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Seasonal and Roofing Material Influence on the Thermoregulation by Captive Asian Elephants and its Implications for Captive Elephant Welfare

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Introduction

Body temperature regulation appears to scale with body mass in vertebrates (McNab 1983). Larger animals need to develop means of dealing with the relatively great amount of heat that they produce (Phillips & Heath 1992). Larger animals cool slower than smaller ones, as surface area-to-volume ratio decreases with increasing body size. They could be expected to favor cold temperatures and fur can also be thicker on larger animals (Schmidt–Nielson 1984). Among the large mammals that inhabit tropical environments, elephants have sparse body hair and few sweat or sebaceous glands (Feldhamer *et al*. 1999). Their body size results in a large amount of metabolic heat apart from heat gain from the environment. The ambient temperature could increase the body temperature of elephants significantly (Buss & Estes 1971; Elder & Rodgers 1975; Weissenbock 2006). In the natural environment elephants avoid getting exposed to heat load by using a number of behavioural mechanisms like increased resting in the shade during hot day hours with frequent mud baths and ear flapping (Hiley 1975; Baskaran 1998) and also by decreasing the time spent on feeding during the daylight hours in the dry season as compared to the wet season (Baskaran 1998).

Asian elephants (*Elephas maximus*) in India are managed under captive conditions by the Forest Department at timber camps and zoos; by religious institutions at Hindu temples, mutts, and mosques; and by private agencies in residential areas (Krishnamurthy 1998). In most of these places, except timber camps, the environment is much hotter than their natural habitats. Further, the daily routine of the elephants are modified according to their use in captivity like daily rituals by temple elephants, cultural procession or begging by private elephants. After work, they are mostly chained inside enclosures. The enclosures are made of different types of roofing materials, namely, asbestos sheets (a construction material banned in many western countries), coconut frond thatching and reinforced cement concrete (RCC) that maintain room temperatures differently. The present study was carried out during May 2007–April 2008 to understand the seasonal influence of ambient temperature and different roofing materials on thermoregulation, through ear flapping frequency by captive elephants managed at six temples in Tamil Nadu, India.

Methods

Six female elephants, ranging in age from 14 to 56 yrs, managed by six Hindu temples located in Thanjavur and Nagapattinam districts of Tamil Nadu, India, were examined in this study. The six elephants were housed in six different enclosures with two each made of asbestos sheet, coconut frond thatching and RCC roofs. The roof height of asbestos houses is marginally higher (by 1-1.5 m) than the other two roof types and remaining architecture (wall and window) were almost same in all the house types. The study area experiences a prolonged summer (March - July), a short rainy season (August - October) and a winter period (November - February) with unusual rainfall occasionally (Fig. 1). The maximum and minimum temperatures range from 37.8°C in May to 19.1°C in December.

Data on time, frequency of ear flapping (randomly either left or right pinna) and major routines/

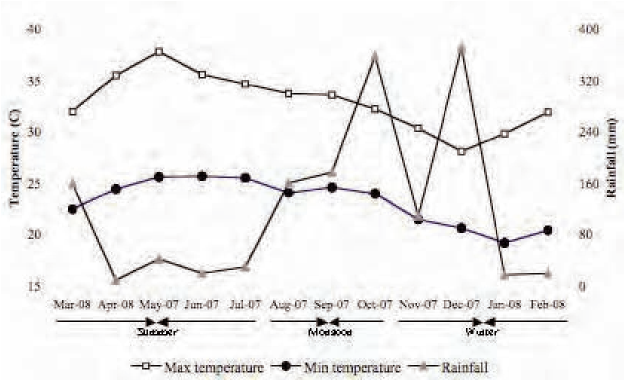

Figure 1. Monthly mean maximum and minimum temperature and rainfall recorded in the study area (source: Tamil Nadu Rice Research Institute, Aduthurai).

activities like daily rituals, green fodder feeding and resting bathing and walking were collected using focal sampling method (Altmann 1974). At the end of every focal sampling session, ambient temperature was recorded using a digital thermometer near the elephant's location. Observation on ear flapping was carried out on each elephant for a period of one year on two days/month from 6:00 to 12:00 hr and 12:00 to 18:00 hr on consecutive days when there was no major difference in the climatic conditions. Observation hours were divided into four sample blocks, with each block of 10 minutes observation and 5 minutes rest.

The daily routines of the elephants (excluding the other activities such as bathing, drinking, walking and supplementary diet feeding that occur in open places in the temple or out side the houses) were broadly classified into two categories—green fodder feeding and resting that take place inside the elephant house, daily rituals in which the elephant is placed inside the temple and quantified the proportion of time spent inside the temples and enclosures during the daylight hours (6:00–18:00 hr).

