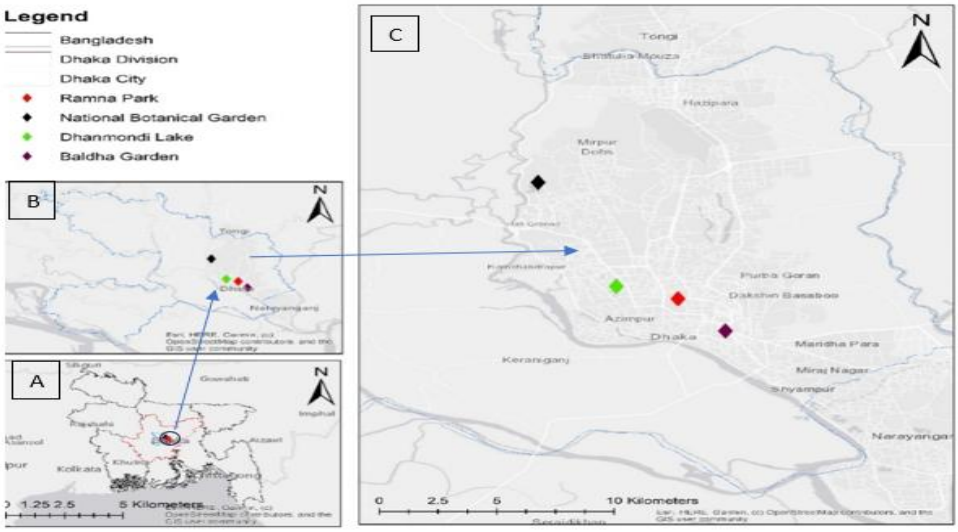

Fig. 1. Map of the Study sites. A: map of Bangladesh, B-C: map of the four green spots in Dhaka City, Bangladesh

study areas (Olesky and Jones 2015, Weber *et al.* 2015). When a feeding occurred we recorded the characteristics of foraging sites, food items, and food species during the study period. It is mentionable here that if we faced any difficulties in identifying food items at night we then again investigated it at day time. We divided the study period into six seasons according to Bengali calendar: summer: mid-April to mid-June, rainy season: mid-June to mid-August, autumn: mid-August to mid-October, late autumn: mid-October to mid-December; winter: mid-December to mid-February, and spring: mid-February to mid-April. Then divided into three: summer: March – May, rainy season: June-

Fig. 2. *P. medius* roosting in the study areas, A-*Acacia auriculiformis*, B-*Ochroma pyramidale*, Ca-*Magnolia champaca*, C-*Couroupita guianensis*, Ch-*Adina sessilifolia*, G-*Albizia richardiana*, H-*Madhuca longifolia*, Ir-*Mesua ferrea*, Ma-*Swietenia mahagoni*, Mj-*Artocarpus lacucha*, M-*Samanea saman*, N-*Azadirachta indica*, S-*Manilkara zapota*, Sp-*Mimusopselengi*, Ta-*Tamarindus indica*, T-*Tectona grandis*, V-*Vitex peduncularis*, i. National Botanical Garden, ii. Ramna Park, iii. Dhanmondi Lake, iv. Baldha Garden, (t)-Temporary Colony.

Fig. 3. Buriganga river and the four study areas.

Fig. 4. *P. medius* roosts in the Botanical Garden.

October, winter: November-February to see the seasonal variation of feeding. Threats were noted during the fieldwork.

Data analysis: We used bats abundance as dependent variable and roosting characteristics independent variable for analysis. Pearson correlation

was used to assess the relationship between roosting trees characteristics and the bats abundance and multiple regressions to investigate the strength of relationship between the roosting characteristics and the bats abundance. We also used x2-test to compare the seasonal variations in feeding of *P. medius* between the seasons.

