Seasonal Variation in the Activity Budget of Indian Giant Flying Squirrel (Petaurista philippensis) in Tropical Deciduous Forest, Rajasthan, India

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Seasonal variation in the activity budget of Indian giant flying squirrel (*Petaurista philippensis*) in tropical deciduous forest, Rajasthan, India

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Abstract. Knowledge of the activity patterns and budget provide insight into how animal adapt to the environment through behavioural modification. Time activity budget of Indian giant flying squirrel (*Petaurista philippensis*) was studied in the tropical deciduous forests of the Sitamata Wildlife Sanctuary, Rajasthan, India, from March 2009 to February 2010. The study revealed that the species exhibited a bimodal activity pattern with a first peak in the early-night, while a second lower peak occurred during the late-night. Annual activity budget was mostly devoted to resting (45.85 %) and feeding (27.72 %) followed by locomotion (10.84 %), grooming (6.20 %), exploring (5.71 %), inside tree cavity (2.15 %), and calling (1.24 %) activities. Except grooming ($P < 0.05$) and inside tree cavity ($P < 0.0001$), all other activities did not show significant difference ($P > 0.05$) among seasons. Among all seasons, the species was found more active in winter season.

Key words: activity pattern, behavioural patterns, bimodal activity

Introduction

Activity pattern is defined as an animal's daily rhythm of activity and inactivity, while the activity budget is defined as allocation of time among different behaviours and most often documented as percentage of activity (MacHutchon 2001). The daily activity is influenced by the individual's need, interaction with conspecifics and other species. Animals modify their activities to maximize energy gain and reproductive output. On the other hand, these compromises should vary according to intrinsic factors of animals such as age, mass, reproductive status, circadian rhythm, social rank and physiological requirement (Crawford 1934, Corp et al. 1997, Ramesh et al. 2015), as well as extrinsic environmental factors such as ambient temperature, humidity, illumination, precipitation, group size, habitat, food availability, predation (Jahoda 1973, Goyal et al. 1983, Kurup & Kumar 1993, Solanki 2000, Fernandez-Duque 2003, Mendiratta et al. 2009, Mekonen et al. 2010, Baskaran et al. 2011, Challender et al. 2011, Kuo & Lee 2012, Lillywhite & Brischoux 2012, Giné et al. 2015) and human interference (Bashir et al. 2013). Knowledge of activity patterns and budget provide insight into how animal adapt to the environment through behavioural modification.

The Indian giant flying squirrel (*Petaurista philippensis* Elliot, 1839) is a nocturnal arboreal rodent and has the widest distribution among all the flying squirrels in the tropical and sub-tropical zones of southeastern Asia (Wilson & Reeder 2005). It is a typical inhabitant of the forests in lowlands and mountains up to 4000 m (Yu et al. 2006). The size of the species is larger (body mass 990-2500 g) (Lee et al. 1992, 1993, Nowak 1999) than other flying squirrels and body length is about 1040 cm, including tail length (about 550 cm) (Corbett & Hill 1992). In India, it has a broader distribution among 13 flying squirrel species (Nandini 2001a, b, Kumara & Singh 2006, Koli 2015). It lives in cavity nests (Koli 2012, Koli et al. 2013a) and feeds on fruits, leaves, buds, flowers and pith (Nandini & Parthasarathy 2008, Bhatnagar et al. 2010, Koli et al. 2013b). The species can glide more than 30 m, but prefers short glides (10-20 m) (Koli et al. 2011). Early summer is considered the breeding season for *P. philippensis* in India (Zacharias & Bhardwaj 1997, Koli et al. 2011). Globally *P. philippensis* is categorized as a species of least concern (LN) (Walston et al. 2008), and near threatened (NT) (Molur et al. 2005). In India, the species is facing the rapid population decline. It is mainly due to

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deforestation, forest fragmentation, anthropogenic disturbances, agricultural encroachment (Kumara & Singh 2006, Kumara & Suganthasakthivel 2011), hunting (Nandini 2001a, b, Kumara & Singh 2004), construction of national highways and cultural myths such as dried body, bones and hairs of flying squirrels are kept in huts of Bhil tribe, pieces of bones are tied around the neck of under weight human infants by Bhil and Garasia tribes and hair of flying squirrels are also used to fumigate the under weight human infants in the hope of weight gain (Koli et al. 2013a).

