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Roost-Colony protection strategy from raiding by enemies in the Indian Flying Fox *Pteropus medius* (Temminck, 1825)

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ABSTRACT

Pteropus medius roost in the open in trees. They are susceptible to attack by different predators and competing species. Roosting bats produce alarm calls in response to perceived danger. To assess anti-predator behaviors to watch the arrival of enemies, in these bats, we collected data on the directions roosting bats faced in two roost trees in West Bengal, India. It is revealed that the bats, irrespective of roost spots, are accustomed to maintaining the hanging posture facing all direction though out the day. These differences in hanging poses were statistically significant ($P<0.05$). We hypothesized that such orientation in hanging stance is the induced impact of anti-predator behavior to ensure vigil in all directions.

Keywords: *Pteropus medius* bats, roost trees, predators, competing species, vigilance strategy

1. INTRODUCTION

Roosting bats are vulnerable to attack by predators and competing species (Table 1). The Indian flying fox *Pteropus medius* roosts in trees. They are attacked by various predators and competing species off and on. We noted the hanging postures of these bats in two roost trees. It is revealed that irrespective of the hours of the daytime some of the colony-members may be seen hanging, watching out for attacks from inimical groups. Such a strategy enables bats to emit alarm calls to alert the colony members to escape the danger. We hypothesized that in such directions hanging, bats keep a vigil. Since there exists no report in this respect, we took the liberty to bring the said fact, at least in tree roosting bats, into, the notice of the research workers.

Table 1 Predators and competing species of bats (1-6 & 8-22)

Predators/Competing Species	Reference
Amazonian giant centipedes (*Scolopendra gigantean*)	Molinari et al., 2005
American crow (*Corvus brachyrhynchos*)	Lefevre, 2005
Belted kingfisher (*Megaceryle alcyon*)	Jung, 2013
Bengal eagle-owl (*Bubo benghalensis*)	Mallick et al., 2021a
Black-crowned night heron (*Nycticorax nycticorax*)	Mallick and Raut, 2020
Boa snakes (*Epicrates inornatus*)	Rodriguez-Duran, 1996
Carnivorous bat (*Phyllostomus hastatus*)	Oprea et al., 2006
Common genets (*Genetta genetta*)	Mas et al., 2014
Crab-eating fox (*Cerdocyon thous*)	Novaes et al., 2010
Crested owl (*Lophostrix cristata*)	Rocha and Lopez-Baucells, 2014
Crested owl (*Lophostrix cristata*)	Bergstrom and Smith, 2017
Domestic cat (*Felis silvestriscatus*)	Rocha, 2015
Domestic dogs (*Canis lupus familiaris*)	Mallick et al., 2021a
Golden jackals (*Canis aureus*)	Mallick et al., 2021a
Hawk-owl (*Ninox scutulata*)	Mallick et al., 2021a
House crow (*Corvus splendens*)	Mallick and Raut, 2020
Indian grey mongooses (*Herpestes edwardsii*)	Mallick and Raut, 2010
Indian rat snakes (*Ptyas mucosa*)	Mallick et al., 2022
Jungle cats (*Felis chaus*)	Mallick et al., 2021a
Northern plains gray langur (*Semnopithecus entellus*)*	Mallick and Raut, 2020, 2021a
Nesting barred owl (*Strix varia*)	Bradley and Marvin, 2017
Peregrine falcon (*Falco peregrines*)	Kuo and Lee, 2001
Red-tailed hawk (*Buteo jamaicensis*)	Kuo and Lee, 2001
Sand Martin (*Riparia riparia*)	Speakman, 1991
Smooth-coated otters (*Lutrogale perspicillata*)	Mallick et al., 2021a
Southeastern four-eyed opossum (*Philander frenatus*)	Patrício-Costa et al., 2010
Spiders (*Avicularia urticans*)	Nyffeler and Knörnschild, 2013
Woolly false vampire bat (*Chiropterus auritus*)	Nogueira et al., 2006

*Competing species

2. MATERIALS AND METHOD

Roost Trees and Study Regions

We selected two big roost trees. Of the two, the silk flower tree *Albizia lebbeck* is located in the village Joteghanashyam (22°31′10.0″ N 87°50′19.2″ E) in Paschim Medinipur district and the tamarind tree *Tamarindus indica* is situated 75 km away of *A. lebbeck* in the village Simla (23022′44.20″ N, 86038′ 47.02″ E) in Purulia district of West Bengal, India. There were big ponds in the vicinity of both the study sites. These trees are umbrella-shaped with a large number of branches and sub-branches. The *A. lebbeck* (16.15 m tall with a 1.73 m diameter trunk) is deciduous while, *T. indica* (17.67 m tall, a trunk 3.33 m in diameter) is evergreen.