RESULTS AND DISCUSSION

Roosts and their Distributions: We recorded 45 colonies comprising 1,940 individuals (range: 7–267, mean = 43.11 sd = ± 46.94). Most (68%) of the colonies were dispersed across multiple trees, while less than one fourth (22%) formed single-tree aggregations. Roosting sites were mostly permanent (92%), with the rest being seasonal or temporary. However, the colony size of *P. medius* fluctuated between seasons and recorded to be higher aggregations in winter than summer during the study period. Roost switching appears to be essential for most bat species, therefore, fluctuates seasonally (Devi and Kumar 2024, Mickleburgh *et al.* 1992, Pierson and Rainey 1992). Ramna park supported the largest population (40%, 10 colonies, n=769), followed by Baldha garden (29%, 15 colonies, n=561), national botanical garden (20%, 13 colonies, n=289), and Dhanmondi Lake (11%, 7 colonies, n=221). In the park, the highest population occupied the smallest area for roosting therefore their presence in the park does not emanate nuisance for the park visitors. The bats density peaked at Baldha garden (0.37individuals/m^2). The density at the garden might reflect the gardens plant species diversity and abundance; moreover, its location near the Buriganga river might offer dense riverside vegetations providing available foods to the bats.

Roosting Characteristics: A total of 45 individual trees belonging to 11families, 17 genera, and 17 species identified as the bats roosting trees. *P. medius* were roosted in well-branched tall trees with dbh (40-80 cm) having large crown volume above or near water bodies in the study areas (Figure 2). They preferred well branched woody tall trees (61% 18–20 m) having a good crown. This might because of tall tress likely provide thermal shelter from extreme hot and cold weather (Chakravarthy and Yeshwanth 2008, Krystufek 2009, Kunz 1982, Altringham 1996, Kunz and Lumsden 2003). Family Fabaceae supported the highest proportion 46.7% (n = 906) followed by Verbenaceae 17.37 % (n = 337), Lecythidaceae 12.5% (n=244), Magnoliaceae 6.13% (n = 119), and Sapotaceae 5.5% (n = 107) respectively. Interestingly, the lowest number (0.36%, n =7) of bats were recorded from the family Moraceae (Table 1). Moreover, highest proportion (n = 608 individuals) were found to roost in *Samanea saman* where only a small proportion (n = 7 individuals) recorded from *Artocarpus lacucha*. Roosting changed seasonally, such as, *Delonix regia* supported 52 individuals in Suhrawardy udyan in winter but no roosts in

Table 1. *P. medius* abundance and roosting characteristics during the study period (no. of trees are given in parentheses).

Family	Scientific Name	English name	Trees (no trees study site)	Bats count	Abundance	DBH (cm)	Range (cm)	Height (m)	Range (m)	Crown volume (m^3)	Range (m^3)
Calophyllaceae	*Mesua ferrea*	Indian rose chestnut	2 (Bg)	64	32±14.14	35±1.41	34-36	19.5±0.7	19-20	539.311±222.88	381.71- 696.912
Fabaceae	*Albizia richardiana*	Gogon sirish	6 (Rm 4, D2)	150	25±12.70	65±17.6	40-86	20±1.67	18-22	1488.77±1103.092	696.61-3053.64
	Samanea saman	Monkey pod	5 (Rm 3, D2)	608	121.6±94.2	101.6±34.9	67-154	18.2±1.1	17-20	2526.402±675.75	1767.15-3575.29
	Tamarindus indica	Tamarind	1Bg	123		52		19		1388.06	
	Acacia auriculiformis	Akashmoni	1Nbg	25		53		16		195.43	
Lecythidaceae	*Couroupita guianensis*	Cannon ball	4 (Rm 1,bg 3)	244	61±46.89	67±5.48	61-73	20.5±1.3	19-22	493.55±280.91	113.09-782.46
Lamiaceae	*Vitex peduncularis*	*Goda Horina*	1(Nbg)	27		35		17		242.95	
Malvaceae	*Ochromapyramidale*	Balsa tree	2 (Bg)	79	39.5±14.85	80±21.21	65-95	19.5±0.71	19-20	998.31	
Magnoliaceae	*Magnolia champaca*	Champak	3 (Bg)	119	39.67±26.9	50±6.56	43-56	20.67±2.5	18-23	457.34±225.79	248.48-696.92
Meliaceae	*Azadirachta indica*	Neem	2 (Dl)	23	11.50±2.12	32±8.49	26-38	15.5±2.12	14-17	146.34±47.015	113.1 -179.59
	Swieteniamahagoni	Mahogany	1 (D)l	15		28		14		170.16	
Moraceae	*Artocarpus lacucha*	Monkey jack	1(Bg)	7		54		18		901.83	
Sapotaceae	*Madhucalongifolia*	Honey tree	2 (Rm)	75	37.5±36.06	78±25.46	60-96	14±2.53	12-16	431.22±375.806	165.45-696.69
	Manilkarazapota	Sapodilla	1(Bg)	10		53		14		696.92	
	Mimusopselengi	Spanish cherry	1(Bg)	22		38		18		1047.39	
Rubiaceae	*Adina sessilifolia*	Chota Holdu	1(Bg)	12		64		17		242.95	
Verbenaceae	*Tectona grandis*	Teak	11(Nbg)	337	30±11.075	52.82±5.4	47-61	19.27±1.4	17-21	297.94±137.148	143.69-523.6