Rajasthan is the largest state of India and its southern part includes the known western distributional range of *P. philippensis* (Tehsin 1980, Koli et al. 2013a). Here we describe the seasonal influence on daily and seasonal activity budget and behavioural patterns of *P. philippensis* inhabiting tropical deciduous forest in south Rajasthan.

Study Area

The study was conducted in the Sitamata Wildlife Sanctuary (74°25′-74°40′ E and 24°04′-24°23′ N), located in southern Aravalli hills of Rajasthan, India (Fig. 1). It covers an area of 423 km^2, and the configuration of the land is hilly and rugged with considerable altitudinal variation ranging from 280 to 600 m. The forest of the sanctuary is tropical deciduous, dominated by *Tectona grandis*, *Terminalia tomentosa*, *T. arjuna*, *Boswellia serrata*, *Madhuca indica*, *Ehrarhatia levis*, *Diospyros melanoxylon*, *Soymida febrifuga*, *Ficus religiosa*, *F. amplissima*, *Cordia dichotoma*, *Aegle marmelos*, *Mangifera indica* and *Emblica officinalis* (Champion & Seth 1968).

The climate of the study area is characterized by three seasons: summer (March-June), monsoon (July-October) and winter (November-February). The maximum daily temperature varies from 45 °C in May to 25 °C in January, and the minimum nighttime temperature from 26 °C in July to 5 °C in January (March 2009-2010 January). The annual rainfall was 793 mm (March 2009-2010). During the annual rainfall cycle, about 82 % of rainfall occurs during the monsoon season (July-October) followed by seven dry months (November-June) (Fig. 2).

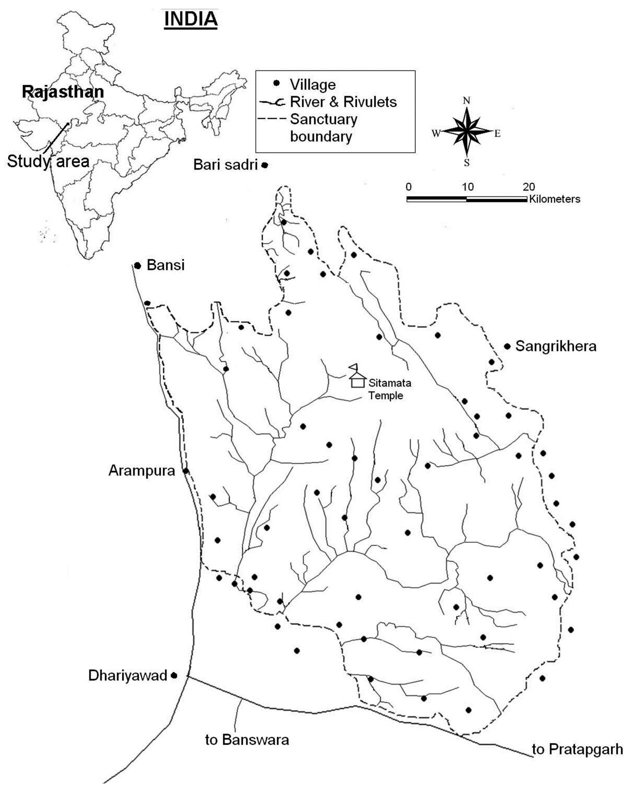

Fig. 1. An outlined map of the study area i.e. Sitamata Wildlife Sanctuary, Rajasthan, India.

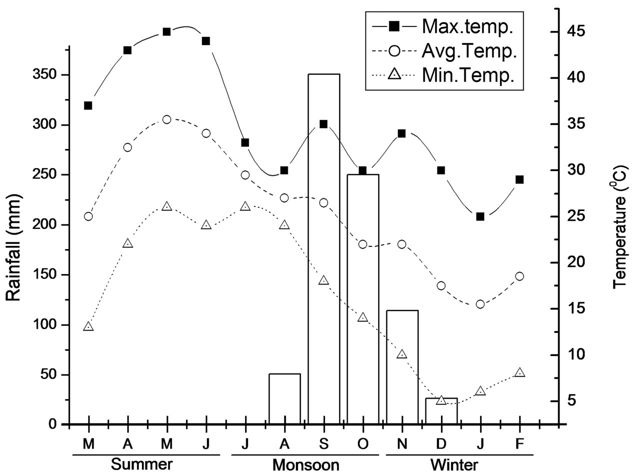

Fig. 2. Monthly temperature (maximum, average and minimum) and rainfall (mm) at Sitamata Wildlife Sanctuary during March 2009 and February 2010.

