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RESEARCH ARTICLE

Population Status and Diurnal Behaviour of the Indian Flying Fox *Pteropus giganteus* (Brünnich, 1782) in Kathmandu Valley, Nepal

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Abstract This study documents the population status and behaviour of the Indian Flying Fox (*Pteropus giganteus)* at two locations in the temperate environment of the Kathmandu Valley, Nepal. During the five-month study, from 14th July, 2014 to 2nd January, 2015, peak populations were observed in October, 2014 at Sallaghari (1550 individuals) and Keshar Mahal (949 individuals). The behavioural study resulted in 1130 observed events of 10 different behavioural activities at Sallaghari and 1158 events of the same activities at Keshar Mahal. Sleeping, grooming, wing spreading and wing flapping were frequently observed at both study sites. The behaviour of *P. giganteus* is influenced by the weather and air temperature irrespective of hours of the day and date of observation. Habitat destruction, lack of food, pollution and misconception were the major threats to *P. giganteus* perceived by local people in course of interviews. Knowledge regarding the population size and behaviours of wildlife species is essential to understand the conservation needs for the survival and management of wild animals and their habitat. This study provides baseline information for two populations of Indian flying fox (*P. giganteus*) in Kathmandu Valley Nepal.

Keywords Bat (*Pteropus giganteus*) · Population · Behaviour · Kathmandu valley

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Introduction

Bats (order Chiroptera) are unique in being the only group of mammals that have developed sustained flight. They are the most speciose order of mammals after the rodents (Srinivasulu et al. 2010; Purohit et al. 2013; Bhandarkar and Paliwal 2014). Approximately 25% of all chiropteran species (nearly 238 species) are considered threatened by the International Union for Conservation of Nature (IUCN) (Kumar and Kanaujia 2009).

Of the 192 mammal species in Nepal, 50 are bats. Four species of frugivorous bats have been recorded from Nepal; greater short-nosed fruit bat (*Cynopterus sphinx*), dawn nectar bat (*Eonycteris spelaea*), Indian flying fox (*Pteropus giganteus*) (Brunnich 1782) and Leschenault's rousette (*Rousettus leschenaulti*) (Thapa 2014). *Pteropus giganteus*, *R. leschenaulti* and *C. sphinx* have been recorded in the Kathmandu Valley (Jnawali et al. 2011). Our study focused on Indian flying fox in the Kathmandu Valley of Nepal, where rich bat assemblages have been found at altitudes ranging between 1300 and 1500 m (Thapa et al. 2012). The Indian flying fox is a fruit bat of the family Pteropodidae and thus belongs to the suborder Yinpterochiroptera (Teeling et al.2005; Szczesniak

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et al. 2013; Lei and Dong 2016). Pteropodids are strictly vegetarian, foraging for fruits, nectar, and pollen using their sight and a sensitive olfactory system (Nowak 1999). Globally, the conservation status of Indian flying fox is assessed as of "Least Concern" (Molur et al. 2008). Nationally in Nepal, the species is also assessed "Least Concern". It is listed under CITES Appendix II (Jnawali et al. 2011).

The Indian flying fox is the biggest and most conspicuous of all fruit bats (Mathur et al. 2012) in Nepal and one of the largest bats in the world (Marimuthu 1996). The Indian flying fox is found in Bangladesh, Bhutan, China, India, the Maldives, Myanmar, Pakistan and Sri Lanka and it is widely distributed across most of Nepal (Jnawali et al. 2011). Its population has been declining locally (Jnawali et al. 2011).

Compared to other bats, the Indian flying fox has few predators. Humans are amongst the potential predators and may hunt this species as a source of protein (Marimuthu 1996). Haphazard urbanization, infrastructure development and industrialization has caused rapid transformations of land use patterns in the Kathmandu Valley and have resulted in encroachment of human activities on areas which were previously major roosting habitats for the bats (Thapa et al. 2012). There is very little information available on the behavioural patterns of roosting bats, movement patterns, habitat use and other general behaviours of Indian flying fox. Our study explores diurnal behaviour, habitat use, and movement patterns as well as assessing the potential for human-wildlife conflict involving the Indian flying fox. This study documents the diurnal behaviour of Indian flying fox and compares numbers of individuals in two camps in urban areas of the Kathmandu Valley in order to provide baseline information which will be helpful in conservation management of the species.

Materials and Methods

Study Area

The study was conducted in Sallaghari and Keshar Mahal of the Kathmandu Valley, Nepal (Fig. 1). The valley is situated in the Bagmati zone of the Central Development Region of Nepal, between latitudes 27°32′13″ and 27°49′10″ North and longitudes 85°11′31″ and 85°31′38″ East, and ranges in elevation between 1300 m and 2760 m above sea level (Fig. 1) (Mohanty 2011). The dominant land use in the Kathmandu Valley is agricultural land (48.78%) followed by forest (31.15%), shrubs (15.73%), barren land (4.12%) and water bodies (0.21%). Proportion of main land use types in Bhaktapur and Kathmandu districts is given in Table 1 (CBS 2012). The study sites lie in the urban area of the valley, where stands of trees fringe built-up areas.

Methodology

A preliminary survey to locate Indian flying fox colonies within the two study locations was carried out on 3rd and 4th July 2014. Primary data on colony size and behaviour of the bats were collected by direct observation (using binoculars) during 14th July 2014 to 2nd January 2015. Semi-structured questionnaire surveys were also performed to assess the perceived threats to the bat populations.

Population Count

The number of individuals of Indian flying fox roosting in trees was counted directly by visually inspecting roost trees with the naked eye and with binoculars (8 × 42) from all possible directions. The counting of individuals was conducted from an approximate distance of 30 m from each roost tree at both study sites. The individuals were found to roost in 44 trees at Sallaghari and 38 trees at Keshar Mahal. Indian flying fox in each tree was counted from all directions and the number of bats in each tree was counted twice by two people at the same time. Counts were conducted in alternate weeks for the two sites (first week at Keshar Mahal and next week at Sallaghari) (Table 2). The co-ordinates of each roosting tree were recorded using a GPS device (Garmin Etrex 10). For each roosting tree, the tree height and diameter at breast height (dbh) was measured using a Silva clinometer and dbh tape respectively (Gulraiz 2014; Hahn et al. 2014).

