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Distribution and Occurrence of Megachiroptera in Bhavnagar and Ghoga Talukas, Gujarat, India

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Abstract

This study investigates the distribution, roosting ecology, and population dynamics of megachiropteran bats (fruit bats) across the Ghogha and Bhavnagar talukas of Bhavnagar district, Gujarat, India. Conducted over a one-year period from January to December 2020, the research identifies three primary species: *Cynopterus sphinx*, *Rousettus leschenaultii*, and *Pteropus giganteus*. Results show that *P. giganteus* (Indian Flying Fox) is the most widespread, utilizing 15 roost sites across rural, urban, and agricultural zones, with a strong preference for tall trees like *Eucalyptus globulus* and *Ficus* species located near water bodies. *R. leschenaulti* was found in abandoned houses and deep wells, while *C. sphinx* was observed constructing tents in coconut trees. The study highlights significant seasonal fluctuations in *P. giganteus* populations, identifying distinct breeding and non-breeding camps that correlate with mating and parturition cycles. These findings provide critical baseline data for the conservation and management of megachiropteran bats in human-modified landscapes.

Keywords: Megachiroptera, Roosting Ecology, *Pteropus giganteus* (Indian Flying Fox), *Rousettus leschenaultia*, *Cynopterus sphinx*, Population Dynamics, Habitat Heterogeneity**,** Breeding Camps

1 Introduction

Bats (Order: **Chiroptera**) represent a significant component of mammalian biodiversity, accounting for approximately 20% of all known mammal species globally (Nowak, 1994). Their unique life history, particularly as the only mammals capable of truly powered flight, makes them a focal point of socio-biological and ecological research. Traditionally, the order is divided into two suborders: **Megachiroptera** (primarily frugivorous) and **Microchiroptera** (predominantly insectivorous), distinguished by their morphological adaptations and feeding specializations (Corbet and Hill, 1991; Elangovan and Kumar, 2015).

About 1,100 species of bats are known to be distributed globally. This is the only group of volant mammals, making up to 20% of the total number of mammals; they are distributed worldwide except for the Arctic, Antarctic, and a few oceanic islands. Distribution, survey, and ecological studies are vital as they provide knowledge about bat fauna diversity, habitat requirements, and conservation strategies. The greatest diversity of bat fauna is in the Neotropic, while Indonesia has the highest number of species. West, central, and southern Africa, as well as Southeast Asia, are also rich areas for bat diversity.

Despite their global distribution—excluding only the extreme polar regions, bats face increasing pressures from habitat loss and climate change. Comprehensive surveys and ecological studies are essential to understanding their habitat requirements and developing effective conservation strategies (Bergallo et al., 2003).

1.1 The Indian Context and Research Gaps

In India, the study of bat fauna began with early surveys in Bangalore by Shortridge (1912) and Wroughton (1920). Subsequent works by Khajuria (1980) and Brosset (1962) expanded our understanding of the biology of bats in Western and Central India. Current estimates suggest that India is home to approximately 114 to 120 species of bats, including 14 species of megachiropterans (Bates and Harrison, 1997; CAMP, 2002).

However, a significant disparity exists in research literature. While distributional data is available, detailed ecological studies—specifically regarding the **Megachiroptera**—remain scarce (Wilson and Engbring, 1997). Authors such as Tidemann et al. (1999) and Fenton et al. (2000) have highlighted a critical lack of data concerning the habitat ecology and roosting behavior of these species in the Indian subcontinent.

1.2 Roosting Ecology and Fidelity

Roosting is a critical aspect of bat biology, as individuals spend over half of their lives within these environments (Gulraiz et al., 2015). Roosts serve as vital hubs for:

- **Protection:** Sheltering from predators and adverse weather.
- **Social Dynamics:** Facilitating mating, rearing young, and social interaction.
- **Physiological Regulation:** Providing microclimates (temperature and humidity) necessary for hibernation or daily torpor (Kunz, 1982).

