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Seasonal influence on Population Dynamics of *Pteropus giganteus* (Chiroptera: Pteropodidae) in Agricultural and Urban Landscapes

Shahid Ali and Rajwinder Singh*

Department of Zoology, Punjab Agricultural University, Ludhiana-141 004, India
**E-mail: rajwinder-singjh@pau.edu*

***Abstract*:** Present study was conducted to investigate roosting preferrence, population of Indian flying fox, *Pteropus giganteus* and its fluctuation with respect to seasonal changes at selected roosting sites in agricultural and urban landscapes for 2017-18 and 2018-19. In urban landscape, higher population of bats roosted on pinus (35.40%) followed by silver oak (19.63%), sterculia (13.73%), mango (13.21%) and eucalyptus (8.99). Interestingly, 5.10% increase in bat population was recorded in the preceeding year. In agricultural landscape, higher population of bats roosted on eucalyptus (97.52%) than banyan tree (2.48%). The 27.20% decrease in population was recorded in preceeding year due to formation of new human settlements. Migration of bats was recorded in both years during May-September which again come back during October-November. There was negative correlation of atmospheric temperature with bat population at urban (r=-0.15 to -0.28) and agricultural landscapes (r=-0.93 to -0.94), whereas positive correlation was found between relative humidity and bat population at both landscapes. Positive correlation (r=0.92 and 0.97) was in emergence time between both landscapes, which was lower in summer and higher in winter months. The study will provide baseline information to study echology, behaviour and conservation programmes of *P. giganteus*.

***Keywords*:** Fruit bat, Chiroptera, Indian flying fox, *Pteropus giganteus*, Roosting

Among mammals, bats are the second largest group which comprised 25% of all living mammals and accounts 1200 species (Bhandarkar and Paliwal 2014). They belong to order Chiroptera which is further divided into two sub-orders, megachiroptera and microchiroptera (Vyas and Upadhyay 2014). India has diversity of 12 species of megachiropteran (Srinivasulu et al 2010) and 101 microchiropteran bats (Wilson and Reeder 2005) of which only three fruit bats are commonly found throughout India, which includes Indian flying fox (*Pteropus giganteus*), fulvous fruit bat (*Rousettus leschenaultia*) and short-nosed fruit bat (*Cynopterus sphinx*). *P. giganteus* commonly known as “Indian flying fox” is largest in its group, belongs to family Pteropodidae and mainly feeds on fruits, nectar, or pollen (McConkey and Drake 2006). It is widely distributed throughout India and other regions of Asian countries (Jones and Holderied 2007). Flying foxes are very conspicuous among tree roosting bats and thus, many studies have been carried out on various aspects such as population ecology, reproductive behaviour, roosting ecology, distribution, and conservation issues (Kumar et al 2017). Population size of *P. giganteus* decreased since few decades due to many reasons like loss of habitat, climate change and shift in urban areas (Jung and Threlfall 2016). Bats are nocturnal mammals and usually live in large aggregates as colonies known as roosting sites, which may vary from hundreds to thousands depending on food availability and breeding season (Williams et al2006). They provide widespread ecological and monetary services via pollination, seed dispersal for hundreds of plant species, pest control and also regulate climate, rejuvenation of forests and nutrient cycling (Goveas et al 2006,Kunz et al2011,Maas et al 2013). Local climate, seasonal food availability and social interactions among bats are main factors responsible for evolving gregarious or solitary foliage roosting behaviour in bats. Richmond et al (1998) recorded that trees that provide better protection from environment and updrafts for easier flight are preferred for roosting. Dey et al (2013) suggested that *P. giganteus* was found to occupy different types of roosting trees at three study sites, which reflect their flexibility to occupy diverse habitat conditions and found roosted in open tree branches. Earlier studies suggested *P. giganteus* as large, noisy and squabbling colonies on trees (McKinney 2006). Under schedule V of Indian Wildlife Protection Act 1972 and International Union for Conservation of Nature and natural resources (IUCN), this species is treated as 'vermin' on the impression that it poaches ripe fruits from orchards and defecates in public places. Although the IUCN Red List of Threatened Species has classified this species as “least concerned”, the numbers of individuals are decreasing consistently primarily due to habitat loss and hunting

(Venkatesan 2007). Present study was conducted with the aim of investigating population size, roosting behaviour of *P. giganteu*s attwo selected roosting sites (agricultural and urban landscapes) and its fluctuation with respect to seasonal change for two years 2017-18 and 2018-19. Output of study may provide baseline information to study echology, behaviour and conservation programmes of *P. giganteus*.

