Chapter II

BEHAVIOURAL ECOLOGY OF THE INDIAN FLYING FOX, *PTEROPUS GIGANTEUS*

A. DIURNAL AND EMERGENCE BEHAVIOUR OF *PTEROPUS GIGANTEUS*

INTRODUCTION

Indian flying fox, *Pteropus giganteus* gregariously live at roosts during daytimes. The roosts are the fundamental site of interaction and exhibition of various behavioural activities between roost mates. The day roost is a typical platform which provides a congenial environment for social behaviour (Granek, 2002). Moreover, the selection of roost is a functional integer of behavioural activities as it provides ample roosting area which is associated with the diurnal activities, predation sensing, luminous scanning and aerodynamic advantages (Richmond et al., 1998; Welbergen, 2006). Although various studies explained that the diurnal activities of flying foxes attracted a large number of regular and occasional visitor and it has a great role in the tourism (Walpole and Leader-Williams, 2002; Pennisi et al., 2004). In addition, they eminently provide pollination and seed dispersal services that offer fitness in the ecological process (Fujita and Tuttle, 1991). Moreover, various plants are mainly dependent on flying foxes for their generation alteration. Hence, keeping them as a forest guardian, the behavioural activities of *P. giganteus* are principally required to understand for conservation implementation.

The emergence behaviour of *P. giganteus* considered as an interesting phase because it bifurcates the diurnal and nocturnal activities. The nocturnal behaviour of *P.
**giganteus** begins with the emergence and ends with home flight. Though, the emergence behaviour of bats triggered by 12:12 h light-dark cycle but it is formally categorized as a predictable event (Erkert, 1982; Isaac and Marimuthu, 1993). Naturally, the emergence behaviour and pattern are greatly influenced by several climatic variables such as clouds, fog, moonlight (Welbergen, 2008), light intensity (Downs et al., 2003), rain (Entwistle et al., 1996), food availability (Lee and McCracken, 2001), predatory risk and age structure (Welbergen, 2006). Further, the pregnant and lactating females prepone their emergence than the rest of colony individuals (Duverge et al., 2000).

In term of behavioural studies, flying foxes such as *Pteropus livingstonii* (Courts, 1996), *P. alecto* (Markus, 2002; Markus and Blackshaw, 2002), *P. poliocephalus* (Connell et al., 2006), *Acerodon jubatus* are extensively studied in the Paleotropical regions (Hengjan et al., 2017). However, a few more studies have been carried out on the emergence behavior of *Pteropus* suggest that the emergence was influenced by twilight in *P. alecto* and *P. poliocephalus* (Welbergen, 2008), predation risk, foraging needs, and social context in *P. poliocephalus* (Welbergen, 2006) and *P. giganteus* (Sudhakaran et al., 2012) but there was no exclusive study on the effect of day length, sunset, and temperature on the emergence behaviour of the Indian flying fox, *Pteropus giganteus*. Therefore, the present study was aimed to fulfill the lacuna on emergence behaviour of *P. giganteus*.

**MATERIALS AND METHODS**

The present study was carried out between January 2013 – December 2015 in a colony of the Indian flying fox, *Pteropus giganteus* at the Northern Railway garden of Mohanlal Ganj (26°40'57.56"N; 80°59'1.49"E), Uttar Pradesh, India. The average day
length and time of bat emergence during summer (March – June), monsoon (July – October) and winter (November – February) were recorded. The behaviour of bats at their roosts was observed from a vantage point at three different time periods, i.e. morning (6 – 8 h), mid-day (11 – 13 h) and pre-emergence (16 – 18 h). Activities such as screaming, grooming, sleeping, wing fanning and roost shifting were recorded throughout the study period. The physical data such as sunset, day length (duration between onset and offset of the sun), and temperature (°C) were obtained from Indian Metrological Department. The time and number of bat emergence were recorded between the emergence of the first and last bat of the colony. The time of bat emergence was correlated with day length, sunset, and temperature. In addition, the time and duration of emergence were compared with different seasons.

RESULTS

The flying foxes were chosen tall and large Eucalyptus trees as their roost while a few trees of Azadirachta indica, Dalbergia sissoo, and Ficus religiosa were also present in the grove. The bats were occupied the well-exposed trees at the periphery of the large garden. The individuals of P. giganteus returned back to their roost before sunrise and they screamed continuously with short circle flights around their roost. They also switched their roosts to a couple of times before settling at a particular branch. Though, the bats spent a maximum of their day time for resting with folded wings, they were actively involved in various diurnal behaviours such as wing fanning (3%), grooming (6%), roost shifting (22%) and screaming (14%) until afternoon. However, they did not actively involve on wing fanning (8%), instead, they spent more time on grooming.
(26%), roost shifting (20%) and screaming (19%) during pre-emergence hours (Figure 2.1).