Material and Methods

We selected seven trails (10 km long each) which covered large part of the sanctuary. We randomly selected a trail and began walking from 18:00 h. Animals were followed and the data was collected for four nights in an every fortnight between March 2009 and February 2010. Flying squirrels emerge from their nest cavities 20-45 minutes after the sunset in the study area (Sharma 2007), thus the study was carried out between 18:00 and 06:00 h. Distinct red eye shine (Jamdar 1985), calls and movement of the animals were used to locate the animals. We first used spot light to spot the animal while walking on the trail. Once the flying squirrel was spotted, we followed the animal and recorded the activity by using the focal animal sampling at 5 min intervals

(Altmann 1974). At each sampling interval, each activity was noted as one activity record. When the animal was lost, we moved further to find another and followed the same procedure until 06:00 h., when flying squirrels stop their activities (Kuo & Lee 2012) and return to nest cavities. Since white light hinders their activities, a red filtered light was used to observe the flying squirrels. More than 5 m distance was maintained from the animal while taking observations, because at this distance, flying squirrels can tolerate human presence and appeared undisturbed (Lee et al. 1993). Following an initial encounter, *P. philippensis* stops activities and in most cases freezes and becomes periodically motionless, but resumes normal activities after a few minutes. Disturbed activities were excluded from the study data. During observations, whenever flying squirrel entered the nest cavity, we waited for the animal to exit the cavity or until 06:00 h. It was very difficult to identify individual animals at night without uniquely marking them. Sex identification was also very difficult during the most of the cases due to its fast movement in dense foliage of the canopy. The similar colour pattern of the squirrels also restricted us from following the same individuals consistently and maintaining separate records for animals. So, every encountered squirrel was considered as a new squirrel during the study. Data collectively represent the species not the individuals. Encounter rate was calculated as number of animals observed/travelled km.

Activity of *P. philippensis* was classified into seven categories: feeding (including handling and ingestion of food items), calling, movement (includes quadrupedal movement, such as walking, running, climbing, jumping and gliding), resting (outside the tree cavity without any activity), exploring (including food searching and scrutinizing surroundings), grooming (squirrels clean itself by licking, biting and scratching through hairs) and nesting inside the cavity (squirrels in tree cavities). Our field study procedures conform to the American Society of Mammalogists guidelines (Animal Care & Use Committee 1998).

Activities of flying squirrels were broadly categorized into active and inactive periods. Active period was defined by calculating the proportion of time squirrels were not resting or inside a tree cavity. Nightly activity was calculated by pooling data at a hour interval between 19:00 and 06:00 h. The active period was divided into three sessions for precise description of daily and seasonal activity: first four hours as early-night, with exit of flying squirrels from nest cavities or start of activities (19:00 to 23:00 h.), second three hours as mid-night (23:00 to 02:00 h.) and remaining

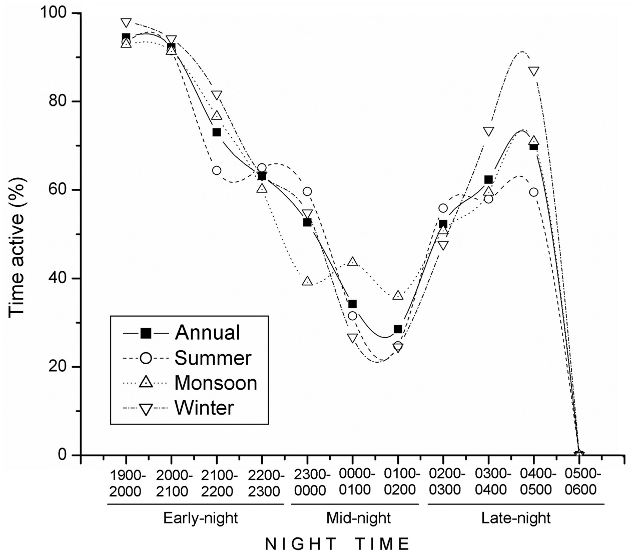

Fig. 3. Annual and seasonal daily activity patterns of *Petaurista philippensis* in tropical deciduous forest, Rajasthan, India from March 2009 to February 2010.

