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Determinants of Roost Selection by the Indian Flying Fox (*Pteropus medius*) in Northern Kerala, India: Implications for a Near-Threatened Species

Cheruthottunkara P. Ashwin[1*], Samidurai Jayakumar[2], and Nagarajan Baskaran[2]

[1]Salim Ali Centre for Ornithology and Natural History, South India Centre of Wildlife Institute of India, Anaikatty, Tamil Nadu-641108; [2]P.G. Research Department of Zoology and Wildlife Biology, A.V.C. College (Autonomous), Mannampandal, Mayiladuthurai – 609 305, Tamil Nadu, India.

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Abstract

Bat roosting sites are critically important to bats; however, only a few studies are available on the factors influencing the roost selection of the Indian Flying Fox, *Pteropus medius*, in India. Such information is essential for wildlife managers to make decisions on conservation of bat roosts, especially in unprotected areas. Surveying 31 roost sites spread across three districts of Kerala, India, we assessed the determinants of roost selection by *P. medius* between November 2017–March 2018. The abundance of *P. medius* was assessed using the total roost count method. The roost-site attributes *viz.* environmental factors (wind speed, temperature, humidity, elevation, distance nearest to water body), tree characteristics (number of roost trees, nativity of roost trees, tree age, tree height, tree bole height, crown height, crown width, diameter at breast height [DBH], foliage cover, disturbance factors [distance nearest to main roads, human settlements, mobile phone towers]) and other anthropogenic pressure were assessed using standard methods. The abundance of *P. medius varied* significantly in relation to roost sites, roost tree species and their families, and years of roost existence. Among the plant species, *Ficus benghalensis* supported the highest number of bats, followed by *Ficus drupacea*, while *Areca catechu* had the lowest number. Attributes, namely tree height, tree crown length, tree crown width, DBH, canopy cover, distance nearest to human settlement and water body, varied significantly between roost and non-roost trees. The abundance of bats increased with DBH, temperature, tree height, crown width, wind speed, area of roost existence, bole height, canopy cover and less anthropogenic pressure. These factors explained 43% of the variation in bat abundance. Hence, the present study points out that the officials and private stakeholders in Kerala should maintain at least a few mature, native tree species with large canopies for providing suitable roost habitats for the threatened *P. medius.*

Keywords: Abundance, Determinants, Roost sites, Indian Flying Fox, Northern Kerala

Introduction

The Indian Flying Fox (*Pteropus medius*) is currently classified as Near Threatened, based on an estimated population decline of 25–29% over three generations, both in the past and projected into the future (Ahmed *et al.*, 2025). The population decline of *Pteropus medius* is driven by increasing persecution due to orchard raiding, and widespread hunting for bushmeat and traditional medicine. Furthermore, habitat loss and degradation have occurred as roosting sites are increasingly destroyed by urban development and agricultural expansion. Roost-site selection is a vital aspect for the Indian Flying Fox, *Pteropus medius,* that provides shelter against unpredictable weather, facilitates better access to mates, potential cooperation, reduces predation, and increases the foraging efficiency (Sagot, 2016, Dias-Silva *et al.*, 2018, Salvi *et al.*, 2024). Bats are the only flying mammals that use roosts nearly 15 hours/day, and thus diurnal roost selection

*Corresponding author: ashwincp95@gmail.com

is an important component to understand the habitat requirements for conservation planning (Barclay and Kurta, 2007). Habitat selection by bats for foraging, roosting, swarming, and other uses is typically linked to factors such as microclimatic conditions, vegetation structure, and resource availability (Ruczyński *et al.*, 2010; Ramos Pereira *et al.*, 2010; Barros, 2014; Champness *et al.*, 2023). Globally, large number of studies have been carried out to estimate the effect of habitat loss and fragmentation, toxins, and anthropogenic and poaching pressures on bat species (Willis and Brigham, 2005; O'Keefe *et al,.* 2009; Hahn *et al.*, 2014; Duarte *et al.*, 2015; Kumar and Kanaujia, 2017).

Pteropus medius falls under the family Pteropodidae, and *Pteropus* is the largest bat genus in India (Vendan and Kaleeswaran, 2011). They live in large diurnal roosts, which comprise several hundred individuals, usually in large trees called 'camps' along with suitable topographic features that offer protection against strong wind, assist them in thermoregulation and provide easier flight (Gulraiz *et al*., 2015). However, populations of *P. medius* have been declining across their distribution range, largely due to increasing anthropogenic pressures such as habitat destruction, agricultural expansion, and urban development (Mildenstein *et al*., 2005, Stier and Mildenstein, 2005). Conflict with fruit growers, owing to crop damage caused by bats, has further heightened their vulnerability (Singaravelan and Marimuthu, 2004; Molur *et al.,* 2005). In Kerala, the rapid pace of urbanization, expansion of cash crop plantations, infrastructure development, and other land-use changes continue to exert substantial pressure on forest habitats and biodiversity, including tree-roosting fruit bats like *P. medius*. They are the most misunderstood species, still treated as vermin and listed in Schedule V due to their negative tendencies enroots for fruit farms, but the benefits of its pollination and seed propagation (Singaravelan and Marimuthu, 2004).

