INFLIGHT AND OUTFLIGHT ACTIVITY PATTERNS OF FIVE SPECIES OF CAVE DWELLING BATS IN SRI LANKA

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ABSTRACT

Wavulgalge, a natural cave situated in Nikapitiya, Koslanda (6°40' - 6°45'N: 80°00'-81°05'E), in the eastern region of Sri Lanka is sympatrically inhabited by five species of bats, i.e., four microchiropterans; *Rhinolophus rouxii* (10000 - 12000 individuals), *Hipposideros lankadiva* (1500 - 2000), *Hipposideros speoris* (200 - 300), *Miniopterus schreibersii* (700 - 1000) and one megachiropteran, *Rousettus leschenaulti* (5000 - 7000). Field studies were carried out from May 1988 to November 1989 in this cave to study the factors influencing the timing of inflight and outflight activity of each bat species. Throughout the study period the outflight commenced ca. 10 minutes before the sunset (light intensity 150-350 lux) and the bats returned the following morning, ca. 10 minutes before the sun rise (light intensity 100 - 200 lux). The light intensity threshold of different species of bats appeared to be different from one another. During the outflight, *R. rouxii* and *M. schreibersii* were the first bats to emerge, followed by hipposiderids and the fruit bat, *R. leschenaulti*. During the inflight in the morning, complete reverse sequence was observed. Results show that the light intensity is the most crucial environmental factor that regulates the time of outward and inward flight activities of the bat species of this cave. In contrast, no relationship was evident between the outward and inward flight activities of the bats and the other environmental factors monitored namely temperature, humidity, rainfall and the velocity of the wind.

Keywords : Microchiroptera, Megachiroptera, inflight, outflight, cave dwelling, light intensity.

INTRODUCTION

Bats, being nocturnal mammals, crowd in day roosts such as caves, buildings and tree tops to pass the day time. Some of these day roosts may contain many thousands of individuals: *Tadarida brasiliensis*, up to 20 millions individuals in Davis cave, Mexico (Davis *et al.*, 1962), *Miniopterus schreibersii*, 100,000 individuals in the Roberts cave, India (Brosset, 1962 b) and *Monophyllus redmaini*, up to 500,000 individuals in a cave in Puerto Rico (Rodrigues-Duran & Lewis, 1987). These bats leave the cave at dusk, often traveling long distances, in search of food and return at dawn. This invariably results in lengthy activity (early outflights/late inflights) periods.

Several factors are claimed to trigger/inhibit the onset of the inflight and outflight activities of bats. These factors include the diet (Rodrigues-Duran & Lewis, 1987), light intensity (Usman *et al.*, 1990 ; Fenton *et al.*, 1977), wind velocity (Usman, 1981), rain (Fenton *et al.*, 1977) and predators (Jones & Rydell, 1994; Fenton *et al.*, 1977). The factors which trigger or inhibit the outflight appear to vary with the species. For example, the bright moon light is reported to inhibit the flight activity of *Rhinophoma harwicki* in India (Usman *et al.*, 1981), *Scotophilus viridis*, *Eptesicus capensis* and *Nycticeius schlieffeni* in Africa (Fenton *et al.*, 1977) but it had no inhibitory effect on the flight activity of *Phyllostomus hastatus* in Trinidad (McCracken & Bradbury, 1981).

In Sri Lanka, eight species of bats are cave dwelling and in some species the colony size exceed several thousands (Rübsamen *et al.*, 1989; Yapa, 1992). The factors that affect the pattern of inflight and outflight activities of these bats are not known. No long term study has been carried out yet in Sri Lanka to investigate the effect of physical factors (light intensity, temperature, humidity, rainfall and velocity of wind) which are known to influence the timings of outflight and inflight activity patterns in multi-species assemblages of bats. Wavulgalge, which is a natural cave situated in Koslanda, Nikapitiya (6°40' - 6°45'N, 80°00' - 81°05'E) in the south eastern region of Sri Lanka, provided an ideal location for such an investigation as it is a permanent day roost for four insectivorous species, namely rufous horseshoe bat (*Rhinolophus rouxii*), Great Ceylon leaf-nosed bat (*Hipposideros lankadiva*), Schneider's leaf-nosed bat (*Hipposideros speoris*) and long-winged bat (*Miniopterus schreibersii*) with different dietary habits (Eckrich & Neuweiler, 1988) and one species of megachiropteran bats, the Ceylon fruit bat *Rousettus leschenaulti*.

