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INFLUENCE OF AMBIENT TEMPERATURE ON THE FREQUENCY OF EAR FLAPPING BY CAPTIVE ASIAN ELEPHANTS (*ELEPHAS MAXIMUS*) IN SOUTHERN INDIA

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Abstract: Elephants under natural conditions are in favour of cool environment due to their large body size and their constraints on thermoregulation. During summer, they use behavioural mechanisms including increased ear flapping. However, under captive condition, they are often managed in environments that are much hotter. We evaluated the rate of ear flapping of six captive elephants placed in houses made-up of asbestos, coconut frond and reinforced cement concrete (RCC) roofs at Hindu Temples in Southern India to understand the influence of ambient temperature in different hours of daylight, season and types of house roofs on ear flapping frequency. The elephants increased the ear flapping significantly with increasing ambient temperature in different hours of daylight ($R = 0.594$, $P < 0.04$) and months ($R = 0.839$, $P < 0.01$) with a highest ear flapping during summer (May - Jun) and lowest during winter (Dec – Jan). Among the three houses, ear flapping increased suddenly around 13:00 hrs when the elephants brought from granite-roofed temple to the asbestos roofed elephant houses and increased gradually in RCC houses. Contrarily, decreased when brought to coconut frond roofed houses. These results indicated the positive influence of ambient temperature on the ear flapping by captive elephants.

Key words: Asian elephants, temperature, house, ear flapping.

INTRODUCTION

Homeotherms have adapted to new or changing environments by varying the size and shape of their bodies and extremities (Phillips and Heath 1992). These physical changes facilitated heat conservation or dissipation as dictated by ambient conditions. Body temperature regulation appears to scale with body mass in vertebrates (McNab 1983). Larger animals need to develop means of dealing with great amount of heat that they produce (Phillips and Heath 1992). Large animals cool slower than smaller ones and would appear to be favored at cold temperature, since surface area to volume ratio decreases with increasing body size and fur can be thicker on larger animals (Schmidt-Nielson 1984). In contrary, among the large mammals that inhabit in tropical environment, elephants have sparse body hair and a few sweat or sebaceous glands (Feldhamer *et al.* 1999). Their large body size results in large amount of metabolic heat apart from heat gain from the environment. The ambient temperature could increase the body temperature of elephants significantly (Buss and Estes 1971, Elder and Rodgers 1975, Weissenbock 2006). In the natural environment, elephants avoid getting exposed to heat load by using a number of behavioural mechanisms like resting in the shade during hot day hours with frequent dust bath, mud bath and ear flapping (Hiley 1975 and Baskaran 1998) and also by decreasing the time spent on feeding during the daylight hours in dry season as compared to wet season (Baskaran 1998). Wright and Luck (1984) have shown that the calculated heat loss from the ears of African elephants is substantial proportion of the total metabolic heat loss required and emphasized the importance of ear fanning. Similarly Phillips and Heath (1992) using infra-red thermography in the ear pinnae of the African elephants have shown that temperature distribution across the ear pinnae changes with ambient temperature and calculated up to 100% heat loss needs can be met out by the movement of ear pinnae and by vasodilatation.

Asian elephants (*Elephas maximus*) in India are managed under captive conditions in the timber camps, zoos, Hindu temples and by private agencies (Krishnamurthy 1998). In most of these places except timber camps, the environment is much hotter than their natural habitats. Further, the daily routines of the elephants are modified according to the kind of work they are used in captivity and after the work they are mostly chained inside the enclosures. The present study is carried out to understand the seasonal influence of ambient temperature on the rate of ear flapping of the captive elephants managed at various temples in Tamil Nadu, Southern India between May 2007 and April 2008. These elephants are housed under enclosures with different types of roof materials namely asbestos sheet, coconut frond thatching and reinforced cement concrete (hereafter referred as RCC), which are known to maintain the room temperature differently. Thus, this study evaluates the effect of the three roofing materials on the ear flapping frequency.