Data Counting Date and Time Slots

We noted hanging postures of *P. medius* bats at frequent intervals during any one of the times scheduled 05:22-11:59h; 12:00-14:59h, 15:00-16:59h and, 17:00h to onwards until they started to leave the roost site for foraging. We recorded their front view hanging direction from August 2, 2008, to December 31, 2014, at Joteghanashym and February 9, 2015, to May 3, 2019, at Simla. The purpose of noting the front view hanging direction was to confirm the visual strategy as an anti-predator behavior of these bats. To note if roost trees have any impact in such type of vigilance, one less bushy and deciduous tree (*A. lebbeck*) and the other bushier as well as evergreen were taken into the study program sequentially one after other.

Observation Strategy

Two persons took part in recording the hanging postures simultaneously but individually to avoid any sort of ambiguity in observations and data records. We used field binoculars (Nikon Aculon A211 12*50) for observations during data collection.

Statistical Analysis

We analyzed the data with R-studio 3.6.3 and PAST 3.14, and one-way ANOVA was applied to ascertain the impact of the roost tree. To assess the fixed and random effects of hanging directions, we applied the Generalized Linear mixed effect Model (GLMM). We used GLMM (Tables S2 & S4), Eigen, and S4 package and conducted Shapiro-Wilk tests for normality followed by the Poisson family and a Kruskal-Wallis.

3. RESULTS AND DISCUSSION

In the course of studies, irrespective of time schedules and study sites, we encountered 552834 bats facing in any one direction, as seen in (Figure 1, 2). From a statistical view-point such, mouth orientation with respect to the four scheduled study hours was typical pattern of distribution. We recorded directions 6-950 and 3-295 P. medius faced in two roosts (Table 2). The results of GLMM (Tables S2 & S4) and ANOVA (P=0) tests suggest that there exists no significant difference with respect to the direction of the bats face in either of the roost trees. The results of the Kruskal Wallis test indicated a standard order of statistics median and distribution of each median value in the four frontal-facing directions (Figure 3).

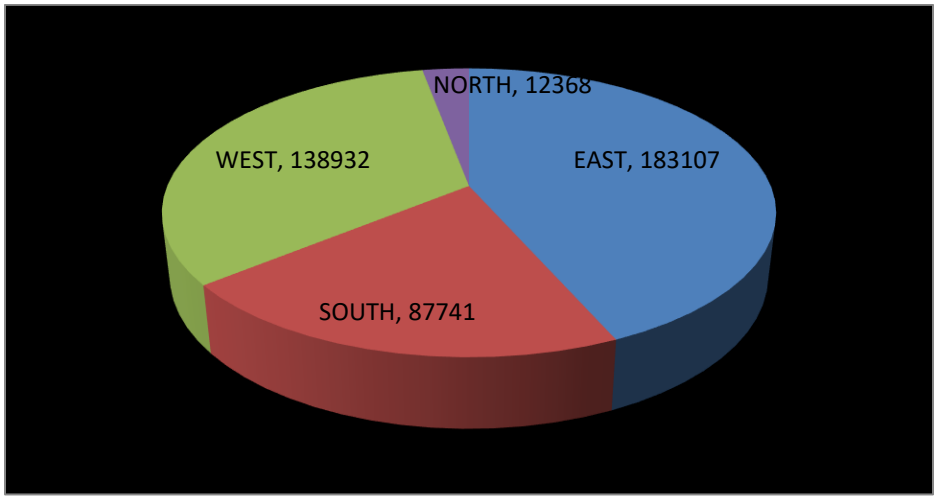

Figure 1 3D-Pie chart showing *P. medius* projecting the mouth towards east, south, north, and west in the *A. lebbeck* roost tree at Joteghanashyam, Paschim Medinipur, West Bengal, India.