MATERIAL AND METHODS

The field studies were carried out at Wavulgalge from May 1988 to November 1989. These data were supplemented by the data collected during the previous studies, carried out from September to November in 1984 and 1986. The Wavulgalge is a large natural underground cave located in a granite rock, midway on a hill slope which rises ca. 100 m above the valley. The cave has four entrances adjacent to each other, all of which are facing the valley (Fig. 1). The area south of the cave is a village occupied by the farmers living in small houses surrounded by paddy fields and vegetable gardens. This valley, which was a thick forest about 10-15 years ago, has recently been cleared for agriculture and human settlement. The cave is now situated at the fringe of the original forest, which stretches to the north. The immediate vicinity of the cave is covered by elephant grass (*Cymboopogon stellata*) and small bushes.

During each field visit, the onset of the flight activity was determined by recording the times at which the 1st, 10th and the 50th bat left the cave. The species which initiated outflight was also noted. To monitor the end of the inflight activity in the morning, the members of the last few returning bats were counted at one-minute intervals until the inflight ceased. By this way, it was possible to determine the arrival time of the 50th - to - last, 10th - to - last and the last bat. In most of the analysis of the activity periods of bats, reference has been made to the "50th bat out" and the "50th - to - last in" in order to exclude fugitives. The inflight and outflight activities of bats were also occasionally monitored throughout the night by counting the numbers of bats leaving and entering the cave at 5 minutes intervals.

A hand net was used to catch random samples of bats during the inflight and outflight activities in order to determine the species, sex, reproductive status and weight. The bats were caught for ca. two hours starting from the onset of the outflight. This time comprises most of the outflying bats as the majority of the bats were leaving the cave during this time. The different species of bats were identified using the description given by Phillips, 1980.

Since day time observations inside the cave can cause a great disturbance to the bats, these observations were restricted to few occasions during the non-reproductive and reproductive periods of the different species. However, the inside of the cave was regularly checked to locate the roosting places of the different species of bats, which usually roost in different parts of the cave. The species could be easily identified while roosting by visual observation using a torch. Thus population sizes of the bats were determined by counting the total number of bats in a unit area of 1 m

x1 m and extrapolating these numbers to the total area occupied by the same species of bat.

Thus the population size of any species could be expressed as $N_x = (A/a) \cdot n$, where N_x = Population size of species x

A = Area occupied by species x in m^2

a = The area in which the number of bats were counted in $1 m^2$

n = Number of bats roosting in area "a"

Data pertaining to the times of sunset and sunrise were obtained from the Meteorological Department in Colombo. The temperature variations inside and outside the cave were measured with min/max thermometers and a thermohygrograph (Thies Nr. 620, Berlin, Germany). The same recorder was also used to measure the fluctuation of humidity and temperature, both inside and outside the cave. A Pshychrometer (KYS Yoshino Keiki, Japan) was used to determine actual humidity gradients at different locations in the cave and its surroundings. Wind velocity was measured using a cup counter anemometer (w1202/2 – Cassella, London, U.K.) fixed to a 3 m pole, which was kept 15 meters away from the cave entrance. The rainfall at the cave site was measured using a standard rainfall gauge ($d=127$ mm). The light intensity outside the cave was recorded with a portable lux meter (Siltolux) at five-minute intervals from about 20 minutes before the onset of the outflight or end of the inflight up to 15 minutes after. On each of the observation date, lunar phase and the intensity was recorded. Since the lux meter was not sensitive enough the intensity of the moonlight was recorded as high, moderate or low by visual observations.

RESULTS

The cave

The inside of the cave consisted of a large empty space ca. 15 m in width and ca. 35m in length (Fig. 1). The maximum height is ca. 15 m. At the far end of the cave, directed to south-west, the roof becomes very low, ca. 1 - 2 m, and eventually the cave narrows down to a few tunnels (diameter ca. 1 m), which run another 5 – 15 m into the rock. These tunnels have no connection to the outside. The entrances 1, 2, 3 and 4 led to separate sections of the cave. Entrances 1 and 2 connect to a single tunnel descending for ca. 10 m before opening into the large hall. Entrances 3 and 4 are connected to the cave by almost vertical shafts.