MATERIAL AND METHODS

Selection of site: Data was collected from twodifferent roosting sites at agricultural and urban landscapes. For urban landscape, campus of Panjab University, Chandigarh(30°76" N and 76°76 E) was selected which is covered by different large trees species and human settlements (where cutting of trees and any kind of threat to bats was strictly prohibited). VillageAyali Khurd, District Ludhiana, (30°89 N and 75°75 E)was selected as agricultural landscape, where different agricultural crops like wheat, paddy, maize, sugarcane, fodders and horticultural crops like ber and guava orchards were grown during whole year, alongwith less human activity. Data was recorded for two years 2017-18 and 2018-19.Selected sites received average 500-800mm rainfall, which was not evenly distributed and most of it (70-80%) received during July, August, and September. Months were divided into seasons as per weather conditions of selected areas (Punjab, India), May and June in summer season, July and August in rainy season, September, October and November in autumn season, December, January and February in winter season, March and April in spring season, respectively.

Roosting preference and population size: Population size of *P. giganteus* at two selected roosting sites (agricultural and urban landscapes) were counted during morning hours (9-11am) at fortnight intervals (pooled on monthly basis) by using direct roost count method (Javed and Koul 2002). Each bat population was counted three times to remove any error of counting during each sampling by using binoculars (Nikon PROSTAFF 7s 10×42) to spot hiding bats in the branches of trees. For estimation of preference in roosting trees by *P. giganteus* bats among other trees, the number and trees grown around the roosted trees were counted from its 1km radius surrounding area to know variety and abundance of trees. The girth of different trees was recorded by using measuring tapeat height of 1.37m from ground surface.

Abiotic factors: Atmospheric temperature (^{0}C) and relative humidity (%) were recorded using a digital thermo-hygrometer (Vel Vetta HTC-2 Digital Tester and Clock) by holding the probe 2m above ground during study period as suggested by Dey et al(2013). Time of emergence (hours) of bats was recorded with naked eyes on watch during evening hours after sunset time (hours).Emergence time (minutes) was calculated by using formula:

Emergence time= Time of emergence of bat−time of sunset

All parameters were recorded at weekly intervals and calculated on monthly basis.

Statistical analysis: Data was put under correlation analysis to find relation between abiotic factors and bat population. Roosting preference was determined using percentages.

RESULTS AND DISCUSSION

Roosting preference and population size at urban landscape: Different trees grown in 1km radius aroundselected roosting site at urban landscape are listed in Table 1, whose number ranged from 2-87 and girth from 0.3-4.90mwherefruit bat *P. giganteus* preferred only eucalyptus (4), mango (3), sterculia (11), pinus (29), jamun (3) and silver oak (22) trees for roosting. The girth of respective trees shows that they are tall enough and give space for roosting of bats. Seasonal shifting pattern from one roosting tree to another and increase or decrease in number of *P. Giganteus* bats species were observed at study site. During 2017-18, total bat population varied from 2787-2830 individuals on different trees with mean of 2809.8 individuals. Interestingly, during winter season, bats preferred to roost on pinus (1405-1469) and eucalyptus (341-512), whereas during summer and rainy season, more bat population was recorded on mango (695-718), sterculia (428-502), jamun (369-402) and silver oak (583-685). Interestingly, during 2018-19 total bat population varied from 2877- 3002 individuals on different trees with mean of 2953 individuals and follow same trend of roosting on trees during all seasons like earlier year. Interestingly, 5.1% increase in bat population was recorded during 2018-19 as compared to 2017-18. During both years, %population of fruit bats roosted on trees (Table 2) was highest on pinus (35.40%) followed by silver oak (19.63%), sterculia (13.73%), mango (13.21%), and lowest on eucalyptus (8.99) and jamun (8.98%) as evidenced by statistical analysis of varience which concluded significant realtion between selections of trees and bat population for years 2017-19.