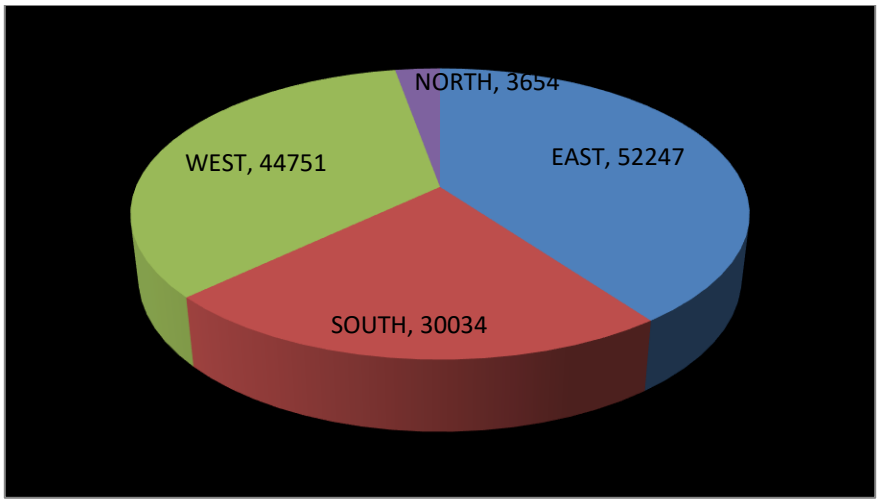

Figure 2 3D-Pie chart showing P. medius projecting the mouth towards east, south, north, and west in the T. indica roost tree at Simla, Purulia, West Bengal, India.

Table 2 Data [range, (mean±SE)] on the front facing hanging directions of P. medius bats in the roost trees, A. lebbeck and T. indica.

TIME (h)	OBSERVATION NUMBER (N)	*Albizia lebbeck* Roost Tree EAST	SOUTH	WEST	NORTH	TIME (h)	OBSERVATION NUMBER (N)	*Tamarindus indica* Roost Tree EAST	SOUTH	WEST	NORTH
5:22 to 11:59	158	390-900 (641.02±8.24)	14 - 250 (84.34 ±4.07)	8 - 136 (63.80 ±2.20)	6 - 95 (28.86±1.82)	5:25 to 11:59	106	220 - 295 (268.51±1.59)	11- 82 (37.54 ± 1.72)	7 - 28 (15.49 ±0.53)	4 - 27 (10.03 ± 0.59)
12:00 to 14:59	103	432 - 950 (666.38±11.04)	16 - 225 (78.11± 5.40)	13 - 114 (55.63± 2.25)	6 - 90 (21.24±1.71)	12:00 to 14:59	76	220 - 295 (267.42±1.86)	12 - 82 (32.0 ±1.85)	4 - 26 (14.72± 0.64)	4 - 26 (9.13 ± 0.43)
15:00 to 16:59	80	9 - 225 (57.86 ±4.23)	450 - 855 (687.8±11.93)	17 - 135 (60.85 ± 3.29)	7 - 75 (20.68±1.8)	15:00 to 16:59	67	7 - 28 (15.36±0.75)	220 - 294 (265.19 ±2.09)	12 - 77 (36.22 ±2.18)	5 - 14 (9.54 ±0.34)
17:00 to 18:55	174	6 - 108 (49.19± 1.92)	16 - 450 (65.21 ±3.92)	315 - 855 (679.62 ±7.82)	8 - 120 (22.79±1.39)	17:00 to 18:55	149	7 - 28 (16.32±0.43)	12 - 82 (39.3 ±1.41)	230 - 295 (265.52±1.47)	3 - 25 (8.44 ±0.3)

From the results, it is apparent that the bats *P. medius* habituated to hang in all directions, viz. east, south, west, and north-facing states throughout the roosting hours (Tables S1 & S3). It is also evident that less than 20% of individuals were in north-facing hanging posture. In contrast, more than 80% were east, south, or west-facing with respect to different hours of the day time following the position of the sun in the sky. This sort of behavior related to the assurance of foraging flight in due time, during post-sunset hours. It is mentioned here that the *P. medius* bat colony was raided by the competing monkey species *Semnopithecus entellus* on several times in the silk flower roost tree. Also, the collection of the bats which were detached and dropped down by the mongooses during the Aila storm Mallick and Raut, (2010) could not rule out the possibility of mongooses as occasional raiders.