Figure 1. Floor plan of the cave (Wavulgalge). Nos. 1 – 4 show the entrances to the cave. The roosting sites of the different species of bats inside the cave are indicated by different symbols. (Δ : *Rhynolophus rouxii*, $\circ$: *Miniopterus schreibersii*, $\times$: *Hipposideros lankadiva*, $+$: *Hipposideros speoris* and $\blacklozenge$: *Rousettus leschenaulti*) The number of symbols does not represent the number of bats.

Temperature and relative humidity

During the observation period, the temperature outside the cave fluctuated by 26°C ; the minimum values of 14°C were measured in February 1989 while the maximum values of 40°C were measured in September 1988 and August 1989 (Fig. 2). Although there was a tendency for inside temperature to follow the shifts observed outside the cave, the total fluctuations were only in the range of 3.5°C , with 26.0°C and 29.5°C being the lowest and the highest values, respectively (Fig. 2). The day night temperature fluctuations recorded by the thermohygrograph outside the cave were mostly in the range of $12\text{--}20^{\circ}\text{C}$. The lowest difference was observed in April 1989 with minimum and maximum values being 19.0°C and 31.0°C , and the highest difference was recorded in September 1988, when the temperature shifted from a night low of 20.0°C to a day high of 40.0°C . The daily temperature variations recorded with the thermohygrograph inside the cave were very small ($\pm 2^{\circ}\text{C}$).

Figure 2. Fluctuations of temperature inside and outside the cave during the study period. (Open circles: maximum temperature outside the cave; Filled circles: minimum temperature outside the cave; Open squares: maximum temperature inside the cave; Filled squares: minimum temperature inside the cave)

During the study period, the relative humidity outside the cave fluctuated between 45% and 100%. The highest values were recorded during the rainy season from October to November 1988 and in February 1989 (Fig. 3). The lowest consistent values were recorded in March and November 1989. Inside the cave, the changes of the relative humidity were restricted to the range 60% - 85% (Fig. 3). As the temperature, the fluctuations of relative humidity inside the cave tended to follow the outside changes. Daily fluctuations of relative humidity outside the cave precisely followed opposite of the temperature, with high values for humidity coinciding with temperature minima at night and low values with temperature maxima during the day. As with temperature, daily fluctuations of relative humidity inside the cave were hardly noticeable.

Figure 3. Fluctuations of relative humidity inside and outside the cave during the study period. (Open circles: maximum humidity outside the cave; Filled circles: minimum humidity outside the cave; Filled squares: ambient humidity inside the cave).

Moonlight

Analysis of data indicated that the outflight and the inflight activities of bats remained essentially the same on days with different intensities of moonlight.

Rainfall

The rainfall in the study area was highly seasonal. Two rainy seasons (March - May and September - December) were separated by two dry seasons (January - February and June - August) (Fig. 4). However, the flight activity of bats was not altered by the rainfall pattern. The actual rainfall at the cave site rarely prevented the bats from leaving the cave. Rainfall that started after the onset of the outflight did not cease the outflight and bats continue to leave the cave albeit in small numbers. Further, rain did not cause the return of bats and bats remained outside the cave despite heavy rain. Only on one occasion when the rain was extremely heavy, most of the bats stayed in the cave although the light intensity dropped below 100 lux. However, as soon as the rain subsided the bats commenced their outflight activity. Rain in the early morning when most of the bats were returning to the cave, was never recorded throughout the study period.

Figure 4. The rainfall recorded at the cave site during the study period from September 1988 to December 1989.

Wind velocity

The velocity of the wind in the study area, which ranged between 0.04 km/h and 8 km/h (Fig. 5), had no effect on the flight activity of the observed bats. The bats commenced the outflight at the times when the light intensity had dropped below 500 lux even on high windy (8 km/h) days.

Figure 5. Velocity of the wind recorded at the cave entrances at the time on onset of the outflight activity of the bats. No recording were made on the days indicated by "*".

