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STUDIES ON THE ACTIVITY AND DAILY EXODUS OF *ROUSETTEUS LECHENAULTI* A CAVE DWELLING BAT IN TWO GEOGRAPHICALLY ISOLATED CAVES OF ORISSA, INDIA

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ABSTRACT
Approximately 330 cave dwelling bats of Udayagiri cave in Bhubaneswar and 170 bats of Ganesh cave, Hinjilikatu in Orissa, India were observed during four different season's spring, summer, Autumn and Winter. The longest pre emergence activity was recorded on June 21, 2009 for Ganesh cave and on June 22, 2009 for Udayagiri cave. The shortest pre emergence activity was recorded on December 20, 2009 for Ganesh cave and on December, 21, 2009 for Udayagiri cave. Significant correlation ($p < 0.05$) was observed between the pre emergence activity and length of the day during all the seasons of study. The intensity of the emergence activity increased sharply and then declined slowly in both the caves. Statistically significant correlation ($p < 0.05$) was observed between the timing of emergence of first bat and the time of sunset in both the caves. The timing of end activity (the time when the last bat returned) precisely preceded the timing of sunrise (of next day) irrespective of the month of study. A statistically significant correlation ($p < 0.05$) was observed between the timing of return of the last bat and the time of sunset. Diurnal rhythm in the activity patterns of the bat colonies were greatly influenced by natural light- dark cycle, temperature and availability of food.

INTRODUCTION

According to season and topography, the timing and duration of sunset and sunrise changes. The behavior of the organisms that depend on sunset and sunrise for information changes with respect to the sunrise and sunset. The circadian rhythm of the organism exhibits comparable variation with sunset and sunrise in different seasons. This has been fairly seen in several avian and mammalian species, including bat of temperate region (Esterla, 1973; Bateman and Vaughan, 1974; Fenton and Kunz, 1977; Anthony *et al.,* 1981). Conservation of various bat species depend on an in depth study on their daily and migratory behavior (Vendan *et al.,* 2008). Some information on the daily onset and end of activity of tropical cave dwelling bats is available (Subbaraj and Chandrashekaran, 1977; Usman, 1981; Marimuthu, 1984; Vaughan and Vaughan, 1986; Biswas and Kanoje, 1992; O'Brien *et al.,* 1993). Therefore the present study was undertaken to observe the emergence and returning activities in a cave dwelling Fulvous fruit bat (*Rousetteus lechenaulti*) in two isolated caves of Orissa state, India.

MATERIALS AND METHODS

Study site

Two caves namely Udayagiri in Bhubaneswar and Ganesh cave, Hinjilikatu, Orissa were selected for observations.

Udayagiri cave (Lat 20º15′ N, Long 85º47′ E) is located atop Kumari parvat on Kumari hill at an altitude of 82 m from MSL. Udayagiri cave is a combination of natural cavern and cared structure of sandstone. There are total 18 caves of which two storied Ranigumpha cave was selected for present study. The cave has two openings, each opening leads to a singe inner chamber. The inner chamber is 3-7 m in width, 15-20 m in length and ½ to 1 and ½ m in height. There are 3 large holes leads to tunnels about ½ m diameter and 1 to 5m long. Many small holes and crevices are also there. Shelves like structures are also present. Out of three large tunnels, one tunnel is very moist throughout the year and in rainy season it is flooded with rain water. Except two entrances, there is another very small outlet of the inner chamber. The temperature inside the cave remains constant throughout the year (28 ± 2ºC). A colony of about 330 bats (*Rousetteus lechenaulti)* inhabits this cave as there roosting site.

The second study site Ganesh cave (Lat 19º29′ N, Long 84º44′ E) near Hinjilikatu at an altitude of 172 m from MSL atop Mendhamara hill, in Ganjam district of Orissa. A small crevice is the entrance of this cave. The main chamber leads to two downward small chambers and two upward large crevices .One of the crevices open outside through a tunnel like opening. A colony of about 170 bats (*Rousetteus lechenaulti)* inhabits this cave as the roosting site.

The timing of emergence and return of the first bat were recorded visually using a hand tally counter (Vendan *et al.,* 2008) during dusk and dawn respectively at the mouth of the

caves during different seasons, Winter (December), Spring (March), Summer (June) and Autumn (September). Observations were made during dusk and dawn until the last bat emerged or returned. The total number of bats emerged or returned during a single daily (dusk of a day with dawn of the next day) activity cycle was noted.

The median timings (m) of emergence or return were computed for calculating the phase angle difference for median emergence (PDM) in relation to seasonal variations in the timings of sunset(c) and sunrise(y). In case of sunset, PDM= m-c and in case of sunrise, PDM= m-y (Biswas and Kanoje, 1992).

RESULTS

Figs. 1 to 4 (23 March 2009, 22 June, 09, 21 September, 09 and 21 December, 09) and Figs. 5 to 8 (22 March 2009, 21 June, 09, 20 September, 09 and 20 December, 09) represent daily exodus of bat of Udayagiri and Ganesh cave respectively.