Roosting preference and population size at agricultural landscape: Trees grown at 1km radius area around selected roosting site in agricultural landscape are listed in Table 3, whose number ranged from 2-270 and girth from 1.1-4.7m where *P. Giganteus* fruit bat preferred to roost only on eucalyptus (20) and banyan tree (1). During 2017-18, total bat population varied from 84-494 individuals on both eucalyptus and banyan trees with mean of 346.57

Table 1. Inventory of tree species grown in and around roosting site at urban landscape

Common name	Scientific name	Order	Family	Tree number	Girth (m)
Devil tree	*Alstonia scholaris*	Gentianales	Apocynaceae	57	2.0-3.0
False ashoka	*Polyalthia longifolia*	Magnoliales	Annonaceae	20	0.9-1.5
Silver oak	*Grevillea robusta*	Proteales	Lecythidaceae	75	1.9-2.6
Bottlebrush	*Callistemon viminalis*	Myrtales	Myrtaceae	28	0.7-1.5
Eucalyptus	*Eucalyptus globules*	Myrtales	Myrtaceae	87	1.4-2.9
Weeping paper bark	*Melaleuca leucadendra*	Myrtales	Myrtaceae	11	1.2-2.4
Jamun	*Syzygium cumini*	Myrtales	Myrtaceae	13	1.6-2.4
Mango	*Mangifera indica*	Spanidales	Anacardiaceae	18	0.6-2.4
Siris	*Albizia lebbeck*	Fabales	Fabaceae	03	1.2-2.0
Sheesham	*Dalbergia sissoo*	Fabales	Fabaceae	11	1.3-1.8
Keekar	*Vachellia nilotica*	Fabales	Fabaceae	21	1.5-1.7
Jungli jalebi	*Pithecellobium dulce*	Fabales	Fabaceae	07	1.0-1.8
Champa	*Plumeria rubra*	Gentianales	Apocynaceae	13	0.4-0.9
Indian crape myrtle	*Lagerstroemia indica*	Myrtales	Lythraceae	09	0.3-0.4
Tej patta	*Cinnamomum tamala*	Laurales	Lauraceae	15	0.8-1.2
Dhak	*Butea monosperma*	Fabales	Fabaceae	10	0.6-1.1
Putijia	*Putranjivaroxburghii*	Malpighiales	Putranjivaceae	03	1.2-2.1
Amla	*Phyllanthus emblica*	Malpighiales	Phyllanthaceae	34	1.0-2.1
Rudraksh	*Elaeocarpus ganitrus*	Oxalidales	Elaeocarpaceae	02	1.5-2.8
Kend	*Diospyros melanoxylon*	Ericales	Ebenaceae	05	1.9-2.9
Sal	*Shorea robusta*	Malvales	Dipterocarpaceae	29	1.7-2.3
Elephant apple	*Dillenia indica*	Dilleniales	Dilleniaceae	04	0.9-1.9
Arjuna	*Terminalia arjuna*	Myrtales	Combretaceae	33	1.5-2.5
Bahera	*Terminalia bellirica*	Myrtales	Combretaceae	15	1.3-2.1
Harar	*Terminalia chebula*	Myrtales	Combretaceae	14	1.1-2.4
Sheoak	*Casuarina equisetifolia*	Fagales	Casuarinaceae	05	1.2-2.3
Kachnar	*Bauhinia variegate*	Fabales	Fabaceae	30	0.9-1.8
Amaltas	*Cassia fistula*	Fabales	Fabaceae	38	0.8-1.3
Pila amaltas	*Cassia glauca*	Fabales	Fabaceae	44	0.7-1.3
Gulmohar	*Delonix regia*	Fabales	Fabaceae	57	0.8-1.7
Ashoka	*Saraca asoca*	Fabales	Fabaceae	65	0.9-1.2
Imli	*Tamarindus indica*	Fabales	Fabaceae	18	0.8-1.9
Lasora	*Cordia dichotoma*	Boraginales	Boraginaceae	07	1.2-2.8
Jasmine	*Jasminum officinale*	Lamiales	Oleaceae	46	0.7-1.3
Kanak champa	*Pterospermum acerifolium*	Malvales	Malvaceae	03	0.8-1.5
Buddha coconut	*Pterygota alata*	Malvales	Malvaceae	06	0.9-1.5
Reetha	*Sapindus mukorossi*	Sapindales	Sapindaceae	09	0.5-1.2
Kusum	*Schleichera oleosa*	Sapindales	Sapindaceae	05	1.1-2.4
Litchi	*Litchi chinensis*	Sapindales	Sapindaceae	27	0.8-1.3
Indian horse chestnut	*Aesculus indica*	Sapindales	Sapindaceae	17	1.9-2.8
Kadamb	*Neolamarckia cadamba*	Gentianales	Rubiaceae	08	1.4-2.8
Neem	*Azadirachta indica*	Sapindales	Meliaceae	36	1.5-1.8
Dharek	*Melia azedarach*	Sapindales	Meliaceae	60	1.1-1.6
Pinus	*Pinus Pinus*	Pinales	Pinaceae	12	1.6-2.9
Pilkhan	*Ficus virens*	Rosales	Moraceae	05	2.0-4.9
Peepal	*Ficus religiosa*	Rosales	Moraceae	29	1.9-4.9
Banyan tree	*Ficus benghalensis*	Rosales	Moraceae	23	2.0-6.1
Fig	*Ficus carica*	Rosales	Moraceae	34	0.4-0.9
Shahtoot	*Morus alba*	Rosales	Moraceae	29	1.4-1.6
Pahadi shahtoot	*Morus nigra*	Rosales	Moraceae	08	1.2-1.7
Mahua	*Madhuca longifolia*	Ericales	Sapotaceae	02	0.6-0.9
Teak	*Tectona grandis*	Lamiales	Lamiaceae	11	1.5-2.1
Sterculia	*Sterculia alata*	Malvales	Malvaceae	55	1.7-2.6

