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## Roost characteristics and habitat preferences of Indian flying fox (*Pteropus giganteus*) in urban areas of Lahore, Pakistan

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## Roost characteristics and habitat preferences of Indian flying fox (*Pteropus giganteus*) in urban areas of Lahore, Pakistan

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**Abstract:** Roost characteristics of Indian flying fox *Pteropus giganteus* at the Jinnah (n = 1052) and Lalazar (n = 40) gardens in Lahore were observed for a period of 1 year to find roost preferences in these bats. The Jinnah garden harbors 4119 trees belonging to 46 families, 103 genera, and 132 species, of which 44 trees belonging to 17 families, 19 genera, and 21 species served as bat roosts. The Lalazar garden harbors 90 trees representing 7 families, 9 genera, and 9 species. Six of these belonging to 2 families, 2 genera, and 2 species each served as bat roosts. Height of the roosting trees varied from 7.5 m (*Dendrocalamus hamiltonii*) to 19.8 m (*Celtis australis*) and diameter at breast height (dbh) ranged from 0.10 m (*Putranjiva roxburghii*) to 0.89 m (*Kigelia pinnata*). Maximum average bats (n = 88) were roosting in *P. roxburghii* with total height of 13.4 m and dbh of 0.1 m, whereas minimum bats (n = 8) were observed on *Manilkara hexandra* having height of 14.4 m and dbh of 0.24 m. It can be concluded from the present study that *P. giganteus* prefers to roost near water bodies on tall trees with relatively smaller diameters.

**Key words:** Tree height, diameter at breast height, bat roost, Jinnah garden, Indian flying fox, *Pteropus giganteus*, *Mangifera indica*

### 1. Introduction

Members of the family Pteropodidae (Old World fruit bats) occupy a broad geographical range and are characterized by an extensive plasticity of habitat features (Pierson and Rainey, 1992; Palmer and Woinarski, 1999). Most of the pteropodids roost in landscapes with emergent trees providing shelter from strong winds, regulating temperature, providing easy exit for upward flight, and serving as food (Cheke and Dahl, 1981; Kunz, 1982; Pierson and Rainey, 1992; Richmond et al., 1998). While many foliage-roosting bats either live solitary or in relatively small colonies without transforming their habitat, the lesser short-nosed fruit bat *Cynopterus brachyotis* and the short-nosed fruit bat *C. sphinx* make tents to attain protection against predation and harsh weather as well as for mating and rearing young (Balasingh et al., 1995; Bhatt, 1995). Local climate, seasonal food availability, and social interactions among bats are the main factors responsible for evolving solitary or gregarious foliage-roosting behavior in bats (Kunz, 1982; Perry-Jones and Augée, 1991; Law, 1993).

Louis et al. (2008) identified 14 roosting sites in and around Coimbatore and Palakkad districts, India: 5 from home gardens and 2 each from temples, roadside plantations, urban parks, agriculture fields, and a factory campus. Roosts of Indian flying fox were also observed in forest plantations of *Casurina* species, *Acacia* species, and indigenous tree species like *Ficus*, *Bauhinia*, rain tree (*Samanea saman*), and Indian date (*Tamarindus indica*) (Chakravarthy et al., 2008).

According to Chakravarthy and Yeshwanth (2008), roost trees in urban areas generally include *Ficus* spp., royal poinciana (*Delonix regia*), *Eucalyptus* spp., *Acacia* spp., *Terminalia* spp., *Casuarina* spp., Indian date (*Tamarindus indica*), mango (*Mangifera indica*), and jackfruit (*Artocarpus heterophyllus*). Their studies concluded that the numbers of smaller roosts were increasing due to different pressures while the numbers of established roosts of Indian flying foxes were continually decreasing in the area.

*Pteropus giganteus* in Pakistan is reported from Sialkot, Lahore, Marala, Renala Khurd, Said Pur (Punjab),

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Jacobabad, Shahpur, Karachi (Sindh), and Islamabad (Roberts, 1997). It has further extended its range in the northwestern part of Pakistan (Mahmood-ul-Hassan et al., 2011). The Indian flying fox is included in the fourth schedule of the Punjab Wildlife (Protection, Preservation, Conservation, and Management) Act 1974, Section 2 (v), which lists it among those species that are given no legal protection and can be hunted (Mahmood-ul-Hassan et al., 2010). In addition, extensive roost tree cutting for urbanization threatens the survival of the species and its role as seed disperser, forest pollinator, and regenerator is ignored. Therefore, there is a dire need to know the habitat requirements of *P. giganteus* for conservation of these environmentally friendly creatures.