Diurnal Behaviour Study

General daytime behaviour of the bats was observed from 7 am to 5 pm on a total of 13 days at each study location. Observation days were spread across three seasons: monsoon (July, August, September), post monsoon (October, November) and winter (December, January). Out of 44 and 38 roost trees at Sallaghari and Keshar Mahal respectively, a single branch (clearly visible and with few bats) on a single roost tree was purposively sampled for studies of daytime behaviour. The same branch was observed for all of the 13 observation days. All bats roosting on the branch were observed and their behaviours were observed and noted. Occasionally, photographs were taken using a Sony digital camera (model number DSC-H*200 V) and 50 × lens magnification. Scan sampling (Altmann 1974; Koju and Chalise 2010), where the observer used binoculars (Bushnell, 8*42) to scan the subjects for two out of every twelve minutes, was used to note the behaviour of the bats. Thus, two minutes of observation were followed by ten minutes during which no observations were made. All two-minute scan periods summed to a total of 21 h and

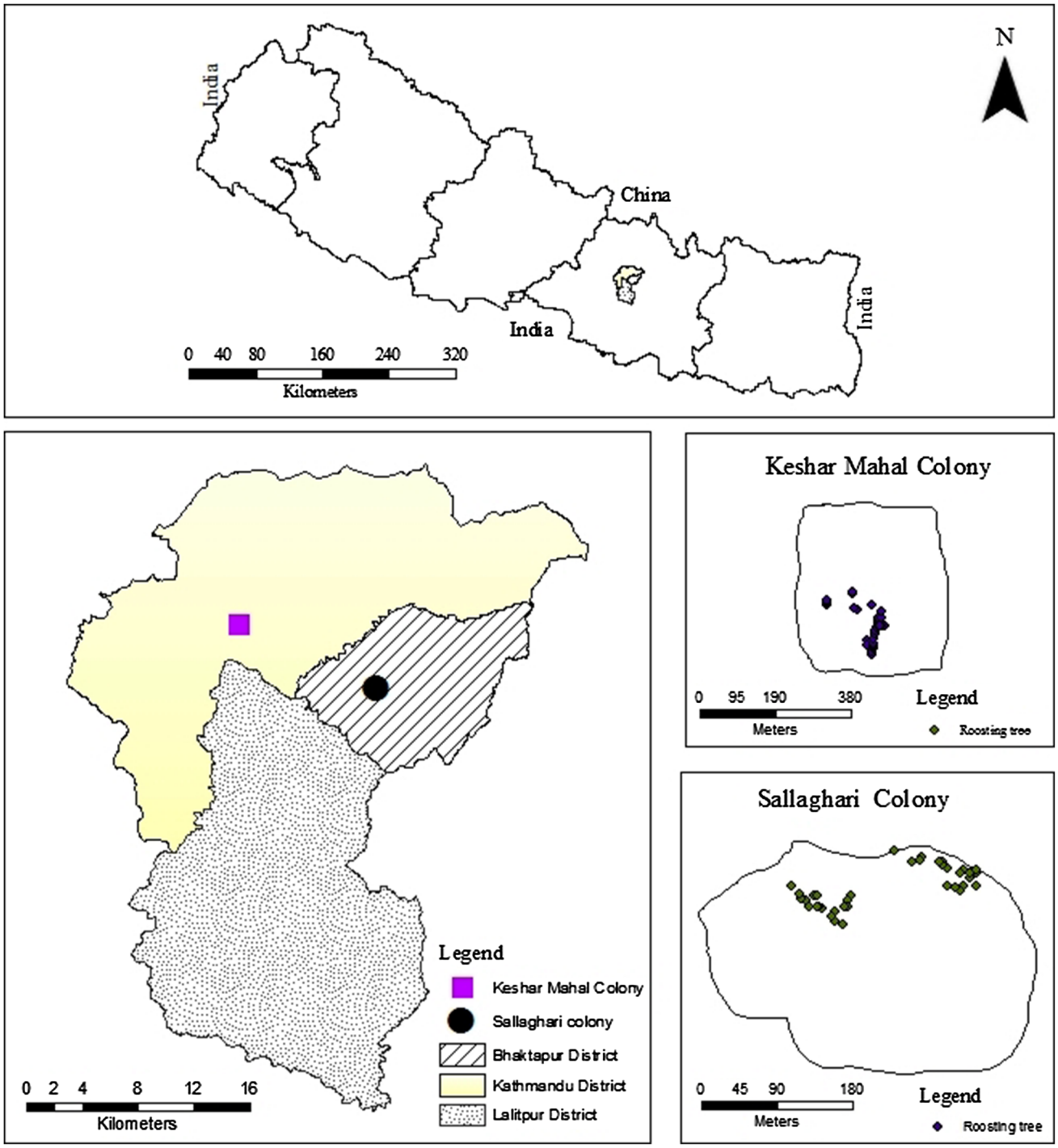


Fig. 1 Map of Nepal showing the location of Sallaghari, Bhaktapur and Keshar Mahal (study sites), Kathmandu, Nepal

40 min of direct observation (50 two-minute scan periods each day; in total 650 two-minute scan periods) at each study location. The various activities of the bats were recorded following Connell et al. (2006).

Air temperature and weather at the study locations were recorded from morning to late afternoon from the website source accuweather.com.

Interviews

Interviews with local people were carried out in order to understand whether people felt any animosity towards the bats and to document any perceived threats to the species. A semi-structured questionnaire was used to explore three essential questions: i.e. problems created by

Table 1 Proportion of land use types in two districts of Kathmandu Valley (*Source* CBS 2012)

District	Total forest area (%)	Shrub (%)	Agri-cultural land/ grass (%)	Water bodies (%)	Barren land (%)	Snow	Others	Total (%)
Bhaktapur	8.39	8.79	78.26	0.01	4.55	0	0	100
Kathmandu	29.47	12.13	52.71	0.16	5.52	0	0	99.99

Table 2 Field visits in the study sites (represented by number)

S.N.	Date of field visit and data collection	
	Sallaghari, Bhaktapur	Keshar Mahal, Kathmandu
1	7/18/2014	7/14/2014
2	8/1/2014	7/25/2014
3	8/15/2014	8/8/2014
4	8/29/2014	8/22/2014
5	9/12/2014	9/5/2014
6	9/26/2014	9/19/2014
7	10/10/2014	9/30/2014
8	10/24/2014	10/17/2014
9	11/7/2014	10/31/2014
10	11/21/2014	11/14/2014
11	12/5/2014	11/28/2014
12	12/19/2014	12/12/2014
13	1/2/2015	12/26/2014

bats, major threats for the survival of bats and the importance of bats.

