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RESEARCH ARTICLE

Effect of temperature on activity budgets of free ranging Dusky Toque Macaques (*Macaca sinica aurifrons*): A case study from Peradeniya University premises, Sri Lanka

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Abstract: *Macaca sinica* is the smallest of all 22 extant macaque species in the world. There are three geographically isolated endemic sub-species of *M. sinica*: *M. s. sinica*, *M. s. aurifrons* and *M. s. opisthomelas* in Sri Lanka. Macaques adjust their activities to deal with changeable environments like weather changes and food availability fluctuations, proving their plasticity nature. Current study focused on assessing the temporal variation of activity budgets and effects of temperature on their activity pattern. Behavioral data were collected using scan sampling method. Overall activity budget analysis found that they allocate more time on resting (32.60 ± 4.97%), whereas less time spent for moving (26.30 ± 3.15%) and feeding (19.60 ± 2.97%). Moving was negatively correlated with monthly average temperature (r= -0.489 *p*= 0.029). The study found that time allocation for moving was reduced to compensate their thermoregulatory cost in terms of energy. This suggests that changes in movements of *M. s. aurifrons* are a useful indicator in assessing environmental changes such as temperature alterations.

Keywords: Temperature effect, Activity budgets, *Macaca sinica aurifrons*

INTRODUCTION

After *Homo*, the genus *Macaca* has the widest geographical range among primates, and both of these genera are present in tropical and temperate regions (Thierry, 2007). There are 22 extant macaque species described to date (Pethiyagoda, 2012). Among that, *Macaca sinica* (Toque macaque) is the smallest of all macaques: males averaging about 5.3 kg and females about 3.5 kg (Fooden, 1979; Cheverud and Dittus, 1992). They are globally endangered (EN) and least concerned (LC) at national level (MOE, 2012). There are three geographically isolated sub species of *Macaca sinica* found in Sri Lanka, *ie*; *M. s. sinica* in low country dry zone, *M. s. aurifrons* in wet zone and *M. s. opisthomelas* in upcountry or hill zone of Sri Lanka. Adult males and females of *M. s. aurifrons* make up almost (60 %) of the group and group size ranges from 8-76 individuals (Vandercone, 2003). There is no distinct breeding season for toque macaques; mating takes place whenever females come into estrus (Phillips, 1980) but births of young peak around February-April. Macaque densities of 1.35 to 1.8 individuals per hectare have been reported from urban areas in Sri Lanka (Wijeyamohan *et al*., 1996).

Studies on activity budgets are fundamental to test hypotheses about primate ecological influences on social behavior and group living (Isbell and Young, 1993). Li (2009) described that primates can flexibly adjust their activity budgets to deal with changeable environmental conditions such as temperature changes, precipitation, seasonal food availabilities and food distribution. Other factors found to be influencing the activity budgets of macaques are the number of individuals in a group (Isbell and Young, 1993) and provisioning and consumption of human food (Saj *et al*., 1999). Even within a species, activity patterns and time budgets can show great differences among populations, sex, ages and habitats (Dunbar, 1992; Isbell and Young, 1993; Fashing, 2001).

Current study provides a quantitative framework for the temporal variations of daily, monthly and overall activity budgets of *M. s. aurifrons* (Dusky toque macaque) and alterations of their activity budgets with respect to fluctuating temperature.

MATERIALS AND METHODS

Study site and study subject

The study was conducted in lower Hanthana area in Peradeniya University premises (7°15′24.63″ N 80°36′08.21″ E). Hanthana region experiences 24.1 °C mean annual temperature and the mean annual precipitation of 2,121 mm which, is distributed throughout the year and influenced by both southwest and northwest monsoons (Kariyawasam, 1998; Ratnayake, 2001). Lower Hanthana part of University land supports three woodland types; *Pinus* woodland (dominated by *Pinus caribaea* a fast growing conifer species), *Albizia* woodland (dominated by *Albizia falcataria*) mixed woodland and *Alstonia* woodland (dominated by *Alstonia macrophylla*) (Kariyawasam, 1998). Other than that there are grasslands dominated by *Megathyrsus maximus*, riverine area and home gardens dominated by flowering and fruit trees. Land use and vegetation cover within the study area is shown in Figure 1.

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Figure 1: Land uses and vegetation cover of University of Peradeniya, Sri Lanka.

Table 1: Dusky toque macaque behaviors listed in the ethogram to facilitate the scan sampling of the study troop.