In majority of the cases when the elephants were placed inside the houses during afternoons, the mahouts would also go home. It was not possible to record the actual room temperature of elephant houses, as we were not permitted to enter the elephant houses for safety reasons but permitted to observe from outside. Therefore, in all the cases room temperature was recorded by placing the thermometer inside the elephant houses.

In addition, directly to obtain the difference in room temperature in the three house types, data on maximum and minimum temperatures from houses with three different roof types were collected in the same area for a period 24 hours for five days. The frequency of ear flapping and ambient temperature were computed and compared in relation to different hours of daylight, months of year and three different roofed (asbestos, coconut frond thatched and RCC) houses.

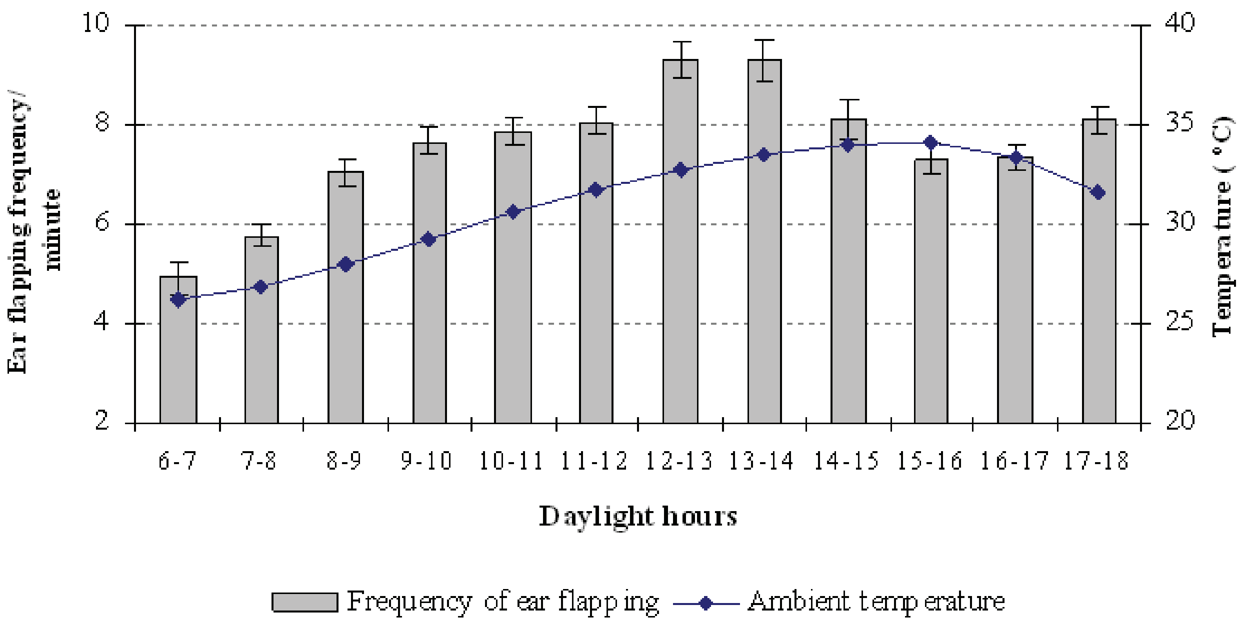

Figure 2. Mean frequency (±SE) of ear flapping by captive elephants and ambient temperature (±SE) recorded in relation to day light hours between May 2007 and April 2008.

Results

Frequency of ear flapping in different daylight hours

The frequency of ear flapping observed during daylight (6:00–18:00) hours increased gradually with ambient temperature from morning hours and reached the peak between 13:00 and 14:00 hr and thereafter declined gradually (Fig. 2). Comparison of the ear flapping frequency and mean ambient temperature recorded during daylight hours showed a significant positive correlation ($R=0.594$, $P<0.04$, $n=12$) suggesting that elephants increase ear flapping frequency with increasing ambient temperature.

Seasonal variation on ear flapping frequency

The rate of ear flapping in captive elephants varied remarkably in a 12-month period. It was the highest (9.2 times/minute) during May–June and dropped almost to half (5.7 times/minute) during December–January (Table 1) coinciding with the highest and the lowest mean ambient temperature record of 36±3.42°C and 28±3.38°C, respectively. Comparison of the ear flapping frequency and the ambient temperature recorded over 12 months showed a positive correlation ($R=0.839$, $P<0.01$, $n=12$) indicating the seasonal influence of ambient temperature on thermoregulation by captive elephants.