METHODS

Study area and animals:

A total of six female elephants ranging from 14 to 56 yrs, managed by various temples located within a radius of 50 km in Thanjavur and Nagapattinam districts of Tamil Nadu, southern India was studied. Every two of them were housed in enclosures made up of asbestos sheet, coconut frond thatching and RCC roofs. The study area experiences a prolonged summer lasting five months from March to July, a short rainy season from August to October and a winter period of four months between November and February with unusual rainfall occasionally (Fig. 1). The maximum and minimum temperature range from 37.8° C (mean maximum) in May to 19.1° C (mean minimum) in December. The annual rainfall recorded during the study period was 1640mm.

Observation :

Data on time, frequency of ear flapping (randomly either left or right pinna) and major activities/routines such as daily rituals, fodder and cooked ration feeding, bathing and resting were collected using focal sampling method (Altmann 1974). At the end of every focal sampling, ambient temperature was recorded using a digital thermometer nearby the elephant's location. Behavioural observation on ear flapping was carried out on each elephant for a period of two days/month from 06:00 to 12:00 hrs and 12:00 to 18:00 hrs on consecutive days when there was no major difference in the climatic conditions for a period of one year. Each observation hour was divided into four sample blocks, with each block of 10 minutes observation and five minutes rest. The daily routines/activities of the elephants were broadly classified into three categories viz. fodder feeding and resting that take place inside the elephant house, daily rituals in which the elephant is placed inside the temple for ritual and blessing devotees and other activities such as bathing, drinking, walking and concentrated diet feeding which occurs open place in the temple or outside.

During the daylight hours (from 06:00 to 18:00 hrs), six elephants were kept in the temples for daily rituals for some time and the rest of the time in the enclosures for resting and green fodder feeding. The study also quantified the proportion of time spent on various activities in different hours of day so as to differentiate, what proportion of time the elephants were placed in the temples as well as in houses within each hours of the daylight hours. In majority cases when the elephants were placed inside the houses during afternoon time, the mahouts also go home. It was not possible to record the actual room temperature of elephant houses, as we were not permitted inside the elephant house for safety reasons. Room temperature data for the three house types was not available to compare directly with ear flapping rate. This lacuna was supplemented by collecting data on maximum and minimum temperatures from houses with similar roof types in the same area for a period of five days.

Analysis

Using data from all the elephants, the frequency of ear flapping and ambient temperature were computed in relation to different hours of daylight, different months of year and three different roofed (asbestos, coconut frond thatched and RCC) houses. Relationship between ear flapping frequency and ambient temperature during different daylight hours and months was tested using Spearman rank correlation through computer software *Statistica* (99 edition).

OBSERVATIONS AND RESULTS

Frequency of ear flapping in different daylight hours

The frequency of ear flapping observed during daylight (06:00-18:00) hrs increased gradually from morning hours and reached the peak between 13:00 –14:00 hrs and thereafter declined gradually (Table 1). Similarly, the ambient temperature also increased gradually from morning hours, but reached the peak between 14:00-15:00 hrs and after 15:00 hrs it declined gradually (Table 1). Comparison of the ear flapping frequency and mean ambient temperature recorded during daylight hours showed a significant positive correlation ($R = 0.594$, $P < 0.04$, $n = 12$).

Rate of ear flapping in different months

The rate of ear flapping in captive elephants varied remarkably in 12 months period. It was highest (9.2 times/minute) during May - June and dropped almost to half (5.7 times/minute) during December - January (Fig. 2) coinciding with the highest and the lowest mean ambient temperature record of 36 ± 3.42 °C and 28 ± 3.38 °C respectively. The ear flapping frequency and the ambient temperature recorded over 12 months showed a positive correlation (Spearman rank correlation $R = 0.839$, $P < 0.01$, $n = 12$).