Figs. 9 to 10 (24 March 2009, 23 June, 09, 22 September, 09 and 22 December, 09) and Figs. 11 to 16 (23 March 2009, 22 June, 09, 21 September, 09 and 21 December, 09) represent the daily return of bat of Udayagiri and Ganesh cave respectively.

Pre emergence activity

The time of pre emergence activity (a) was recorded just prior to the beginning of sunset during all the four seasons. The length of the pre emergence activity was found to be different during different months of study. PEAD (pre-emergence activity duration) = b-a, where "b" is the time of emergence of first bat and "a" is the time of start of pre-emergence activity. The longest pre emergence activity was recorded on June 21, 2009 for Ganesh cave of Hinjilikatu and June 22, 2009 for Udayagiri cave of Bhubaneswar and shortest on December, 20, 2009 for Ganesh cave of Hinjilikatu and December, 21, 2009 for Udayagiri cave, Bhubaneswar. The length of the pre emergence activity was statistically analyzed by using correlation test and found to be significant with the length of the day. (For Udayagiri cave r= 0.87, $p<0.05$, Fig. 19; for Ganesh cave r=0.84, $p<0.05$, Fig. 20).

Emergence activity

In the beginning, emergence of bats occurs singly or in small groups. The intensity of the emergence activity increased rapidly and then declined slowly in both the caves. Median timings (m) of emergence activities were computed and phase angle difference were determined in relation to respective sunset timings during different months under study.

A statistically significant linear relationship was observed between the timing of emergence of first bat and the time of sunset (For Udayagiri cave r= 0.82, ($p<0.05$), Fig. 21; for Ganesh cave r=0.87, $p<0.05$, Fig. 22).

Return activity

The timing of end activity(x) (the time when the last bat returned) precisely preceded the timing of sunrise (of next day) irrespective of the month of study. A statistically significant correlation was observed between the timing of return of the last bat and the time of sunset. (For Udyagiri cave r= 0.84, ($p<0.05$), Fig. 23; for Ganesh cave r=0.82, $p<0.05$, Fig. 24).

DISCUSSION

The activity of animals are very much dependant on the timing of sunrise and sunset. In nocturnal animals the sunset and sunrise timings is most important factor for beginning and for end of activity respectively. (Davis and Dixon, 1976; Erkert, 1982). The bats are nocturnal mammals and depends more upon auditory rather than visual stimuli (Griffin, 1958; Vaughan, 1976). Therefore, the relationship between bats exodus flight activity and daily light cycle are of great interest.

Under natural day length condition the onset of emergence activity in *Hipposideros speonis* at lower latitude (Madurai, Lat 9°58′ N, Long 78°10′ E) was found to occur within a

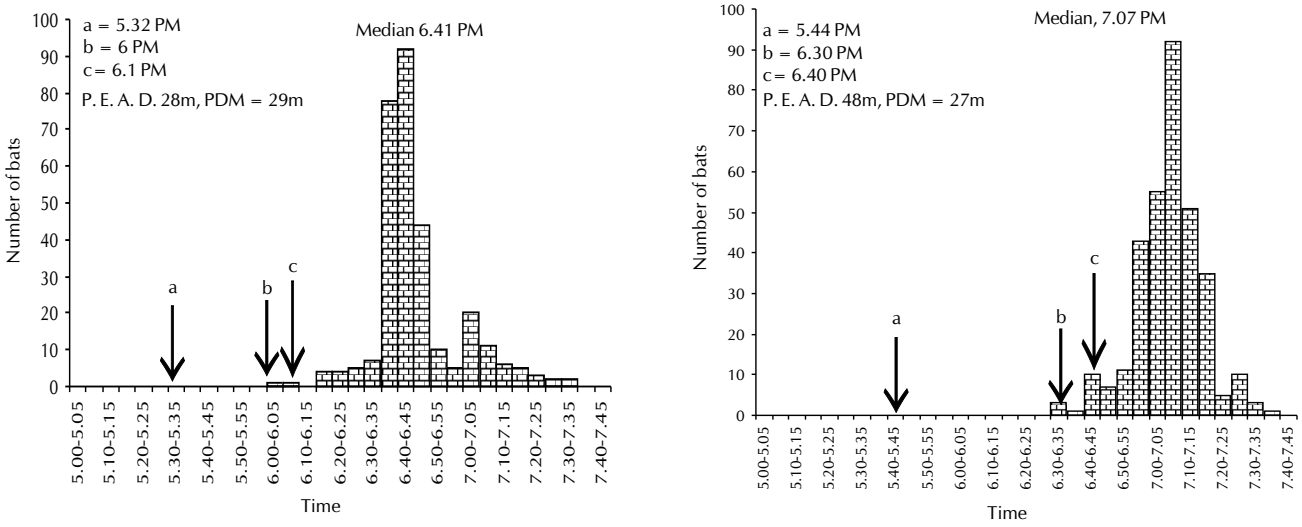
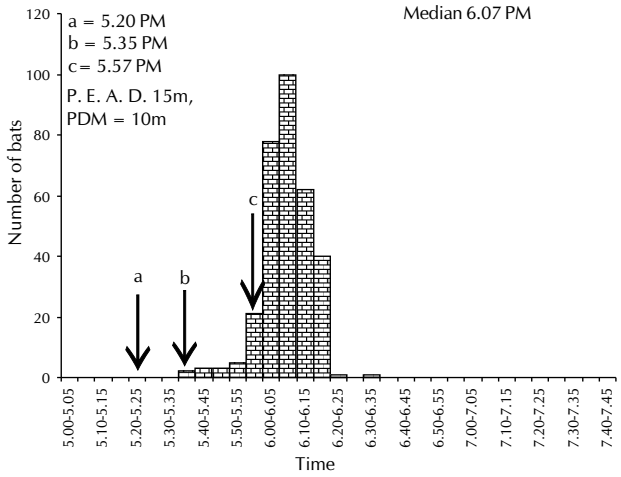