There are still relatively few data available on roost sites of *P. medius* in the Indian subcontinent (Chakravarthy and Yeshwanth, 2008; Hahn *et al*., 2014; Gulraiz *et al.*, 2015; Kumar *et al*., 2017; Kumar *et al*., 2022; Kumar and Kanaujia, 2017). Therefore, more studies on *P. medius* are needed with more comprehensive approaches to enable forest managers and officials to make informed decisions concerning the conservation of bats along with their roosts. This is especially important in the Indian state of Kerala, where no ample attempts have been made to date on bat conservation. Existing research on the roost ecology of *P. medius* in the Indian subcontinent remains limited (Chakravarthy and Yeshwanth, 2008; Hahn *et al*., 2014; Gulraiz *et al*., 2015; Kumar *et al*., 2017; Kumar *et al*., 2022; Kumar and Kanaujia, 2017). Therefore, there is a pressing need for region-specific studies that can inform conservation planning and management. This study aims to address that gap by documenting the ecological and anthropogenic factors influencing roost-site selection by *P. medius* in northern Kerala. By generating baseline data, this research intends to support the conservation strategies for bats and their habitats in the region.

Materials and Methods

Study Area

The study was conducted in the northern part of Kerala, a state located along the southwestern coast of Peninsular India, between 8°18′–12°48′ N latitude and 74°52′–77°22′ E longitude. Covering an area of 38,863 km², Kerala accounts for 1.8% of India's total geographical area. It is bordered by Karnataka to the north and northeast, Tamil Nadu to the east, and the Arabian Sea to the west, with a coastline extending approximately 590 km. The present study focused on three districts in northern Kerala—Kasaragod, Kannur, and Wayanad—collectively referred to as the "crown of Kerala" due to their rich ecological diversity. These districts are bounded by the Western Ghats to the east, Kozhikode and Wayanad to the south, the Lakshadweep Sea to the west and Kasaragod to the north (Figure 1).

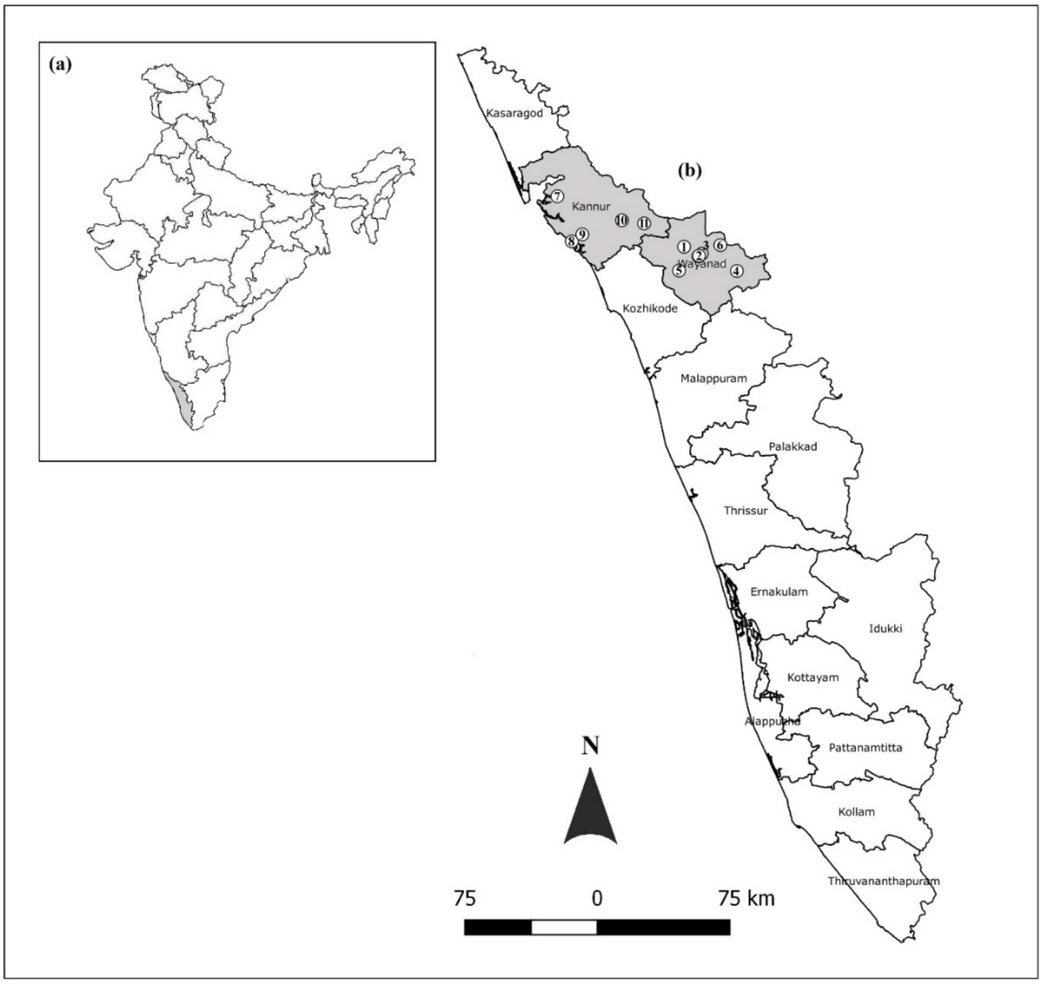

Figure 1. Study area map

Preliminary survey and methods

Field surveys were conducted in selected districts of Kerala to document the distribution, abundance, and roost-site characteristics of *P. medius*. A total of 31 sampling sites were selected based on direct observations, consultations with forest department officials and local residents, and existing literature. Each roost site was monitored over four consecutive days. The abundance of *P. medius* was estimated using the direct roost count method (Kunz *et al.,* 1996; Barlow, 1999), with visual counts conducted twice per day using binoculars (Olympus 10x50) to avoid double counts. Roost coordinates and elevation were recorded using a handheld GPS (Garmin eTrex 10).

