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# Temporal Variations in Diurnal and Emergence Behavior of the Indian Flying Fox (*Pteropus giganteus*)

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*Abstract:* The Indian flying fox (*Pteropus giganteus*) is a gregarious fruit bat that plays a vital role in ecosystem services through pollination and seed dispersal. This study investigates the behavioral ecology of the Indian flying fox (*Pteropus giganteus*), focusing on its diurnal activities and seasonal emergence patterns. Conducted between January 2020 and December 2022 in Bhavnagar, Gujarat, the research examines how environmental cues such as sunset timing, day length, and ambient temperature influence bat activity. Results indicate that emergence timing is highly correlated with sunset (r = 0.858) and day length (r = 0.733), with bats typically emerging approximately 30 minutes after sunset. Seasonal variations were significant: shorter winter days led to earlier emergence and longer foraging windows (approx. 14 hours), while longer summer days delayed emergence and shortened the foraging period (approx. 11 hours). Additionally, higher ambient temperatures were found to delay emergence. Diurnal observations revealed a suite of social and maintenance behaviors, including wing fanning, grooming, and squawking, which intensified prior to emergence. Population dynamics also shifted seasonally, with peak densities during the monsoon reproductive aggregation and declines during summer and winter. These findings underscore the critical role of environmental parameters in shaping the temporal dynamics of *P. giganteus*, offering essential insights for the conservation of this ecologically vital species.

*Index Terms - Pteropus giganteus*, Behavioral ecology, Diurnal activity, Roost selection, Photoperiod, Foraging duration, Seasonal dynamics, Conservation.

# 1. Introduction

Indian flying foxes (*Pteropus giganteus*) are gregarious mammals that live in communal roosts during the daytime. These roost sites are fundamental to their survival, serving as primary locations for social interaction and various behavioral activities among colony members. The selection of a roost is functionally critical, providing the necessary space for diurnal activities, predator sensing, and aerodynamic advantages for flight. Beyond their biological needs, these bats hold significant ecological importance; they provide vital pollination and seed dispersal services that maintain forest health. Furthermore, their diurnal activities can even play a role in local tourism.

A particularly critical phase of their daily cycle is emergence behavior, which marks the transition from diurnal rest to nocturnal activity. This emergence signals the start of the nocturnal phase, which concludes when the bats return to the roost after foraging. While the light-dark cycle is the primary driver of this predictable event, various environmental and climatic factors—such as cloud cover, fog, moonlight, light intensity, and rain—can significantly influence emergence patterns. Internal factors, including food availability, age structure, and reproductive status, also play a role; for instance, pregnant and lactating females are often observed emerging earlier than other colony members.

Despite extensive behavioral research on various *Pteropus* species globally, a significant knowledge gap remains regarding the specific influences on the Indian flying fox. While studies on related species suggest that factors like twilight and social context are influential, there is a lack of dedicated research investigating how day length, sunset timing, and ambient temperature specifically affect the emergence patterns of *P. giganteus*. Understanding these temporal dynamics is essential for identifying critical foraging periods and habitats, which is vital for effective conservation planning and reducing human-wildlife conflict.

This study aims to address this gap by examining the behavioral ecology and emergence patterns of *P. giganteus* in relation to seasonal and environmental variables.

# 2. Materials and Methodology

## 2.1 Study Area and Period

The study was conducted over a three-year period from January 2020 to December 2022. Observations were focused on a colony of the Indian flying fox, *Pteropus giganteus*, located at Hathab (21°34'59.08"N; 72°15'45.61"E), Bhavnagar, Gujarat, India.


Figure. 1 Study area.

## 2.2 Observational Schedule and Seasonality

Data collection was categorized into three distinct seasons to account for phenological and climatic variations:

- **Summer:** March to June
- **Monsoon:** July to October
- **Winter:** November to February

### 2.3 Diurnal Behavioral Observations

The behavior of the colony was monitored from a fixed vantage point to minimize disturbance. Observations were partitioned into three daily time blocks:

- **Morning:** 06:00 – 08:00 h
- **Mid-day:** 11:00 – 13:00 h
- **Pre-emergence:** 16:00 – 18:00 h

Specific behavioral ethograms were maintained, recording activities including grooming, vocalization (screaming), sleeping, wing fanning, and roost shifting.