individuals. During winter season, bats preferred to roost on eucalyptus (407-472) tree. During 2018-19, total bat population varied from 51-351 individuals on different trees with mean of 252.28 individuals. Again during winter season, more bat population was recorded on eucalyptus (324-332) tree. Interestingly, it was observed that during May to September months of both years of study period, bats migrate from their roosted trees else where for survival and come back again during October-November months. This may be due to less availability of trees surrounding the roosting site or environmental conditions. Nearly 27.20% decrease in *P. giganteus* bat population was observed during 2018-19 as compared to 2017-18. Since, during year 2018-19, a colonizer had made a new colony for human settlement in agricultural landscape near roosted site which may cause disturbance and be the reason for decrease in bat population during 2018-19. During study period 2017-19percent population of *P. giganteus* roosted on trees was highest on eucalyptus (97.52%) as compared to banyan tree (2.48%)as evidenced by statistical analysis of varience which give significant realtion between selection of trees and bat population for year (2017-19) (Table 4).

Similar observations were recorded by Khatun et al (2014) observed minimum changes in the population fluctuation (720-775 individuals) of *P. giganteus* at the Kacharighat roosting site of the Dhubri town area of Assam, during rainy period as compared to other seasons. Kumar et al(2018) suggested that bats preferred large, tall and well exposed eucalyptus trees as their roost. Roost sites are critical resources for bats as they provide a safe location with proper abiotic conditions for foraging and drinking areas (Granek 2002). Vyas and Upadhyay (2014) reported largest colony of *P. giganteus* in Gujarat having approximately 11,000 bats roosted on various tall trees. Similar

Table 2. Number of *P. giganteus* bat roosted on different tree species at urban landscape during 2017-18 and 2018-19