Rate of ear flapping among elephant housed under different roof types

The room temperature noted in three different roofed houses showed a remarkable difference in their maximum and minimum range. The difference between maximum and minimum was highest (mean of 12.7 ± 7.0 °C) in the asbestos roofed houses (minimum and maximum 26.3 – 39 °C) and lowest (2.7 ± 2.0 °C) in the coconut frond thatched houses (minimum and maximum 30.6 – 33.3 °C), while the RCC roofed houses maintained an intermediate fluctuation (4.3 ± 2.5 °C) in room temperature (minimum and maximum 31 – 35.3 °C).

Among the three types of roofs evaluated, elephants from the granite roofed temple yards when brought to asbestos roofed houses around 12:00 hrs showed a sudden spurt in the mean rate of ear flapping from about 6 times/minute between 11:00 –12:00 hrs to nearly 10 times/minute between 12:00 – 13:00 hrs and the flapping rate remained around 8 times/minute until 15:00 –16:00 hrs (Fig. 3a). After 16:00 hrs the ear flapping reduced to < 6.5 times/minute when the elephants were taken out from the house to temple yard for daily rituals (Fig. 3b). On the other hand, when the elephants brought to the coconut frond thatched houses, during afternoon time around 13:00 hrs, a remarkable drop in the ear-flapping rate was observed (Fig. 4). On the contrary, the elephants brought under the RCC roofed houses showed a gradual increase in ear flapping rate even after 12:00 hrs, reaching the peak by 13:00 hrs and then gradually declined (Fig. 5). In this case, the rate of ear flapping gradually increased even after brought to the elephant houses, as RCC roofs maintained room temperature only moderately unlike coconut thatched house as shown by the maximum and minimum temperature data in different houses.

DISCUSSION

Since heat dissipation could be a problem for elephants especially in the warm tropical environment, under the natural condition elephants avoid exposing to heat load by using number of behavioural mechanisms like resting in the shade during hot day hours with frequent dust bath, mud bath and ear flapping (Hiley 1975, Baskaran 1998). The high surface to volume ratio of the ear pinnae (Wright 1984) along with the prominent and extensive vascular network (Sikes 1971) and their mechanism of vasodilatation with an increase in blood flow and simultaneously frequent ear flapping under warm conditions increase convective heat loss (Wright 1984).Weissenbock (2006) using infrared camera on Asian elephants in Sri Lanka has shown a positive correlation between body surface temperature and ambient temperature and this study has also revealed that the surface temperature of ear pinnae approximated the ambient temperature in the morning hours and exceeded the same during the day hours indicating roll of ear pinnae in thermoregulatory mechanisms.

The present study area of Nagappattinam and Thanjavur districts being located in the plains region experience relatively a higher ambient temperature unlike the natural habitats of elephants, which is mostly in the Ghats or high rainfall areas. Additionally, the prolonged dry spell in the study area could also influence the body temperature remarkably. The positive increase in the ear-flapping rate with the ambient temperature observed during daylight hours indicates that the environmental temperature influences the rate of ear flapping among elephants. In general summer season in the study area commences in March and continues up to July with maximum temperature remaining above 35 °C during April – June. The rainy season starts in August and ends in October and thereafter climate turns into cool winter season with temperature range from a minimum 19 °C to a maximum 32 °C during November to February supporting the fact that ambient temperature influences the ear flapping rate of elephants. These results are in accordance to findings of Buss and Estes (1971) and Asia by McKay (1973), who have observed an increase in ear flapping rate with ambient temperature.

The results on room temperature suggest that asbestos roof merely absorbs the heat from ambient temperature and radiates to the interior part of room unlike coconut frond roof, which reflects the heat outside and thus keeps the room temperature without much fluctuations. In support of this, studies of Roma *et al.* (2008) have shown that asbestos sheet transfers temperature inside room significantly more than tiles reinforced with vegetable fibers. Therefore the asbestos roof houses tend to have the highest maximum and lowest minimum temperatures respectively during mid-day and night hours resulting in wider fluctuations in room temperature. The roof made up of RCC, has an intermediate fluctuation indicating that they are moderate in maintaining the room temperature. Therefore elephants housed under the three types of roofs are expected to have different levels of ear flapping rate, as ambient temperature levels are different in these houses.