### 2.4 Emergence and Return Monitoring

Weekly visual censuses were performed to monitor the flight dynamics of the colony.

- **Counting Method**: Bats were counted as silhouettes against the sky during dusk (emergence) and dawn (return) using 8x42 binoculars and a manual tally counter.
- **Temporal Parameters:** For emergence, the time of sunset, first emergence, and last emergence were recorded. For return flights, the time of sunrise, first return, and last return were noted.
- **Spatial Parameters:** The primary flight direction (North, South, East, and West) was documented for each session.

### 2.5 Environmental Data Acquisition and Statistical Analysis

Meteorological data, including sunset/sunrise times, total day length, and ambient temperature (°C), were obtained from the Indian Meteorological Department (IMD).

To determine the influence of abiotic factors on bat activity, correlation analyses were performed between environmental parameters (temperature, day length) and emergence metrics (timing and population count). Comparative analyses of emergence duration across the three seasons were conducted to identify significant seasonal shifts in behavior.

## 3. Results

### 3.1 Roost Selection and Microhabitat Preference

The colony of *Pteropus giganteus* exhibited a distinct preference for roosting sites despite the availability of diverse flora. Although Neem (*Azadirachta indica*) and Tamarind (*Tamarindus indica*) trees were present within the grove, the bats predominantly selected tall, large-diameter Eucalyptus trees for roosting. Preferred trees were characterized by high exposure and were strategically located at the periphery of the garden.

### 3.2 Diurnal Activity Budgets

Diurnal behavior patterns showed significant shifts between mid-day and the pre-emergence period (Figures 2 and 3).

#### 3.2.1 Morning and Mid-day Behavior

Observations from sunrise until the afternoon revealed that the most frequent activity was screaming (31%), followed by sleeping (24%) and roost shifting (22%). Wing fanning and grooming accounted for 16% and 7% of the activity budget, respectively. Early morning return to the roost was marked by high-intensity activity, including circular flights and multiple shifts in position before the bats settled with folded wings.

### 3.2.2 Pre-emergence Behavior

During the hours immediately preceding emergence, activity patterns shifted toward self-maintenance and environmental assessment. Sleeping remained the most prevalent activity (26%), but grooming increased significantly to 25%. Screaming and roost shifting decreased to 21% and 20%, respectively, while wing fanning was the least frequent (8%).