Activity	Justification
Resting	Instances when a monkey in inactive mode, usually sitting or lying down on a tree branch or ground
Feeding	Instances when a monkey plucks food item, ingesting, masticating and swallowing
Moving	Any locomotor behavior including walking, running or climbing that results its spatial position
Mating	Instances when two opposite sexes copulate
Grooming	Instances when a monkey uses its hands to explore or to clean the body of another monkey
Social-play	Chasing, hitting, wrestling and other vigorous activities involving exaggerated movements and gestures by ≥2 monkeys that were clearly interacting with each other in a non-aggressive manner
Vigilant	Instances when a monkey peers intensely in a certain direction
Aggression	Instances when a monkey chased, bit, grabbed, threatened another monkey
Self-grooming	When a monkey engaged with scratching, cleaning oneself
Other	Activities that do not fit to these ten categories

The study focused on *M. s. aurifrons*. Out of 6-5 macaque troops inhabited in the University premises, only one troop was observed as the study troop due several circumstances. The study troop contained 30-34 individuals throughout the study period. Facial marking patterns and other morphological features including fur colour and tail variations were used to identify individuals in the study troop.

Collection of Behavioral data

Ethograms were used as a tool to construct activity budgets. Dusky toque macaques were engaged in a diverse set of activities (Table 1). Resting, moving and feeding were considered as their main activities. Mating, grooming and social play were categorized under social activities and vigilant, aggression and self-grooming were considered as other activities.

Data were collected 4-5 days/month using scan sampling method (Altmann, 1974) from the dawn until dusk (0700 hour-1700 hour) for five consecutive months, from February to June 2016. Only whole day follows were taken to the analysis and January was omitted due to low data collection. Each scan lasted for ≤3 minutes for every 10 minute interval (Vandercone *et al*., 2012). All age and sex classes were included in each scan, which comprised of many adults and sub-adult individuals (Vandercone *et al*., 2012). Infant activities were not included because they usually stay tied up

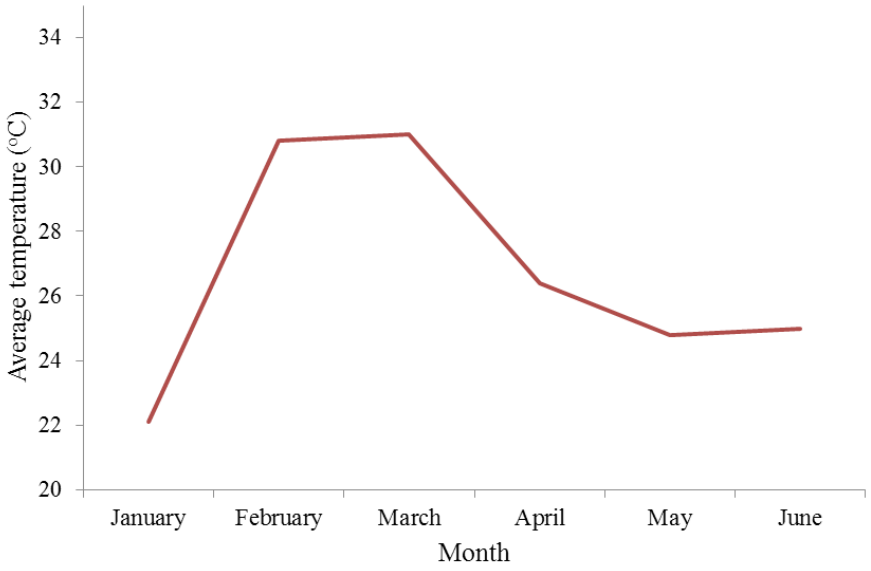

Figure 2: Monthly average temperature variations in the study period in 2016 recorded at the weather station installed at the Department of Geography, University of Peradeniya, Sri Lanka.

with their mother. When an individual was spotted, first activity that last >3 seconds was recorded to minimize over-representation of eye-catching ephemeral activities (Fashing, 2001).

Weather data

Temperature for January to June 2016 was obtained from the station located at the Department of Geography, University of Peradeniya, Sri Lanka (Figure 2).

Statistical analyses

Activity budget data were analyzed under three sections as overall activity budget, monthly activity budgets and daily activity budgets (Shanee and Shanee, 2011). Activity budget data were treated with non-parametric tests, since data were not normally distributed and percentage values were taken for the statistical analysis.

Overall activity budget for the entire study period was calculated. Kruskal-Wallis test (H) was performed for overall activity budget to check the differences in time allocation of separate activities. Mann- Whitney U tests (U) was performed for pairwise comparisons when the Kruskal-Wallis test indicated significant differences between them (Li, 2009).