Tree characteristics such as height, bole height, and diameter at breast height (DBH) were measured using a Silva Clinometer and Freeman Fiberglass Tape (Gulraiz *et al.,* 2016). Distances from roost trees to nearby roads, human settlements, water bodies, and mobile towers were estimated using a rangefinder (Hawke LRF 600), following standard ecological protocols (Gulraiz *et al.*, 2015; Kumar *et al*., 2017). Crown height was calculated by subtracting bole height from total tree height, while crown width was averaged from measurements in two perpendicular directions (N–S and E–W). Foliage cover was estimated visually based on sunlight penetration (0–100%). Environmental parameters such as temperature and humidity were measured using a digital hygro-thermometer (HTC 288-ATH) and wind speed using a digital anemometer (GM8908). Supplementary weather data were obtained from AccuWeather.com (Manandhar *et al.*, 2018). Roost and non-roost trees at each site were documented, including species name, family, and nativity following (Bentham and Hooker, 1862). Roost longevity (in years) was estimated through interviews with local residents aged 24–75 years. Anthropogenic disturbances—including tree cutting, poaching, pollution, traffic, fireworks, noise, and infrastructure development—were assessed via semi-structured questionnaires. Each type of disturbance was scored on a scale from 0 (none) to 3 (high) for subsequent analysis.

Statistical Analysis

All data were first tested for normality. Descriptive statistics, including mean and standard error, were calculated. One-way analysis of variance (ANOVA) was performed to assess variations among observations. Where significant differences were detected, Tukey's post hoc test was applied to identify pairwise differences between group means (Zar, 1999). Multiple regression analysis was used to evaluate relationships among variables. A significance level of $p < 0.05$ was adopted for all statistical tests. All analyses were conducted using IBM SPSS Statistics, version 25.0.

Results

Abundance of P. medius in relation to roosts and roost-sites

The abundance of *P. medius* in relation to environmental, tree characteristics, disturbance, and other factors were assessed and summarized in Table 1. The roost-sites with lesser wind speed had a higher number *P. medius*. The roost-sites with the maximum temperature (28–31°C) had the highest number of bats, and the sites with lower relative humidity (<70%) and lower elevation (<500m) had the highest number of bats, indicating the importance of temperature for thermoregulation activity across roost sites. The abundance of *P. medius* was found to be higher in the roost-sites closer to water bodies. The number of bats with reference to roosting trees species varied significantly (One way ANOVA; F=5.952; $p<0.05$; df=55). Among the 56 tree species studied, *Ficus drupacea* had the highest number of *P. medius* (300+0 individuals) followed by *Calophyllum inophyllum* (172.5±76.3), while *Areca catechu* (0.3 ± 0.2) had the least (Table 2). The abundance of *P. medius* was relatively higher on the matured trees (37.8 ± 2.8) than that of the younger trees. Similarly, a greater number of *P. medius* roosted on native tree species than the exotic species. The roost-sites on trees that are tall in tree height (>20m) and tree pole height (>15m) had the highest number of *P. medius*. Similarly, trees with higher crown height (>15m), crown width (>10m) and large diameter at breast height (DBH) had the maximum number of *P. medius*, suggesting the significance of microhabitats on the trees for the bats to select their suitable roost-sites (Table 1). The abundance of *P. medius* based on the density of tree branches characterized by an umbrella of dense foliage cover was assessed and the results revealed that the trees with 30–60% foliage cover had the highest number of bats (23.1 ± 3.0) followed by the trees with 60–90% of foliage cover (18.0 ± 1.7). Furthermore, the roost-site located closer to human settlements or towns had a relatively higher number of bats, whereas sites with heavy anthropogenic pressures, including poaching and presence of mobile phone tower stands, had relatively less bats. However, the difference was not statistically significant ($p>0.05$) (Table 1).

Drivers of roost selection of *P. medius*

To understand the preferences for roost-site characteristics of *P. medius*, tree height, bole height, crown height, crown width, DBH, crown closure, distance nearest to town, water bodies, and main roads were assessed from both roosting and non-roosting trees (Table 3). Among the attributes studied, except for roost-site distance nearest to the road, the remaining attributes significantly varied between roosting and non-roosting trees, highlighting the fact that *P. medius* is known to prefer taller trees with maximum tree height, bole height, crown height, crown

Table 1. Roost abundance of *P. medius* in relation roost and roost-site attributes.

Attributes	Category	Abundance Mean ± SE (N)	AANOVA F F value	*p* value
Environmental factor				
Wind speed	1–3 m/hr	22.3 ± 1.9 (538)	16.215	0.000
	4–6 m/hr	9.6 ± 1.4 (202)		
Temperature	22–25 °C	16.8 ± 1.3 (359)	24.288	0.000
	25–28 °C	15.3 ± 2.0 (325)		
	28–31 °C	52.6 ± 11.6 (56)		
Humidity	<70 %	16.9 ± 1.4 (506)	4.036	0.045
	>70 %	23.1 ± 3.3 (234)		
Elevation	<500 m	18.7 ± 1.4 (426)	0.014	0.907
	>500 m	19.1 ± 2.8 (314)		
Distance to nearest water body	<90 m	17.9 ± 2.3 (109)	0.070	0.791
	>90 m	19.0 ± 1.6 (631)		
Tree Character				
Nativity of roost tree	Exotic	17.9 ± 2.5 (231)	0.222	0.638
	Native	19.3 ± 1.7 (509)		
Tree age	Matured	37.8 ± 2.8 (324)	166.702	0.000
	Young	4.1 ± 0.6 (416)		
Tree height	>20 m	25.3 ± 1.9 (531)	55.432	0.000
	<20 m	2.5 ± 0.5 (209)		
Tree bole height	>15 m	33.0 ± 4.2 (129)	21.217	0.000
	<15 m	9.7 ± 2.0 (611)		
Crown height	>15 m	60.2 ± 9.5 (70)	98.738	0.000
	<15 m	14. ± 1.1 (670)		
Crown width	>10 m	40.2 ± 5.6 (141)	56.194	0.000
	<10 m	13.8 ± 1.1 (599)		
Tree diameter at breast height (DBH)	>1 m	30.5 ± 2.3 (421	98.575	0.000
	<1 m	3.5 ± 0.5 (319)		
Foliage cover	>30 %	9.2 ± 2.5 (75)	3.925	0.020
	30–60 %	23.1 ± 3.0 (254)		
	60–90 %	18.0 ± 1.7 (411)		
Disturbance factor				
Distance to nearest town	<500 m	21.2 ± 3.2 (248)	1.351	0.245
	>500 m	17.7 ± 1.4 (492)		
Distance to nearest main road (tar road)	<400 m	18.2 ± 2.4 (103)	0.037	0.848
	>400 m	19.0 ± 1.6 (637)		
Roost site distance to mobile tower	>500	12.7 ± 7.1 (45)	1.000	0.368
	500–1500	21.1 ± 3.2 (234)		
	<1500	18.3 ± 1.4 (461)		
Other anthropogenic pressure around the roost tree	Less	18.7 ± 2.2 (421)	0.011	0.915
	Moderate	19.0 ± 1.7 (319)		
Other factor				
Years of roost existence	10–20	38.1 ± 2.4 (119)	31.101	0.000
	21–40	47.3 ± 7.8 (32)		
	41–60	13.4 ± 1.6 (589)		
Area of roost extant	5–30	17.7 ± 2.5 (218)	0.163	0.687
	30–55	19.2 ± 1.8 (522)		