Roost selection is influenced by a complex interplay of sensory cues (vocalizations, olfactory markers, and echolocation) and environmental factors (Shoener, 1971). Many species exhibit high **roost fidelity**, returning to the same site across seasons. This fidelity is often highest during maternity periods but can be disrupted by human disturbance or shifts in food availability (Kunz et al., 2003). For migratory frugivorous bats, the challenge is even greater, as they must locate suitable roosts in unfamiliar landscapes while following the seasonal rhythms of flowering and fruiting trees (Nelson, 1965b).

1.3 The Present Investigation

Given the rapid rate of habitat degradation and the limited data on megachiropteran ecology in Gujarat, this study seeks to bridge the gap in local chiropterology. The present investigation focuses on the Bhavnagar district, aiming to provide a clear picture of how these "flying foxes" interact with their environment.

The primary objectives of this study are:

1. To survey and map the **distributional patterns** of megachiropterans within the Ghogha and Bhavnagar talukas.
2. To analyze the **roost characteristics** and environmental variables influencing roosting ecology.
3. To assess the **population structure** and dynamics of the Indian flying fox (*Pteropus giganteus*).

2. Study area

The study area encompasses a diverse range of environments, including rural and urban areas, agricultural land, coastal zones, and forest areas. Detailed descriptions of the two primary talukas are as follows:

2.1. Bhavnagar Taluka

Bhavnagar Taluka (21.77 N, 72.15 E) serves as the administrative hub of the district. The region is characterized by a semi-arid climate with significant topographical heterogeneity. For the purposes of this study, the taluka was stratified into three distinct ecological zones based on habitat suitability for chiropterans:

- **Coastal and Intertidal Zones:** Dominated by mudflats and hypersaline soils. These areas are subject to regular tidal inundation and are largely devoid of significant floral cover. Due to the lack of arboreal roosting sites and foraging resources, these zones serve as ecological voids for bat populations.
- **Urban Matrix (Bhavnagar City):** An anthropogenic landscape featuring a high density of legacy trees (e.g., *Ficus* spp.), public gardens, and perennial water bodies. These features create a favorable microclimate and offer stable roosting sites, particularly within temple complexes and heritage parks.
- **Agro-Rural Zones:** These areas are defined by extensive fruit orchards and traditional agricultural practices. The high density of phenologically diverse fruiting trees provides a continuous food supply, supporting the highest concentrations of bat colonies observed in the study.

2. 2. Ghogha Taluka

Ghogha Taluka is situated on the mid-western coast of the **Gulf of Khambhat**. Historically a prominent maritime port, the contemporary landscape is primarily agro-industrial. The inland areas are dominated by horticulture and orchards, which transition into coastal shrublands and mudflats toward the east.

The prevalence of large-canopy fruit trees and relatively lower levels of urban noise pollution compared to Bhavnagar city make Ghogha an ideal habitat for *P. giganteus*. The proximity of these orchards to coastal flyways suggests that this taluka plays a critical role in the regional movement and foraging ecology of the species.

General Habitat Classifications

The researchers further classified the roosting habitats within these talukas into five types:

- **Isolated:** Located roughly 500 meters away from human settlements.
- **Rural/Village:** Found within smaller inhabited areas with limited populations.
- **Agricultural:** Situated in the center of orchards, gardens, or farmlands.
- **Urban:** Located within crowded city limits.
- **Water-proximate:** All identified roosts were primarily located adjacent to water bodies like rivers or ponds.