## 2. Materials and methods

Roberts (1997) reported 3 roosts of Indian flying fox, *Pteropus giganteus* in Lahore. These include populations in the Jinnah garden, the residence of the Governor of the Punjab, and the Mohalandar mango garden. Lahore is the second most populated city of Pakistan, covers approximately 1775 km<sup>2</sup> of area, and lies between 31°15'N and 31°42'N and 74°01'E and 74°39'E at an altitude of 208–213 m above sea level. The Badian Ravi Bombanwala canal is an important physiographic and ecological feature of the city that runs all across the district. The city experiences extreme weather; the summer season starts in April and continues until September, during which the temperature fluctuates from 26.8 to 40.4 °C. May and June are the hottest and driest months of the year and summer ends with heavy downpour and the humid monsoon season. Winter lasts from November until March and the temperature ranges from 4 to 18 °C. Average annual precipitation in Lahore is 629 mm with 34 rainy days per year (NESPAK and LDA, 2004).

The city of Lahore and its suburbs were thoroughly searched to relocate all these and any new *Pteropus* roosts. One of these was relocated at the Jinnah garden (35°55'N, 74°33'E) while another was relocated at the Lalazar garden (31°28'N, and 74°14'E). Digitized maps of both these localities were prepared using Arc GIS (Figures 1 and 2).

The roosting sites were visited monthly throughout the year from May 2009 to April 2010 and data regarding roost tree species, its origin (native or exotic), diameter at breast height (dbh), height, and flowering season were recorded.

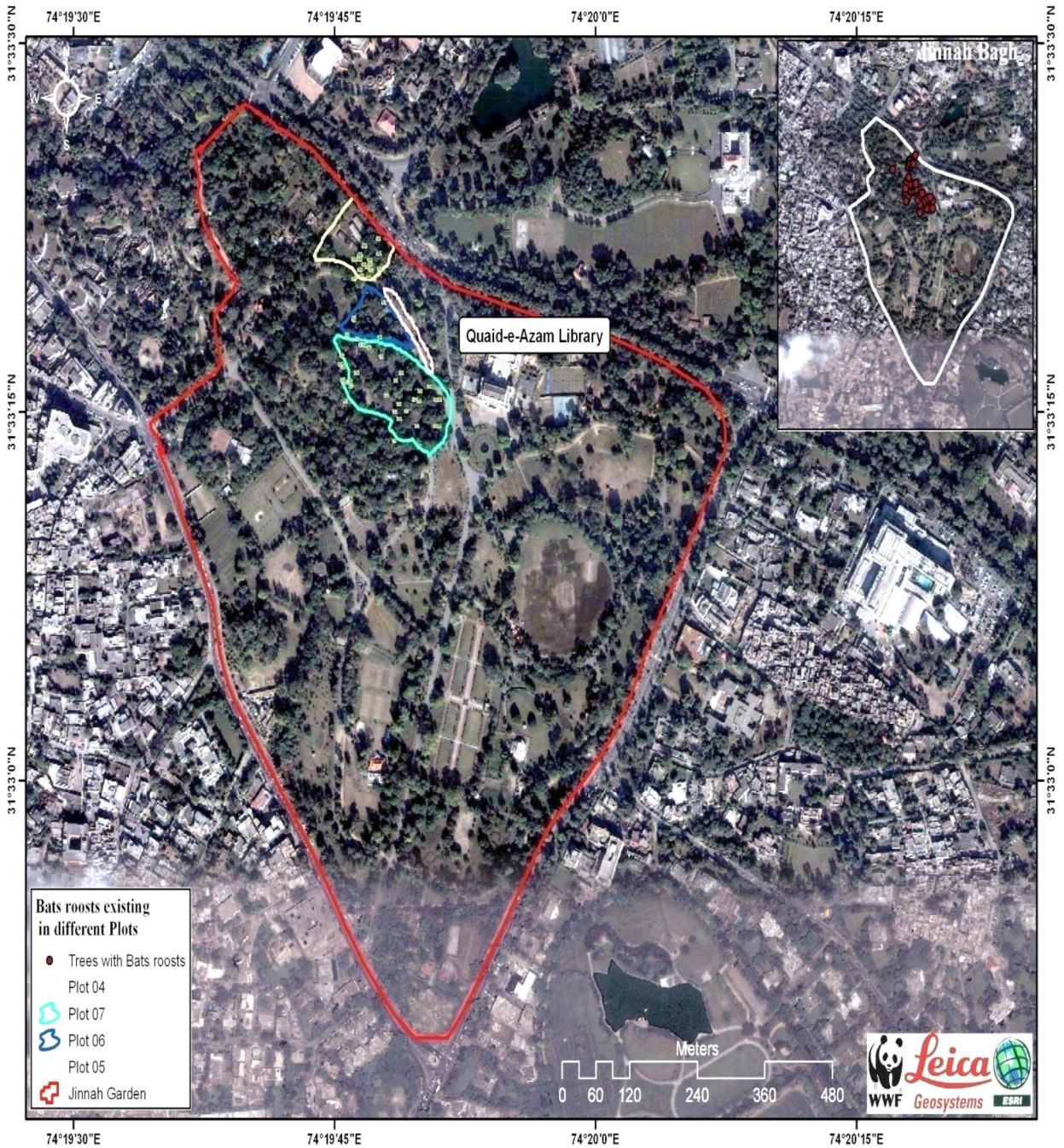
Bats were counted in each roost through direct roost count method following Kunz et al. (1996). Tree height was estimated by taking a consensus of 2 or 3 observer estimates and the circumference of the tree trunk was measured at breast height using a measuring tape, while dbh was calculated following Granek (2002). The flowering and fruiting of roosting trees were observed during monthly visits.