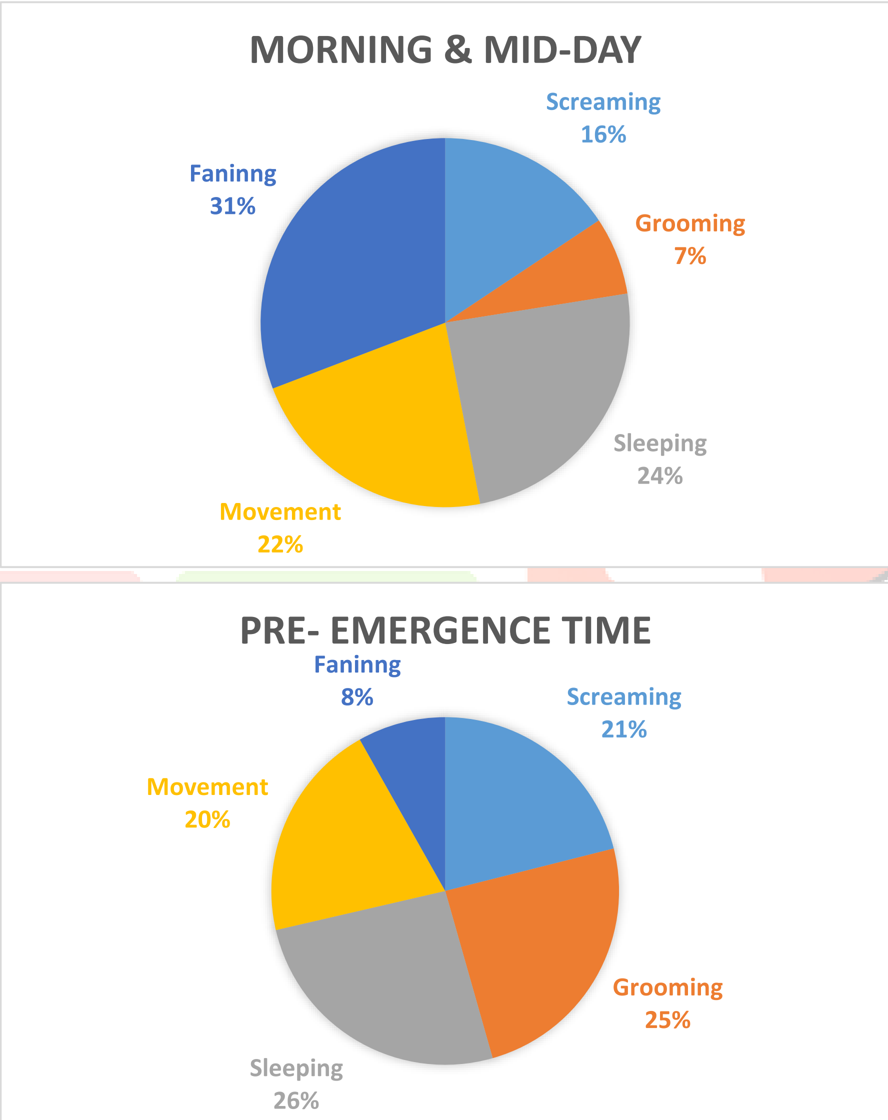


**Figure 2.** Percentage of diurnal and pre- emergence activates of *Pteropus giganteus.*

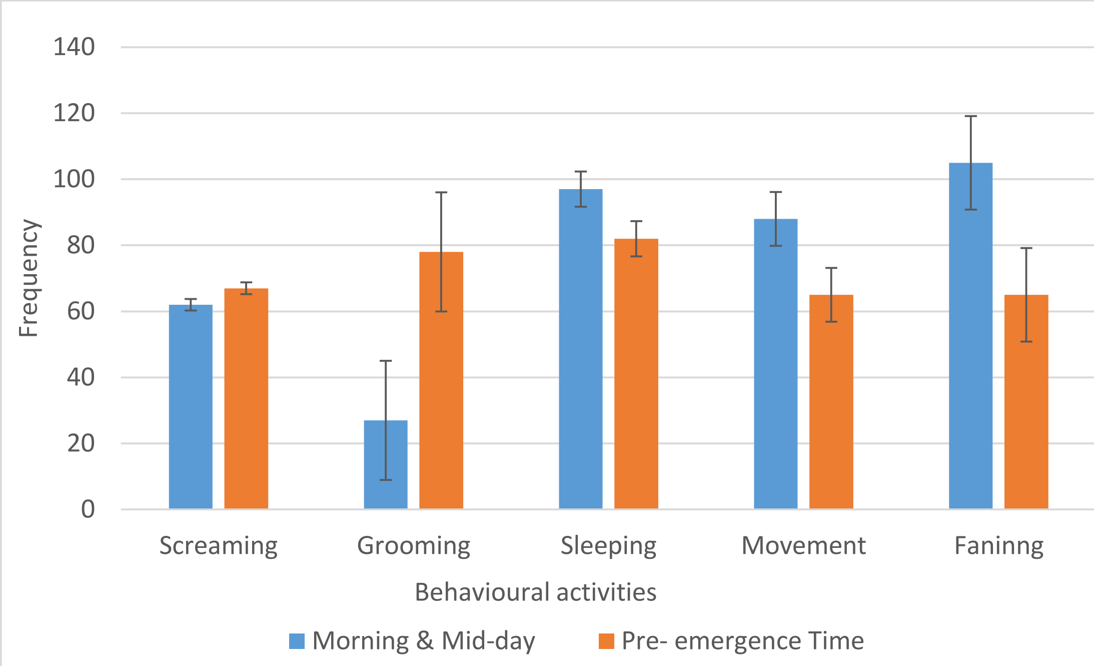


**Figure 3.** Diurnal and Pre- emergence activates of *Pteropus giganteus*

### 3.3 Emergence Phenology and Environmental Correlations

The emergence of *P. giganteus* followed a structured sequence, initiated by a few individuals from the peripheral canopy before the mass emergence of the colony. On average, emergence occurred 0.35 ± 0.12 hours post-sunset (Table 1).

| Month | Sunset | Emergence | Sunrise | Return flight |
|---|---|---|---|---|
| January | 18:14 | 17:20 | 07:16:00 | 07:32 |
| February | 18:39 | 18:21 | 07:15:00 | 07:55 |
| March | 18:55 | 18:40 | 06:52 | 06:42 |
| April | 19:04 | 18:52 | 06:24 | 06:36 |
| May | 19:02 | 19:02 | 06:21 | 06:52 |