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\begin{align*}
\text{Screaming} & \quad \text{Grooming} & \quad \text{Sleeping} & \quad \text{Movement} & \quad \text{Fanning} \\
\hline
\text{Frequency} & \quad 140 & \quad 105 & \quad 70 & \quad 35 & \quad 0 \\
\end{align*}
\]

**Figure 2.1.** Diurnal and pre-emergence activities of *Pteropus giganteus* at the day roost.

*Pteropus giganteus* made a few circling flights around their roosts before emergence, presumably to assess the light and weather conditions for the emergence. The emergence was initiated by a few individuals which were occupied the peripheral canopy of the tree, followed by other individuals emerged from the roosts. An average bat emergence was observed 0:32 ± 0:10 h:m after the sunset. The time of peak emergence was varied throughout the year and seasons (Figure 2.2 a and b), and early emergence was observed during winter (17:30 – 18:37 h:m) than monsoon (18:37 – 20:04 h:m) and summer (18:38 – 19:46 h:m).
Figure 2.2. Mean frequency and emergence pattern of *Pteropus giganteus* over the study period (January 2013 to December 2015). a) Pattern of emergence from January to June, and b) Pattern of emergence from July to December.
The time of bat emergence was highly correlated with the time of sunset \( (r = 0.952, n = 12, \text{Figure 2.3}) \) and day length \( (r = 0.889, n = 12) \). Similar to the time of sunset, the day length varied over seasons \( (12:04 \pm 01:10 \text{ h:m}) \), and the shortest day length \( (10:48 \text{ h:m}) \) was observed during winter while longest day length \( (13:02 \text{ h:m}) \) observed during the summer season. Though, the bats were altered their time of emergence according to the day length, i.e. shorter the day length, earlier the emergence and longer the day length, later the emergence. Thus, time of bat emergence was highly correlated with the duration of day length \( (r = 0.889, n = 12, \text{Figure 2.4}) \). Further, the duration of emergence spread over a short span during winter compared to other seasons.

In addition to the time of sunset and day length, the temperature also influenced the time of emergence of \( P. \text{giganteus} \). The bat emergence was delayed with increasing ambient
temperature ($r = 0.886$, $n = 36$, Figure 2.5). The population of *P. giganteus* increased during monsoon season due to the aggregation of male individuals for reproduction and decreased steeply during summer and non-reproductive seasons possibly due to male dispersal (Figure 2.2 a and b).

![Graph](image)

**Figure 2.4.** Effect of day length on the time of bat emergence. The increasing day length delayed the emergence time of *Pteropus giganteus*. 

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Figure 2.5. Effect of ambient temperature on the time of emergence of *Pteropus giganteus*.

**DISCUSSION**

The results of present study suggest that the individuals of *P. giganteus* emerged from their day roost around 30 min after the sunset. The bats exhibited pre-emergence activities such as wing stretching, squawking, grooming and short flight around the roosts possibly to advertise the time of emergence to the roost mates. The few individuals which were exhibited the pre-emergence behaviour might hold dominancy in the colony. The roost shifting behaviour of *P. giganteus* observed throughout the day hours associated with finding out the suitable foliage for roosting, thermoregulation and social interaction with the group members. Though, *P. giganteus* reproduces seasonally, the reproductive behaviour such as pair bonding, courting the females, licking the face and genitalia of females by males were observed throughout the year (Maruthupandian and Marimuthu,
The successful male undergone pair bonding and subsequently copulated with the females and the unsuccessful males kept on shifting the roost over the day. The roost shifting behaviour facilitates acquiring suitable foliage, social interaction, and reproduction in *Eptesicus fuscus* (Willis and Brigham, 2004). The wing fanning during sunny hours make them maintain thermoregulation with ambient temperature, *P. hypomelanus* increased wing fanning with increasing temperature while decreased with decreasing temperature (Ochoa-Acuña and Kunz, 1999). *Pteropus giganteus* altered their diurnal activities as they approached emergence time. They actively involved in wakeup, body warm up, sensing of weathers, and suitability of emergence. Grooming and wing stretching make them ready for emergence while vocalization synchronizes their wake up (Sudhakaran et al., 2012). The bat emergence was entirely based on group size and their reproductive conditions, perhaps the males of larger groups emerge at the end (Welbergen, 2006). The lactating females of many species of bats prepone their emergence, like *Chaerephon pumila* (McWilliam, 1989), *Lasiurus cinereus* (Barclay, 1985), *Myotis velifer* (Jones and Rydell, 1994), and *Nyctalus noctula* (Jones, 1995).