## 3. Results and discussion

Although fruit bats have received international conservation attention as forest pollinators and seed dispersers, especially in tropical, rain, and cloud forests, for nearly 2 decades, their populations are still declining throughout their range (Fujita, 1988, 1991; Power et al., 1996; Wiles et al., 1997). Although Indian flying fox *P. giganteus* has abandoned 2 of its permanent roosts in Lahore, it has been roosting in the Jinnah garden for more than a century (Roberts, 1997) and has established another colony in the Lalazar garden. Fruit bats categorize their roosts by preferring specific biotic, abiotic, and geographic factors for roosting and are sturdily associated with flora and other habitat variables (Kalko, 1997). During the present survey, the roosting sites of *P. giganteus* at both localities were observed near water bodies and were well surrounded by dense vegetation, sheltering the bats from wind, cold climate, and sun at warmer hours of the day. Similar roost observations were noted for *P. alecto* (Palmer and Woinarski, 1999) and *P. livingstonii* (Granek, 2002).

In Southeast Asia, where half of the world's flying fox species are found, these environmentally friendly creatures remain unstudied. In addition, there is extensive fruit bat hunting and natural habitat loss, and no official bat conservation assurance from governments (Whitmore, 1997). In Pakistan, *P. giganteus* is not protected by law and is hunted by local medical practitioners for its body fats to be used as potions for rheumatic pains (Roberts, 1997). The largest South Indian fruit bat, the Indian flying fox (*P. giganteus*) is known to live in close proximity of humans and was observed roosting in botanical gardens, cities, and villages (Chakravarthy et al., 2008; Krystufek, 2009). In Pakistan, bats are considered loathsome and fearful creatures and that is why they remain unexplored. During the present study, the roost characteristics of *P. giganteus* in urban areas of Lahore were explored, which is the first step towards ecological conservation at the local level as it provides information contributing to local management. Average bat number throughout the year at the Jinnah garden and Lalazar garden was 1052 and 40, respectively. At the Jinnah garden, which is administratively divided into 47 plots, the roosting trees of the bats were observed in 4 plots only, i.e. plots 4, 5, 6, and 7. These plots are located near the main entry gate of the garden, covering 8.5% of the total garden area and harboring 12.3% of the total trees. The bats were consistently recorded in these plots and never roosted on any other tree outside these plots. Chakravarthy et al. (2008) reported a roosting site of *P. giganteus* extending on 0.40 ha in Tumakooru, India. The roosting site had 50% vegetation cover of forest plantation and the roosting trees included indigenous tree species like *Acacia*, *Casurina*, *Bauhinia*, *Ficus*, *Samanea*, and *Tamarindus*.