Prospective participants were approached randomly by researchers, informed about the bats and the study, and invited to participate in an interview. At each site 30 individuals including pedestrians, farmers, teachers, business people, etc. (in total 60 individuals at two sites) participated. After interviews with 20 respondents, repetitive answers were obtained, so interviews were limited to 30 respondents in each site.

Data Analysis

Primary data regarding population sizes and behaviour of bats were compiled in MS-Excel. The compiled data were analyzed using MS-Excel and presented in bar diagrams.

The frequency of the 10 categories of behaviour (Table 3) was calculated by dividing the number of observations of the particular behaviour by the total number of observations.

The time of day was categorized into five different parts to understand the roosting activities in response to time of day, i.e. early morning (7–9 am), morning (9–11 am), noon (11 am to 1 pm), afternoon (1–3 pm) and late afternoon (3–5 pm). Similarly, weather was categorized as cloudy, light rain, sunny, heavy rain, partly sunny, partly cloudy and foggy to understand the roosting activities in response to weather. Air temperature was divided into various classes, i.e. <10 °C, 10–15 °C, 15–20 °C, 20–25 °C and ≥ 25 °C.

Statistical Analysis

Statistical Package for the Social Sciences (SPSS) Statistics 17.0 software was used for data analysis. Chi square ($\chi 2$) tests were used to examine whether differences in frequencies of observed bat behaviour were likely to be related to differences in air temperature. Calculated Chi Square was compared with tabulated values for relevant degrees of freedom at a 95% confidence level.

Table 3 Description of the daytime behaviour (activities) of bats

S.N.	Behaviours	Description
1	Sleep	Eyes closed and wings wrapped around body
2	Groom	Licking and scratching body and/or head
3	Wing spread	Wings wide open, extended on side or in front of body
4	Wing flap	Fanning body with wing(s)
5	Movement in tree	Climbing along branch or trunk
6	Nursing/maternal behaviour	Juvenile attached/nursing
7	Mate	Males licking and/or copulating with female
8	Fight/aggression	Fighting between individuals, which was not directly related to mating or courtship
9	Flight	Within tree or out of and into tree
10	Others	Other behaviours than above

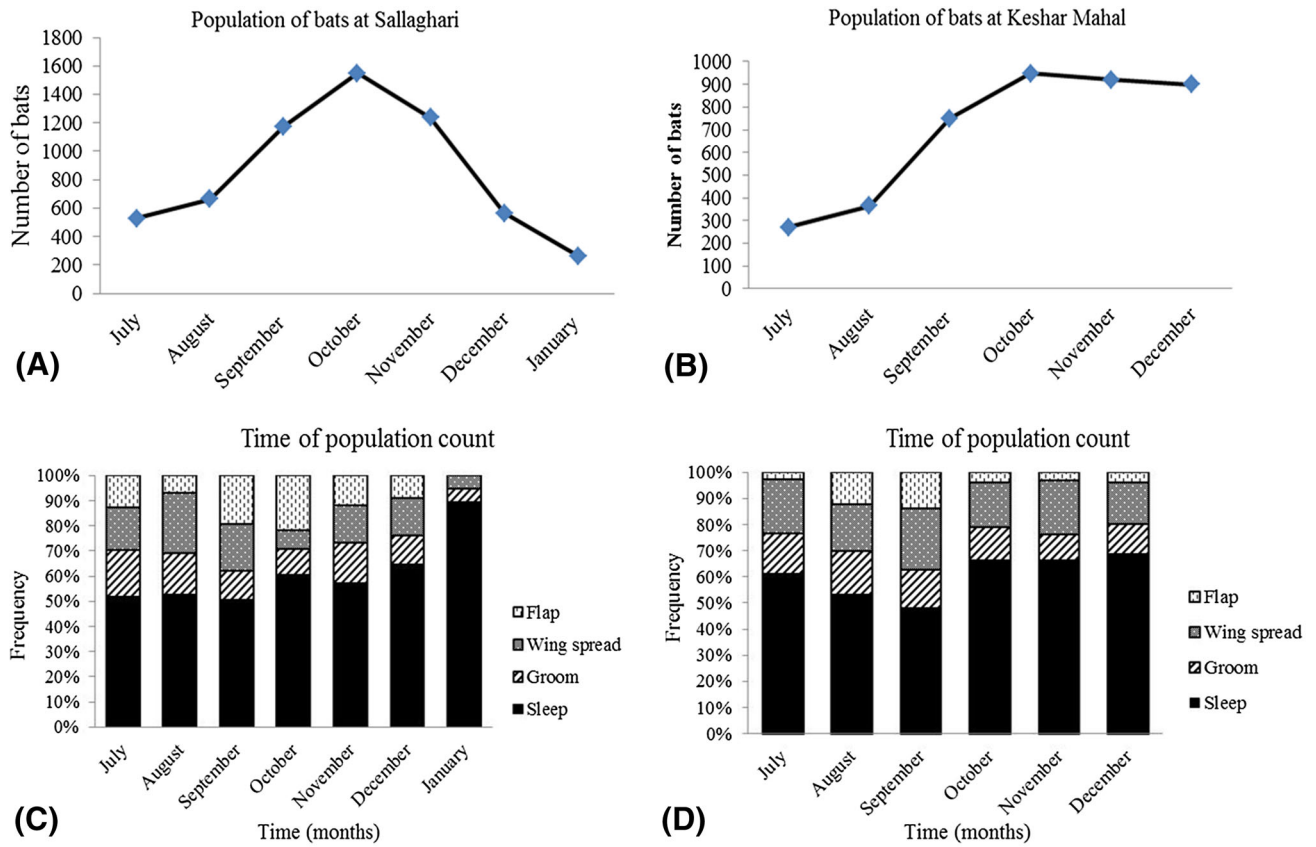


Fig. 2 Population of bats in Sallaghari (**a**), Keshar Mahal (**b**), Frequency of behaviours at Sallaghari (**c**), Keshar Mahal (**d**)

Results

Population Status

The number of individual bats counted at the Sallaghari colony ranged between a minimum of 264 individuals in January 2015 to maximum of 1550 in October of 2014 (997 ± 492, n = 6). The bats reached their peak population (1550) in October 2014 (Fig. 2a) and was lowest (264) in January 2015.

Similarly, the number of individual bats counted at the Keshar Mahal colony ranged between a minimum of 269 individuals in July and maximum of 949 in October of 2014 (692 ± 274, n = 6). The bats slowly increased to peak population (949) in October 2014 (Fig. 2b). The population decreased at a slower rate than that of Sallaghari.