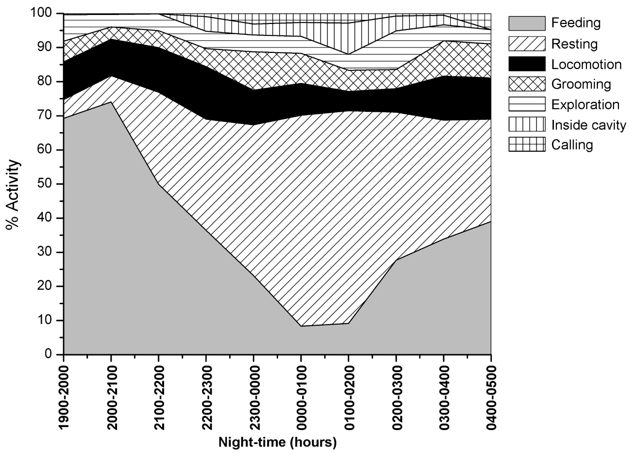

Fig. 4. Daily activity pattern of different activities of *Petaurista philippensis* in tropical deciduous forest, Rajasthan, India from March 2009 to February 2010.

four hours as late-night (02:00 to 06:00 h.) with squirrels entering nest cavities or the end of activities. Data were pooled for monthly periods and the daily activity pattern was evaluated by calculating amount of time allocated to each behaviour as a percentage of total time for all activities recorded. Activity budget devoted to each activity type was expressed as a percentage of total activity time.

Data are reported as mean ($\overline{X}$) ± SD. The normality of the data was tested with the Kolomogorov-Smirnov goodness of fit procedures. For multiple-group comparisions of normally distributed data, we used one-way analyses of variance (ANOVA) to test for significant differences between periods (night sessions and seasons), and Tukey's test for multiple pairwise

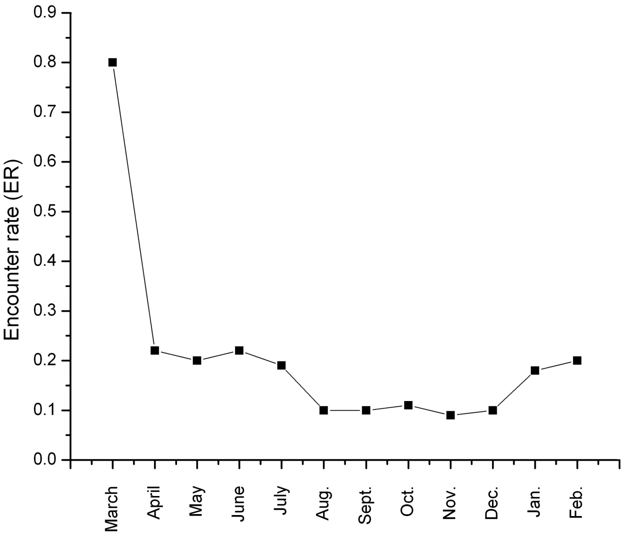

Fig. 5. Encounter rate of *Petaurista philippensis* during the study period in tropical deciduous forest, Rajasthan, India from March 2009 to February 2010.

Table 1. Activity budget of *P. philippensis* observed during March 2009 and February 2010 in tropical deciduous forests, Rajasthan, India. Data show active time as percentage of total observation time.

Total observation hours	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.
	10.4 h.	12.3 h.	20.5 h.	19.6 h.	18.3 h.	22.4 h.	14.8 h.	21.3 h.	13.4 h.	12.1 h.	17.5 h.	23.4 h.
Resting	49.33	48.94	44.25	48.35	43.53	46.37	44.42	50.04	49.97	43.04	42.26	38.25
Inside cavity	1.06	0.87	0.86	1.19	2.91	1.83	2.69	3.41	2.62	2.58	2.54	1.78
Feeding	25.64	25.54	29.73	22.86	28.33	27.60	30.29	25.41	21.03	29.73	32.02	37.33
Locomotion	12.80	12.19	11.96	10.92	11.89	11.94	10.11	10.18	10.68	8.54	8.38	12.09
Grooming	6.13	7.30	8.36	9.20	4.99	6.88	5.00	3.00	6.37	6.07	6.43	5.52
Exploration	3.34	4.36	4.06	6.47	6.50	4.24	5.68	6.16	8.30	9.07	7.65	3.62
Calling	1.70	0.80	0.78	1.01	1.85	1.14	1.81	1.80	1.03	0.97	0.72	1.41

Table 2. Percentage behavioural classes in different seasons. *P* values show the significant (ANOVA) of seasonal comparisons. Means within each behaviour sharing a common superscript do not differ (multiple comparison with the Tukey test, *P* < 0.05). NS = non significant.