**Figure 1.** GIS-based map of Jinnah garden showing roosts of Indian flying fox populations.

Total trees at the Jinnah garden were 4119, belonging to 46 families, 103 genera, and 132 species, while 44 trees belonging to 17 families, 19 genera, and 21 species served as bat roosts. The roosting trees include *Albizia procera* (n = 1), *Aegle marmelos* (n = 1), *Alstonia scholaris* (n = 1), *Bombax cecilia* (n = 2), *Cedrela toona* (n = 1), *Celtis australis* (n = 1), *Cinnamomum camphora* (n = 1), *Dalbergia sissoo* (n = 1), *Dendrocalamus hamiltonii* (n = 2), *Diospyros*

*peregrina* (n = 1), *Ficus elastica* (n = 2), *F. glomerata* (n = 4), *F. retusa* (n = 2), *Kigelia pinnata* (n = 1), *Mangifera indica* (n = 4), *Manilkara hexandra* (n = 6), *Pterospermum acerifolium* (n = 1), *Putranjiva roxburghii* (n = 1), *Syzygium jambolanum* (n = 9), *Taxodium mucronatum* (n = 1), and *Terminalia arjuna* (n = 1) (Table). These 21 bat roost tree species belongs to 17 families: vAnacardiaceae, Apocynaceae, Bignoniaceae, Cannabaceae, Combretaceae,





Figure 2. GIS-based map of Lalazar garden showing its boundary and roosts of the Indian flying fox populations.

Cuperssaceae, Ebanaceae, Fabaceae, Lauraceae, Malvaceae, Meliaceae, Moraceae, Myrtaceae, Poaceae, Putranjivaceae, Rutaceae, and Sapotaceae. Among these families, 3 tree species ( $n = 3$ ) of Moraceae served as roosting trees ( $n = 8$ ) and the maximum number of roost trees were jambolan plum ( $n = 9$ ), belonging to the family Myrtaceae. Ali (2010) documented *Caesalpinia inermis*, *Ficus bengalensis*, *F. religiosa*, *F. glomerata*, *Eugenia jambolana*, *Alstonia scholaris*, *Eucalyptus globossus*, *Polyalthiya longifolia*, *Mangifera indica*, and *Artocarpus heterophyllus*, and

among these the major roosting tree species used by *P. giganteus* were *C. inermis*, *F. bengalensis*, *F. religiosa*, and *E. jambolana* in western Assam.

Eleven native and 10 exotic tree species served as roosting trees (Table). Most of the roosts bloom in spring ( $n = 8$ ), while Indian gaabh, jambolan plum, and white siris showed summer blooming. Only Indian devil tree blossoms in winter and the rest of the roosts ( $n = 9$ ) showed biannual flowering: camphor tree, dinner plate tree, drypetes tree, ficus microcarpa, giant bamboo, Indian