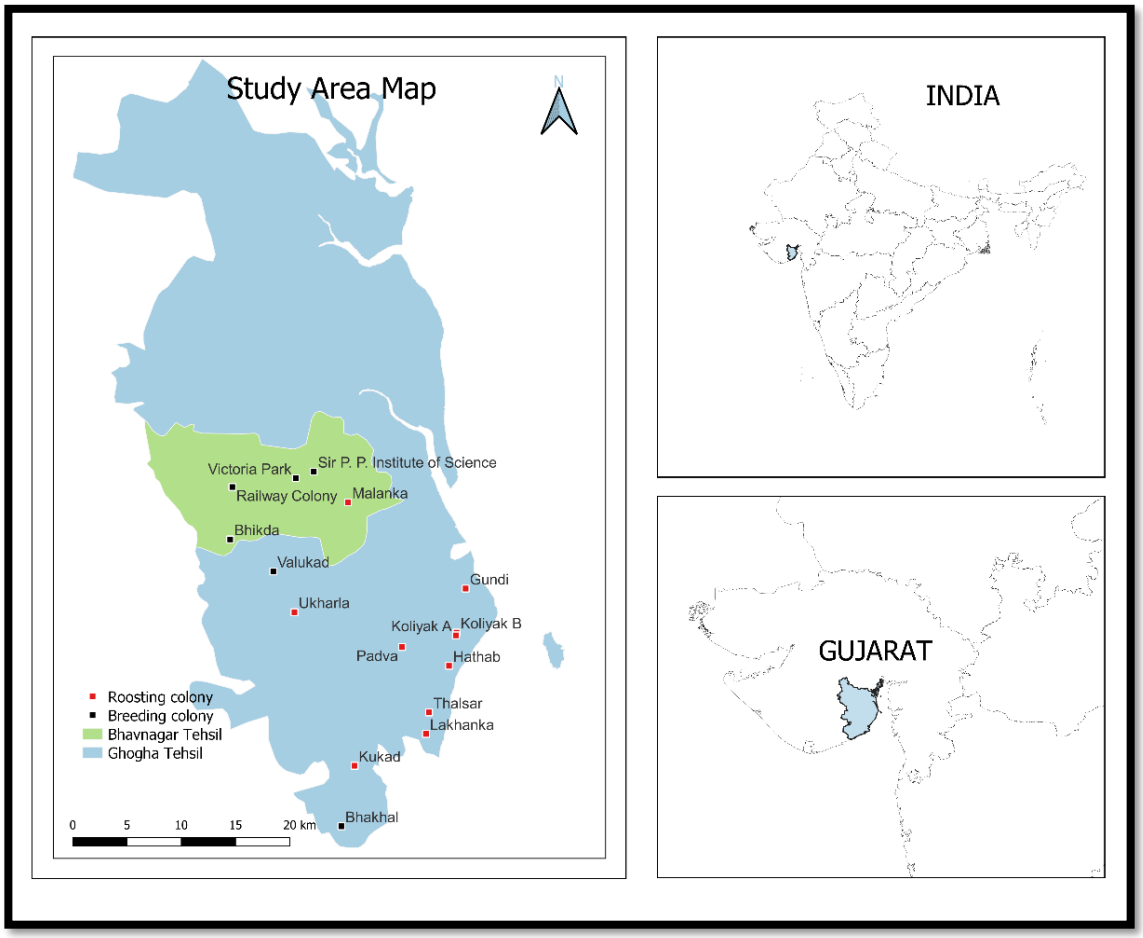

Figure.1. Map of the study area.

3. Materials and Methods

3.1 Study Area and Period

A systematic survey was conducted to assess the distribution and population dynamics of Megachiropteran bats (Family: Pteropodidae) across the **Ghogha** and **Bhavnagar** talukas of the Bhavnagar district, Gujarat, India. The study spanned a 12-month period from **January 2020 to December 2020**. This region encompasses a mosaic of rural, semi-urban, and agricultural landscapes, providing diverse roosting opportunities.

3.2 Roost Identification and Survey Design

Potential roosting sites were initially identified through a combination of literature reviews and **Local Ecological Knowledge (LEK)**, gathered via structured interviews with residents, farmers, and forest department personnel.