	Summer		Monsoon		Winter		
Behaviours	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	*P*
Resting	48.19^{a}	2.12	$46.59^{a,h}$	3.38	$43.82^{a,h}$	4.84	NS
Inside cavity	1.09^{b}	0.17	$3.11^{b,e,f,g,i}$	0.35	$2.53^{b,e,f,g,i,l,m,n,o}$	0.43	< 0.0001
Feeding	25.94^{c}	2.83	$27.93^{c,j}$	2.05	$30.03^{c,j}$	6.79	NS
Locomotion	11.84^{d}	0.63	$11.03^{d,e,k}$	1.02	$9.92^{d,e,f,k,l,m,p}$	1.78	NS
Grooming	$7.74^{d,e}$	1.32	$4.96^{b,e,f,g,i,k,l}$	1.58	$6.34^{b,d,e,f,g,i,k,l,m,n,o,p}$	0.63	0.035
Exploration	$4.55^{b,e,f}$	1.34	$5.64^{b,e,f,g,i,k,l,m}$	0.99	$7.31^{b,d,e,f,i,k,l,m,n,o,p,q}$	2.60	NS
Calling	$1.07^{b,f,g}$	0.43	$1.65^{b,e,f,g,i,l,m,n}$	0.34	$1.03^{b,f,g,i,l,m,n,o,q}$	0.28	NS

comparisons. Multiple-group comparisions with non-normally distributed data were analyzed with the Kruskal-Wallis ANOVA to examine difference between seasons and sessions. To produce a normal distribution, proportions were arcsine-square root transformed before analysis. Results were considered significant at $P < 0.05$ level. All statistical analysis were performed in GraphPad Prism statistical software (Version 3.02).

Results

P. philippensis exhibited a bimodal activity pattern (Fig. 3). The first initial peak was between 19:00-20:00 h., whereas the second peak occurred in the late-night session (04:00-05:00 h). Mid-night was a reduced activity period. Daily active periods varied among night sessions (Kruskal-Wallis H = 7.2, df = 3, $P < 0.05$) but not among seasons (Kruskal-Wallis H = 0.05, df = 10, $P > 0.05$). Each activity showed a different pattern and peaks in daily routine (Fig. 3). Feeding, movement and exploration were highest during early night and dropped in late night. Grooming was more or less similar throughout the night. Entrance into the tree cavities was mostly performed during the mid-night, while calling and resting were highest in mid- and late-night (Fig. 4).

A total of 158 flying squirrels were encountered during the study period. The highest encounter rate was in March 2009 while the lowest was in November 2009 and January 2010 (Fig. 5).

Flying squirrels were more active during the winter season (54.24 ± 2.42 %) followed by summer (51.28 ± 3.18 %) and monsoon season (51.20 ± 5.17 %) respectively. The difference was also statistically significant ($F = 3.34$, $df = 2$, $P < 0.05$)

Flying squirrels were active 46.6-60.0 % of the observation time each month (Table 1). The majority of active time was spent on feeding. The annual activity budget of *P. philippensis* was 45.9 % resting, 27.7 % feeding, 10.8 % locomotion, 6.2 % grooming, 5.7 % exploring, 2.2 % inside tree cavity, and 1.2 % calling. Except grooming ($P < 0.035$) and inside tree cavity ($P < 0.0001$), all other activities did not show significant difference ($P > 0.05$) among seasons (Table 2). Resting was the most common behaviour in all seasons. Feeding was more in monsoon, and less in summer season. Movement was higher in summer and less common in winter. Time spent in grooming was higher in summer and lower in monsoon. Calling was higher in monsoon (Table 2).

Discussion

During the study, *P. philippensis* showed bimodal activity pattern. Activity commenced at dusk and it gradually decreased until the mid-night session, with a second smaller activity peak in the late-night session. Resting and feeding were most accounted activites in the activity budget. Seasons had no significant effect on different activities except grooming and inside tree cavity.

Kuo & Lee (2012) highlighted the importance of bimodal activity pattern in *P. philippensis* and reported that the species commenced its activity between 17:00-18:00 h. with a first peak between 19:00-20:00 h., while a second peak between 03:00-04:00 h. The first activity peak was similar to our study, but the time of second burst was delayed by one hour. Nandini (2001a) found *P. philippensis* most active around 22:00 h. in Western Ghats, India. Similarly, Baba et al. (1982) also reported that *P. leucogenys* performed most activities at dusk with a similar decrease in activity around mid-night, but late-night observations were lacking in both studies. The bimodal activity pattern has been also noted in *Glaucomys sabrinus* (Weigl & Osgood 1974, Urban 1988, Cotton & Parker 2000).