Habitat Characteristics

Bats used 44 trees of seven different species for roosting at Sallaghari while 38 trees of six species were used at Keshar Mahal. Large numbers of Masala (*Eucalyptus* sp.) (27) were used at Sallaghari followed by Himalayan poplar (*Populus ciliata*) (8) (Table 4). In Keshar Mahal Silky oak (*Grevillea robusta*) (29) was the most commonly used roosting tree (Table 5).

The average height of roosting trees at Sallaghari was found to be 34.77 ± 9.30 (ranged from 27 to 38.37 m, n = 44) whereas the average dbh was found to be 53.05 ± 12.40 (ranged from 48.28 to 86 cm, n = 44). Similarly, the average height of the roosting trees at Keshar Mahal was found to be 19.71 ± 4.88 (ranged from 17 to 20 m, n = 38) whereas the average dbh was found to be 56.27 ± 25.48 (ranged from 24.4 to 86 cm, n = 38).

The roosting area at Sallaghari is comparatively peaceful with negligible air and noise pollution than Keshar Mahal where there is heavy traffic incurring excessive air and noise pollution.

Threats

Habitat destruction, lack of food, pollution and misconceptions about the bats were the major perceived threats observed for Indian flying foxes at both study sites. According to the respondents at Sallaghari, the threats to the bats included habitat destruction (30%) followed by lack of food (26.67%); pollution (16.67%); others (crowd of the people) (6.67%); habitat destruction and lack of food

Table 4 Species of roost trees used by *P. giganteus* at Sallaghari

S.N.	Name of trees	No. of trees	Average		
			Population	Height (m)	Dbh (cm)
1	*Populus* sp.	8	169	29.25	63.59
2	*Persea* sp.	1	2	27	60.5
3	*Lindera* sp.	2	1	29	58
4	*Eucalyptus* sp.	27	704	38.37	48.28
5	*Celtis australis*	2	17	30.5	53.25
6	*Pinus roxburghii*	1	<1	30	86
7	*Grevillea robusta*	3	16	28	51

(3.33%); habitat destruction and pollution (3.33%); hunting (3.33%). However, 10% of the respondents were unknown to the threats on bats. Similarly, at Keshar Mahal, the threats were habitat destruction and pollution (33.33%) followed by habitat destruction (26.67%); pollution (16.67%); habitat destruction, pollution and lack of food (6.67%), hunting (3.33%), lack of food (3.33%) and 3.33% of the respondents did not know about threats to bats.

During construction of the Army College at Sallaghari, two roosting trees i.e. one each *Lindera* sp. and *Populus* sp. were cut down on 15th August and 29th August 2014 respectively. At Keshar Mahal, cattle egrets and little egrets shared roost trees with Indian flying foxes. Several branches were removed from trees on 21st December 2014, in order to deter the birds and reduce their excreta. This affected not only the birds but the bats as well, since these animals were forced to migrate out from the location. The new location of those bats is unknown.

In the area, foraging sites for Indian flying foxes are diminishing and also becoming more distant from roost trees, which is an alarming threat to Indian flying foxes population.

Many local people do not tolerate Indian flying foxes roosting on trees on their land and some throw stones at the bats to encourage them to fly away. Some of the interview respondents expressed a belief that bat flesh may cure diseases such as cancer and asthma.

Diurnal Behaviour

Observed patterns of behaviour for Indian flying foxes were similar at both study locations. Altogether 10 daytime activities were recorded: Sleeping was the most frequent behaviour (>50%) followed by grooming, wing spreading and wing flapping (Fig. 3). Other activities, such as movement in the tree, nursing, mating, fighting, flying were much less frequently observed (<5%) in both sites.

In total, 1130 events of 10 activities were observed at Sallaghari ptero-camp while 1158 events of the same activities were observed at Keshar Mahal ptero-camp. Most frequently, Indian flying foxes were seen sleeping throughout the day and sleeping was the most frequent behaviour at the both sites. From July to September, grooming was recorded at higher frequencies than in other months at both sites. Wing spreading was frequently recorded from July to September. Wing flapping was more frequently recorded at Sallaghari (Fig. 2c) compared to Keshar Mahal (Fig. 2d). The frequency of wing flapping was found to increase from August to October at Sallaghari. Likewise wing flapping was found to be highest in September and decreased during the rest of the time at Keshar Mahal.

Daytime Behaviour in Response to Time of Day, Temperature and Weather Condition

Behaviour Pattern of Indian Flying Fox in Response to Time of Day

Indian flying foxes were found to sleep most in the early morning at Sallaghari; and during early morning and morning at Keshar Mahal. Sleeping decreased later in the

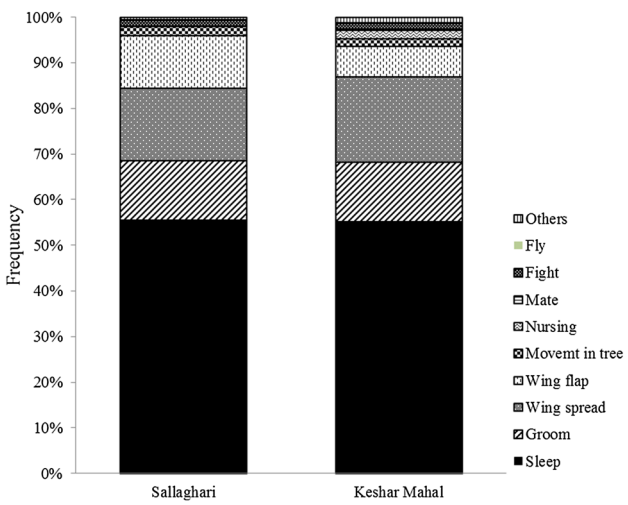


Fig. 3 Daytime behaviour of Indian Flying Fox (*P. giganteus*)

day at both sites. Sleeping behaviour was recorded least frequently during noon (13.33%) in July at Sallaghari (Fig. 4a) and during late afternoon (15.96%) in July at Keshar Mahal (Fig. 4b).

Grooming was more frequent in the morning at Sallaghari and during the early morning at Keshar Mahal. Grooming was more frequent in the morning (56.25%) in October at Sallaghari (Fig. 4c) while during early morning (41.94%) in August at Keshar Mahal (Fig. 4d). It was less frequent during the afternoon (2.31%) at Sallaghari and during noon (4.17%) at Keshar Mahal. Grooming was recorded only during late afternoon in January 2015 at Sallaghari.