Among the three houses examined, elephants rapidly increased their ear flapping frequency after 13:00 hrs when they brought to the house made up of asbestos sheet roof. Contrarily, in the case of coconut frond roof houses, elephants remarkably decreased their ear-flapping rate after 13:00 hrs when they brought to the house. Unlike the above two cases, the elephants brought to houses made up of RCC roofs without any sudden response to house environment, continued increasing their ear flapping gradually. The rate of ear flapping and the variation in temperature observed in the three types houses reveal the positive influence of room temperature on the ear flapping frequency by elephants. The large body size of elephant resulting in greater metabolic heat (Phillips and Heath 1992) and thus cools slower than smaller animals, since surface area to volume ratio decreases with increasing body size (Schmidt-Nielson 1984). Further their sparse body hairs and a few sweat glands (Feldhamer *et al.* 1999) impose constraints in heat dissipation and therefore prefer cold temperature. On the contrary, asbestos roof for the captive elephant does not maintain room temperature. Therefore modifications are needed to elephant house roofs considering the present findings.

Conclusions and Recommendations

- The present study evaluated the rate of ear flapping in relation to ambient temperature in different daylight hours and months among six captive elephants managed at the Hindu temples between May 2007 and April 2008. The study also compared the ear flapping frequency in relation to three different types of roofs used in the elephant houses in order to identify the ideal roof type for the elephant houses.

- The comparison of ear flapping frequency with temperature recorded during different hours of daylight (06:00-18:00 hrs) showed a positive correlation indicating elephants increase the ear flapping frequency with an increase in ambient temperature. Similarly a significant correlation observed between the mean monthly ambient temperature and ear flapping frequency and a highest ear flapping frequency during summer (May - Jun) and lowest during winter months (Dec - Jan) indicate the significant influence of ambient temperature on the ear flapping frequency.

- Among the three different houses, ear-flapping rate increased suddenly around 13:00 hrs when the elephants brought from granite-roofed temple yard to the asbestos roofed elephant houses. On the other hand, ear-flapping frequency decreased when brought to coconut frond thatched roof. But in the RCC houses elephants did not show any remarkable change. The relatively higher room temperature recorded in asbestos roofed houses increases the ear flapping, while the lower room temperature in the coconut frond thatched houses reduces the ear flapping. The RCC houses with a moderate temperature fluctuation gradually reduce the ear-flapping rate.

- Based on the results we suggest that the asbestos roof should be avoided, as they do not maintain the temperature unlike the coconut fronds and thus are unsuitable as far as elephant physiology is concerned especially in warm places like the plains of Tamil Nadu. Therefore asbestos roofed elephant houses need to be replaced by coconut fronds. The existing RCC houses could be additionally supported by false roof using coconut fronds on the upper side of RCC roofs, or a shade tree be planted on side of elephant houses, so as to minimize the exposure of RCC roof to the solar heat load.

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Table 1. Frequency of ear flapping by captive elephants and ambient temperature recorded in relation to day light hours between May 2007 and April 2008

Time (Hrs.)	Rate of ear flapping /minute		Ambient Temperature (°C)	
	Mean	SD	Mean	SD
06:00 – 07:00	4.9	3.50	26.3	2.83
07:00 – 08:00	5.8	4.00	26.8	2.82
08:00 – 09:00	7.0	4.34	27.9	3.10
09:00 – 10:00	7.7	4.42	29.3	3.44
10:00 – 11:00	7.9	4.78	30.6	3.39
11:00 – 12:00	8.1	5.00	31.8	3.03
12:00 – 13:00	9.3	5.75	32.8	3.00
13:00 – 14:00	9.3	7.40	33.5	3.20
14:00 – 15:00	8.1	7.07	34.1	3.36
15:00 – 16:00	7.3	5.35	34.1	3.47
16:00 – 17:00	7.3	4.48	33.3	3.50
17:00 – 18:00	8.1	4.41	31.7	3.43