| Jun | 19:27 | 19:19 | 05:58 | 06:25 |
| July | 19:28 | 19:38 | 06:08 | 06:30 |
| August | 19:14 | 18:58 | 06:18 | 06:48 |
| September | 18:53 | 17:26 | 06:28 | 07:12 |
| October | 18:20 | 17:34 | 06:34 | 07:10 |
| November | 17:58 | 17:28 | 06:51 | 07:34 |
| December | 18:02 | 17:26 | 07:09 | 07:45 |

### 3.3.1 Seasonal Variations in Timing

Emergence timing exhibited significant seasonal plasticity (Figure 4):

- **Winter:** Characterized by the earliest emergence, occurring between 17:30 and 18:37 h.
- **Summer:** Emergence was delayed, occurring between 18:38 and 19:46 h.
- **Monsoon:** The latest emergence window was recorded between 18:37 and 20:04 h.

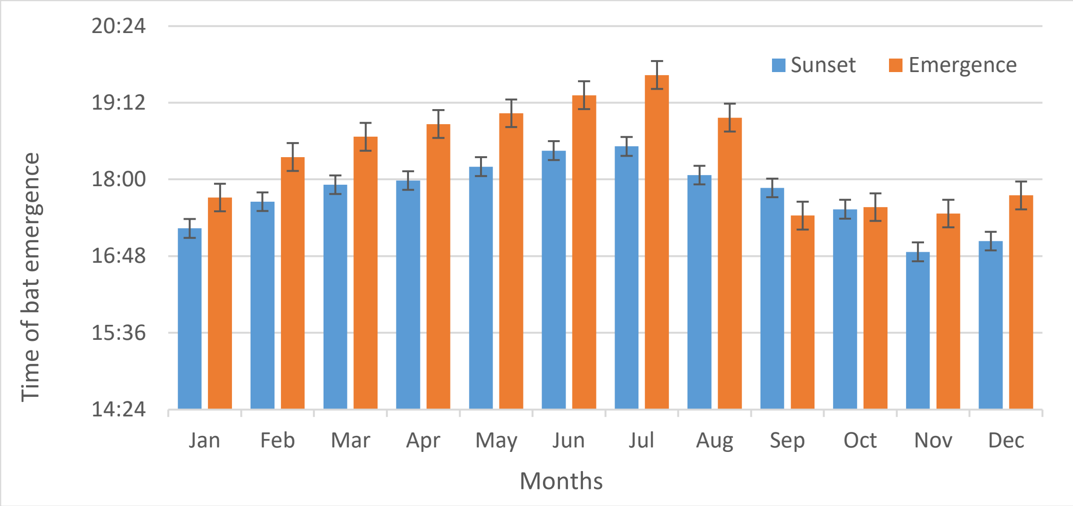


**Figure 4.** Relationship between sunset timing and the emergence activity of *Pteropus giganteus* across summer, monsoon, and winter seasons.