Trees species	Year	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mean population	%Population /tree speies
Pinus (29)	2017-18	1395	856	563	576	581	589	783	940	1094	1405	1469	1418	972.4	35.40
	2018-19	1421	960	814	606	577	728	984	1210	1294	1485	1501	1418	1083.1	
Silver oak (22)	2017-18	439	541	634	583	578	586	654	685	638	503	391	396	552.3	19.63
	2018-19	513	584	648	606	673	567	593	581	668	492	437	502	572.0	
Teak (11)	2017-18	276	389	431	428	446	502	474	411	446	212	181	235	369.2	13.73
	2018-19	412	390	381	525	578	585	568	476	333	328	221	285	423.5	
Jamun (3)	2017-18	109	263	402	396	369	356	376	228	212	166	133	96	258.8	8.98
	2018-19	97	317	383	390	359	328	308	255	252	97	135	156	256.4	
Eucalyptus (4)	2017-18	357	303	132	106	113	177	188	197	206	341	452	512	257.0	8.99
	2018-19	281	312	142	108	164	178	193	182	213	358	497	531	263.2	
Mango (3)	2017-18	214	435	635	718	748	613	334	333	215	182	198	173	399.8	13.21
	2018-19	153	340	618	731	596	519	297	287	221	209	174	110	354.6	
Total	2017-18	2790	2787	2797	2807	2835	2823	2809	2794	2811	2809	2824	2830	2809.6	
	2018-19	2877	2903	2986	2966	2947	2905	2943	2991	2981	2969	2965	3002	2952.9	

Table 3. Inventory of tree species grown in and around roosting site at agricultural landscape

Common name	Scientific name	Order	Family	Tree number	Girth (m)
Eucalyptus	*Eucalyptus globules*	Myrtales	Mytraceae	270	1.6-2.6
Sheesham	*Dalbergia sisso*	Fabales	Fabaceae	04	1.2-1.4
Banyan	*Populus deltoids*	Rosales	Moraceae	02	3.9-4.4
Peepal	*Ficus benghalensis*	Rosales	Moraceae	06	3.1-4.7
Kikar	*Acacia nilotica*	Fabales	Fabaceae	08	1.1-1.8
Neem	*Azadirachta indica*	Sapindales	Meliaceae	07	2.0-2.8
Mango	*Mangifera indica*	Spanidales	Anacardiaceae	11	1.8-2.7
Teak	*Tectona grandis*	Lamiales	Lamiaceae	02	1.1-1.4

observations were recorded by Louis et al (2008) where he identified 14 roosting sites; five from home gardens and two from each, temples, roadside plantations, urban park, agriculture field and a factory campus in and around Coimbatore and Palakkad (Tamil Nadu). Roosts of Indian flying fox were also observed in forest plantations of *Casurina* sp., *Acacia* sp. and indigenous tree species like *Ficus* sp., *Bahunia* sp., rain tree (*Samanea saman*) and Indian date (*T. indica*) (Chakravarthy et al 2008). During a study near Itiadoh dam reservoir near Gothangaon village, Bhandarkar and Paliwal (2014) reported an increase in population trend of roost from 410 (year 2010) to 692 (year 2014) individuals and the colony preferred to roost on *Terminalia arjuna*. The major roosting tree species used by *P. giganteus* individuals were *Caesalpinia inermis*, *Ficus bengalensis*, *Ficus religiosa* and *Eugenia jambolana*. In other study, Dey et al (2013) reported that most preferred trees by bats were *Eucalyptus* sp., *Terminalia arjuna*, *Dalbergia latifolia* and *Tamarindus indica* outside village near water bodies. Similar study carried out in Wayanad (Kerela), showed that *P. giganteus* preffered 12 tree species for their day roosting. Earlier reports indicated that *P. giganteus* also preferred to roost on different tree species like Banyan (*F. Bengalensis*), mango (*M. indica)* and tamarind (*T. indica)*, but, the roosts varied from dense foliage which provided shades and protection from open exposed areas (Vendan 2003).