Wing spreading was frequent at different periods of time. It was more frequent in the morning (58.33%) in October and occurred least during late afternoon (8.33%) in October at Sallaghari (Fig. 4e). Likewise, it was more frequent during late afternoon (50%) in July and least frequent in the early morning (6.45%) in November at Keshar Mahal (Fig. 4f). Wing spreading was recorded only during late afternoon in January 2015 at Sallaghari.

Wing flapping was more frequently recorded during the afternoon than other time periods in a day. It was recorded maximum during afternoon (52.38%) in November at Sallaghari (Fig. 4g) and also during afternoon (66.67%) in December at Keshar Mahal (Fig. 4h). It was least recorded in the early morning (5.5%) in August at Sallaghari and during late afternoon (9.51%) in September at Keshar Mahal.Rest of the behaviours was not so frequent and they occurred in only some parts of the day.

Behaviour Pattern of Indian Flying Fox in Response to Weather

Chi square test for changes in behaviour of bats in response to weather showed that the behaviour of Indian flying fox is dependent on weather (i.e. $\chi 2$ cal. $= 95$, $p < 0.05$) for Sallaghari and ($\chi 2$ cal. $= 59.33$, $p < 0.05$) for Keshar Mahal.

Sleeping occurred in all weather conditions. Sleeping behaviour of bats was mostly recorded during heavy rain and foggy weather at Sallaghari (100%) (Fig. 5a) and during heavy rain and partly cloudy weather at Keshar Mahal (100%) (Fig. 5b).

Grooming was more frequent during partly cloudy weather at Sallaghari (30.77%) and during light rain at Keshar Mahal (17.95%).

Wing spreading was observed at maximum frequency during sunny weather at both Sallaghari and Keshar Mahal (17.43 and 20.91% respectively).

Wing flapping was more frequent in sunny weather. It was recorded in three different weather conditions among which it was frequently recorded during sunny weather at Sallaghari (16.18%). Similarly it was recorded only during cloudy and sunny weather in case of Keshar Mahal and it was also frequently recorded during sunny weather (9.19%). Others were recorded only in some few weather conditions.

Behaviour Pattern of Indian Flying Foxes in Response to Air Temperature

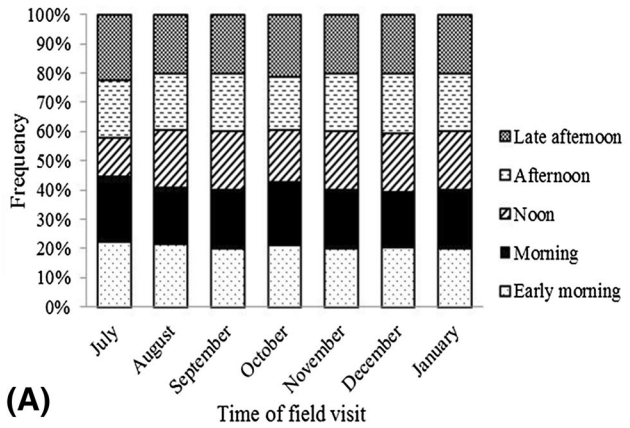
Chi square test for changes in behaviour of bats in response to air temperature showed that the behaviour of Indian flying fox is dependent on air temperature (i.e. $\chi 2$ cal. $= 100.29$, $p < 0.05$)for Sallaghari and ($\chi 2$ cal. $= 46.14$, $p < 0.05$) for Keshar Mahal.

Sleep occurred frequently in all the temperatures at both the sites i.e. Sallaghari (Fig. 5c) and Keshar Mahal (Fig. 5d) but gradually decreased as temperature increased. Chi square test showed that, the sleeping behaviour of bats decreased with increase in air temperature (i.e. $\chi 2 = 210.68$, $p < 0.05$) for Sallaghari and ($\chi 2$ cal. $= 188.32$, $p < 0.05$) for Keshar Mahal. The frequency percentage of groom gradually increased with rise in temperature up to 20–25 °C and then decreased at ≥25 °C. The pattern was same for both sites of study. Wing spread increased with increase in air temperature. Wing flap was not recorded at <10 °C and 10–15 °C at Sallaghari and at <10 °C at Keshar Mahal. Like groom and wing spread, frequency percentage of the behaviour increased with rise in temperature.