Table 1. Mean frequency of ear flapping per minute by captive elephants and ambient temperature (°C) recorded during different months between May 2007 and April 2008.

Month	Ear flapping ± SD	Temp. ± SD
January	6.2 ± 4.3	27.8 ± 3.7
February	7.3 ± 4.3	29.4 ± 3.2
March	6.7 ± 4.9	29.7 ± 3.1
April	7.2 ± 5.3	32.0 ± 3.4
May	9.0 ± 4.7	35.6 ± 3.5
June	9.4 ± 5.0	36.0 ± 3.4
July	8.1 ± 5.4	32.7 ± 3.4
August	9.3 ± 6.0	32.0 ± 2.8
September	8.7 ± 6.2	31.8 ± 2.5
October	7.9 ± 6.6	30.1 ± 3.4
November	7.7 ± 5.2	29.3 ± 3.3
December	5.2 ± 4.0	28.2 ± 3.0

Influence of various housing roofs on ear flapping frequency

The room temperature noted in three different roofed houses showed a remarkable difference in their range. The difference between maximum and minimum was the highest (mean of 12.7±7.0°C) in the asbestos-roofed houses (min. and max. 26.3–39°C) and the lowest (2.7±2.0°C) in the coconut frond thatched houses (min. and max. 30.6–33.3°C), while the RCC-roofed houses maintained an intermediate fluctuation (4.3±2.5°C) in room temperature (min. and max. 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 hr, showed a sudden spurt in the mean rate of ear flapping from about 6 times/minute between 11:00 and 12:00 hr to nearly 10 times/minute between 12:00 and 13:00 hr. The flapping rate remained at around 8 times/minute until 15:00–16:00 hr (Fig. 3a). After 16:00 hr, it reduced to <6.5 times/minute when the elephants were taken out from the houses to the temple yards for daily rituals. On the other hand, in the two elephants brought to the coconut frond thatched houses, during afternoon time around 13:00 hr; a remarkable drop was observed in the ear-flapping rate (Fig. 3b). The two brought under the RCC-roofed houses showed a gradual increase in ear flapping rate even after 12:00 hr, reached the peak by 13:00 hr and then gradually declined (Fig. 3c). In this case, the rate of ear flapping gradually increased even after they were 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 natural conditions they avoid exposure to heat load by using a number of behavioural mechanisms like resting in the shade during hot day hours with frequent and mud baths and ear flapping (Hiley 1975; Baskaran 1998). The high surface-to-volume ratio of the ear pinnae (Wright & Luck 1984) along with the prominent and extensive vascular network (Sikes 1971) and their mechanism of vasodilatation with an increase in blood flow and simultaneous frequent ear flapping under warm conditions increase convective heat loss (Wright & Luck 1984). Weissenbock (2006) using an infrared camera on Asian elephants in Sri Lanka has shown a positive correlation between body surface temperature and ambient temperature and 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 the role of ear pinnae in thermoregulatory mechanisms.