Relation of atmospheric temperature and relative humidity with bat population in: Depending upon atmospheric temperature and relative humidity of surrounding environment of roosting sites, bats showed their seasonal shifting pattern on different tree species as said earlier. In urban landscape roosting site, bats preferred shaded area for roosting during year 2017-18 and 2018-19. During 2017-18, in summer season when there was high atmospheric temperature (30.9-32.7°C) and low relative humidity (39.8-60.4%) bat population recorded was 2797-2807 individuals whereas in winters, when there is low atmospheric temperature (11.8-14.7°C) and high relative humidity (77.7-82.5%) slightly higher population (2809-2830 individuals) was recorded. Similar results were observed during 2018-19 (Table 5). During 2017-18, in summer season at roosting site in agricultural landscape, when there was high atmospheric temperature (32.4-32.6°C) and low relative humidity (42.0-60.8%) no bat population was recorded due to migration whereas in winter season, when there is low atmospheric temperature (12.6-16.1°C) and high relative humidity (64.0-82.0%) higher bat population (425-494 individuals) was recorded (Table 6). Similar results were observed during 2018-19.

The study observed negative correlation of atmospheric temperature with bat population (Table 5) at both urban landscape {correlation coefficient, r=-0.15 (2017-18) and r=-

Table 4. Number of *P. giganteus* bat roosted on different tree species at agricultural landscape during 2017-18 and 2018-19

Trees species	Year	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mean population	%Population /tree speies
Eucalyptus (20)	2017-18	367	142	0	0	0	0	0	84	426	472	469	407	338.14	97.52
	2018-19	284	94	0	0	0	0	0	51	285	324	332	327	242.42	
Banyan (1)	2017-18	16	0	0	0	0	0	0	0	0	0	25	18	19.66	2.48
	2018-19	17	0	0	0	0	0	0	0	0	27	16	9	17.25	
Total	2017-18	383	142	0	0	0	0	0	84	426	472	494	425	346.57	
Total	2018-19	301	94	0	0	0	0	0	51	285	351	348	336	252.28	

Table 5. Relationship between abiotic parameters and correlation coefficient in different landscapes during 2017-18 and 2018-19

Parameters	Urban landscape				Agricultural landscape			
	2017-18		2018-19		2017-18		2018-19	
	Correlation coefficient (r)	R^2 value	Correlation coefficient (r)	R^2 value	Correlation coefficient (r)	R^2 value	Correlation coefficient (r)	R^2 value
Atmospheric temperature (^{0}C)	-0.15	+0.02	-0.28	+0.07	-0.93	+0.86	-0.94	+0.88
Relative humidity (%)	+0.65	+0.42	-0.05	+0.002	+0.19	+0.03	+0.35	+0.12
*Emergence time (minutes)	--	--	--	--	+0.92	+0.84	+0.97	+0.94

*Emergence time (minutes) was compared during 2017-18 and 2018-19 between bothlandscapes

0.28 (2018-19)} and agricultutral landscape {r=-0.93(2017-18) and r=-0.94 (2018-19)}. A positive correlation was between relative humidity and bat population at agricultutral landscape {r=+0.19 (2017-18) and r=+0.35 (2018-19)} and urban landscape {r=+0.65 (2017-18), r=-0.05 (2018-19)}. In urban landscape, there was abundance of big trees all around which gives congenial environmental conditions throughout year due to which there was less variation in bat population. So, bats do not migrate from the campus site as there were human settlements nearby also. This may be a reason that 5.1% increase in bat population was recorded at this site during the preceeding year. Interestingly, at agricultutral landscape, it was observed that during summer season when there is high atmospheric temperature (31.6-32.4°C) and lowest relative humidity (42.0-44.0%), bats migrate from their roosted trees to a long distance and come back again during October-November which may be due to less availability of trees surrounding the roosting site. At agricultural landscape, 27.20% decreases in bat population was recorded during the preceeding year. Neuweiler (2000) observed that in active state, fruit bats could maintain their body temperatures between 35 and 39^{0}C. However, mention may be made that a small fraction of the bat population from the present study location made local migrations to take shelter and returned to their home of roosting site when environmental conditions become congenial, which may be the reason for lower *P. giganteus* population during summer months. Climate change has been predicted to have profound impacts on the natural environment (Laurence 2010) and the present study has provided an example of how high temperature might affect the population of fruit bats. About 48% declines in *P. giganteus* population from a roosting site in Assam (India) had been reported by Ali (2010) during his 10 years of study from 2001 to 2010 due to change in abiotic factors.