Population sizes

Four species of microchiropteran bats (*Rhinolophus rouxii*, *Hipposideros lankadiva*, *Hipposideros speoris*, *Miniopterus schreibersii*) and one species megachiropteran bats *Rousettus leschenaulti* were found to be regularly inhabiting in the cave. The population sizes of each of these species are given in Table 1. The dominant species of bats inhabiting Wavulgalge was *R. rouxii* consisting a population of ca. 10,000 – 12,000 individuals, followed by *R. leschenaulti* and *H. lankadiva* with populations of ca. 5000 – 6000 and ca. 1500-2000 individual respectively. The colony sizes of other two microchiropterans were comparatively low (*H. speoris*: 200 – 300 individuals; *M. schreibersii*: 700 – 1000).

Table 1. Population sizes of the five species of bats recorded in Wavulgalge.

Species	Population size
<i>Rhinolophus rouxii</i>	10,000 – 12,000
<i>Hipposideros lankadiva</i>	1500 - 2000
<i>Hipposideros speoris</i>	200 – 300
<i>Miniopterus schreibersii</i>	700 - 1000
<i>Rousettus leschenaulti</i>	5000 - 6000

During the breeding seasons, a large number of pregnant females invaded the cave resulting in an increase in population size by 4-5 folds of the corresponding species. Throughout the year, each species occupied the same area inside the cave (Fig. 1), although slight variations occurred during the time of reproduction of the different species.

Outflight and inflight activities

The activity of bats inside the cave commenced ca. 30-40 minutes before the onset of the outflight. The outside light intensity during this time was usually above 5000 lux. At first, bats started to fly around their respective hanging site. Around this time uninterrupted vocalizations (social calls which are audible to the human ear) and steady sounds of wing flapping became evident which indicated a high degree of

restlessness within the colonies. Next, the bats slowly moved towards the cave entrances and about 15-20 minutes before the outflight commenced, 5-10 bats started circling in and around the cave entrances. During this time the light intensity fluctuated around 1500-5000 lux. These circling flights were mostly performed by rufous horseshoe bats at the entrances 3 & 4. Gradually these circles were enlarged, with 5-6 bats escaping 6-7 away from the cave entrance. The outflight was initiated by one of these circling bats. However, species such as *M. schreibersii* and *H. lankadiva* did not perform circling flights. When the outflight was initiated by one individual of these species, others directly flew away without performing circling flights. Other bats either followed immediately or commenced the outflight with a delay of ca. 10 minutes. In any case, as soon as 40 – 50 bats had left the cave, there was a continuous stream of outflying bats most of which headed towards the nearby forest north of the cave. The cave remained in complete darkness (0 lux) throughout the day and the night having no effect by the fluctuations of the light intensity outside the cave.

R. rouxii and *M. schreibersii* were the first species of bats to leave the cave. Soon they were followed by *H. speoris*, and with a delay of ca. 10-15 minutes followed *H. lankadiva*. *R. leschenaulti* emerged last, about 20-30 minutes after the onset of outflight. However, their outflight behavior was highly variable, and on certain occasions they did not leave the cave for about 1-2 hours after the sunset. In the morning, the reversed sequence of inflying bats was observed. This inflight and outflight patterns were evident almost throughout the year.

At the beginning of the outflight, bats emerged only from entrances 3 and 4 (Figs 6 b & c). After ca. 10-15 minutes they started to fly out from the interconnected entrances 1 and 2 (Fig. 6 a). The megachiropteran, i.e., *R. leschenaulti*, almost exclusively emerged from entrances 3 and 4 and as soon as they commenced the outflight, the majority of the microchiropterans left the cave by entrances 1 and 2.

Figure 6. Outflight activity at the cave entrances 1 + 2, 3 and 4.

Figure 7. Outflight activities throughout the night (a) in October 1984 and (b) in October 1986. filled triangles: outflying bats, Open triangles: returning bats. The dotted lines in Fig. (a) indicate the estimated onset of outflight and end of inflight. (The most of the bats have left the cave two hours after the onset of the outflight and there is a small increase in the number of outflying bats between 04.00 h and 05.00 h. The inflight activity increase after midnight although most of the bats return to the cave between 05.00 h and 06.00 h.