Following the preliminary identification, periodic field visits were conducted to confirm occupancy. Roosts were classified into three primary architectural categories:

1. **Open Roosts:** Tree canopies and foliage of large fruiting trees.
2. **Tent Roosts:** Modified palm fronds or large leaves.
3. **Enclosed Roosts:** Abandoned buildings, temples, wells, and man-made structures.

3.3 Data Collection and Roost Characterization

Each confirmed site was documented using a standardized protocol to evaluate physical and biological parameters.

3.3.1 Physical Parameters

For **enclosed roosts**, variables including dimensions (height, width, depth), entrance orientation, lighting patterns, and the nature of the substrate were recorded.

- **Tent Roosts:** Measurements included tent dimensions, total tree height, and host plant species.
- **Open Foliage Roosts:** Tree species, total height, and crown area were documented. All physical measurements were obtained using a standard linear measuring tape and a laser rangefinder where applicable.

3.3.2 Habitat and Environmental Classification

Roosting sites were categorized based on their proximity to human activity and environmental features:

- **Habitat Type:** Isolated (>500m from settlements), Rural (small villages), Agricultural (orchards/farmland), or Urban (city limits).
- **Surrounding Environment:** Classified as agricultural fields, water bodies, or human settlements.
- **Disturbance Level:** Defined as "Used" (frequent human interaction) or "Unused" (minimal human disturbance).

3.4 Population Dynamics of *Pteropus giganteus*

To analyze the population ecology of the Indian Flying Fox (*Pteropus giganteus*), 15 representative roosts were selected for longitudinal monitoring.

3.4.1 Census Techniques

Colony size was estimated using two complementary methods to ensure accuracy:

1. **Direct Count Method:** Counting individuals during diurnal resting periods using binoculars.
2. **Evening Dispersal Count:** Counting bats as they emerged from the roost at sunset to forage.

3.4.2 Biological Observations

Observations were facilitated using **10x50 binoculars** and a **Canon 1500D** digital camera for photographic evidence.

- **Sex Ratio:** Determined through visual inspection; males were identified by the presence of external scrotal sac/testes.
- **Colony Composition:** Sites were categorized as "Breeding" or "Non-breeding" camps based on the presence of pregnant females or pups.
- **Fidelity:** Roost fidelity and interspecific associations with other bat species were monitored through monthly census intervals.

4 Results

The survey identified three megachiropteran species—*Cynopterus sphinx*, *Rousettus leschenaultii*, and *Pteropus giganteus*—distributed across the Bhavnagar and Ghogha talukas of Gujarat.

4.1 Species Distribution and Roosting Ecology

A total of 19 roosting sites were identified across the study area. *Pteropus giganteus* was the most prevalent species, accounting for 15 sites, followed by *R. leschenaultii* (3 sites) and *C. sphinx* (1 site).

(A) *Cynopterus sphinx*

The distribution of *C. sphinx* was highly restricted. Only a single roosting tent was identified in Fulsar village, Bhavnagar taluka, containing 7 individuals. No presence was recorded in Ghogha taluka. Roosting was exclusively observed in *Cocos nucifera* (coconut) trees. Tents were constructed in areas of low light intensity under the fronds, evidenced by the presence of rejected fruit boluses and droppings beneath the roost.

(B) *Rousettus leschenaultii*

Three roosts of *R. leschenaultii* were recorded: one in Bhavnagar (Nesvad) and two in Ghogha (Lakadiya and Lakhanka). The species exhibited a clear preference for anthropogenic and subterranean structures, specifically abandoned houses and deep wells (Table 3.1).

- **Colony Size:** Populations fluctuated between 265 and 3,700 individuals, with a cumulative count of 6,800 (Table No. 1)

- **Roost Characteristics:** Roosts were primarily located in semi-dark (approx. 80% light reduction) interior chambers or well shafts. Entrances were oriented along an East-West axis. Habitats were predominantly located within village limits or adjacent to agricultural fields.