Figure 1. Monthly mean maximum and minimum temperature (^{o}C) and rainfall (mm) recorded in the study area (Data from Tamil Nadu Rice Research Institute, Aduthrurai)

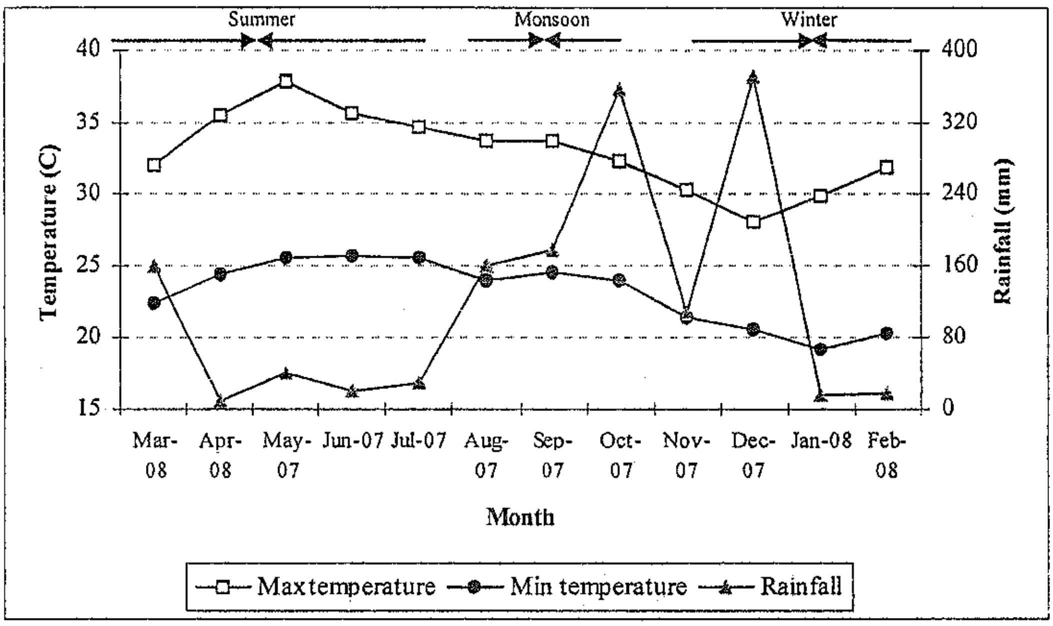


Figure 2: Mean frequency (± SE) of ear flapping by captive elephants and mean ambient temperature (± SE) recorded during different months between May 2007 and April 2008