Day length is an explicit feature of the environment that decide the behavioural activities. Nevertheless, the bats emerged after sunset but the duration of emergence varied among seasons. The early emergence was observed during winter (17:30 h:m), delayed emergence during summer adhered to the sunset. Thus, the sunset triggers the emergence of *P. giganteus*. However, the duration of emergence was near similar during summer (01:08 h:m) and winter (01:07 h:m) than the monsoon season (01:27 h:m). The long duration emergence during monsoon season corresponds to reproductive activities at the day roosts. Although, long dark hours available to bats during the winter season but
the bats did not delay their emergence, instead they emerged soon after the sunset. The outcome of this study revealed that the time of emergence was absolutely based on time of sunset and thus yielded a correlation coefficient of $r = 0.952$. The emergence of *Pteropus* soon after the sunset was reported by various studies (Welbergen, 2006; Sudhakaran *et al.*, 2012). It was previously observed that several nontropical vertebrates altered their behaviour such as diurnal movement, foraging strategies, pelage pattern, and sleep duration according to day length (Heldmaier *et al.*, 1989; Sauter *et al.*, 2012). Though, the emergence was influenced by various physical factors, the time of sunset played a crucial role. Although, *P. giganteus* roosts in well-exposed trees over the day, the emergence occurred after sunset. Albeit, the ambient temperature also played a significant role in the emergence of *P. giganteus*. The emergence of *P. giganteus* was also determined by temperature as it was observed in *Tadarida brasiliensis* (Frick *et al.*, 2012).

The amiable environmental conditions during monsoon season favour reproduction of *P. giganteus* hence the aggregation increase the population size while segregation of individuals during non-reproductive seasons (summer and winter) declined the population size. It was reported that the population of *Pteropus* steeply decreased during non-breeding period (summer season) due to scanty food and sometimes local migration (Tidemann and Nelson, 2004a). Thus, the present study reveals that the emergence behaviour of the Indian flying fox, *Pteropus giganteus* influenced by the physical parameters such as day length, sunset, and temperature.
B. REPRODUCTIVE BEHAVIOUR OF *PTEROPUS GIGANTEUS*

INTRODUCTION

The order chiroptera represents one such an amazing diversity of 1300 extant paleotropical and neotropical species (Shi and Rabosky, 2015). However, inaccessible roosting nature makes them a typical species and hence very few studies have focused on the reproductive aspect of bats (Maruthupandian and Marimuthu, 2013). During reproductive seasons, flying foxes involved in various reproductive activities such as grooming of body parts and genital organ (Tan et al., 2009; Maruthupandian and Marimuthu, 2013; Sugita, 2016). Indian flying fox, *Pteropus giganteus* roosting on tall trees which is almost faraway from eyesight. Hence, it is tough to observe the behavioural activities particularly the reproductive behaviour of *P. giganteus*. Presumably, it might be a reason for information scarcity on the reproductive behaviour of *P. giganteus*. Therefore, this study was carried out to investigate the reproductive behaviour of *Pteropus giganteus*.

MATERIALS AND METHODS

An extensive field observation was carried out between 2013 and 2016 during the reproductive seasons of *Pteropus giganteus* in a colony located at Nassulapur, Ambedkar Nagar district, Uttar Pradesh, India (26°32′40.81″N; 82°33′40.59″E). The individuals of *P. giganteus* were roosting on *Ficus benghalensis* (*n* = 1), *Azadirachta indica* (*n* = 1), *Mangifera indica* (*n* = 13) and *Ficus religiosa* (*n* = 1). The reproductive behaviour of *P. giganteus* was observed from a vantage point. In addition, the frequency, time and duration of copulations were observed. Further, the frequency of wing stretching, vulva
licking, and grooming was observed through binocular and precisely recorded through stopwatch. The Pearson correlation \((r)\) was applied to study the relationship between the duration of vulva licking and copulation.