Table 2. Variation in abundance of *P. medius* in relation tree species.

Tree family	**Roosting trees**	**Mean** ± SE	**N**
Anacardiaceae	*Anacardium occidentale* (E)	42.5 ± 18.5	10
	Holigarna arnottiana (N)	46.8 ± 21.9	8
	Mangifera indica (Nand D)	4.4 ± 1.7	33
	Spondia spinnata (N and D)	20.7 ± 7.4	3
Apocynaceae	*Alstonia scholaris* (N)	145.5 ± 102.9	4
Arecaceae	*Areca catechu* (N)	0.3 ± 0.2	15
	Caryota urens (N)	16.8 ± 3.3	18
Bignoniaceae	*Oroxylum indicum* (N)	38.2 ± 22.5	5
	Spathodea campanulata (E)	1.8 ± 1.1	8
Bombacaceae	*Bombax ceiba* (N)	50.0 ± 0	1
	Butea monosperma (N)	0.5 ± 0.5	2
Calophyllaceae	*Calophyllum inophyllum* (E)	172.5 ± 76.3	4
Casuarinaceae	*Casuarina equisetifolia* (E)	17.6 ± 8.4	7
Combertaceae	*Anogeissus latifolia* (N)	8.0 ± 0	1
	Terminalia bellirica (N and D)	3.8 ± 3.8	5
	Terminalia catappa (E and D)	5.3 ± 5.3	8
	Terminalia elliptica (N)	8.5 ± 6.8	8
Dipterocarpaceae	*Hopea parviflora* (E)	80.0 ± 0	1
	Hopea ponga (N)	23.1 ± 3.8	35
Euphorbiaceae	*Hevea braziliensis* (E)	1.2 ± 0.5	37
	Macaranga peltata (N)	11.5 ± 6.7	27
Fabaceae	*Adenanthera pavonina* (E)	55.0 ± 23.6	4
	Albizia odoratissima (N)	38.0 ± 12.0	2
	Albizia procera (E)	42.7 ± 31.0	3
	Albizia saman (E)	22.3 ± 7.0	25
	Artocarpus fraxinifolius (N and D)	48.0 ± 17.0	2
	Dalbergia latifolia (N)	5.7 ± 4.0	10
	Delonix regia (E)	63.7 ± 48.5	3
	Leucaena leucocephala (E)	8.0 ± 2.8	6
	Pterocarpus marsupium (N)	68.4 ± 22.3	5
	Racosperma auriculiforme (E)	10.5 ± 5.0	10
	Racosperma mangium(E)	18.6 ± 3.1	62
	Tamarindus indica (N and D)	5.7 ± 5.7	3
Loganiaceae	*Strychnos nux-vomica* (N)	11.5 ± 6.0	11
Lythraceae	*Lagerstroemia microcarpa* (N)	3.6 ± 3.6	7
	Lagerstroemia speciosa (N)	26.0 ± 5.5	4
Meliaceae	*Swietenia mahagoni* (E)	10.0 ± 10.0	2
Morceae	*Artocarpus heterophyllus* (N and D)	12.3 ± 2.9	54
	Artocarpus hirsutus (N and D)	37.7 ± 4.8	69
	Ficus drupacea (N and D)	300.0 ± 0	1
	Ficus exasperate (N and D)	3.0 ± 3.0	2
	Ficus hispida (N and D)	16.8 ± 16.8	4
Myrtaceae	*Eucalyptus tereticornis* (E)	24.0 ± 7.5	5
Poaceae	*Bambusa bambos* (N)	16.9 ± 5.8	17