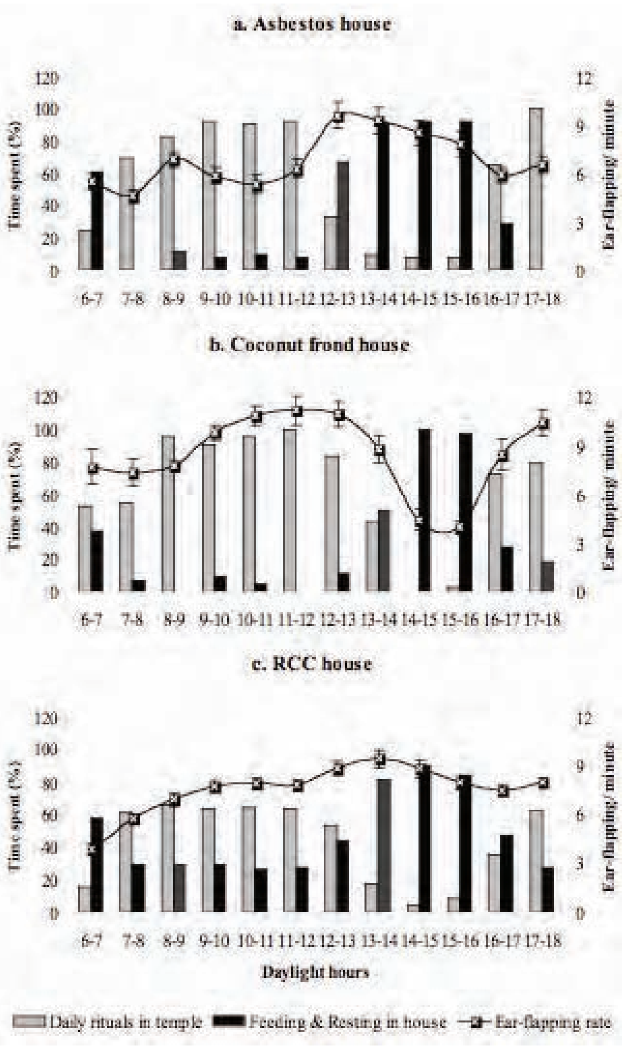

Figure 3. Mean rate (±SE) of ear flapping in relation to daily routines during daylight hours among elephants housed in shed with (a) asbestos, (b) coconut frond thatching and (c) RCC roofs.

The study area of Nagappattinam and Thanjavur districts being located in the plains region experiences relatively higher ambient temperatures unlike the natural habitats of elephants, which are 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 ranging from a minimum 19°C to a maximum 32°C during November–February support the fact that ambient temperature influences the ear-flapping rate of elephants. These results are in accordance with the findings of Buss & Estes (1971) and 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 fluctuation. In support of this, studies of Roma *et al*. (2008) have shown that asbestos sheets transfer temperature to the inside of the room significantly more than tiles reinforced with vegetable fibers. Therefore, asbestos roof houses tend to have the highest maximum and lowest minimum temperatures, respectively, during mid-day and night hours resulting in wide fluctuations in room temperature. Further, asbestos has been banned in many western countries, as it is known to cause serious health problems such as lung cancer and respiratory diseases among human beings (Doll & Peto 1985; Mossman 1993). The roof made of RCC has an intermediate fluctuation indicating that it is 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.

Of the three houses examined, elephants rapidly increased their ear flapping frequency after 13:00 hr when brought to the house made of asbestos sheet roof. In contrast, in the case of coconut frond roof houses, elephants decreased their ear-flapping rate remarkably after 13:00 hr when they were brought to the houses. Unlike the above two cases, the elephants brought to RCC roof houses 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 of houses reveal the positive influence of room temperature on ear flapping frequency. The large body size of elephants results in greater metabolic heat (Phillips & Heath 1992) and slower cooling than smaller animals, since the surface area-to-volume ratio decreases with increasing body size (Schmidt-Nielson 1984). Further, the presence of a few sweat glands (Feldhamer *et al*. 1999) could impose constraints in heat dissipation and therefore prefer cool temperature, as shown by free living elephants in the wild (Hiley 1975; Baskaran 1998). On the contrary, asbestos roofs do not maintain room temperature, as shown by maximum minimum temperature data of this study. In view of the present findings, some modifications are suggested to elephant house roofs to reduce the heat on the elephants.

Conclusions and recommendations

The effects of adverse seasonal climate (temperature) are compounded by the undesirable properties of asbestos used in roofing of the elephant housing. Such situations exist in not only the study area, but elsewhere too. Therefore, some of the recommendations made here may be applicable to other areas also, where similar conditions on climate and/or roofing of the elephant housing exist.

The present study assessed the influence of ambient temperature in different seasons and housing roofs on the ear-flapping frequency among six captive elephants managed in Hindu temples in Tamil Nadu between May 2007 and April 2008.

The comparison of ear flapping frequency with temperature recorded during different hours of daylight (6:00–18:00 hr) 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 with 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. Captive elephant facilities need to keep in mind the daylight and seasonal influence of ambient temperature on the physiology of elephants and schedule their workload accordingly.

Among the three different houses, ear-flapping rate increased suddenly around 13:00 hr when the elephants were brought from granite-roofed temple yards to the asbestos-roofed elephant houses. On the other hand, its frequency decreased in coconut frond thatched roofs, and there was no remarkable change in RCC houses. The relatively higher room temperature recorded in asbestos-roofed houses and the lower room temperature in the coconut frond thatched houses could have respectively increased the ear flapping in asbestos houses and decreased in coconut frond houses. RCC houses with a moderate temperature regulation continue to increase the rate of ear flapping.

Based on the findings we suggest that asbestos roofs be eliminated 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. Further, asbestos is known to cause serious health problems such as lung cancer and respiratory diseases among human beings (Doll & Peto 1985; Mossman 1993). Therefore, roofs made with asbestos need to be replaced urgently, ideally with coconut fronds. False roofs of coconut fronds be built on existing RCC houses (on the upper side) or a shade tree be planted on the sides of elephant houses to minimize the exposure of RCC roof to the solar heat load.

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