Since the outflight activity of the microchiropterans at entrances 1 and 2 was not disturbed by that of *R. leschenaulti*, this site was selected for regular observations. The majority of the outflying bats left the cave within 2 hours after the onset of the outflight (Figs 7 a & b). Very few bats were seen to enter the cave ca. 30 mins after the onset of the outflight, but most probably these bats may have again left the cave at a later occasion. Return flights were increased after midnight and the peak activity of the inflying bats was observed during the last hour (after 5.00 a.m.) of their activity period (Figs 7 a & b).

Observations throughout the study period revealed systematic time shifts in the outflight and inflight activities of bats. The onset of the outflight varied between 17 39 h in October and 18 28 h in July. Measurements of the light intensities in the evening showed that bats started to leave the cave only when the light intensity dropped below 500 lux. It was the absolute light intensity that triggered the outflight since the rate at which the light intensity decreased in the evening had no effect on the timing of the outflight activity. Regular measurements from July 1988 to November 1989 disclosed the relationship between seasonal shifts of the onset of the outflight and corresponding iso-lux values (Fig. 8). The outflight always commenced at the light intensities between 100-500 lux. However, during the reproductive periods, *R. rouxi* and *H. speoris* (October in 1988 and 1989) commenced their outflight activity at higher light intensities.

Figure 8. Onset of the outflight activity and evening iso-lux contours at the cave entrances.

Although there was no heavy threat of predation at the cave site, on many occasions, a crested hawk-eagle (*Spizaetus cirrhatus cirrhatus*) arrived at the cave site ca. 15 minutes before the onset of the outflight and often caught one of the outflying bats.

Figure 9. End of inflight and the morning iso-lux contours at the cave entrance.

The end of the inflight was also closely related to the actual changes of the light intensity. The earliest end of the inflight was recorded both in May and September at 05 35 h and the latest in January at 06 20 h. Throughout the observation period, all bats returned to the cave when the light intensity was below 500 lux (Fig. 9). Although the timings of onset of the inflight and outflight activities varied, the succession of the emergence of the bats remained unchanged throughout the year except for the breeding periods. During the breeding periods, the pregnant / lactating females left the cave relatively early, and during this period the onset of the outflight activity was often initiated by the pregnant / lactating females of *H. lankadiva* in March and *M. schreibersii* in August.

A significant positive correlation ($r = 0.94$, $p < 0.01$) was observed between the time of the sunrise and the end of the inflight (Fig. 10 a) and between the time of the sunset and the onset of the outflight ($r = 0.94$, $p < 0.01$, Fig. 10 b). The length of the nocturnal activity period of the bats showed a significant positive correlation with the length of the night ($r = 0.87$, $p < 0.01$, Fig. 10 c).

Figure 10. Flight activity of the bat species in relation to the time at sunrise, time at sun set and length of night.

DISCUSSION

The onset and the end of the flight activity of bats in Wavulgalge were strongly related to the light intensity. Both inflight and outflight activities matched with the light intensities prevailed at the cave entrances. Consequently, a strong relationship between the annual pattern of sunset and sunrise and the onset of outflight activity and end of inflight activity of the bats was observed. As such, bats were never active outside the cave when light intensities were above 500 lux.

The results indicate that different species of bats have different threshold levels for light intensities. While early emerging bats such as *R. rouxii* have tolerance for higher light intensities, *H. lankadiva* and *R. leschenaulti* were active only at lower light intensities. Sunset and sunrise dependent inflight and outflight activity patterns have also been observed by Usman *et al.* (1990) in *Rhinophoma hardwickei*. Erkert (1982) speculated that almost in all species studied to date, evening emergence proceeds almost parallel with the time of sunset. Although the outflight was not studied in detail, Phillips (1980) also reported that rhinolopids, hipposiderosids, *Pipistrellus* sp. and *M. schreibersii* appear early in the evening, while some bats (e.g. *Megaderma* spp. and *Scotophilus heathi*) appear rather late. However, rather contradictory observations regarding these activities have been made by Brosset (1962 a). According to him *R. rouxi* in India appears only 30 minutes after the sunset.