Emergence time of bats: Time of sunset hour and time of emergence of *P. giganteus* bats has strong association with their emergence time for foraging activity (searching of food and water). Emergence time of bats varied significantly and follow same trend during both years of study period and landscapes. In urban landscape (Fig. 1), emergence time ranged from 21.5-46.5minutes, which was lowest in summer (21.5-24.0 minutes) and higher in winter months (40.5-46.5 minutes). Similarly, in agricultural landscape, emergence time of bats varied significantly and ranged from 19.5-45.0minutes which was lowest in summer (19.5-22.0minutes) and higher in winter months (41.0-45.0 minutes). Among both landscapes, there was non significant difference between values corresponding to months and seasons. A positive correlation in emergence time was recorded between urban and agricultural landscapes (r=0.92-0.97). In both

Fruit bat roosting over different trees

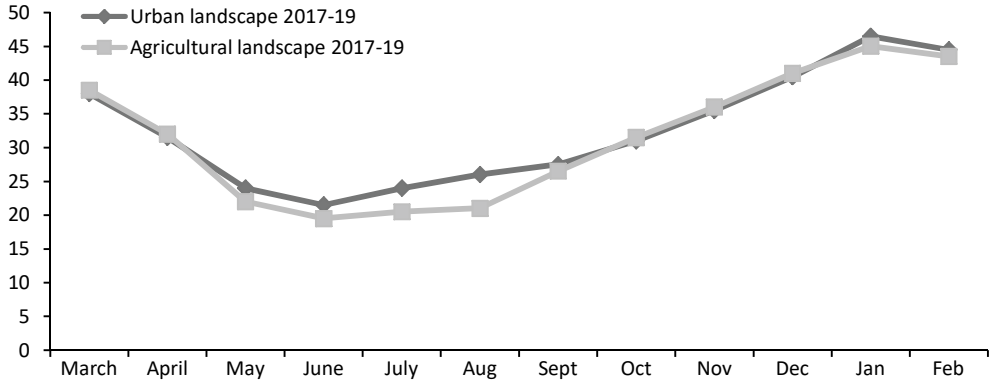

Fig. 1. *P. giganteus* emergence time (minutes) in urban and agricultural landscapesduring 2017-18 and 2018-19

landscapes, as move from June to January, emergence time of fruit bats increases and then starts decreasing from February to May. This lowest difference during summer may be due to more water requirements due to high atmospheric temperature. Time of emergence in bats is an adaptive behaviour to meet foraging needs and decreasing risks of predation and competition. According to a study, Indian Flying Fox emerged 30 minutes after sunset during rainy season and in summer season emerged 50minutes after sunset (Duverge et al 2000). In a study during October, Walton and Trowbridge (1983) reported that the time of departure of *P. giganteus* bats from the roost was 18:00 hrs and the emergence of *P. giganteus* mostly occurs 10 to 20 minutes after sunset. Jacobsen and Duplessis (1976) reported that in Africa, the time of emergence of *R. aegyptiacus* was usually 20 to 40minutes after sunset and may be to avoid dehydration. Gaisler (1963) reported that subtropical bats (*Rhinolophus hipposideros*) leave the roost relatively at the same time in relation to sunset throughout the year.

CONCLUSION

In urban landscape, percent population of fruit bats roosted was highest on pinus followed by silver oak, sterculia, mango, eucalyptus and jamun and 5.1% increase in bat population was recorded in the preceeding year, whereas in agricultutral landscape % bat population roosted was highest on eucalyptus and banyan trees and 27.20% decrease in bat population was recorded in the preceeding year due to formation of new human settlements. Interestingly, migration of bats was recorded for both years during May-September in agricultural landscape which again comes back during October-November. Negative correlation of atmospheric temperature and positive correlation of relative humidity with bat population was recorded at both landscapes. Positive correlation was recorded between emergence time in urban and agricultural landscapes, which was lower in summer and higher in winter months.

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