Discussion

Population Status

The number of individuals roosting in the two camps (locations) fluctuated markedly between summer and winter months and the number of roost trees used varied with colony size (bat population). The pattern of fluctuation in the two camps was similar. The maximum population of Indian flying fox was recorded at Sallaghari. In both camps, an increased number of individuals was observed from July 2014 until October 2014, which indicates migration of the flying fox to the camp. Neither the original location of the immigrant bats, nor the reasons behind their immigration are known. However, migratory behaviour in bats seems to be a common phenomenon as could be revealed from the past studies (Taylor 2006; Venable 1999; Department of Environment, Climate Change and Water NSW 2009). The seasonal availability of food resources may also cause migration of the tropical bat species (Burland and Wilmer 2001). It is possible that bats moving into the camps at Sallaghari and Keshar Mahal were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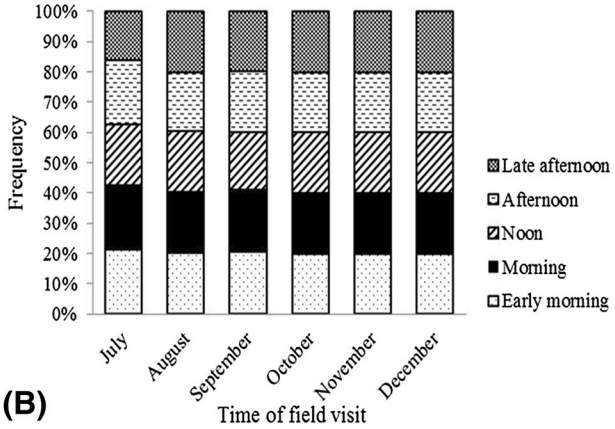
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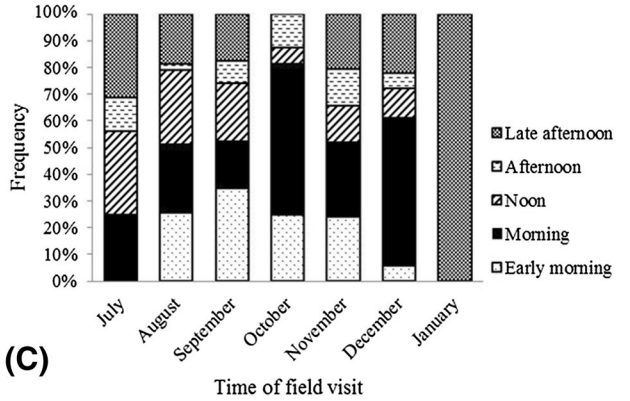
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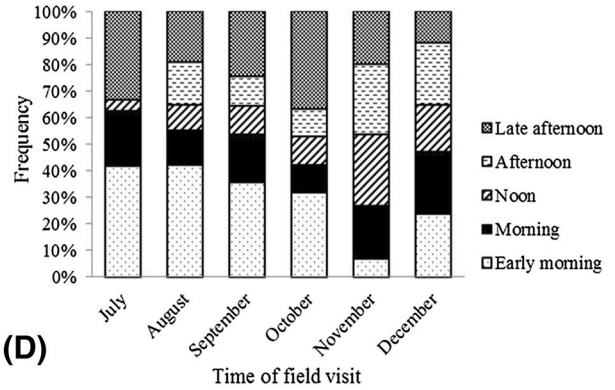
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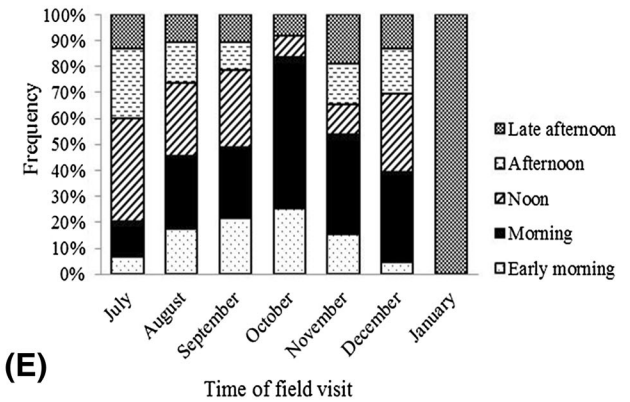
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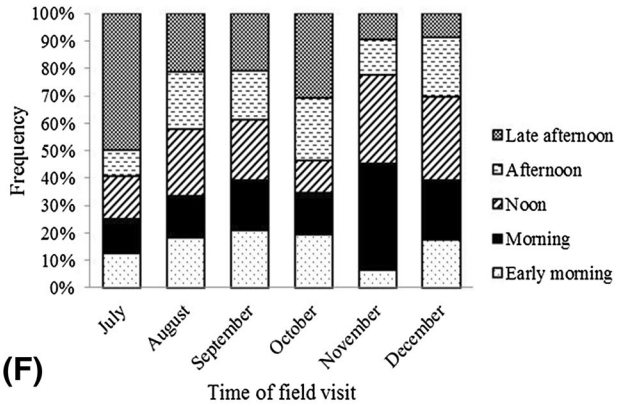
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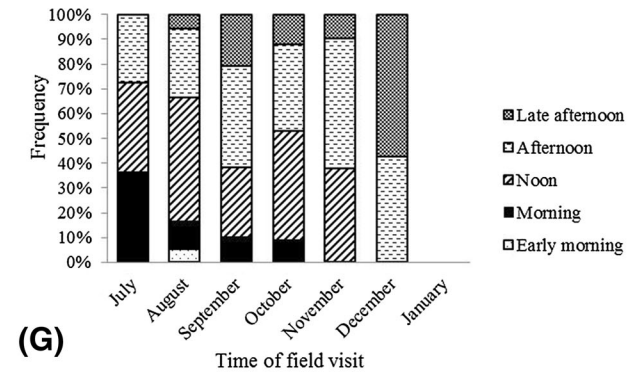
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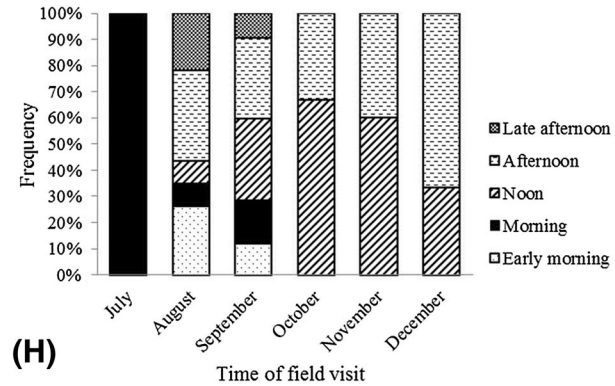
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60%
50%
40%
30%
20%
10%
0%
Frequency
July
August
September
October
November
December
Time of field visit
Late afternoon
Afternoon
Noon
Morning
Early morning

(H)

◀**Fig. 4** Frequency of sleep at Sallaghari (**a**) and Keshar Mahal (**b**) in different hours of day; Frequency of groom at Sallaghari (**c**) Keshar Mahal (**d**) in different hours of day; Frequency of wing spread at Sallaghari (**e**) and Keshar Mahal (**f**) in different hours of day; Frequency of wing flap at Sallaghari (**g**) and Keshar Mahal (**h**) in different hours of day

following fruit ripening in both cultivated and wild habitat in and around the Kathmandu valley.

Only a few individuals remained at the Sallaghari camp during the months of December 2014–January 2015. This may reflect the consequences of extreme cold in the Kathmandu valley during those winter months. It can be assumed that these bats might have migrated to avoid chilling temperature.

At Sallaghari, the population of Indian flying fox was at its maximum during this study (1129) in October 2014 and nil in the month of January, 2015 (Koju 2008). The population of *P. giganteus* was found to be maximum (1324) in November 2006 and no bats were found in January 2015 (Acharya 2008). The present study shows increase in their population at Sallaghari with maximum population (1550) in October 2014. Interestingly, presence of small number of bats (264) in the month of January of the year 2015 (Fig. 6a) clues temperature rise in winter or adaptation towards cold or the previously immigrated roosts have degraded or collapsed (Table 5).

At Keshar Mahal, the peak population of Indian flying fox was 809 in November, 2006 (Acharya 2008). However, the population in this camp was found increasing (983) in December 2011 (Timalsina and Ghimire 2011) and this trend was observed again in the current study.

Peak population of the Indian flying fox during October may be due to favourable weather conditions including temperature. Also flowering of *G. robusta* which are rich nectar source may attract fruit bats. In contrast to Acharya (2008) the rate of population decrease at Keshar Mahal camp was slow in the current study (Fig. 6b) after gain in the peak population. Probably, increase in the air temperature due to heavy traffic around the roost can be the reason behind.. However, extensive research should be carried out for confirmation.