Proteaceae	*Grevillea robusta* (E)	7.8 ± 2.1	16
Rhizhophoraceae	*Carallia brachiata* (N)	7.5 ± 7.5	2
Rutaceae	*Melicope lunu-ankenda* (N)	1.8 ± 1.8	9
Sapindaceae	*Dimocarpus longan* (N)	10.8 ± 2.9	5
	Schleichera oleosa (N)	2.7 ± 1.8	7
Sapotaceae	*Chrysophyllum cainito* (N and D)	3.5 ± 3.5	2
Simaroubaceae	*Ailanthus triphysa* (E)	2.8 ± 1.0	6
Sterculiaceae	*Sterculia guttata* (N)	122.0 ± 122.0	2
	Sterculia urens (N)	108.0 ± 0	1
Ulmaceae	*Trema orientalis* (N)	37.3 ± 13.9	12
Verbenaceae	*Gmelina arborea* (N)	121.0 ± 0	1
	Tectona grandis (N)	25.0 ± 4.6	45

width and DBH. Furthermore, a significantly higher number of *P. medius* were found roosting near to water bodies (Table 3, $P<0.05$). Similarly, the bats are avoiding the roost sites with heavy anthropogenic pressures and disturbance. To understand the driving factors of roost-site selection by *P. medius*, the multiple regression tests (stepwise model) were performed (Table 4 and Figures 2-4). The model predicted that the tree diameter at breast height (DBH), temperature, tree height, tree crown width, wind speed and the area coverage of roosts positively influence the roost site selection of bats, whereas variables including anthropogenic pressure, pole height of the trees, and tree crown closure have influenced them negatively (Multiple Regression-Stepwise model; $R^2=0.43$; ANOVA F= 61.509; $p<0.05$; df=18). The data, based on a multiple regression stepwise model, suggests that the tree DBH, temperature, tree height and tree crown width, and wind speed correlated with the roost area coverage, thus suggesting that these were the driving factors which can determine the roost-site selection of *P. medius* in Northern Kerala.

Table 3. Variation of roost site attributes between roosting and non-roosting trees.

S. No.	**Roost site attributes**	**Roosting trees (n=336)**	**Non-roosting trees (n=404)**	**ANOVA**	
				***F* value**	***P* value**
1	Tree height (m)	22.6 ± 0.3	14.9 ± 0.3	390.211	0.000
2	Bole height (m)	11.6 ± 0.3	8.1 ± 0.2	119.426	0.000
3	Crown height (m)	10.4 ± 0.2	6.6 ± 0.2	207.524	0.000
4	Crown width (m)	7.7 ± 0.2	6.5 ± 0.1	32.433	0.000
5	DBH (m)	1.3 ± 0.0	0.8 ± 0.0	198.864	0.000
6	Crown closure	52.2 ± 1.2	56.4 ± 1.1	6.773	0.009
7	Distance to nearest town (m)	478.2 ± 24	544.1 ± 21.9	4.104	0.043
8	Distance to nearest water bodies (m)	30.2 ± 2.0	35.6 ± 2.1	3.576	0.05
9	Distance to nearest main road (m)	140.8 ± 8.5	135.2 ± 8.2	0.224	0.636

Table 4. Multiple regressions show the determinants of roost-site selection by P. *medius*.

S. No.	Variables entered	Un-standardized Coefficients		Standardized Coefficients			ANOVA		
		B	Std. Error	Beta	t	Sig.	F	Sig	R^2
	(Constant)	-258.719	24.480		-10.569	0.000			
1	DBH (m)	24.464	2.939	.338	8.324	0.000			
2	Temperature (°C)	7.452	.786	.409	9.480	0.000			
3	Tree height (m)	2.336	.303	.389	7.708	0.000			
4	Crown width (m)	2.351	.516	.177	4.560	0.000			
5	Wind speed (m/hr)	5.534	.859	.237	6.440	0.000	61.509	0.000	0.431
6	Anthropogenic Pressure	-11.899	2.538	-.152	-4.688	0.000			
7	Bole height (m)	-1.145	.384	-.136	-2.981	0.003			
8	Area of roost extent (ha)	0.247	.113	.089	2.177	0.030			
9	Crown closure (%)	-0.118	.054	-.066	-2.175	0.030			

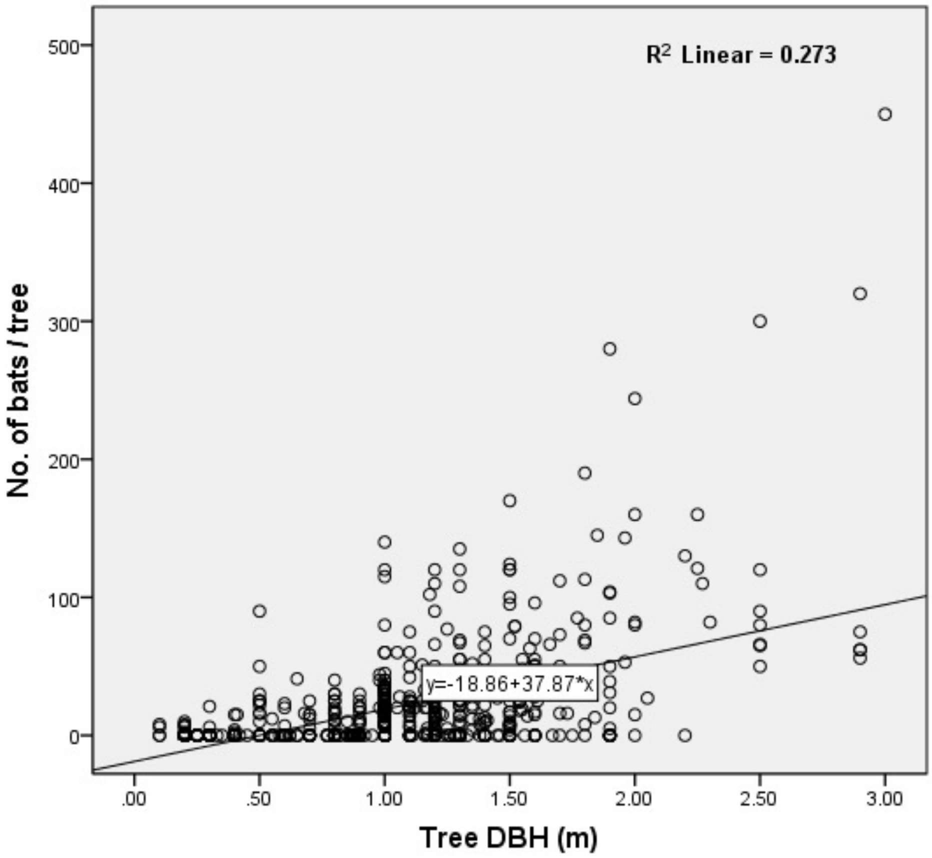

Figure 2. Relationship between diameter of tree at breast height (DBH) and abundance of bat recorded in the study area during November 2017 to January 2018 (Beta = 37.89, F = 277.7, p = 0.000).