Monthly activity budgets were constructed for five consecutive months. Kruskal-Wallis test was performed to analyze for monthly activity budget to check differences in time allocation of five activity types throughout the study period. Spearman's correlation coefficient (r) was calculated to assess the relationship between monthly average temperature and time allocation for activities.

Daily activity budgets were calculated on the basis of hourly intervals from 0700 hour to 1700 hour, and they were analyzed by hourly changes in activity types among five months using Kruskal-Wallis test for the study period. All statistical analyses were performed using Minitab 17.1.0 (©2013 Minitab Inc.). Statistical significance was set at $p \leq 0.05$.

RESULTS AND DISCUSSION

A total of 202 observation hours of the study troop comprising of 1,152 scans and 5,886 behavioral records are made. The amount of time devote to different activities vary throughout the sample period. Time allocation variations are significant for different activities (H= 22.74 p= 0.001). Overall activity budget of the study troop with reference to five categories of activities (rest, move, feed, social, other) shows in Figure 3. Mann-Whitney U test shows that five types of activities are significantly different from each other (rest and move: U= 38 p= 0.036, social and other: U= 15 p= 0.012, all other pair wise possibilities: U= 40 p= 0.012). The study found that time is an important resource to *M. s. aurifrons*. The study has been carried out on the basis of entire toque macaque troop with reference to five major activities. Low visibility, habitat complexity and low labor intensity do not allow following the focal animal sampling method (Altman, 1974). Therefore, scan sampling method (Altman, 1974) is found to be the best suited method for this study in order to construct activity budgets of free ranging *M. s. aurifrons*. Researchers have studied activity budgets extensively in different primate species because, they reflect the different constraints on time-energy balances, or the species' ability to survive under the ecological limits of their tolerance determinants of activity budgets (Xiang *et al*., 2010). However, relatives of *M. s. aurifrons* seemed to have different activity budgets in comparison to the current study (Table 2).

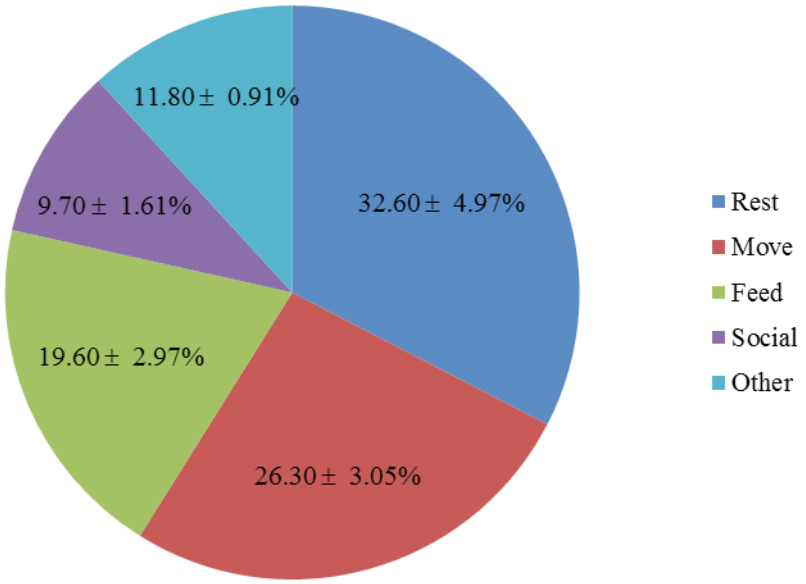

Figure 3: Overall activity budget for the study troop with reference to five categories of activities from February to June 2016.

Table 2: Activity budgets of major activities of some Macaca species.

***Macaca* species**	**Feeding/ Foraging (% time)**	**Travelling (% time)**	**Resting/ inactive (% time)**	**Source**
Macaca assamensis	40.0	25.0	13.0	Sarkar and Srivastava, 2012
Macaca fascicularis	18.8	20.3	17.1	Hambali *et al*., 2012
M. f. umbrosa	36.1	22.4	15.7	Rajeshkumar and Raghunathan, 2014
Macaca fuscata	16.0	38.0	32	Hanya, 2004
Macaca mulatta	36.2	11.0	36.8	Jaman and Huffman, 2012
Macaca silenus	15.0	> 50	27	Kurup and Kumar, 1993
Macaca sinica sinica	~46.0	~9.5	~35.0	Dittus and Ratnayeke, 1989
M. s. aurifrons	**19.6**	**26.6**	**32.6**	**Present study**

Monthly activity budget is shown in Figure 4. However, differences in time allocation for activity types in five months are not significant except for other activity category, which includes aggression, vigilant, and self- grooming (H= 9.95 p= 0.040). Hourly basis daily activity budgets vary within the study period, but resting is the only activity that shows significant difference among months (H= 19.16 p= 0.024). Average daily activity budget shows that there are two major resting peaks: 0900- 1100 hour and 1300-1500 hour (Figure 5).