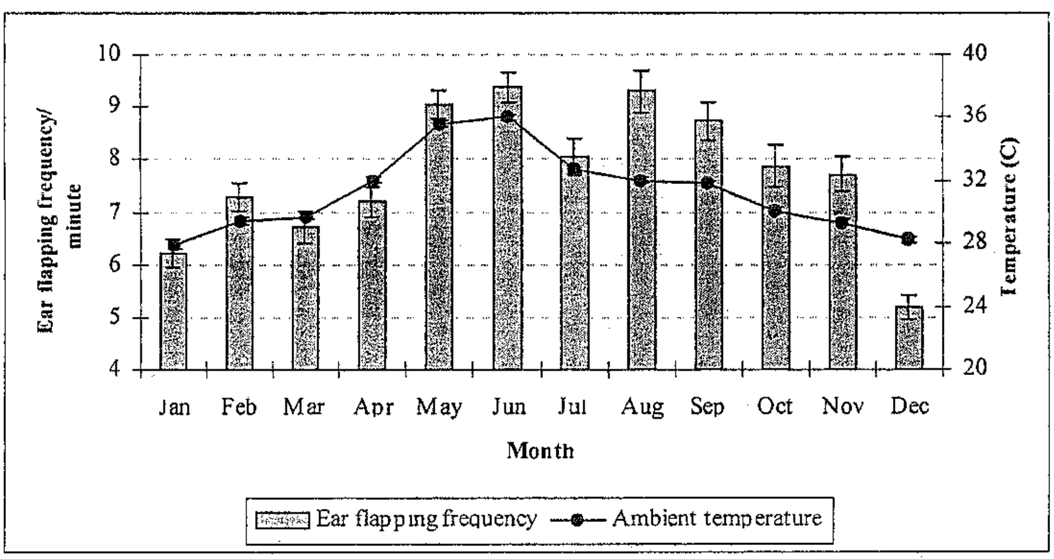
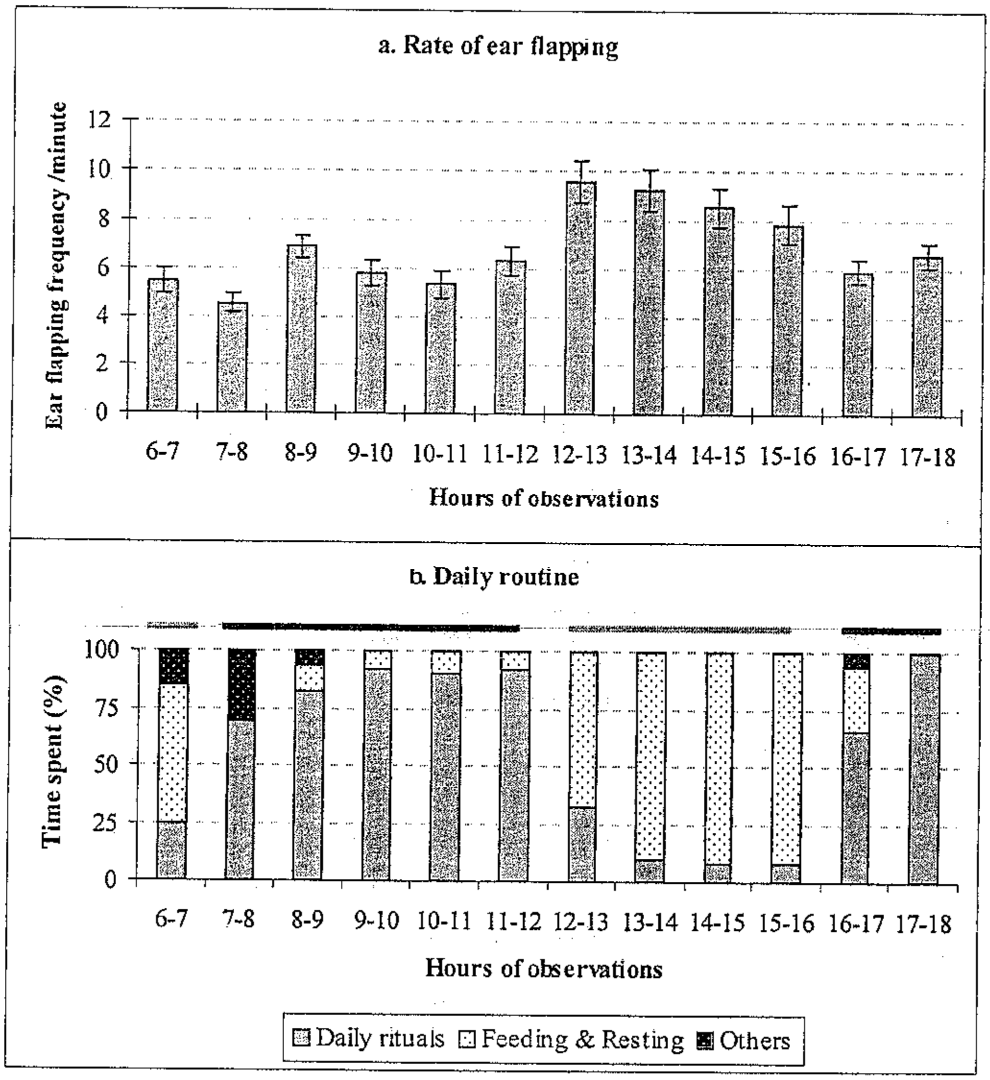