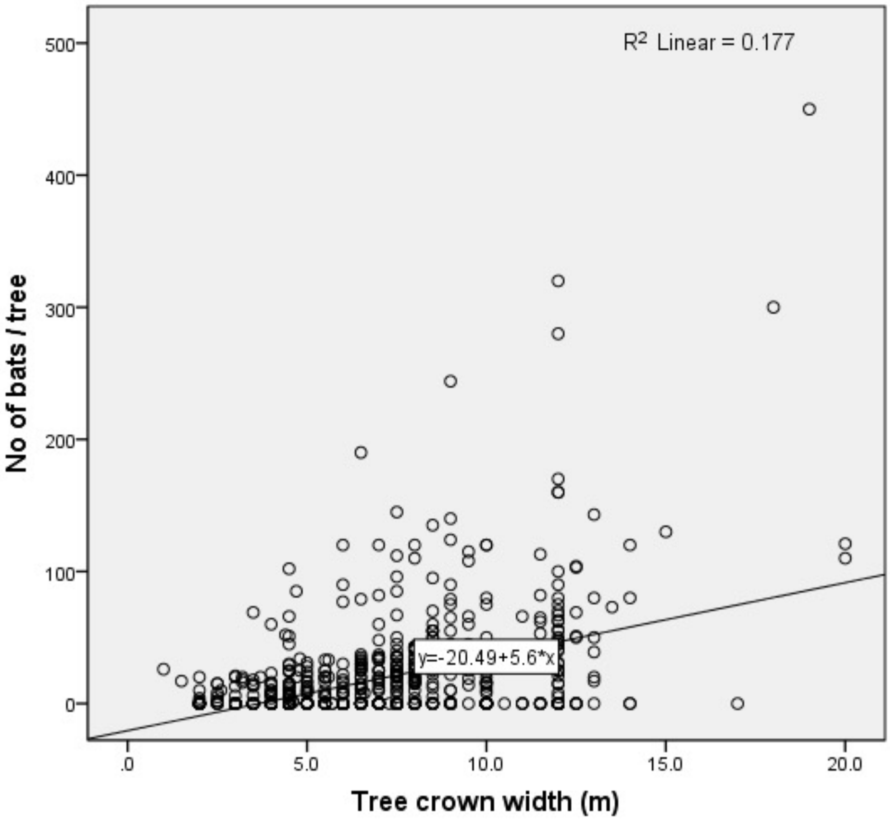

Figure 3. Relationship between tree crown width and abundance of bat recorded in the study area during November 2017 to January 2018 (Beta = 5.559, F = 158.551, p = 0.000

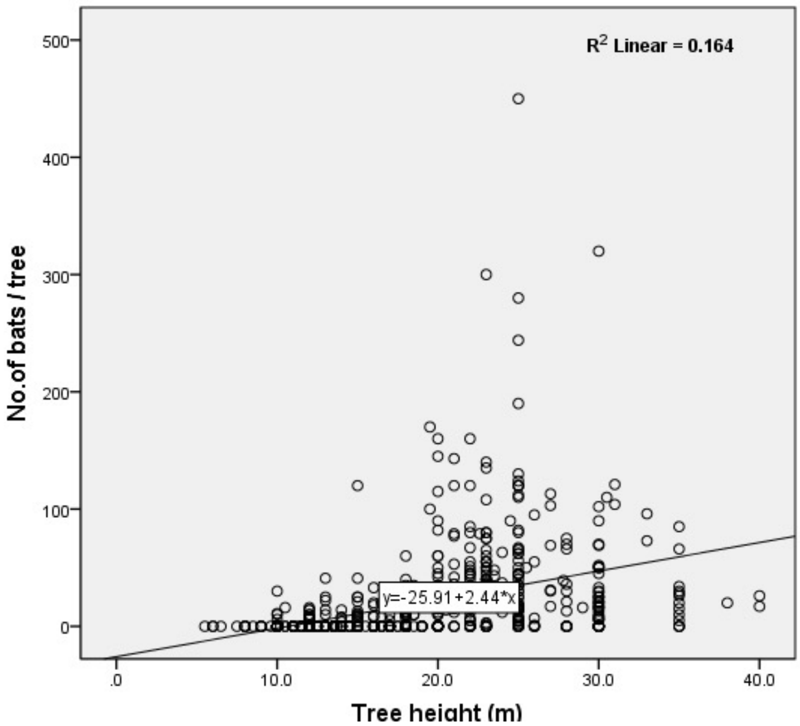

Figure 4. Relationship between tree height and abundance of bat recorded in the study area during November 2017 to January 2018 (Beta = 2.4359, F = 145.151, p = 0.000).