**Table.** Roost details of Indian flying fox (*Pteropus giganteus*) at Jinnah garden and Lalazar garden, Lahore.

Family	Roost species	Common names	Quantity (native/ exotic)	Flowering season (type: tree/shrub)	dbh (m)	Height (m)	Roost trees serve as food	Average bat count/year
Jinnah Garden								
Anacardiaceae	<i>Mangifera indica</i>	Mango	4 (N)	Spring (T)	0.17	13.30	+	22.58
Apocynaceae	<i>Alstonia scholaris</i>	Indian devil	1 (E)	Winter (T)	0.16	19.2	-	59.42
Bignoniaceae	<i>Kigelia pinnata</i>	Sausage	1 (E)	Summer and autumn (T)	0.89	16.8	+	74.83
Cannabaceae	<i>Celtis australis</i>	European nettle	1 (E)	Spring (T)	0.25	19.8	-	69.08
Combretaceae	<i>Terminalia arjuna</i>	Arjun	1 (N)	Spring (T)	0.32	18.3	-	41.25
Cuperssaceae	<i>Taxodium mucronatum</i>	Sabino	1 (E)	Spring (T)	0.25	17.4	-	30.00
Ebanaceae	<i>Diospyros peregrine</i>	Gaabh	1 (N)	Summer (T)	0.69	16.8	+	75.08
Fabaceae	<i>Albizia procera</i>	White siris	1 (E)	Summer (T)	0.16	14.3	-	52.58
	<i>Dalbergia sissoo</i>	Indian rosewood	1 (N)	Spring and summer (T)	0.51	11.9	-	87.92
Lauraceae	<i>Cinnamomum camphora</i>	Camphor	1 (E)	Spring and summer (T)	0.32	14.9	-	37.92
Malvaceae	<i>Bombax ceiba</i>	Cotton	2 (N)	Spring (T)	0.12	13.70	-	35.58
	<i>Pterospermum acerifolium</i>	Dinner plate	1 (E)	Spring and autumn (T)	0.22	14.3	-	56.58
Meliaceae	<i>Cedrela toona</i>	Cedrus	1 (E)	Spring (T)	0.22	18.2	-	63.83
Moraceae	<i>Ficus elastica</i>	Rubber	2 (E)	Summer and autumn (T)	0.34	14.45	-	29.92
	<i>F. glomerata</i>	Cluster fig	4 (N)	Spring (T)	0.17	15.63	+	29.75
	<i>F. retusa</i>	Ficus microcarpa	2 (N)	Summer and winter (T)	0.73	17.50	+	38.75
Myrtaceae	<i>Syzygium Jambolanum</i>	Jambolan plum	9 (N)	Summer (T)	0.41	15.11	+	25.33
Poaceae	<i>Dendrocalamus hamiltonii</i>	Giant bamboo	2 (N)	Summer and winter (S)	0.21	7.56	-	64.08
Putranjivaceae	<i>Putranjiva roxburghii</i>	Drypetes	1 (E)	Summer and winter (T)	0.10	13.40	-	88.25
Rutaceae	<i>Aegle marmelos</i>	Giant bamboo	2 (N)	Spring and winter (T)	0.32	17.5	-	61.42
Sapotaceae	<i>Manilkara hexandra</i>	Drypetes	1 (E)	Spring and winter (T)	0.25	14.47	-	7.58
Lalazar Garden								
Anacardiaceae	<i>Mangifera indica</i>	Mango	4 (N)	Spring (T)	0.55	13.10	+	
Myrtaceae	<i>Syzygium Jambolanum</i>	Jambolan plum	4 (N)	Summer (T)	0.50	15.13	+	

rosewood tree, rayan tree, rubber plant, and sausage tree. All the roosts are woody trees except giant bamboo and rubber plant (Table). Our findings are in line with those of Reginald et al. (2008), who documented *Ficus religiosa*, *Tamarindus indica*, *Albizia lebbeck*, *Delonix regia*, *Polyalthia longifolia*, *Acacia* spp., *Azadirachita indica*, and *Samanea saman* as roosting tree species for *P. giganteus* in a public park of Tamil Nadu, India.

The dbh of roosting trees ranges from 0.10 m (drypetes tree) to 0.89 m (sausage tree). The minimum roost tree height was recorded as 7.56 m (giant bamboo), while the

tallest roost tree was European nettle tree at 19.8 m with a dbh of 0.25 m. Evelyn and Stiles (2003) reported that the frugivorous bat species *Sturnira lilium* prefers to roost on trees with large diameters while *Arbiteus intermedius* prefers trees with smaller diameter.

Among the total 21 roosting tree species, 5 tree species, *D. peregrine*, *F. glomerata*, *K. pinnata*, *M. indica*, and *S. jambolanum*, also served as food sources for Indian flying foxes. Most of the roosting trees blossom in spring: *A. marmelos*, *B. ceiba*, *C. toona*, *C. australis*, *F. glomerata*, *M. hexandra*, *T. arjuna*, and *T. mucronatum*. Only *F. retusa*

was biflorus and *A. scholaris* was a hibernal species. *A. procera*, *D. peregrina*, and *S. jambolanum* were observed as summer annual trees. *C. camphora*, *D. sissoo*, and *P. acerifolium* showed flowering during spring and summer, *D. hamiltonii* and *P. roxburghii* bloom from winter to spring, and *F. elastica* and *K. pinnata* bloom in summer and winter. The maximum average numbers of bats of 88.25 was counted on *P. roxburghii* and the minimum number of bats of 7.58 was recorded on *M. hexandra* in the Jinnah garden (Table). Vendan and Kaleeswaran (2011) surveyed 4 roosting sites of *Pteropus giganteus* in Madurai district, India, and observed that *Albizia lebbek*, *Artocarpus integrifolia*, *Eucalyptus globules*, *Eugenia jambolana*, *Ficus benjamina*, *F. glomerata*, *Mangifera indica*, *Peltophorum ferrugineum*, *Tamarindus indica*, *Toona ciliate*, *Dilonea regia*, *Tamarindus indica*, *Azadirachta indica*, *Polyalthia longifolia*, *Terminalia cattapa*, *Millingtonia hortensis*, *Cocos nucifera*, *F. religiosa*, *Tamarindus indica*, and *Peltophorum ferrugineum* trees served as roosts for *Pteropus giganteus*.