**RESULTS**

After the home flight, the individuals of *P. giganteus* were actively engaged in roost alteration which facilitated them for finding suitable mates. The male bats made many circling flights around the roost and exhibited quadrapedal movement until finding a suitable mating partner. The bats have selected a few tree species such as *Ficus benghalensis* \((n = 1)\), *Azadirachta indica* \((n = 1)\), *Mangifera indica* \((n = 13)\) and *Ficus religiosa* \((n = 1)\). The roosting pattern of *P. giganteus* varied over reproductive season, a few individuals of *P. giganteus* were roosting at the base branches of the roost tree while reproductively active individuals observed at peripheral canopies. The reproductive activities of bats were observed from peripheral canopies rather than dense and leafy area. The reproductive behaviour of *P. giganteus* was varied over the reproductive season from July to November. The higher number of copulation was recorded during September \((6.3 \pm 5.7 \text{ SD})\) followed by October \((3.3 \pm 3.0 \text{ SD})\) while very few copulations were observed during July \((1.2 \pm 0.4 \text{ SD})\) and November \((1.0 \pm 0.5 \text{ SD}, \text{ Figure 2.6})\).
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Figure 2.6. The frequency of copulation during the reproductive season of *Pteropus giganteus*.

Figure 2.7. The pattern of reproductive activity of *Pteropus giganteus* during day hours.
Pteropus giganteus screams during copulation and they were more active during cloudy hours than sunny period. The male bats were very active and involved in courting of females mainly during forenoon (cloudy hours) than afternoon (Figure 2.7). As pre-copulation activity, the male bat approached a female and courted by stretching its wings. The male exhibited an average $16.2 \pm 4.5$ SD wing stretching and $65.5 \pm 26.8$ SD vocalization prior to copulation. The courting behaviour was associated with sexual potentiality of male and determine mate choice in P. giganteus. Once a male courted a female, the male engaged in vulva licking ($36.3 \pm 6.4$ sec, $n = 84$, Plate 2.1a) before copulation. During the copulation, the male grips the female through claws and mouth and sometimes wraps by patagium. The duration of vulva licking by a male was directly proportional to the duration of copulation ($r = 0.835$, Figure 2.8). The copulation was observed from both dorsal and ventral side of the body (dorsal mounting in the Plate 2.1b). After the copulation, both the sexes were segregated from each other and settled for a while. They also engaged in grooming of genital organ, snout, and patagium for an average $50.3 \pm 9.8$ sec (Plate 2.1c). On various occasions, the potentially active male was exchanged the roost trees for exploring other mating opportunities while the female retained the same roost.
Figure 2.8. The effect of vulva licking on copulation duration of _Pteropus giganteus_.

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Plate 2.1. The reproductive activities of *Pteropus giganteus* during copulation such as vulva licking (a), dorsal mounting (b) and grooming of body organs after copulation (c).
DISCUSSION

In the present study, it was observed that the individuals of *P. giganteus* actively involved on copulation between July and November, while the peak copulation was observed during September. However, similar observation on the reproduction of *P. giganteus* was also reported by various studies (Mathur *et al*., 2012; Maruthupandian and Marimuthu, 2013; Baki *et al*., 2015). The high frequency of copulation observed at forenoon suggest the existence of pleasant weather and biologically active period than afternoon. It may also be a matter of physical fitness, as the bats accumulate higher energy after their home flight. Moreover, warm weather conditions favours reproduction and fetus development while hot and dry seasons inhibit the reproduction and even cause mortality in flying foxes (Welbergen *et al*., 2008).

The exhibition of various behavioural activities such as wing stretching, vocalization and licking of genital region was commonly observed in this study. Generally, male stretches wings for demonstration of it potentiality and attracting the females. The pre-copulatory activities had a significant impact on the duration of copulation. It suggest that male spent more body energy in pre-mating activities than rest of the social activities. Therefore, the physical strength of male have a crucial role in reproductive behaviour (Kyogoku, 2015; Takakura and Fujii, 2015). It is obvious that the foreplay altered copulation and played a significant role in the reproductive aspects of bats (Tan *et al*., 2009; Maruthupandian and Marimuthu, 2013; Sugita, 2016). In the present study, it was also observed that *P. giganteus* copulates from both dorsal and ventral sides. Though, dorsal and ventral copulation are well elaborated in flying foxes
but still it's need further investigation on the role of body plan in flying foxes reproduction (Maruthupandian and Marimuthu, 2013; Baki et al., 2015).

The segregated mating partner grooms patagium, toes and genital organs independently which presumably enhanced reproductive fitness in P. giganteus (Maruthupandian and Marimuthu, 2013). The outcome of this study may pave various novel approaches on the reproduction of Indian flying fox, Pteropus giganteus.