Figure 1 and 2: (for Udayagiri cave) x axis represnets time, y axis represented by bar, the total number of bats leave the cave over 5 minutes. The arrow marking a, b,c in each column indicates the time of pre emergence activity, emergence of 1st bat and time of sunset respectively.PEAD = pre existing activity duration (b-a). PDM = phase angle differences for median emergence (m-c)



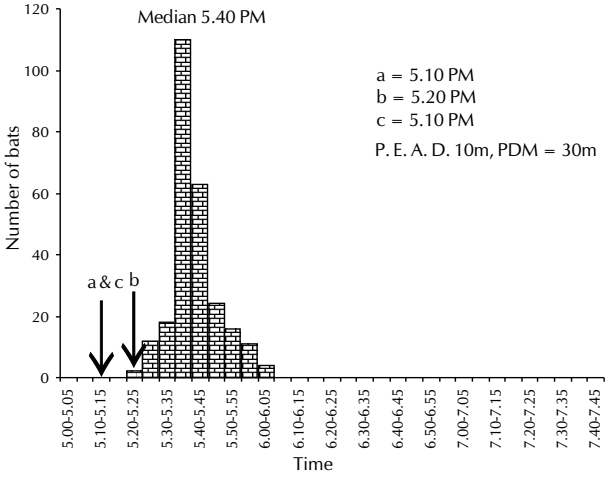
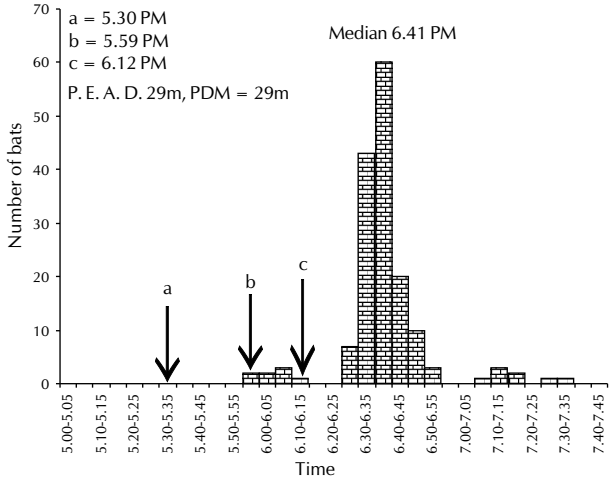


Figure 3 and 4: (for Udayagiri cave) x axis represnets time, y axis represented by bar, the total number of bats leave the cave over 5 minutes. The arrow marking a, b,c in each column indicates the time of pre emergence activity, emergence of 1st bat and time of sunset respectively.PEAD = pre existing activity duration (b-a). PDM = phase angle differences for median emergence (m-c)