Lalazar is a small garden spaced on 1.62 ha with a total of 90 trees belonging to 7 families, 9 genera, and 9 species, while *Pteropus giganteus* was roosting on 6 trees belonging to 2 families, 2 genera, and 2 species. The roosting tree species include mango tree, *Mangifera indica* (n = 2), which blossoms in spring season, and jambolan plum, *Syzygium jambolanum* (n = 4), which blooms in summer. Both species are native in origin (28.6%), belonging to families Anacardiaceae and Moraceae (28.6%), respectively. All roosting trees also served as food for the Indian flying foxes. According to Vendan et al., (2008) *P. giganteus* prefers to roost on *Ficus* species, *E. globulus*, *M. indica*, and *T. indica*.

The average dbh of roosting trees in the Lalazar garden ranged from 0.50 m to 0.55 m and the height ranged from 13.10 m to 15.13 m. The maximum average numbers of bats of 21.58 was counted on *S. jambolanum*, having minimum dbh of 0.50 m and maximum height of 15.18 m (tallest roosting tree observed at Lalazar garden), while the minimum number of average bats of 18.71 was counted on *M. indica* with maximum dbh of 0.55 m and minimum height of 13.10 m (Table). According to Granek (2002), mean roost tree dbh for *P. livingstonii* is 0.103 m while average height is 24.35 m.

Altogether 50 roosting trees representing 21 species served as roost trees at both localities. Forty trees belonging to 11 species were native: wood apple *Aegle marmelos* (n = 1), cotton tree *Bombax ceiba* (n = 2), Indian rosewood

*Dalbergia sissoo* (n = 1), iron bamboo *Dendrocalamus hamiltonii* (n = 2), Indian gaabh *Diospyros peregrina* (n = 1), cluster fig tree *Ficus glomerata* (n = 4), ficus microcarpa *F. retusa* (n = 2), mango tree *Mangifera indica* (n = 6), rayan *Manilkara hexandra* (n = 6), jambolan plum *Syzygium jambolanum* (n = 13), and arjun *Terminalia arjuna* (n = 1). Vendan (2003) observed that *P. giganteus* in the Madurai region preferred *Ficus* species, blue gum tree, *Eucalyptus globules*, *M. indica*, and *T. indica* for roosting. A dependence on native trees was an indication of roost characteristic preference specific to *Pteropus* (Nelson et al., 2000).

Seasonal shifting pattern from one roosting tree to another and increase and/or decrease in bats were observed at both sites. In winter, fruits bats were observed roosting with closed wings at the edge of naked branches of roosting trees, notably *Manilkara hexandra*, and in summer they were observed underneath the thick foliage cover in the middle of the tree canopy flapping one wing and mostly populating *Aegle marmelos*, *Dendrocalamus hamiltonii*, and *Ficus* species. In spring and autumn the roosting trees were observed to have a noisy, almost evenly distributed bat population, whereas *Diospyros peregrina* was observed to be heavily populated throughout the year and bats were usually observed walking on the branches. The roosting trees of plots 4 and 5 were also observed as maternal colonies with pups clinging to the mothers' bodies in May and June. Throughout the year the maximum total number of fruit bats (n = 1059) was counted on *Putranjiva roxburghii*, whereas the minimum number of bats (n = 71) was counted on *Manilkara hexandra* at Jinnah garden. At Lalazar garden, the maximum number of bats (n = 323) was counted on *Syzygium jambolanum* while the minimum number of bats (n = 229) was observed on *Mangifera indica* throughout the study period (Table). *Pteropus* species display remarkable seasonal changes in roost composition and colony size (Mickleburgh et al., 1992; Pierson and Rainey, 1992; Wiles et al., 1997) and *P. giganteus* was no exception, showing variation in roost sizes and roost occupancy during monthly surveys in spring, summer, autumn, and winter (Granek, 2002). This behavior pattern was also observed in other species of the genus *Pteropus* (Mickleburgh et al., 1992).

It can be concluded from the present study that *Pteropus giganteus* prefers to roost near water bodies, on tall trees with relatively smaller diameters.

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