### 3.3.2 Environmental Cues and Photoperiod

Statistical analysis confirmed that emergence timing is tightly regulated by exogenous cues. A strong positive correlation was found between emergence and sunset time (r = 0.858, n = 12) as well as day length (r = 0.733, n = 12; Figure 5).

The day length varied from 10 h 32 min in winter to 13 h 12 min in summer. Shorter photoperiods in winter triggered earlier emergence, whereas longer summer days and higher ambient temperatures resulted in significantly delayed departure from the roost.

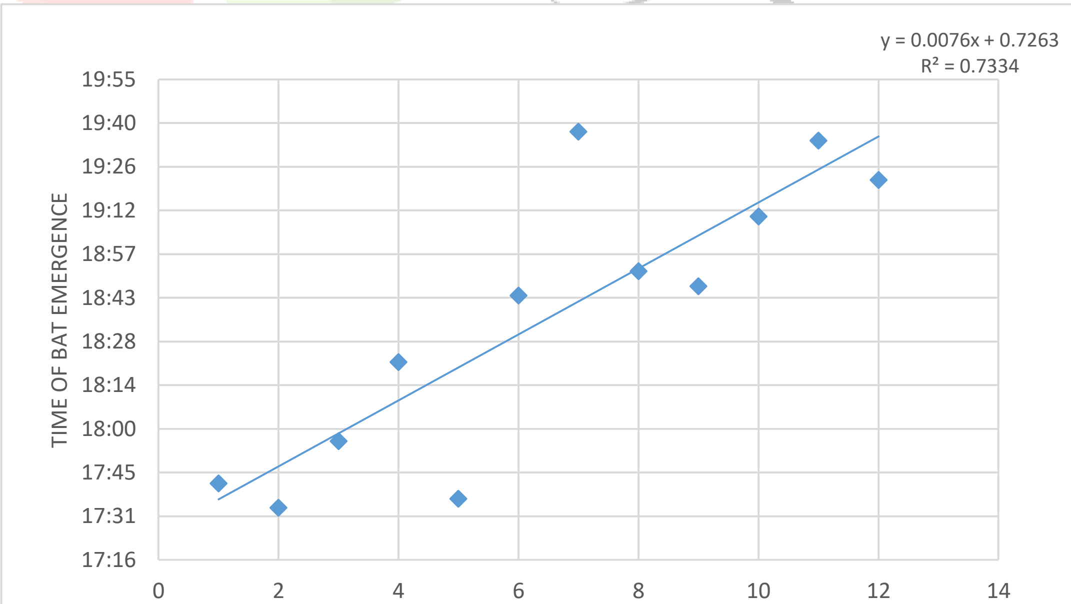


**Figure 5** Relation of day length and the time of bat emergence.

### 3.4 Population Dynamics

The colony size fluctuated significantly across seasons. A population peak was observed during the monsoon season, coinciding with the aggregation of males for reproductive purposes. Conversely, population declines were noted during the summer and non-reproductive periods, likely due to the dispersal of males from the primary roosting site.

Sleeping

Branch shifting

Screaming

Wing fanning

Plate 1 Diurnal activities of *Pteropus giganteus*

## 4. Discussion

### 4.1 Temporal Patterns and Environmental Cues for Emergence

The findings of this study demonstrate that *Pteropus giganteus* follows a strictly crepuscular emergence pattern, typically exiting the day roost approximately 30 minutes after sunset. This timing suggests that ambient light levels serve as the primary exogenous cue (Zeitgeber) for the colony. The strong positive correlation between emergence time and sunset (r = 0.858) aligns with previous observations of *Pteropus* species (Welbergen, 2006; Sudhakaran et al., 2012), reinforcing the hypothesis that sunset triggers a shift from diurnal resting to nocturnal foraging.