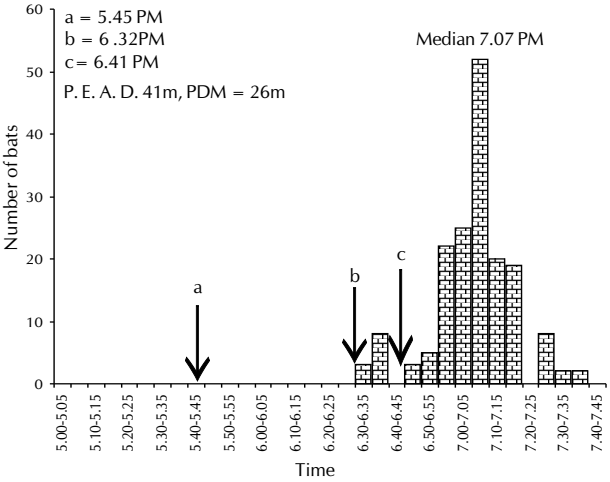
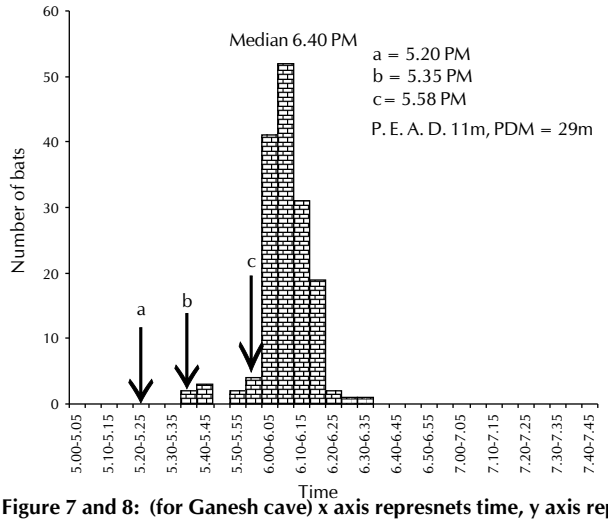


Figure 5 and 6: (for Ganesh cave) x axis represnets time, y axis represented by bar, the total number of bats leave the cave over 5 minutes. The arrow marking a, b,c in each column indicates the time of pre emergence activity, emergence of 1st bat and time of sunset respectively.PEAD = pre existing activity duration (b-a). PDM = phase angle differences for median emergence (m-c)



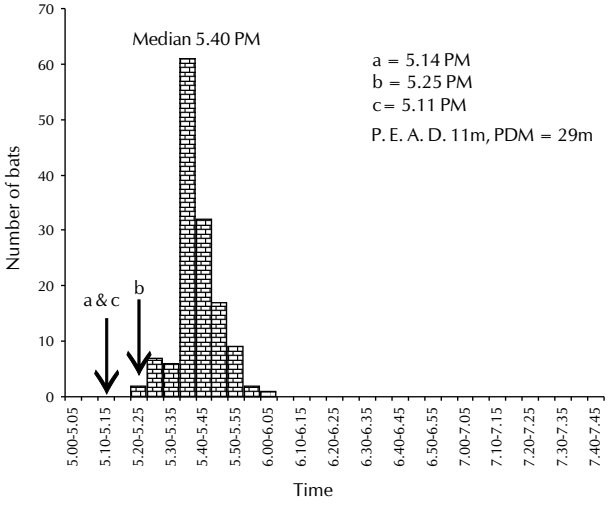
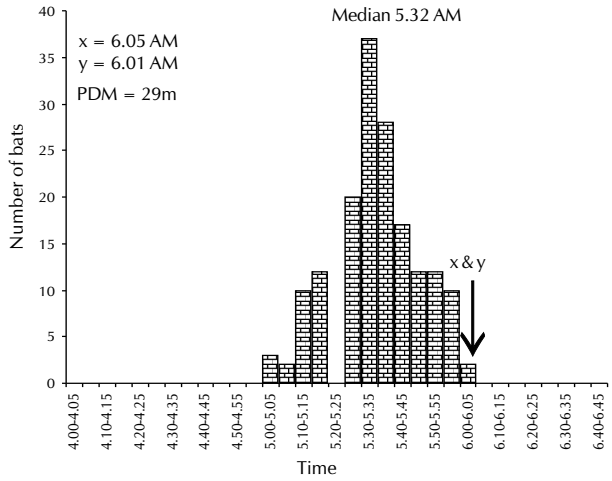


Figure 7 and 8: (for Ganesh cave) x axis represnets time, y axis represented by bar, the total number of bats leave the cave over 5 minutes. The arrow marking a, b,c in each column indicates the time of pre emergence activity, emergence of 1st bat and time of sunset respectively.PEAD = pre existing activity duration (b-a). PDM = phase angle differences for median emergence (m-c)



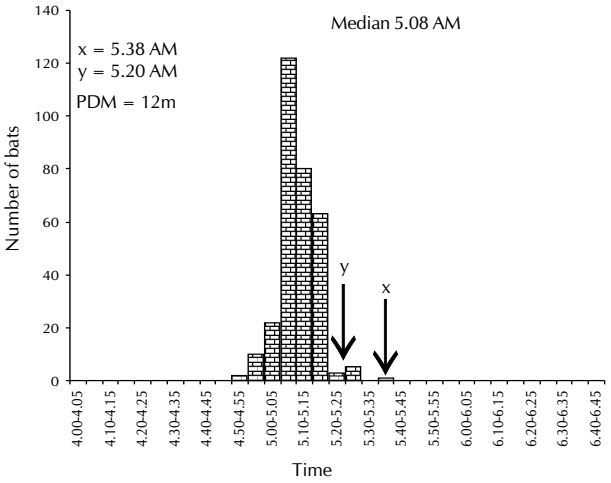
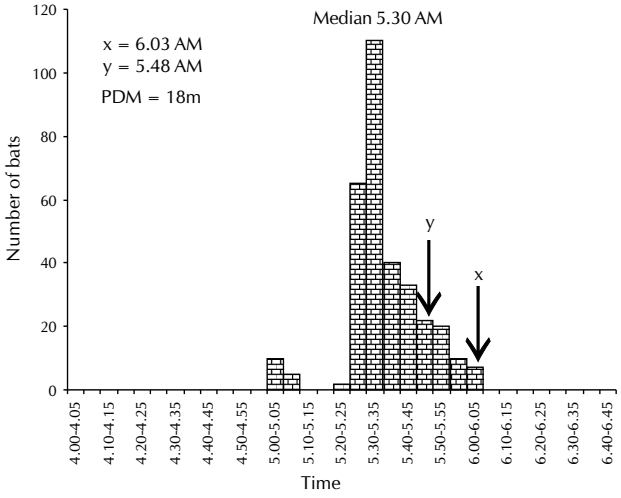