Roosting location	Roosting place	Colony size
Lakadiya	Abandoned house	265
Nesvad	Well	2835
Lakhanka	Well	3700

Table 1: Distribution *of Rousettus leschenaultia.*

(C) *Pteropus giganteus*

P. giganteus was the most widely distributed species with 15 roost sites (9 in Bhavnagar, 6 in Ghogha).

- **Population Density:** The total recorded population was 7,405 individuals, with Bhavnagar taluka supporting 5,045 and Ghogha supporting 2,360. Colony sizes ranged from 175 to 1,150 individuals (Table No. 2)

- **Floristic Preferences:** Bats were observed roosting in 12 tree species. *Eucalyptus globulus* was the most preferred (43.3% of roosts), followed by *Ficus benghalensis* (10%) and *Ficus religiosa* (3.3%).

Name of taluka	No. of roost site	Location	Roost Environment	Name of roost tree	No of roost tree	Population	Method Used to Count Bats	Protection Information
Bhavnagar	9	Jewels circle	Reserve Forest	*Tamarindus indica, Delonix regia, Ple. pterocarpum, Leucaena glauca*	7	420	Tree estimation	Protected by government
		Malanka	Temple Area	*Sterculia foetida, Azadirachta indica, Ficusbengalensis, Eucalyptus globulus, Tamarindus indica, holoptelea integrifolia Leucaena glauca*	10	355	Tree estimation	Protected by local community
		Gundi	Road Side	*Ailanthus excelsa, Eucalyptus*	6	485	Tree estimation	Not protected

				globulus Azadirachta indica				
		Koliyak	Roadside	*Eucalyptus globulus, Ailanthus excelsa, Tamarindus indica, Azedarach indica*	11	390	Tree estimation	Not protected
		Hashab	Private Orchard	*Eucalyptus globulus, Tamarindus indica, Azedarach indica*	6	1150	Tree estimation	Not protected
		Thalasar	Private Orchard	*Ficus bengalensis*	1	235	Exact count	Protected by local community
		Railway colony	Governme nt Area	*Azedarach indica, Leucaena glauca*	4	175	Tree estimation	Protected by governmen t
		Sir P. P. Ins. Of science	Public Place	*Ficus religiosa*	1	220	Exact count	Protected by governmen t
		Lakhanka	Private Orchard	*Ficus bengalensis, Ailanthus excelsa* Leucaena glauca, *Mangifera indica*	12	560	Tree estimation	Protected by local community
Ghogha	6	Kukad	River Side	*Ficus bengalensis, Azedarach indica, Albizia lebbeck*	9	1055	Tree estimation	Not protected
		Bhakhal	Private Orchard	*Ficus bengalensis*	1	265	Exact count	Not protected
		Padava	Private Orchard	*Ficus bengalensis*	3	370	Exact count	Protected by local community
		Kantala	Private Orchard	*Ficus bengalensis*	3	185	Exact count	Not protected
		Bhikada	Dam Site	*Ailanthus excelsa, Azadirachta indica*	3	235	Tree estimation	Not protected
		Valukad	Public Place	*Ficus bengalensis*	1	250	Exact count	Not protected

Table 2 Population status of *Pteropus giganteus* in Bhavnagar and Ghogha taluka.

Plate 1: Megachiropteran bat and their roost

Pteropus giganteus

P. giganteus colony in a foliage roost

Rousettus leschenaulti

R. leschenaulti colony in well roost

Cynopterus sphinx

Roost site of *C. Sphinx*

4.2 Roost Selection and Environmental Variables

Roosting trees for *P. giganteus* were characterized by significant height (45.82 ± 12.86 feet) and large canopy cover (22.98 ± 3.91 feet). A strong correlation was observed between roost location and proximity to water bodies; all 15 sites were situated near rivers, ponds, or within the coastal zone (Table 3.3).