As bats occurring in different geographical regions of the world are attacked by different types of predators viz, sand martin Speakman, (1991); boa snake Rodriguez Duran, (1996); Amazonian giant centipedes Molinari et al., (2005); Indian rat snake Mallick et al., (2022); falcons and hawks Lee and Kuo, (2001); Mallick et al., (2021a); crows Lefevre, (2005); kingfishers Jung, (2013); owls Rocha and Lopez-Baucells, (2014); Mallick et al., (2021a); carnivorous and omnivorous bats Nogueira et al., (2006); Oprea et al., (2006); cats Rocha, (2015); jungle cat Mallick et al., (2021a); genets Mas et al., (2014); opossum Patrício-Costa et al., (2010); fox Novaes et al., (2010); barred owl Bradley and Marvin, (2017); jackal Mallick et al., (2021a); dog Mallick et al., (2021); mongoose Mallick et al., (2021a); otter Mallick et al., (2021a) and monkeys Mallick and Raut, (2020), it is sure that these bat species have also developed assured effective strategies to escape the enemies in respect to their roosting behavior.

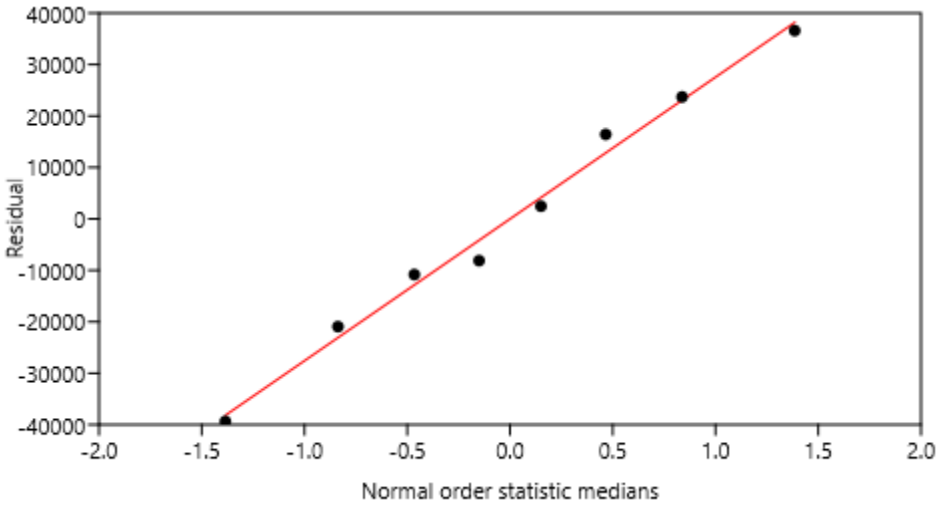

Figure 3 Normal order of statistic medians and distribution of *P. medius* bats' mouth facing directions irrespective of roost trees, based on the results of Kruskal Wallis test.

In this context, it is pertinent to pay due attention to studying the anti-predator behavior, with relation to the type of predators of the concerned bat species, as has been discussed by (Lima and O'Keefe, 2013). On the basis of investigation at Joteghanashyam we reported the fact that alarm calls are produced by *P. medius* to warn the colony against all possible danger (Mallick and

Raut, 2020). Information on the said aspect also enables us to interpret the anti-predator behavioral strategies developed by *P. medius* bats species against the predation of night herons, monkeys and humans (Mallick et al., 2021a). Even it is mentioned here that a subtle psychological intention at the individual level to ensure self-protection is pronounced in *P. medius,* as could be justified by capturing preferred roost tiers in a roost tree (Mallick et al., 2021b). It is evident from all available sources, we have come across, such a study has never been conducted earlier. Studies in this field in cases of other bat species occurring in different parts of the globe would enable us to develop conservation strategies in a befitting manner.

4. CONCLUSION

The Indian flying fox *Pteropus medius* has developed the device to protect their colony members confined to a roost tree from the attack of enemies, a way to guard the colony visually, in all directions.

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Authors' Contributions

All the authors uniformly contributed in data collected works, analysis of the data and preparation of the manuscript.

Informed consent

Not applicable.

Ethical Approval

The guidelines on Animal Ethics, supplied by the University Grants Commission, New Delhi were followed to accomplish this work.

Conflicts of interests

The authors declare that there are no conflicts of interests.