The average population of Indian flying fox at Sallaghari exceeds than that in Keshar Mahal which may be due to greater number of trees and less disturbance (pollutions due to traffic) at Sallaghari than at Keshar Mahal. The rapid fluctuation in the population of Indian flying fox at Sallaghari and slow rate of fluctuation at Keshar Mahal in two

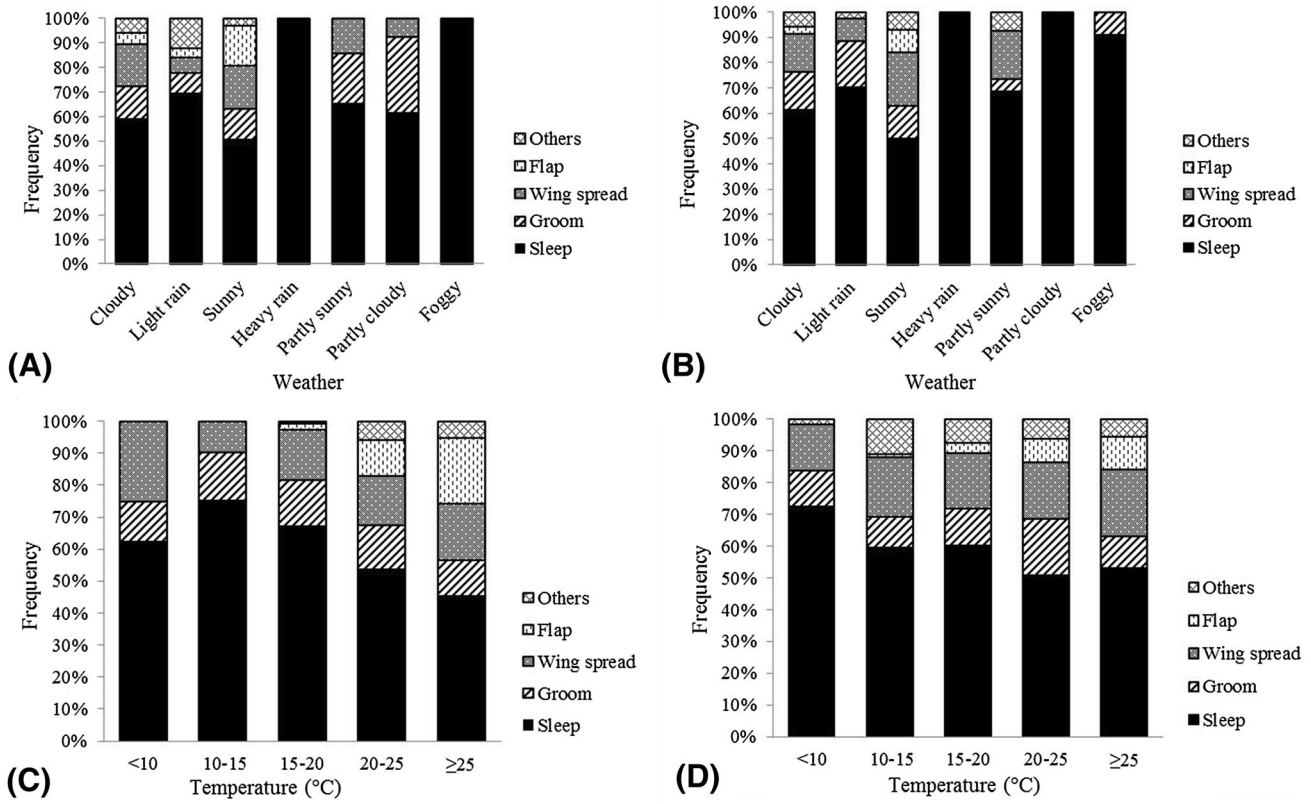

Fig. 5 Frequency of behaviour at Sallaghari (**a**) and Keshar Mahal (**b**) under different weather condition; Frequency of behaviour at different temperatures at Sallaghari (**c**) and Keshar Mahal (**d**)

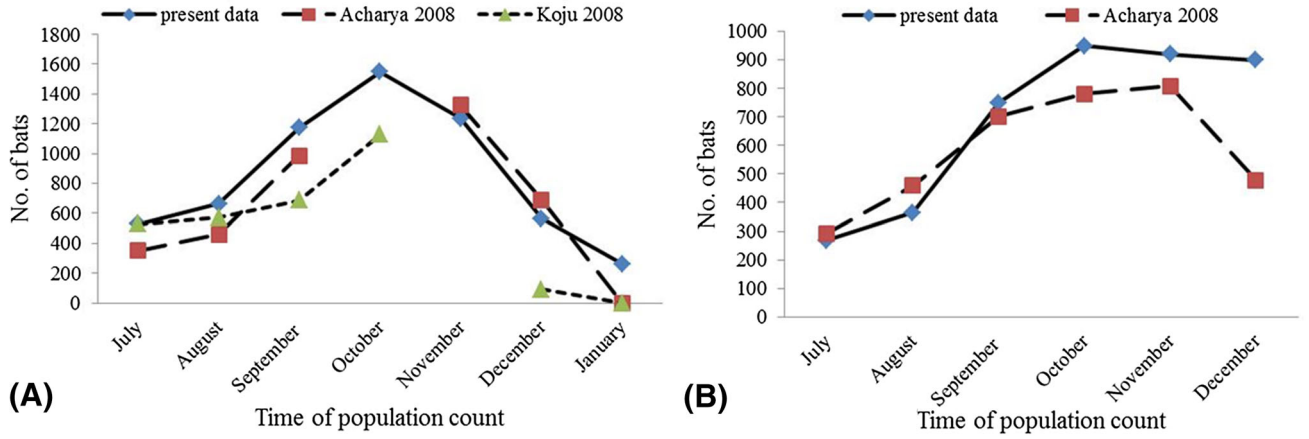

Fig. 6 Comparison of population of bats at Sallaghari (**a**) and Keshar Mahal (**b**)

weeks time interval was noticed, which needs an extensive research to understand the reasons.