Furthermore, the seasonal variation in emergence—earlier in winter (17:24 h) and later in summer—indicates a high degree of behavioral plasticity. In winter, the extension of foraging duration to over 14 hours likely serves as an adaptive response to increased metabolic demands for thermoregulation and potentially lower fruit abundance, requiring bats to maximize their time in the field. Conversely, the delayed emergence observed during high-temperature periods suggests a thermal threshold; excessive heat may deter flight activity until the environment cools, a phenomenon also documented in *Tadarida brasiliensis* (Frick et al., 2012).

**4.2 Social Dynamics and Pre-Emergence Behavior**

The repertoire of pre-emergence behaviors—grooming, wing stretching, and vocalization—serves as more than physical preparation. These activities likely function as social signals to facilitate group synchronization. Our observation that only a subset of individuals initiated these behaviors suggests a hierarchical structure within the colony. Dominant individuals may act as "scouts" or leaders, where their departure cues a mass emergence, potentially reducing individual predation risk through the "dilution effect."

The influence of physiological state was also evident: individuals with higher energetic deficits (empty stomachs) emerged earlier. This supports the optimal foraging theory, where the need for nutrient acquisition outweighs the potential risks of emerging in higher light levels (e.g., predation by diurnal raptors).

**4.3 Reproductive Influence and Roost-Shifting**

Seasonal and reproductive status significantly modulated roosting dynamics. The increased emergence duration during the monsoon (01:26 h) coincided with peak reproductive activity. This suggests that the social complexity of the roost—including mate guarding by harem-holding males and the high energetic needs of lactating females—disrupts the "burst" emergence pattern seen in other seasons.

Roost-shifting during daylight hours, particularly by "unsuccessful" males or in response to solar tracking, highlights the importance of microclimatic selection. Bats relocated to cooler foliage to manage heat load, emphasizing that roost choice is a dynamic process driven by both social competition and thermoregulatory requirements. This behavior mirrors findings in *Eptesicus fuscus*, where shifting is a strategic move to optimize mating opportunities and energetic conservation (Willis and Brigham, 2004).

**4.4 Conservation and Ecosystem Implications**

The predictable relationship between *P. giganteus* activity and environmental variables has significant implications for conservation and public health. As a keystone species, their role in seed dispersal and pollination is concentrated during these identified foraging windows. Understanding these peaks is essential for:

1. **Reducing Human-Wildlife Conflict:** Identifying when bats are most active near orchards or urban centers.
2. **Habitat Management:** Protecting the specific tall-canopy trees used for thermoregulatory roost-shifting.
3. **Ecosystem Services:** Quantifying the temporal contribution of bats to forest regeneration.

## 5. Conclusion

The behavioral ecology and emergence patterns of the Indian flying fox (*Pteropus giganteus*) are fundamentally shaped by a complex interplay of environmental cues, social dynamics, and seasonal changes. This study highlights several key conclusions:

- **Environmental Triggers:** The timing of emergence is primarily governed by photoperiodic cues, specifically sunset timing and day length. Bats emerge significantly earlier during the shorter days of winter compared to the longer days of summer. Additionally, higher ambient temperatures were found to delay emergence, indicating a thermoregulatory influence on nocturnal onset.

- **Preparatory Social Behavior:** Emergence is not an isolated event but is preceded by a distinct shift in diurnal activities. Pre-emergence behaviors including increased grooming, wing stretching, and vocalization serve as critical social cues that synchronize the colony for flight.

- **Roost Selection and Utility:** The preference for tall, peripheral trees (such as Eucalyptus) underscores the importance of roost selection for predator sensing and aerodynamic ease. Diurnal activities like wing fanning and roost shifting are essential survival strategies for thermoregulation and social hierarchy maintenance.

- **Population Dynamics:** Seasonal population fluctuations at roost sites are driven by reproductive needs. The monsoon season see a population rise due to reproductive aggregation, while summer and winter see declines as bats disperse, likely due to changes in food availability or mating cycles.

- **Conservation Significance:** As vital "forest guardians" providing essential pollination and seed dispersal services, understanding these temporal and behavioral dynamics is crucial. These insights are necessary for developing effective conservation plans that protect critical foraging periods and habitats, ultimately helping to mitigate human-wildlife conflict.

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