The differences in timings of outflight activity can be roost-specific, through the inhibitory effect of the light. In a particular species, the colonies emerge later if the entrance to the roost is fully exposed to light, and the species of which the roost is hidden and shaded would appear earlier as recorded for *Phyllostomus hastatus* (Williams and Williams, 1970) and *Myotis velifer* (Kunz, 1974). This indicates that the light intensity dependant emergence time of bats may be an adaptation to avoid or reduce the threat of predation. By detecting the outside light intensity, bats seem to be able determine the time at which the visually orienting predators have retired and time their outflight accordingly.

The differences of light intensity thresholds observed for different species of bats could be explained by their foraging strategy. For example, *R. rouxii* always forage in dense foliage and was never found foraging over open grassland or paddy fields (Neuweiler *et al.*, 1987). Such foraging behaviour probably provides adequate safety from a potential predator. If a bat species is exclusively foraging in thick forest and the route to the foraging ground also provided adequate cover, then they can afford to emerge rather early as the predators have very little success in catching them. At least this holds true for *R. rouxii*. Other early emerging bat species, namely *M. schreibersii*, was found flying over the paddy fields and foraging in open ground.

They are excellent and high speed fliers. They may be able to escape from predation due to their high speed and therefore could afford to fly early in the evening. On the contrary, sluggish flyers such as *R. leschenaulti* appear when it is considerably dark, when visually orienting predators are not active.

The inhibitory effect of light on the locomotive activity is clearly demonstrated for number of bat species. The locomotive activity of bats is not only inhibited by relatively higher light intensities prevailing before emergence, but also, in certain species, it is altered by relatively lower light intensities such as moonlight (Usman *et al.*, 1990; Fenton *et al.*, 1977). However, the present study indicates that moonlight had no significant effect on the timings of onset of outflight activity of the bats. These results are in agreement with the observations made by McCracken and Bradbury (1981) who reported that the polygynous bat (*Phyllostomus hastatus*) in Trinidad was equally active on both dark and moonlit nights. They also did not find any correlation between the lunar cycle and the duration of the evening flights. Fenton *et al.* (1977) speculated that activity of the insects was not inhibited by the moonlight, and the lunar-phobia of bats may be a strategy to reduce the probability of encountering with visually orienting nocturnal predators such as owls. Such difference in activity may be due to the extent of the threat of predation. If the threat of predation is very high in a certain area, bats would curtail their flying activity even in low light intensities. However, the same species may be found active during similar conditions if the threat of predation is less.

Another factor which may influence the nocturnal activity of bats is their dietary requirements. Bats will time their activity period when there is high abundance of insects. Rodriguez-Duran and Levis (1987) showed that in three sympatric cave dwelling bats in Puerto Rico, the 4 hour difference observed in the outflight activity was related to the peak activity period of the insect species on which they prey.

The different foraging patterns among the sympatric bat species might lead to separate peak exit times and such a species specific outflight time appears to be not related to the roosting position of the bats in relation to the cave entrances. These differences in exit times facilitate coexistence of large numbers of bats in a single cave, specially in narrow mouthed caves, as this behavioural pattern minimizes the inter-specific competitions for positions in the queue of bats leaving the cave (Rodriguez-Duran and Lewis, 1987). The present observations at Wavulgalge are in agreement with this hypothesis. The three dominant species, namely *R. rouxii*, *H. lankadiva*, and *R. leschenaulti* commence their outflight activity at different time intervals. The dietary requirements of these bats are different too. The two

insectivorous species, namely *R. rouxi* and *H. lankadiva* do not compete for food (Eckrich and Neuweiler, 1988) and *R. leschenaulti* is frugivorous.

The differences in peak emergence times of three sympatric species reported by Rodrigue – Duran and Lewis (1987) were up to 4 hours, where as in this study, these differences were only about 20-30 minutes. As such, more research is needed to relate the difference in exit times to the food habits. However, the difference in timing of the outflight activity appears to be related to environmental factors, namely light intensity, rather than diet. The reverse succession of the bat species during the inflight activity (i.e. first to emerge last to come and last to emerge first to come) observed in this study supports this hypothesis.