Discussion

Influence of environmental factors on roost selection

P. medius is one of the most widely distributed bat species across the Indian subcontinent (Storz 1998, Kumar and Kanaujia 2015) and their abundance recorded in the present study compares well with studies reported elsewhere (Talmale 2014, Gulraiz *et al*. 2015, Kumar and Kanaujia 2015, 2017, Jeyapraba 2016, Madala *et al.* 2022). In the present study, roost-sites with lesser wind speed, high humidity (>70%), lower elevation (<500m) and high temperature (28–31°C) had the highest number of bats, indicating the importance of temperature and humidity for thermoregulation activity in roost-sites, which agrees with previous studies (Hodgkison *et al*., 2004; Willis and Brigham, 2005; Gulraiz *et al*., 2015; Kumar and Kanaujia, 2017). The majority of bat species that belong to pteropodids roost in habitats with matured trees providing shelter from strong winds, regulating temperature, and providing easy exit for upward flight (Kunz, 1982; Richmond *et al*., 1998; Gulraiz *et al*., 2015; Kumar *et al*., 2017). The ambient temperature and wind speed recorded at the roost site also support the hypothesis that physical factors associated with roosts provide energetic benefits (Willis and Brigham, 2005). In the present study, *P. medius* found roosting near to water bodies, which is in line with *P. alecto* (Palmer and Woinarski, 1999), P. *livingstonii* (Granek, 2002), *Artibeus watsoni* (Cholewa *et al.*, 2001; Chaverri and Kunz, 2006), *Lasiurus borealis* and *Perimyotis subflavus* (O'Keefe *et al*., 2009), *Eptesicus fuscus* (Agosta, 2002), as well as with previous reports on *P. medius* (Gulraiz *et al.*, 2015; Kumar and Kanaujia, 2017). The presence of water bodies closer to roost-sites and on the foraging pathways of bats were reported as one of the essential requirements for bat population, because water bodies are serving as a source of drinking water as well as store house that helps reduce temperature in the roost sites (Welbergen *et al.,* 2008; Russo and Ancillotto, 2015).Availability of such microhabitats is important for nocturnal foraging animals like bats (Kumar and Kanaujia, 2017). Because summer nights are short at the roost-sites located in high latitudes, bats may be confined to roost sites for long periods without access to food or water. Under these circumstances, selecting roosts with specific microclimate conditions plays an important role in maintaining positive energy budgets (Willis and Brigham, 2005; Conenna *et al.,* 2025).

Influence of tree characteristics on roost selection

A total of 659 trees belonging to 56 species in 27 families served as roost trees for *P. medius*. Among the species, the larger and taller hardwood trees species, namely *Ficus drupacea, Calophyllum inophyllum, Alstonia scholaris,* and *Gmelina arborea* had the highest number of bats (Table 1 and 2). Among 56 roosting tree species, 11 species also serve as part of the diet for *P. medius*, which adds value to these roosting trees (Singaravelan and Marimuthu, 2004; Madala *et al.,* 2022). The selection of roost trees by bats recorded in the current study corresponds well with number of other studies, e.g. *Acacia nilotica* (Gulraiz *et al.*, 2016), *Albizzia lebbek* (Baskaran *et al.,* 2016), *Alstonia scholaris* (Ali, 2010), *Azadirachta indica* (Vendan and Kaleeswaran, 2011; Kumar and Elangovan, 2019), *Bassia latifolia* (Senthilkumar & Marimuthu, 2012), *Dalbergia sissoo* (Vyas and Upadhyay, 2014; Kumar and Elangovan, 2019), *Eucalyptus* sp., (Gulraiz *et al.*, 2015; Kumar and Elangovan, 2019), *Ficus racemosa* (Maruthupandian and Marimuthu, 2013; Kumar and Elangovan, 2019), *Ficus benghalensis* (Chakravarthy and Girish, 2003; Goveas *et al.*, 2006; Kumar and Elangovan, 2019), *Holoptelea integrifolia* (Suthari and Raju, 2012), *Mangifera indica* (Singaravelan and Marimuthu, 2004; Kumar and Elangovan, 2019), *Polyalthia longifolia* (Caughlin *et al.,* 2012), *Syzygium cumini* (Tangavelou *et al.*, 2013) and *Terminalia* *arjuna* (Dey *et al.*, 2013). Similarly, Javid *et al.* (2017) reported that fruit bats prefer roosting trees that include *Syzygium jambolanum*, *Mangifera indica*, *Manilkara hexandra*, *Ficus glomerata*, *F. elastic*, *F. retusa*, *Bombax ceiba*, and *Dendrocalamus hamiltonii*, and our study coincides well with these findings. Furthermore, Chakravarthy *et al.* (2009) documented that the tree species, namely *Ficus* spp., *Deloni xregia*, *Eucalyptus* spp., *Acacia* spp., *Terminalia* spp., *Casuarina* spp., *Tamarindus indica*, *Mangifera indica*, and *Artocarpus heterophyllus* are the most preferable roosting trees for *P. medius,* which concur well with present observation. The large colony size of *P. medius* was found in large trees such as *F. religiosa, F. glomerata, F. Benghalensis* and *F. virens* (Kumar and Kanaujia, 2015; Madala *et al.*, 2022). The present findings showed that the size of the bat colony was linked to specific tree species, likely due to architectural differences among tree species that allow a larger number of bats to congregate in tree species with numerous branches. Perusal of literature has suggested that these large bats roost in tall trees because they need room to free-fall during take-off (Hahn *et al.*, 2014; Javid *et al*., 2017; Kumar and Elangovan, 2019) and therefore, the larger size of trees is one of the important factors which determines the colony size of *P. medius* both in urban and rural areas.