Some of macaques show more time allocation for feeding/ foraging while others show more time allocation for travelling. Only *Macaca fuscata* and *M. mulatta* show more time allocation for resting similar to *M. sinica*. Nevertheless, the results obtained indicate that, time allocation for different activities are significant. Feeding, travelling and being vigilant or aggressive have immediate impact on fitness (Korstjens *et al*, 2010). However, resting reflects not only time which is to be allocated to something more useful, but also time which is needed for recuperation, predator avoidance, digestion and thermoregulation (Herbers, 1981). Therefore, resting is considered as an energy saving state for the benefit of other energy intensive activities. In this aspect, *M. s. aurifrons* spends more time on energy saving for the better functions of other activities including moving to a nutritious food source/resting place, to encounter predators and rival attacks and for successive mating. Grooming and social play are prominent when they were at rest. However, the time allocated for resting seems to be inversely correlated with moving and feeding activities.

Moving is the second most common activity in *M. s. aurifrons*. The study troop was surrounded by plenty of food sources either naturally occurring or human food waste. Macaques' major task is to move to a better quality food source by minimizing the energy

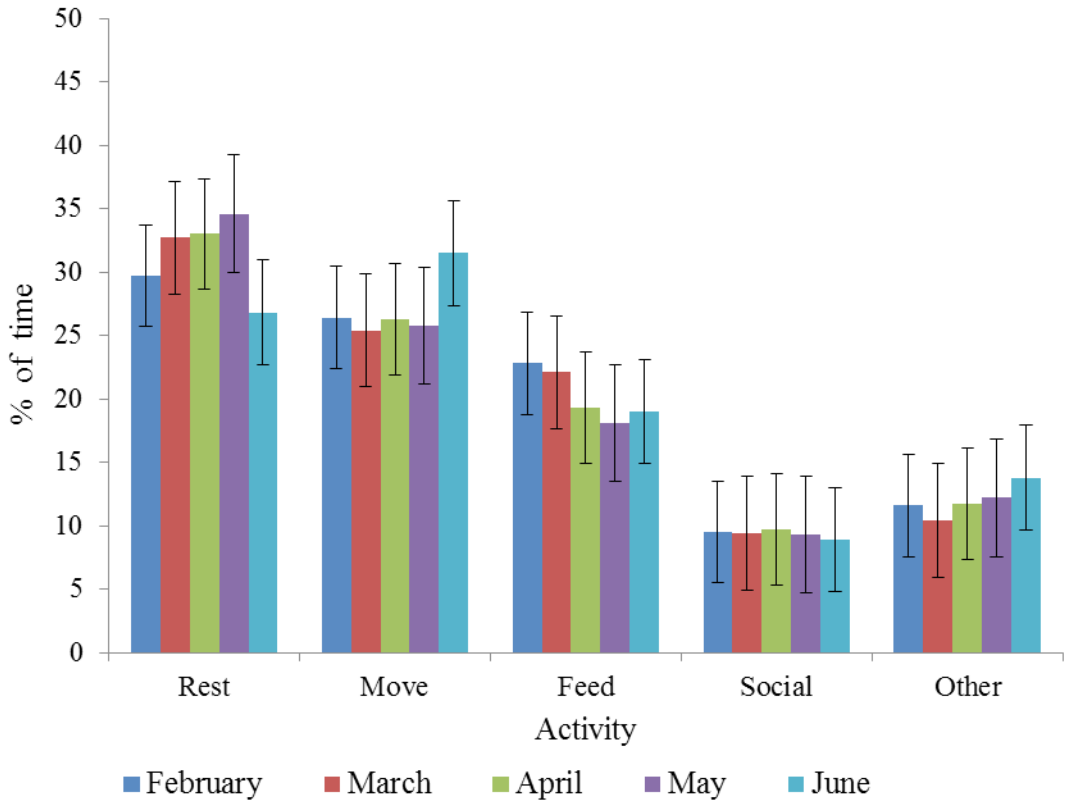

Figure 4: Monthly activity budgets of Macaca sinica aurifrons study troop from February to June 2016. Vertical lines indicate the standard error of the mean (SEM).