the rainy season. However, it was a permanent roost in India (Devi and Kumar 2024). *Madhuca longifolia* (n = 52 individuals) in Ramna park, *Azadirachta indica* (n = 2) and *Swietenia mahagoni* (n = 1) in Dhanmondi lake used only for summer roost during the study period. Similar characters were made for *P. giganteus* (Hasan *et al.* 2015, Kalko 1997), *P. alecto* (Palmer and Woinarski 1999), *P. livingstonii* (Granek 2002). This knowledge is of primary importance to establish conservation plan for this species (Stebbings 1988). Therefore, we can manage landscape to increase the extent of these habitat types and protect the bats (Carmel and Safriel1988).

Most bats (66%) roosted in tall trees 18–20 m with dbh between 40–80 cm (mean = 0.69 cm, range = 26-154 cm), mean height 18.62m (range = 12 - 23 m), crown volume = 793.93 m^3 (range=113.09 - 3575.29 m^3) (Table 1). Roosts used by the bats in relation to trees characteristics were analyzed to see how the different roosting characteristics influenced bats abundance. A multiple regression analysis showed that dbh explained 44% of the variation in bat abundance (R^2 = 0.449, n = 41, p = 0.001), while crown volume 22% (R^2 = 0.217, p = 0.05), and height only 5% (R^2 = 0.054, p = 0.23). We found a significant positive correlation between bats abundance and dbh (r = 0.647, n = 44, p < 0.000); and crown volume (r = 0.466, n = 44, p = 0.0011). *Pteropus medius* prefer large trees with greater height, diameter, crown volume, therefore preserving large trees for bats conservation is crucial (Devi and Kumar 2024, Kumar *et al.* 2018, Gulraiz *et al.* 2015, Bahn *et al.* 2014).

Dietary Composition and their temporal variation: we observed P. medius feeding in roosting site (n =112) *and out of the roosting site (n* = 68) during the study period*. They* made several wing flapping before starting foraging. The bats primarily consumed fruits (75.56%), followed by flowers (14.44%) and nectar (10%). Feeding behavior involved selecting ripe, juicy pulp fruits, and discarding the hard or fibrous portions. Occasional insect feeding was observed during the study period (Silva *et al.* 2024). Fruit consumption remained high (≈70%) throughout the year except in the spring when drinking nectar peaked at 53.94% (Figure 5). They preferred feeding on ripe fruits (63.72%) over unripe (36.28%). Feeding on fruits was observed highest (74.08%) in the Rainy season likely due to increased fruit availability in this period. We observed *P. medius drank n*ectar from *Adina sessilifolia*, *Borassus flabellifer*, *Musa acuminata*, *Madhuca longifolia*, *Tamarindus indica*, *Vitex parviflora*, and *Mimusops elengi during the study period* (Table 2).