Figure 9 and 10: (for Udayagiri cave) x axis represnets time, y axis represented by bar, the total number of bats return to the cave over 5 minutes. The arrow marking x, y in each column indicates the time of returning of last bat and time of sunrise respectively. PDM = phase angle differences for median emergence (m-y)



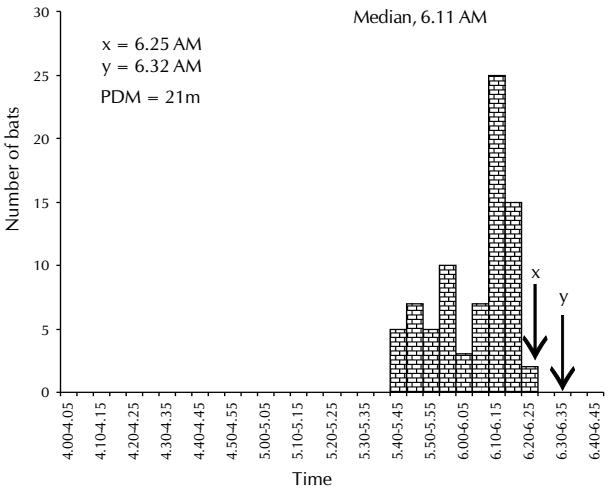
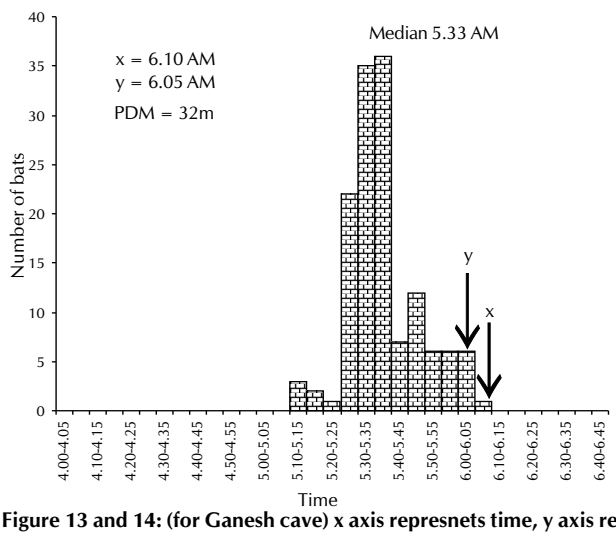


Figure 11 and 12: (for Udayagiri cave) x axis represnets time, y axis represented by bar, the total number of bats return to the cave over 5 minutes. The arrow marking x, y in each column indicates the time of returning of last bat and time of sunrise respectively. PDM = phase angle differences for median emergence (m-y)



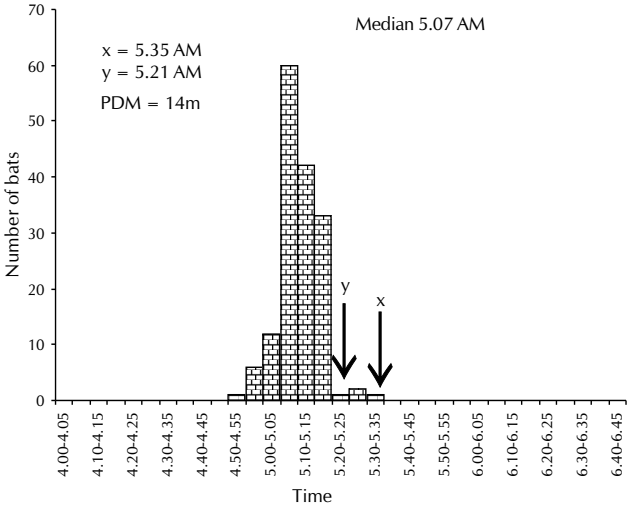
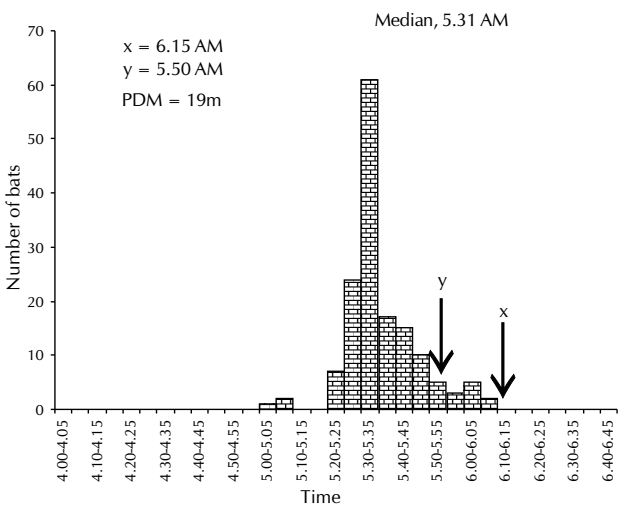