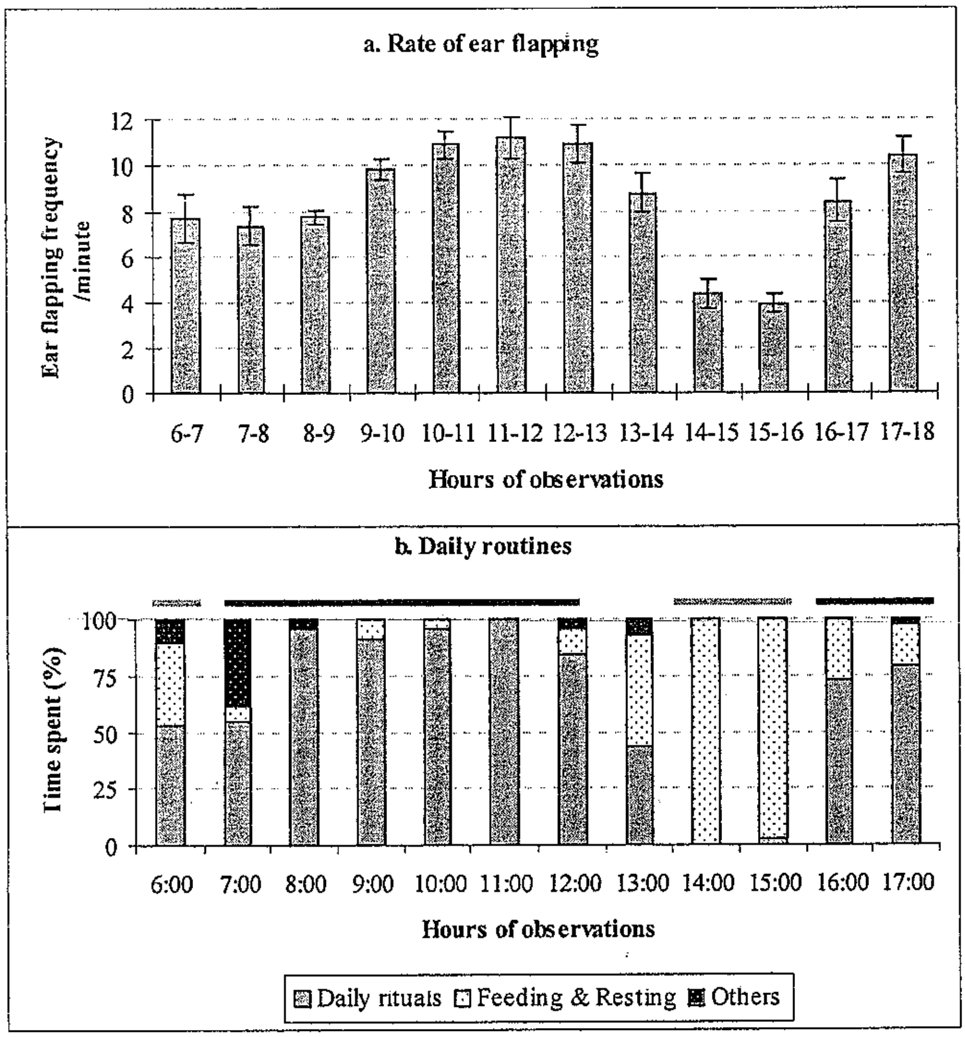
Figure 3: Mean rate (± SE) of ear flapping and daily routines in relation to daylight hours among captive elephants housed in shed with asbestos roofs



Note: Grey and black lines above the bar represent a higher proportion of time in these hours of observations elephants were in shed and temple respectively.

Daily rituals take place in Temple roof, Feeding and resting take place in elephant shed and others, which include drinking, walking and bathing, mostly take in the open places without any roof.