A total of 15 food plant species from 11 families were recorded. Family Rubiaceae contributed the largest proportion (38.80%), followed by Moraceae (22.38%), Sapotaceae (8.21%), Anacardiaceae (6.72%), Putranjivaceae (6.72%),

Annonaceae (6.72%), and Fabaceae (2.98%) (Table 2). Among the food species, *Neolamarckia cadamba* accounted for the highest consumption (38.06%), followed by *Ficus benghalensis* (13.43%), *Mangifera indica* (6.72%), *Putranjiva roxburghii* (6.72%), *Polyalthia longifolia* (6.72%), *Mimusops elengi* (5.97%), *F. glomerata* (4.48%), and *F. racemosa* (4.48%) respectively (Table 2). Of them *N. cadamba*, *P. longifolia*, *P. roxburghii* and *F.* spp. were consumed nearly year-round as well as fallback period. *Anthocephalus cadamba* a potential food item of *P. medius* (Marimuthu 1988, Ali 2022, 2013). Seasonal food scarcity was observed in winter, with fruits consumed from *Neolamarckia cadamba*, *Musa acuminata*, and *Putranjiva roxburghii*, *etc*. Time spent feeding on different food items (x2 =22.11, n = 6, p = 0.0011) and food species varied significantly seasonally (x2 =11.59, n = 28, p = 0.05). Similar observations of seasonal food scarcity and dietary shifts have been documented in other bat-inhabited regions (Dobat and Peikert-Holle1985, Marshall 1985, Mickleburgh *et al.* 1992, Wiles and Fujita 1992, Banack 1998).

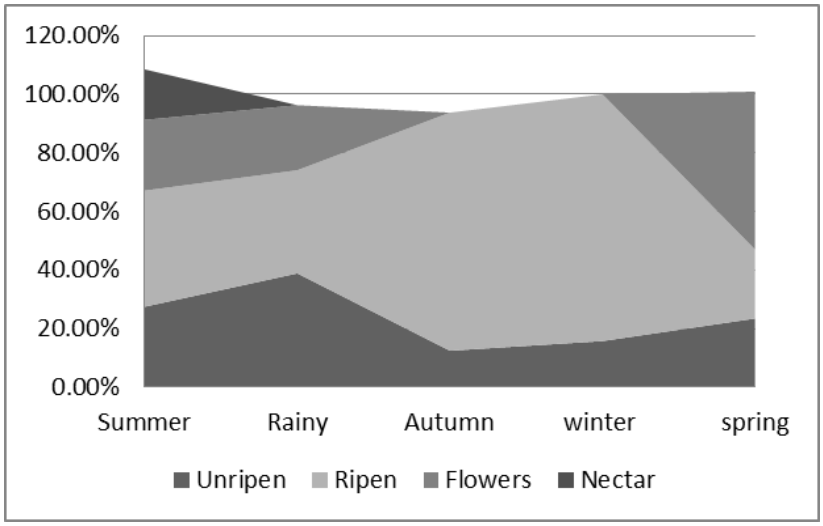

Fig. 5. Seasonal fluctuations of food items in feeding during the study period.

Conservation challenges and prospects: Habitat destruction by cutting down tall trees, and by heavy storm in the rainy season because of root soil erosion, clear felling of under shrub bushes, destruction of water bodies by dumping debris and polythene, and spraying insecticides in the park areas are the major threats facing bats in the areas. Fruits consumption by the bats posed negative attitudes towards it, entangled in flying kite rope, and electrocution around the foraging sites were observed. Destruction of roosting habitats by clear felling of large trees, hunting for bush meat and medicinal use (Nowak

1999, Padmanaban and Sujana 2008, Katuwal *et al.* 2019), human-bats conflict towards crop raiding and people's beliefs on bats role in transmission of Nipah virus (Nahar *et al.* 2020) largely threaten bats in Bangladesh.