Observations at Wavulgalge showed that the bats tolerate moderate rain, but during heavy rain the onset of outflight activity was delayed. Neuweiler *et al.* (1987) also reported that despite torrential rain, *R. rouxii* emerged from the cave albeit in small numbers, but heavy rain delayed their departure. Similar observations have been made by McCracken and Bradbury (1981) for *Phyllostomus hastatus*. On the contrary, Fenton *et al.* (1977) stated that the deterrent effect of rain on the patterns of locomotive activity of some African microchiropterans is very strong. These bats delayed the onset of outflight activity when it was raining, and if the rain has started after the bats become active, the activity was suppressed and some species such as *Nycticeius schlieffeni* retires to its night roots even during the activity period.

This deterrent effect of rain on the activity of bats may be due to several reasons. Thermoregulation by the bats may be impaired by wet fur and for related physiological reasons, bats may avoid flying in the rain (Fenton *et al.*, 1977). It has also been reported that high humidity causes attenuation of high frequency echolocation signals, and rain drops add a clutter to echoes. Thus, the avoidance of rain may reflect an interference with the echolocation system of bats. At the same time severe rain could physically handicap the flight activity of small insectivorous bats like *R. rouxii*. This hypothesis is supported by the fact that in few occasions during severe rain, the outflight activity of microchiropteran bats was suppressed while the megachiropteran species, *R. leschenaulti*, a larger bat, which is also capable of orienting visually and by means of echolocation (Novick, 1977) continued to fly as usual. The lack of activity of bats during the rain is not a reflection of the absence of potential food as it had been reported that rain did not strongly suppress the flight activity of the insects (Fenton *et al.*, 1977).

Wind had no effect on the onset of the flight activity of the observed bat species in Wavulgalge, and even on the evening on which the highest wind was recorded (8 km/h), the bats left the cave as usual. Previously it had been reported

that when the velocity of the wind exceeds 7 m/s (ca. 25 km/h) *Rhinophoma hardwickei* did not emerge from the cave (Usman *et al.*, 1990). Apparently, the wind velocities that prevailed in the area during the study was easily tolerated by the bats.

For heterothermic microchiropteran bat species in temperate zones, ambient temperature has long been recognized as a crucial exogenous factor controlling seasonal timing and the course of hibernation (Erkert, 1982). Laufens (1973) reported earlier arousal and slight advancing of the emergence time of some heterothermic bat species in high ambient temperature. Although the effect of the temperature on tropical microchiropteran bats would be minimal, Phillips (1980) found a colony of 6 - 7 *Pistrellus mimus*, (= *P. tenuis*) the Indian Pigmy bat, in Southwest of Sri Lanka completely torpid on a comparatively cold monsoon morning. The adults were unable to fly more than 1-2 meters when disturbed and could be easily captured by hand and flew away only when the temperature had risen. However, any significant correlation between the ambient temperature and the flight activity of the bats in Wavulgalge was not observed during the present study. Thus the effect of the temperature on the timings and patterns of locomotive activity of bats appear to be species specific.

The significant positive correlation between activity period and the length of the night and the bimodal activity pattern seen in the evening and morning in this study suggest that bats spend the entire night outside the cave. Therefore, for the majority of the bats, the foraging flight is confined to a single evening flight. Similar observations have been reported by McCracken and Bradbury (1981) for *Phyllostomus hastatus*. In contrast, lactating *Myotis lucifugus* (Anthony & Kunz., 1977) and *Rhinophoma hardwickei* (Usman *et al.*, 1990) were found to return to the cave periodically to feed the young. But such multiple feeding visits were not observed for *R. rouxii* during the period of lactating. Neuweiler *et al.* (1987), based on their observations at the same cave, also reported that it was very unlikely that the lactating *R. rouxii* return to the cave in between to feed the young. It was even observed that the lactating bats leave the cave earlier than the others do during the rest of the year and return to the cave at last. This may be due to the high energy demand required during lactation. Lactating bats have an increased food consumption (Anthony & Kunz, 1977), and this may be achieved by prolonging the feeding time.

In conclusion, the results of this study show that the light intensity is the most important environmental factor regulating the timings of inflight and outflight activities of the resident species (*R. rouxii*, *H. lankadiva*, *H. speoris*, *M. schreibersii* and *R. leschenaulti*) in Wavulgalge.

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