4.3 Seasonal Population Dynamics and Breeding Cycles

Longitudinal observations revealed significant seasonal fluctuations in colony size, driven by a migratory shift between **Breeding** and **Non-Breeding** camps.

1. **Breeding Camps:** These sites (e.g., Hathab) served as mating hubs. Female recruitment began in March, peaking during the mating season in August and September (N-1,700 at Hathab).
2. **Non-Breeding Camps:** These served as parturition sites. Peak occupancy by pregnant and nursing females occurred from October to March, coinciding with the birthing period in February and March.
3. **Dispersal:** Post-parturition (after March), females migrated back to breeding camps. While female distribution was highly dynamic, the male population remained relatively stable across both camp types throughout the year.

Plate 2 Variation in population of *p. giganteus* during breeding and non-breeding season.

Increased population size during breeding season

Decreased population size during non-breeding season

4.4. Roosting Preferences

Each species exhibited distinct preferences for their roosting environments:

- **P. giganteus:** Exclusively roosted in **large, tall trees** (average height of 45.82 ft) with extensive crown areas. The most preferred tree was *Eucalyptus globulus* (43.3% of roosts), followed by *Ficus benghalensis*.
- **R. leschenaultii:** Preferred **enclosed, semi-dark environments** (80% light) such as abandoned houses, deep wells, and caves.
- **C. sphinx:** Known for "tent-making," these bats constructed roosts by modifying the leaves of **Cocos nucifera (coconut palms)** to create shaded tents.

4.5. Population Dynamics of P. giganteus

The study highlighted a sophisticated social structure involving two types of camps:

- **Breeding Camps:** These sites saw peak populations in **August and September** during the mating season.
- **Non-Breeding Camps:** Primarily used for births (parturition) in February and March, these camps hosted high numbers of pregnant and nursing females from **October through March**.
- **Seasonal Shifts:** After March, female populations in non-breeding camps decreased as they migrated back to breeding camps.

4.6. Environmental Influences

- **Proximity to Water:** All identified roosts were located near water bodies like rivers or ponds.
- **Coastal Presence:** 8 out of the 15 *P. giganteus* roosts were situated within coastal zones.
- **Habitat Richness:** Greater species richness was noted in areas like Ghogha taluka due to the proximity to orchards and wild fruit-bearing trees, which provide ideal foraging conditions.

Name of roost site	Environment	Protection Information	Lighting pattern	Distance from road (m.)	Distance from water bodies (m.)	Disturbance
Victoria park	Reserve forest	Protected by government	Semi-dark	300	25	Birds, Human beings
Malanka	Temple area	Protected by local people	Bright light	5	45	Birds, Human beings
Gundi	Roadside	Not protected	Semi-dark	25	33	birds, Small mammals
Koliyak	Roadside	Not protected	Semi-dark	7	30	Birds, Human beings
Hathab	Private orchard	Not protected	Semi-dark	450	150	Birds, Human beings
Thalsar	Private orchard	Protected by local people	Dark	140	200	Birds.
Railway colony	Government area	Protected by government	Semi-dark	260	70	Birds
Sir P. P. institute	Government area	Protected by government	Semi-dark	220	--	Birds, Human beings
Lakhanka	Private orchard	Protected by local people	Dark	1600	160	birds, Small mammals
Kukad	River side	Not protected	Dark	550	25	birds, Small mammals
Bhakhal	Reserve	Not protected	Bright	180	35	Birds

	forest		light			
Padva	Private orchard	Protected by local people	Semi-dark	620	60	Birds
Ukharla	Private orchard	Not protected	Semi-dark	400	40	Birds, Human beings
Bhikada	Dam Site	Not protected	Bright light	970	10	Birds
Valukad	Government area	protected by government	Bright light	350	10	Birds, Human beings

Table 3 Roost characteristic of *Pteropus giganteus*

5. Discussion

The present study characterizes the distribution and roosting ecology of three megachiropteran species—*Cynopterus sphinx*, *Rousettus leschenaultii*, and *Pteropus giganteus*—within the Bhavnagar and Ghogha talukas of Gujarat. Our findings underscore how species-specific roosting requirements and habitat heterogeneity shape the chiropteran community in this semi-arid landscape.