Table 2. Feeding of *P. medius* in response to seasonal change during the study period

Family	Scientific name	Summer	Rainy	Autumn	Winter	Spring	Total
Anacardiaceae	*Mangifera indica*	21.43% RF	-	-	-	-	6. 72%
Annonaceae	*Polyalthia longifolia*	9.52% URF, RF	13.51% URF, RF		-		6.72%
Arecaceae	*Borassus flabellifer*	-	5.41% RF	3.83% RF	-	-	2.24%
Elaeocarpaceae	*Elaeocarpus serratus*	-	2.7% URF		-		0.75%
Fabaceae	*Tamarindus indica*	4.76% N	-	-	-	15.38, N	2.99%
Moraceae	*Ficusbenghalensis*	16.67%' RF, URF	13.51% ,URF, RF	23.07%, RF			13.43%
Musaceae	*Musa acuminate*	-	-	-	(1)RF	-	0.75%
	Ficus glomerata	-	5.41% URF,RF	4.64% URF,RF	-	15.38% URF, RF	4.48%
	Ficus racemose	-	5.41% URF,RF	4.64% URF,RF	-	15.38% URF,RF	4.48%
Putranjivaceae	*Putranjiva roxburghii*	7.41% URF, RF	8.11% URF, RF		3 (URF, RF)	-	6.72%
Rubiaceae	*Neolamarckia cadamba*	33.33% Fl	32.43% Fl	33.27% RF	(12) RF	-	38.06%
	Adina sessilifolia	2.38% N	-	-	-	-	0.75%
Sapotaceae	*Madhuca longifolia*	-	-	-	-	30.77% ,N	2.99%
	Mimusopselengi	4.76% N, URF	8.11% , URF		-	23.08%, N	5.97 %
Verbenaceae	*Vitex parviflora*	-	5.41% N	7.97 % N, RF	-	-	2.99%

Notes:Fl: flower; URF: unripen fruit; RF: ripen fruits; N: nectar.

We observed seed raining of *P. longifolia*, *P. roxburghii*, and *M. elengi,* all along the bats foraging sites, e.g., parks and gardens, road isles, administrative office premises, academic institutions, and residential areas around the study areas. Therefore, protection of urban non-protected areas as well as their plant species diversity is very important. This finding demonstrates the importance of chiropterochory and chiropterophily in the restoration of urban landscape (Silva *et al.* 2024, Kunz *et al.* 2011). *P. medius* observed eaten insects. Bats eat insects more than half of its body weight every night; also they are fond of eating flying moths whose youngs are destructive caterpillars feed on crops which rendered most important ecosystem services (Primack 2014). Therefore, mapping the

existing roosting and foraging sites as well as ensuring food resources throughout the year to provide legal protection are fundamental. Moreover, planting food plants and nectar-producing trees in the present foraging grounds might meet their nutritional needs round the year. Conservation of water bodies in Dhaka city is another important issue for the species. Additionally, community engagement plays a crucial role in successful conservation program in home and abroad. For example, conservation of bushbuck (*Tragelaphus scriiptus*) by Efutu people of Winneba, Africa (Gordon 1992), two primates *Cercopithecus campbelli, Colobus polykomos* in Africa (Fargey 1992, Laidler 1982), locals from Shai Hills Resource Reserve, Ghana protected four bat species *Eidolon helvem*, *Glauconycteris poensis, Hipposideros abae*, *H. Cyclops* (Decher 1997) as same bats are protected from being killed in India (Fargey 1992, Laidler1982). Conservation education programs in academic institutions schools, local communities, and urban parks can highlight the ecological services provided by bats that might encourage a culture of human bat coexistence as same human common langurs coexistance at Keshabpur, Jessore, Bangladesh (Khatun *et al.* 2014).

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