Figure 13 and 14: (for Ganesh cave) x axis represnets time, y axis represented by bar, the total number of bats return to the cave over 5 minutes. The arrow marking x, y in each column indicates the time of returning of last bat and time of sunrise respectively. PDM = phase angle differences for median emergence (m-y)



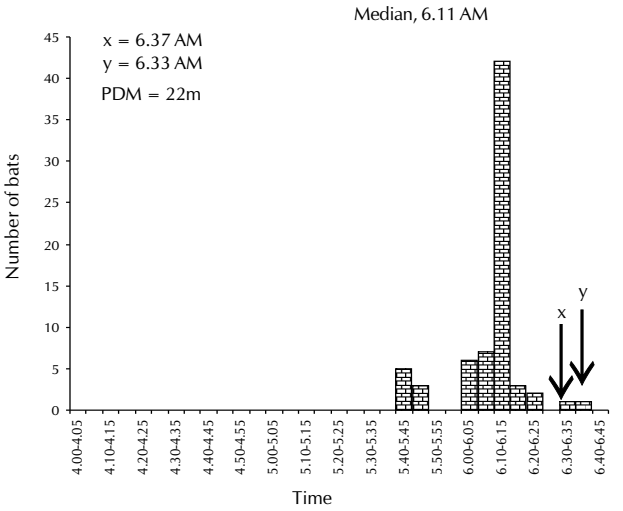
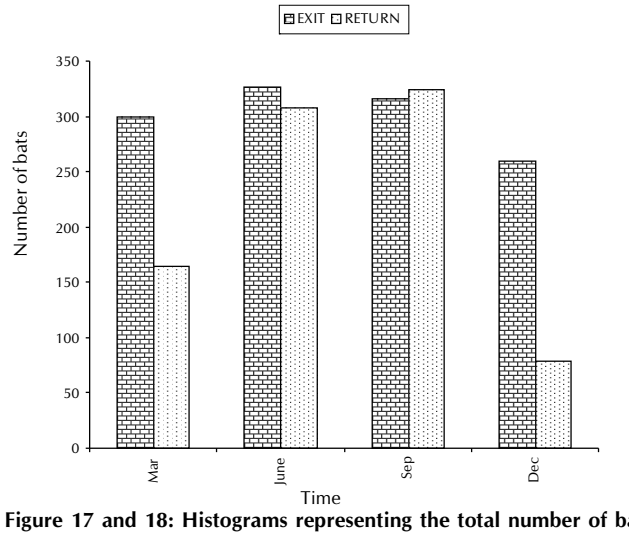


Figure 15 and 16: (for Ganesh cave) x axis represnets time, y axis represented by bar, the total number of bats return to the cave over 5 minutes. The arrow marking x, y in each column indicates the time of returning of last bat and time of sunrise respectively. PDM = phase angle differences for median emergence (m-y)



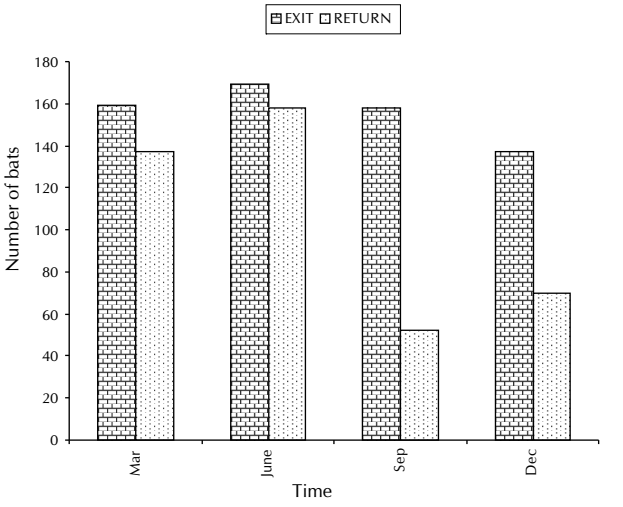
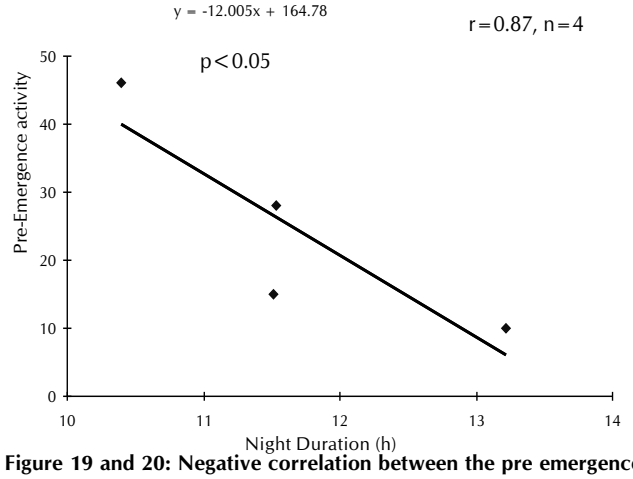