Large arboreal folivore mammals usually occupy small home range size due to the ubiquity of foliage. *P. philippensis* is also identified as folivorous (Kuo & Lee 2003, Nandini & Parthasarathy 2008, Bhatnagar et al. 2010) and it feeds mostly during early night (Koli et al. 2013b). Thereby, after a heavy meal in early-night, high stomach content which require time for digestion may be a causal factor for less activity of *P. philippensis* in mid-night.

In the study, the cavity use by animals occurs most often during the mid-night and was most frequent during the monsoon possibly due to rainfall. Resting in tree cavities after a heavy meal may also avoid predators. However, Baba et al. (1982) found that only lactating female flying squirrels periodically returned to their dens during night.

Body size and ambient temperature play an important role to regulate animals' activity (Muul 1968, Ramesh et al. 2015). The low feeding ratio of *P. philippensis* in summer with high ambient temperature is seen consistent with the hypothesis that high temperature confined energy expenditure (metabolic rate) in body and demand less food intake (Collin et al. 2001). In temperate regions, small sized flying squirrels (i.e. *Glaucomys* spp.) (Muul 1968, Weigl & Osgood 1974, Urban 1988, Cotton & Parker 2000) reduced their activities in the winter. Muul (1968) also reported less activity of flying squirrels for energy saving or to minimize thermoregulatory costs through behavioural adjustment as making large aggregations in nest cavities and reducing their foraging activity. Cotton & Parker (2000) observed that activities of flying squirrels in harsh winter condition (temperature range from 0 °C to –30 °C) shifted towards short activity bouts. During the winter, nightly temperature (range 5-10 °C) of the present study area mostly goes down at subfreezing level (Koli et al. 2013b), while rarely reach at freezing point. Larger body size of animals also demands high caloric requirement. Therefore, *P. philippensis* has no need to drop its activity level during winter in the study area as reported in other studies (Muul 1968, Weigl & Osgood 1974, Urban 1988, Hanski et al. 2000, Cotton & Parker 2000), but a higher activity in this season seems likely to be associated with energy requirement.

Summer was the time of less feeding and higher locomotion activities of flying squirrel during study period. This ratio became reverse in winter with higher feeding and less locomotion activity. Most trees of tropical deciduous forests in India, including our study area (Chhangani 2004a), show flowering and fruiting during the summer (Singh & Kushwaha 2006). Consequently, food availability increases during this time for flying squirrels. Therefore an easy approach to food and higher food density, decrease the time devoted by *P. philippensis* feeding in this season. Contrary, in Japan, *P. leucogenys* increases its feeding activity in response to low food availability in mixed temperate deciduous forests (Kawamichi 1997). The higher locomotion activity in this season is probably related to reproduction. Early summer season is identified as a breeding period for *P. philippensis* in India (Zacharias & Bhardwaj 1997, Koli et al. 2011). At this time, flying squirrels increase their activities for territory establishment and mating interactions such as searching for a mate, associated movements of male and females and nesting behaviour (Kawamichi 2010). Kuo & Lee (2012) also observed that males of *P. philippensis* increase their home ranges as well as dispersion during the reproductive period. Therefore, all these activities demand more movements, including gliding that is more energy saving than quadrupedal movements. But in winter, flying squirrels have to maintain their body temperature in low ambient temperature. Consequently, *P. philippensis* showed high feeding in this season what seems to be related with body heat production for thermoregulation and less locomotion for energy saving.

Only a few trees show flowering and fruiting in monsoon, but this is the time of leaf-flush by the most of deciduous trees in the study area (Chhangani 2004b). High leaf density decreases visibility during night. Downpour also restricts gliding and climbing of flying squirrels (Ando & Shiraishi 1993) and play an important role in reducing their home ranges (Weigl & Osgood 1974). Hence, probably *P. philippensis* used more calling in monsoon to contact their relatives along with energy saving.

In conclusion, we documented that, nightly activity pattern of *P. philippensis* was bimodal. Early night was the most active period, with a second low peak in late night. The species did not alter most of its activities in seasons along with few variation. Resting and feeding were the most common activities throughout the year. Higher activity in winter seems related to fulfill energy requirement and found different from other previous studies.

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