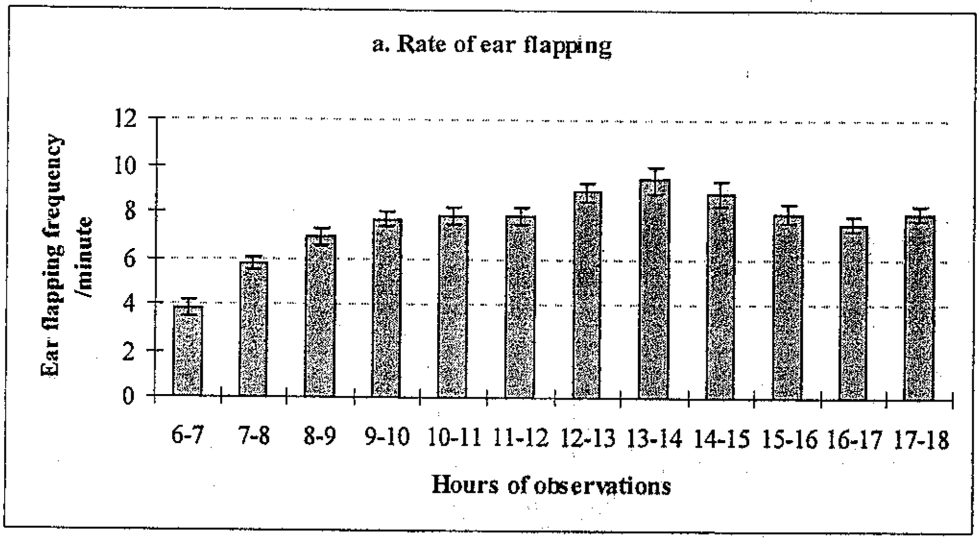
Figure 4: Mean rate (± SE) of ear flapping and daily routines in relation to daylight hours among captive elephants housed in shed with coconut frond thatched roofs

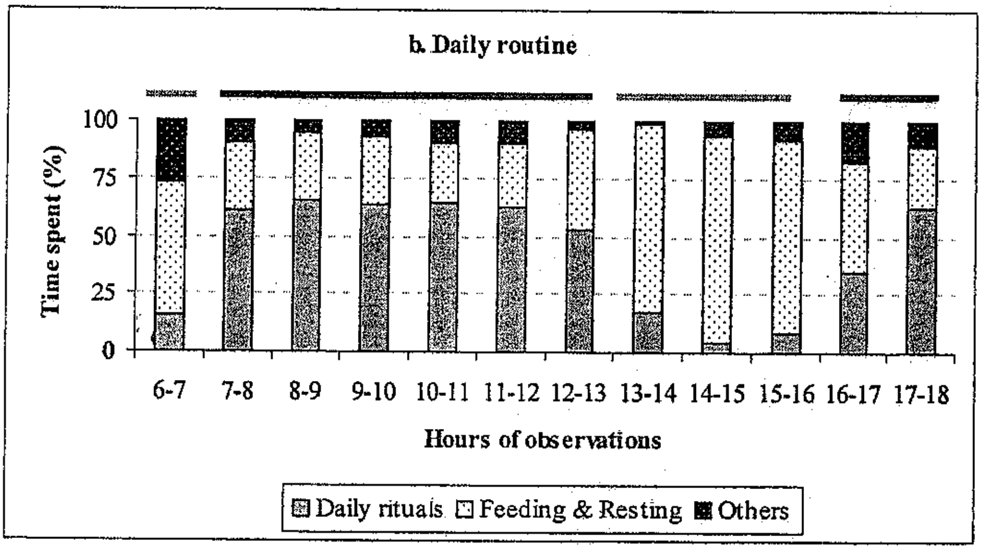


Note: Grey and black lines above the bar represent a higher proportion of time in these hours of observations elephants were in shed and temple respectively.

Daily rituals take place in Temple roof, Feeding and resting take place in elephant shed and others, which include drinking, walking and bathing, mostly take in the open places without any roof.

Figure 5: Mean rate (± SE) of ear flapping and daily routines in relation to daylight hours among captive elephants housed in shed with RCC roofs





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