Figure 17 and 18: Histograms representing the total number of bats emerging from the cave as well as returning back to the cave at four different months of the year of Udayagiri and Ganesh cave respectively



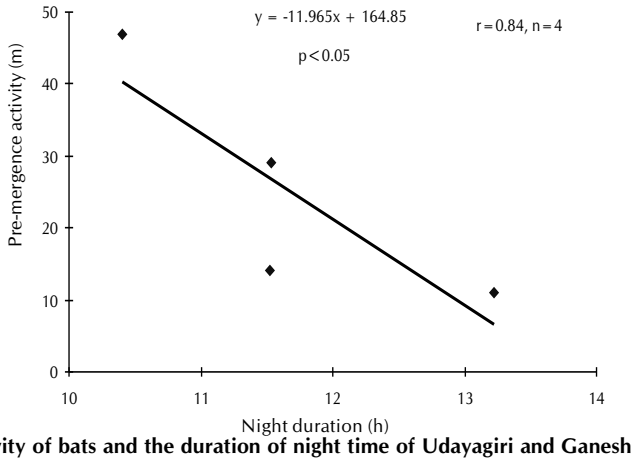


Figure 19 and 20: Negative correlation between the pre emergence activity of bats and the duration of night time of Udayagiri and Ganesh caves respectively

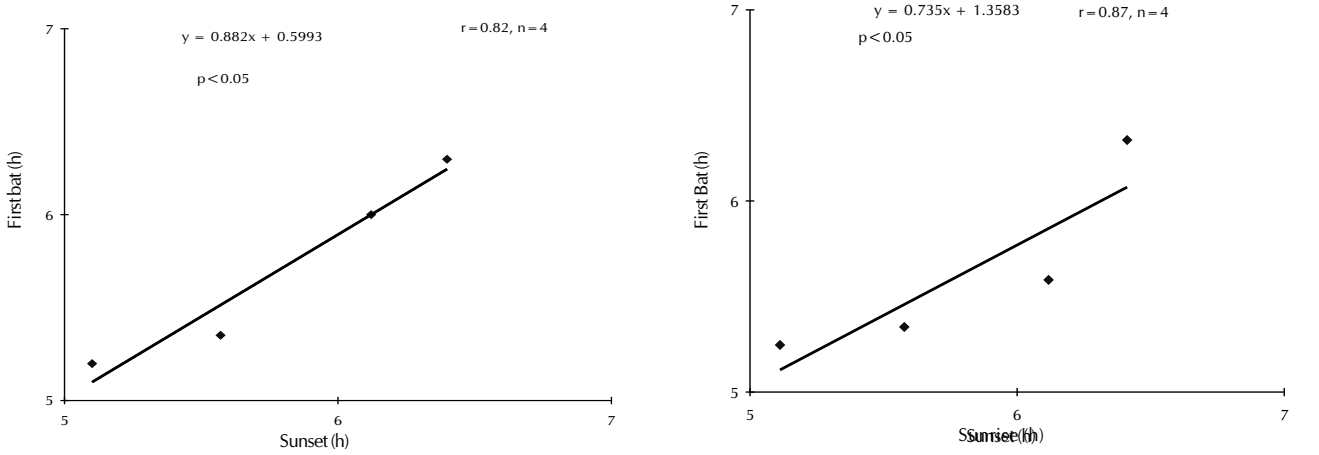


Figure 21 and 22: Linear regression of time of emergence of the 1st bat in relation to the time of sunset of Udayagiri and Ganesh caves respectively