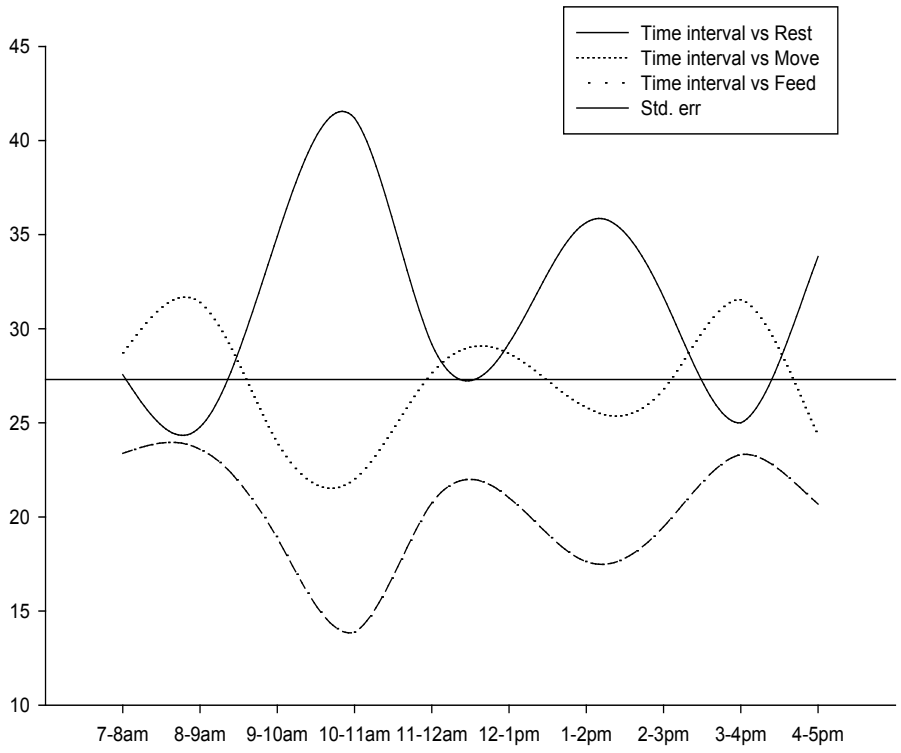

Figure 5: Smooth line curve of overall daily activity budget of Macaca sinica aurifrons study troop from February to June 2016.

Table 3: Spearman's correlation coefficient values to assess the relationship between activity and average temperature.

Activity	r	p
Rest	0.182	0.443
Move	-0.489	0.029
Feed	0.420	0.066
Social	0.179	0.450
Other	-0.503	0.024

spent for travelling and protection. Therefore, decisions about time allocation have always been at the core of optimal foraging theory. The third highest activity is feeding. Individuals with high social ranks always get the privilege to access most part of the food while others depend on rest of the remaining food or they move to seek unoccupied food sources.

Monthly average temperature shows a significantly negative correlation towards moving and other activities whereas, remaining activities do not significantly correlate (Table 3).

Percentages of time allocation for moving and other activities are reduced due to increased temperature whereas, low temperature causes to increase their time allocation for moving and other activities. However, moving and feeding are considered as energy-consuming activities (Coelho *et al*., 1976), and it is difficult to maintain an energy-conserving (curled) posture during moving as compare to during resting (Korstjens *et al*, 2010). Therefore, macaques alter their moving time only to adjust to fluctuating thermoregulatory costs (Hanya, 2004). High temperatures at midday can cause primates living in the tropics to overheat, so they stay inactive to reduce the level of heat-generating activity (Xiang *et al*., 2010). Similarly, *M. s. aurifrons* decreases the time allocated for moving inversely to the temperature to reduce over-heating for energy conserving purpose. In addition, other activity categories comprise of high energy consuming activities including vigilance and aggression. Thereby, they are negatively correlated with temperature similar to moving. This type of similar behavioral pattern in respect to temperature changes (Xiang *et al*., 2010) are shown by *Macaca fuscata* (Hanya, 2004), *Macaca sylvanus* (Ménard and Vallet, 1997). Moreover, comparing the activity budgets of captive macaques with free ranging wild macaques has been able to assess the management level of captive conditions (Melfi and Feistner, 2002). Thereby, management qualities can be improved in macaque captive centers including zoos. Finally, these qualitative findings are valuable for conservational purposes, since *Macaca sinica* is considered as endangered primate under Global Conservation Status.

CONCLUSION

Moving, vigilance and aggression are high energy consuming activities. Thus, Dusky toque macaques remained inactive or reduced high energy consuming activities during high temperature periods to compensate the thermoregulatory cost. This study suggests that macaques are highly adaptive mammals in reference to changing temperatures, proving their potential behavioral plasticity. In such conditions, macaques are useful as indicator organisms to assess environmental differences such as temperature alterations.

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