Habitat Characteristics

Likewise, in the present study, generally, Indian flying fox population has been found roosting in multiple tree species (Chakravarthy and Yeshwanth 2008; Bhatnagar and Salvi 2011; Senthikumar and Marimuthu 2012; Dey et al. 2013; Ali 2014; Timalsina and Ghimire 2011). The present study showed that the Indian flying fox roosted in seven species of trees at Sallaghari. Three are new tree species occupied by the bats than earlier i.e. *Persea* sp., *Lindera* sp. and *G. robusta* out of six species of trees (Koju and Chalise 2010). Likewise, they roosted in six species of trees at Keshar Mahal. *G. robusta* and *D. sissoo* are only the tree species occupied by Indian flying fox out of five species of trees (Timalsina and Ghimire 2011) from then till now.

Indian Flying fox preferred Eucalyptus sp. at Sallaghari and G. robusta at Keshar Mahal for roosting. Their favoured food is the pollen and nectar of Eucalypt blossoms, pollen producing flowers of melaleucas, followed by other hardwood blossoms, such as figs (Department of Environment and Natural Resources 2011). Although the tree height differs in both locations, bats selected the tallest trees with greater dbh amongst the fringes of plantation regardless of tree species.

Threats

The present study also finds out similar results; habitat destruction, lack of food, pollution and misconception as the major threats to the Indian flying fox at Kathmandu Valley. Koju (2008) mentioned that anthropogenic activities are the most crucial threats to bats survival. Similarly, Acharya (2008) stated that Keshar Mahal ptero-camp was found most threatened due to ongoing habitat loss, roost ageing and lack of conservation efforts.

Diurnal Behaviour of Indian Flying Fox

Indian flying fox exhibited various behaviours during daytime with fluctuation in the frequency. Sleep, groom, mate/courtship and wing spread were the most frequently occurring behaviours of Grey-headed Flying Fox (Connell et al. 2006). Similarly, among the behaviours observed, more time was spent in rest, groom, flap and wing spread (Koju 2008). The present study also revealed similar results. Arbitrarily, Indian flying fox were observed

Table 5 Species of roost trees used by *P. giganteus* at Keshar Mahal

S.N.	Name of trees	No. of trees	Average		
			Population	Height (m)	Dbh (cm)
1	*Grevillea robusta*	29	563	20	57.68
2	*Ficus religiosa*	1	58	20	86
3	*Elaeocarpus ganitrus*	1	2	17	24.4
4	*Dalbergia sissoo*	5	28	19.2	47.04
5	*Ficus lacor*	1	<1	17	54.8
6	*Celtis australis*	1	46	19	65

spending most of the day for sleep as they are nocturnal in habit.

Monsoon occurs from July to September during which bats clean their body frequently after rain. The grooming behaviour may occur for the removal of ecto-parasites from their body.

The brightness of the sun and the air temperature are higher during monsoon season. So wing spread was frequently recorded. Although, during the winter these bats spread wings for sun bath, in contrast the frequency of wing spread decreased at both study sites with the onset of the winter. The total frequency of wing spread at Keshar Mahal colony is higher than at Sallaghari colony which may be a consequence of nuisance created due to air and noise pollution from the heavy traffic there.

Wing flapping of Grey-headed Flying Fox was recorded frequently especially during periods of higher temperatures and strong sunlight (Connell et al. 2006). Likewise, wing flap of Indian flying fox was frequently recorded from August to September in the Kathmandu valley. The behaviour decreased with the beginning of the winter season and completely disappeared when it was too cold.

Daytime Behaviour in Response to Time of Day, Temperature and Weather Condition

Behaviour Pattern of Indian Flying Fox in Response to Time of Day

The frequency of sleep changed significantly throughout the day. During early morning at both sites, bat sleep was maximum than during other parts of day which may be because at this time bats has just returned back from foraging. However, the sleep behaviour continued in other parts of day since it saves energy to fly out in the evening for foraging.

The Indian flying fox were found involved in grooming during the early morning and morning inorder to clean their body after their arrival from foraging in both locations. Also they may have done so to get rid of biting of ectoparasites. Individuals of Black Flying Fox were observed to groom thoroughly following their return to camp in the morning and repeatedly throughout the day. Morning grooming activity was often triggered by the first rays of sun reaching bats in the tops of trees and comprised of extensive and thorough cleansing of all body surfaces (Markus and Blackshaw 2002).

Wing spread began with sunrise and continued when it was hot in the afternoon. However, the behaviour was frequent in the morning. Though decreased during the cold days. On calm sunny mornings, open-wing displays of Samoan Flying Fox (*Pteropus samoensis*) on Tutuila Island, American Samoa seem to be thermoregulatory in nature and bats roosting on prominent and exposed branches opened one or both wings as sunlight first fell on them, faced towards the sun and slowly rotated back and forth (Brooke 2000).

Although, bats probably reduce their activity levels and their basal metabolic rates during severe winter conditions (Funakoshi et al. 1991), this study reported increase in wing flap during the colder days and mostly observed during afternoon as compared to other parts of day during November and December as it is hotter during the afternoon, they fan their wings to cool down. Wing-fanning of Black Flying Fox decreased during hotter periods and in the middle of the day, when a breeze picked up and increased when it dropped (Markus and Blackshaw 2002).

Behaviour Pattern of Indian Flying Fox in Response to Weather

Although grooming activity was seem irrespective of the weather, bats were found grooming to clean their body as stated earlier by the Department of Environment and Natural Resources (2011) and Mathur et al. (2012), it is most likely that the Indian flying fox frequently flapped their wings to increase air circulation and thereby cool themselves during sunny hours whereas less flapped during cloudy hours.

Behaviour Pattern of Indian Flying Fox in Response to Air Temperature

In the present study at both locations, wing spread occurred frequently with rise in air temperature. When the air temperature rises, intensity of heat of the sun becomes higher, so in order to keep them cool, therefore, wing flap was recorded maximum. In between <10 °C and 15 °C, their wings were wrapped around themselves to protect their body from cold. At higher temperature, their wings were found spread.

Conclusion

Indian Flyting fox's population and the number of trees occupied by the bats varied with the study sites from Keshar Mahal and Sallaghari. Among the different daytime behaviour of this species at both locations; sleep, groom, wing spread and wing flap were the most frequent behavioural events. The frequency of wing spread of Indian flying fox at Keshar Mahal was found to be slightly higher than at Sallaghari. The major perceived threats to the bats are habitat destruction, lack of food, pollution and

misconception. Understanding animal behaviour is essential for development of animal welfare standards in farms, zoos and in conservation areas (Mandal 2012). Thus, the results of present investigation indicated that the bat population in the Kathmandu valley is very much under threats and further studies on the bioecology of these flying mammals are to be carried out with a view to conserve the species.

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