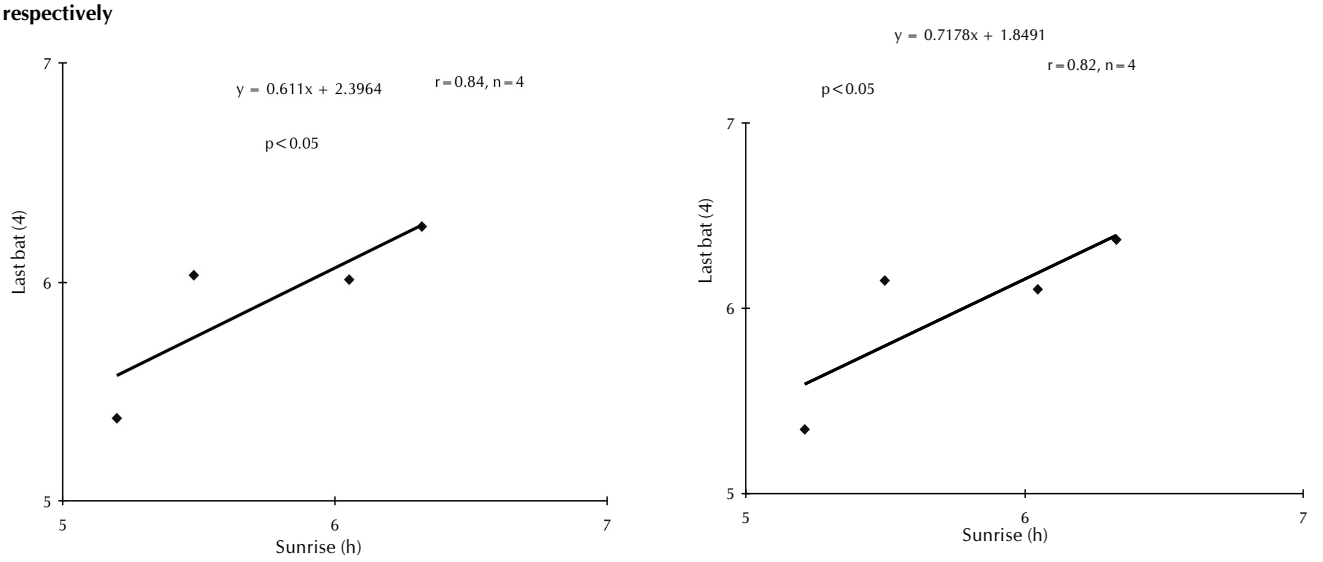


Figure 23 and 24: Linear regression of time of return of the last bat in relation to the time of sunrise of Udayagiri and Ganesh caves respectively

certain range of environmental light which varied over the season. However, it was found to be independent of any fixed threshold value of light (Davis and Dixon, 1976; Marimuthu, 1984). It was also found that the seasonal changes in the timing of daily activity in tropical bat *Hipposideros fulvus* keep pac with the different components of the changing light- dark cycle during different seasons of the year (Biswas and Kanoje, 1992). But all the previous studies were conducted in single study site. The present study was conducted in two different caves at two different regions. The time lag between the onset of pre emergence activity and emergence timing was fund to be different during different seasons for the year for *Rousetteus lechenaulti* at both the caves. The caves exhibited striking similarities.

In this study the median timings for both the emergence and returning activities have been completed and the phase angle differences have been determined taking into consideration median timings of these activities rather than the time when the 1st bat emerged or the last bat entered in to the cave. The central tendency in the behavioural pattern of the entire population reflects the characteristic of a circadian oscillation more precisely (Biswas and Kanoje, 1992). The spread of the phase angle calculated was found to be minimum (10m in Udayagiri cave, 11m in Ganesh cave) with respect to sunset times. In contrast, in relation to sunrise timings the spread phase angle was relatively more. On the basis of these observations it could be concluded that the sunset timings are more important for synchronization of the daily activity rhythm of *Rousetteus lechenaulti*. Similar pattern of emergence has been observed in different bat species by several authors (Licht and Leitner, 1967; Usman, 1981; Erkert, 1982; Marimuthu, 1984; Speakman, 1990). Even median timing of emergence and returning activity has been taken into consideration for computation of the phase angles during different seasons of the year (Vaughan and Vaughan, 1986; Biswas and Kanoje, 1992). Yet none has taken more than one study site of the two different locations for new results.

Bats inhabiting temperate zone caves have been known to undergo hibernation (Davis, 1970; Ransome, 1990; Fleming and Eby, 2003; Cryan, 2003; Isabelle *et al.*, 2009). Usually the temperature of any cave reflects the annual mean temperature of the particular area where the cave is located

(Barr, 1968). Results of the present study clearly reveals that *Rousetteus lechenaulti* does not undergo hibernation. However, the duration of activity during winter months was found to be greatly reduced. A marked difference in the intensity of emergence and return during December in both the caves (Figs. 17 and 18) suggest that the time duration for return is relatively wider and spreads all over the night length. It shows that the external temperature may be unfavorable for activity of bats during winter but not bad enough for total suspension of the activity. Similarly the unusual pattern in September reflects that the temperature at night is very favorable to bats. So the number of bats exits and return during night is very common throughout the night.

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