The abundance of bats is high on the matured and taller native tree species, with higher crown height, crown width, and diameter at breast height (DBH) representing the significance of tree characteristics for tree roosting bats to select their suitable roosts (Perry *et al.*, 2007; Limpert *et al.*, 2007; Madala *et al*., 2022). Several studies have reported that the frugivorous bat species prefers to roost on trees with large diameters (Evelyn and Stiles, 2003; Gulraiz *et al.*, 2015; Kumar and Elangovan, 2019). The majority of the previous studies have found that cavity roosting bats select taller trees and of greater DBH than randomly selected non-roost trees located near roost sites (Kalcounis and Brigham, 1998; Lacki, 2000; Mager and Nelson, 2001). We found that *P. medius* also has similar preference, therefore suggesting that that the larger trees with greater DBH, crown length, and width facilitate bats to gain good protection, presumably from human interference, and enable them to take off and land more easily and provide more space for these large colonies (Hahn *et al.,* 2014; Gulraiz *et al.*, 2015; Kumar and Elangovan, 2019; Madala *et al*., 2022). Furthermore, it could be noted that the larger trees are more stable and long-lasting, whereby providing consistent protection to bats during natural disasters such as high velocity wind, torrential rain, hailstorm, and high intensity sun rays (Hahn *et al.*, 2014). The abundance of *P. medius* was analyzed in correlation to the density of tree branches characterized by an umbrella of dense foliage cover. The results of the present study revealed that the tree species with 30–60% foliage cover had the highest number of bats. Several studies have found a similar behavior of bats selecting their roost sites (Kunz *et al*., 2003; Veilleux *et al*., 2003; Chaverri and Kunz, 2006). Few recent studies have also found that foliage-roosting bats select roosts based on microhabitat characters associated with suitable microclimatic conditions (Willis and Brigham, 2005) or concealment from predators (Perry *et al.*, 2007).

Influence of disturbance and other factors on roost selection

The roost-sites closer to human settlements/town had a relatively higher number of bats, whereas the sites with heavy anthropogenic pressures, including poaching and logging activities, and the presence of mobile phone tower stands had fewer numbers of bats. Previous studies have shown similar observations, where *P. medius* were found roosting in botanical gardens, cities, and villages closer to human settlements but completely avoided the sites with poaching activities (Krystufek, 2009; Devi and Kumar, 2024). *Pteropus* roost selection is strongly influenced by food availability and food proximity (Palmer and Woinarski, 1999). The reason for *P. medius* roosting preference in forests near areas of high human density is that homestead gardens provide a diversity of food resources that may not be available in natural forests. It is also observed that the abundance of generalist frugivorous bats was positively associated with the fragmentation of the landscape and it is proposed that their ability to feed on a variety of plant species allowed them to utilize heterogeneous landscapes (Gorresen and Willig, 2004). Subsequently, Pierson and Rainey (1992) found that *P. medius* were documented in forest remnants in populated areas as opposed to only in undisturbed natural forests. Pteropid bats are threatened throughout their range primarily due to hunting and habitat loss (Epstein *et al.*, 2008). Rapid human population growth and deforestation in India will continue to threaten *P. medius* unless comprehensive protection policies and land management practices are established (Streatfield and Karar, 2008). The survival of *P. medius* was severely threatened due to human interference. The present study confirms through inquiries with local people that *P. medius* is being hunted for food and alternative medicine practices in some day roosts. Its meat and oil were believed to cure paralysis, asthma and breathing disorders, and body pains in some villages (Gulraiz *et al.*, 2015; Tackett *et al.*, 2022), which has led the local people to hunt the bats easily as they live closer to human settlements

On the other hand, bats are recognized as the reservoir hosts for viruses that can cause serious human disease (Calisher *et al.,* 2006; Epstein *et al.*, 2008). In Bangladesh, *P. medius* have been implicated as the primary reservoir of Nipah virus (Luby *et al.*, 2009), a disease recently spreading across Kerala and forcing the people to kill the bats or destroy their roosting sites. According to a report by the World Health Organization (WHO), there is strong evidence that the emergence of bat-related viral infections can be attributed to the loss of the animal's natural habitats.

As the *P. medius* habitat is destroyed by human activities, the bats get stressed and hungry, their immune systems get weaker, their viral load goes up and a lot of virus spills out in the urine and saliva. Conservationists fear that the outbreaks could spark a knee-jerk reaction of calls for bat culling. It may seem an easy solution, but studies warn that instead of reducing the outbreak of such diseases, it could cause even more ecological damage.

Despite the ecological, economic, and public health significance of flying foxes, little is known about their habitat requirements. Understanding their habitat selection can provide information for the design of forest management strategies that preserve roosting and foraging landscapes (Mildenstein *et al.*, 2005; Timmiss *et al.*, 2021). Our study explored the determinants of roost selection by *P. medius* in northern districts of Kerala, which may be of highly useful in the conservation of roost sites at the local level, as it provides information contributing to local forest management. Despite their beneficial roles, fruit bats have been hunted as a source of protein and for alternative medicinal uses and are persecuted as fruit-eating pests (Tackett *et al.*, 2022). The Indian Flying Fox (*Pteropus medius*) is one of the most misunderstood species in India and is listed under Schedule V of the Wildlife (Protection) Act, 1972, categorizing it as vermin, permitting capture or killing. As per the 2024 IUCN Red List assessment, it is classified as Near Threatened (NT) due to a significant population decline (Ahmed *et al.*, 2025) and now it is appropriate that the policy makers working in the concerned department has to revisit this issue and to remove these pollinators and seed dispersers from the vermin list under the Wildlife (Protection) Act 1972. Additionally, the land managers and forest officials should come forward to stop the logging activities, particularly cutting down mature tress vicinity to bats' roosting sites and encourage the local people to take part in understanding the habitat requirements of bat species in the entire Kerala. Such efforts may be of useful in conserving this mammalian pollinator in near future and also maintaining their ecosystem.

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