Funding

The study has not received any external funding.

Data and materials availability

All data associated with this study are present in the paper.

Supplementary Tables

Table S1 Total number (%) of bats *P. medius* encountered at different hanging directions during the four scheduled study period at Joteghanashyam, Paschim Medinipur, India

Time (h)	EAST	SOUTH	WEST	NORTH	TOTAL
(5:22 - 11:59)	101281 (78.36%)	13325 (10.31%)	10080 (7.79%)	4560 (3.53%)	129246 (99.99%)
(12:00 - 14:59)	68637 (81.13%)	8045 (9.51%)	5730 (6.77%)	2188 (2.57%)	84600 (99.98%)
(15:00 - 16:59)	4629 (6.99%)	55024 (83.15%)	4868 (7.36%)	1654 (2.5%)	66175 (100%)
(17:00 - 18:34)	8560 (6.02%)	11347 (7.98%)	118254 (83.20%)	3966 (2.79%)	142127 (99.99%)

Table S2 Results of GLMM studies on hanging direction of *P. medius* encountered at four times i.e., intercept (5:22-11:59h, TIME_hp), TIME_hq (12:00-14:59h), TIME_hr (15:00-16:59h) & TIME_hs (17:00 h onwards) scheduled at Joteghanashyam study site.

Albizia lebbeck Roost Tree			
Hanging Directions	Variables	T - value	P - value
East	TIME_hp	104.255656	0.0000000000
	TIME_hq	3.392206	0.0006933227
	TIME_hr	-55.943922	0.0000000000
	TIME_hs	-71.229592	0.0000000000
South	TIME_hp	16.7037264	0.0000000000
	TIME_hq	-0.8397496	P>0.05
	TIME_hr	69.0811700	0.0000000000
	TIME_hs	-2.8174448	0.004840743
West	TIME_hp	12.5562743	0.0000000000
	TIME_hq	-1.0123567	P>0.05
	TIME_hr	-0.3431688	P>0.05
	TIME_hs	87.8914163	0.0000000000
North	TIME_hp	18.710350	0.0000000000
	TIME_hq	-3.084392	0.002039684
	TIME_hr	-3.084846	0.002036577
	TIME_hs	-2.867971	0.00413113

Table S3 Total number (%) of bats *P. medius* encountered at different hanging directions during the four scheduled study period at Simla, Purulia, India

Time (h)	EAST	SOUTH	WEST	NORTH	TOTAL
(5:25 - 11:59)	28462 (80.98%)	3979 (11.32%)	1642 (4.67%)	1063 (3.02%)	35146 (99.99%)
(12:00 - 14:59)	20324 (84.59%)	2432 (9.89%)	1119 (4.55%)	694 (0.95%)	24569 (99.98%)
(15:00 - 16:59)	1029 (4.7%)	17768 (83.25%)	2427 (11.10%)	639 (0.95%)	21863 (100%)
(17:00 - 18:55)	2432 (4.95%)	5855 (11.92%)	39563 (82.36%)	1258 (0.77%)	49108 (100%)

Table S4 Results of GLMM studies on hanging direction of *P. medius* encountered at four times i.e., intercept (5:25-11:59h, TIME_hp), TIME_hq (12:00-14:59h), TIME_hr (15:00-16:59h) & TIME_hs (17:00 h onwards) scheduled at Simla study site.

Tamarindus indica Roost Tree			
Hanging Directions	Variables	t-value	P- value
East	TIME_hp	234.7993248	0.0000000000
	TIME_hq	-0.6150203	P>0.05
	TIME_hr	-137.7627101	0.0000000000
	TIME_hs	-168.5712577	0.0000000000
South	TIME_hp	22.5572081	0.0000000000
	TIME_hq	-2.1504067	0.03152306
	TIME_hr	85.1356162	0.0000000000
	TIME_hs	0.8073317	P>0.05
West	TIME_hp	11.6164081	0.0000000000
	TIME_hq	-0.3716243	P>0.05
	TIME_hr	9.6758173	0.0000000000
	TIME_hs	143.3259456	0.0000000000
North	TIME_hp	26.1266808	0.0000000000
	TIME_hq	-1.5096846	P>0.05
	TIME_hr	-0.7960539	P>0.05
	TIME_hs	-3.1572192	0.001592816

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