5.1 Roosting Plasticity and Tent-Making in *C. sphinx*

The rarity of *C. sphinx* in the study area, particularly its absence in Ghogha taluka, suggests a high degree of habitat specificity or a localized response to resource scarcity. The identification of only a single roosting tent in Bhavnagar taluka aligns with the solitary or small-group social structure typical of this species (Balasingh et al., 1995).

The selection of *Cocos nucifera* for tent construction corroborates previous observations of "foliage-tenting" behavior in Paleotropical fruit bats (Kunz et al., 1994). By modifying large fronds, *C. sphinx* gains a thermoregulatory advantage and protection from aerial predators. Furthermore, the preference for lower canopy levels in *Polyalthia longifolia* likely serves as a strategy to mitigate wind-induced stress, a behavior mirrored by Neotropical species such as *Uroderma bilobatum* (Timm & Lewis, 1991). The urban-centric distribution of *C. sphinx* suggests that anthropogenic landscapes—offering a mix of ornamental palms and fruit-bearing trees like *Psidium guajava*—act as critical refugia for this species.

5.2 *R. leschenaultii*: Microclimate Extremes and Site Fidelity

Unlike the foliage-roosting *C. sphinx*, *R. leschenaultii* demonstrated a clear preference for subterranean and enclosed structures, specifically deep wells and abandoned buildings. This habitat specialization is likely driven by the need for stable microclimates. Deep wells offer high humidity and low temperature fluctuations, which are vital for reducing evaporative water loss in the arid climate of Gujarat (Webb et al., 1995).

Our observations of strong site fidelity and gregariousness in *R. leschenaultii* support the findings of Brosset (1962), who noted that this species often forms massive colonies in areas where human disturbance is minimal. The proximity of these roosts to water bodies suggests that *R. leschenaultii* utilizes "flyways" or riparian

corridors for foraging, highlighting the importance of maintaining water-proximal habitats for the conservation of this species.

5.3 *P. giganteus*: Selection of Emergent Roost Trees

P. giganteus was the most widely distributed species in the study area, utilizing 15 roost sites across both talukas. The selection of large, emergent trees such as *Ficus benghalensis* and *Terminalia arjuna* reflects a trade-off between accessibility and safety. High, broad crowns facilitate easy take-off for these large-bodied bats and provide a vantage point for predator detection (Barclay et al., 1988).

Notably, the preference for *T. arjuna* as a roosting site despite it not being a primary food source indicates that for *P. giganteus*, roost architecture (height and spread) may be more critical than immediate food proximity. This distinguishes them from other Pteropodids like *P. mariannus*, which often roost within their forage trees (Wiles et al., 1991). The ability of *P. giganteus* to persist in both forested and heavily modified human environments confirms its status as a relatively resilient species capable of navigating the urban-rural interface.

5.4 Seasonal Dynamics and Landscape Heterogeneity

The identification of distinct breeding and non-breeding "camps" suggests a complex social and reproductive phenology. The aggregation of females during the August-September mating season indicates that certain roosts serve as critical reproductive hubs. While long-distance migration was not observed, the documented local shifts in roosting sites likely track the phenological peaks of local fruit trees.

The higher species richness observed in Ghogha taluka is likely a function of its coastal proximity and greater ecological heterogeneity. The convergence of orchards, wild fruiting trees, and permanent water sources creates a "resource mosaic" that satisfies the diverse requirements of all three species. As suggested by Kunz (1982), bat diversity is a direct reflection of roosting site availability and the spatio-temporal distribution of food resources.

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