# Effect of urbanization on roosting, feeding and reproductive behaviour of Asiatic Lesser Yellow bat, *Scotophilus kuhlii*

## THESIS

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**Year 2020**

*This thesis is dedicated to my family and teachers*

# DECLARATION

I hereby declare that the thesis entitled **"Effect of urbanization on roosting, feeding and reproductive behaviour of Asiatic Lesser Yellow bat, *Scotophilus kuhlii*"** submitted by me for the degree of **Doctor of philosophy** in **Applied Animal Science** is the result of my original research work carried out under the supervision of **Dr. V. Elangovan**, Associate professor, Department of Applied Animal Sciences, Babasaheb Bhimrao Ambedkar University (A Central University), Lucknow and it has not been submitted for the award of any other degree or diploma, associateship of any university or institution. I also declared that the thesis is essentially free from all kinds of plagiarism.

**Date:** 22/12/2020
**Place:** Lucknow

Signature of candidate
**(Shani Kumar Bhartiy)**

# CERTIFICATE

This is to certify that the thesis entitled **“Effect of urbanization on roosting, feeding and reproductive behaviour of Asiatic Lesser Yellow bat, *Scotophilus kuhlii”*** submitted by **Mr. Shani Kumar Bhartiy** is an original research work and has not been previously submitted in part or full for the award of any other degree or diploma to this or any other university.

The thesis submitted to Babasaheb Bhimrao Ambedkar University (A Central University), Lucknow, satisfies all the requirements as stipulated in the Doctor of philosophy (Ph.D.) regulation- 1999 as amended in 2013 and it is fit for submission and evaluation for the award of the degree Doctor of philosophy of the university.

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**Head of the Department**

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# ABBREVIATIONS

| | |
|---|---|
| Cm | Centimeter |
| ° | Degree |
| °C | Degree Celsius |
| dbh | Diameter at breast height |
| DP | Degree of protection |
| e.g. | Example |
| %f | Percentage of frequency |
| hrs | Hours |
| $Km^2$ | Kilometer square |
| Min | Minute |
| Mg | Milligram |
| No. | Number |
| m | Meter |
| $m^2$ | Meter-square |
| % | Percentage |
| Sec | Second |
| mm | Millimeter |
| SD | Standard deviation |
| r | Radius |
| % Vol. | Percentage of Volume |
| AB | Abandoned Building |

# General Introduction

Bats make a significant contribution to mammalian species richness and biomass in the tropics. About 1400 known species of bats distributed worldwide (Simmons and Cirranello, 2020). A Sum of 128 species of bats are reported from Indian subcontinents which belong to nine families, namely Pteropodidae, Rhinopomatidae, Megadermatidae, Rhinolophidae, Hipposideridae, Molossidae, Emballonuridae, Vespertillionidae and Miniopteridae (Bates and Harrison, 1997; Simmons, 2010). Insectivorous bats occupy high trophic levels, are indicators of habitat quality (Jones *et al.,* 2009). They may undergo population decrease in response to environmental disturbances (Tuttle, 1979). Bats provide a unique set of challenges for conservation biologists because many species of conservation concern occur outside forests, in degraded or open habitats. Furthermore, as many species aggregate in conspicuous and accessible roosts that are often accessible to people, successful conservation measures should include the protection of roost sites, as well as foraging habitats (Kofoky *et al.,* 2006). The non-forest areas (human dwellings, palaces, old monuments, caves in urban and suburban areas) constitute important habitats for bats. Roosting ecology of bats is well studied in temperate zone species. Its selection is a subset of habitat selection which influence the survival and fitness of a species.

The roost selection of bats influenced by many factors such as microclimate, structural characteristics of roosts, surrounding habitats, disturbance by humans and risk of predation (Brigham and Fenton, 1986; Sedgeley and O’Donnel, 1999). Physical characteristics such as the space, shape, thickness of wall and orientation of roost entrance alter the microclimates of roosts and in turn affect the roost quality and roost selection of bats (Kurta, 1985; Sedgeley, 2001). Further, the shape, size and coverage of entrance and height of the tunnel or roost entrance influence the probability of predation (Medway and Marshall, 1972; Vonhof and Barclay, 1996; Jenkins *et al*., 1998). Many features, such as microclimate, structural characteristics of the roosts, surrounding habitats, disturbance by humans and risk of predation, may influence roost selection by bats (Brigham and Fenton, 1986).

Microclimate can affect bats energy budget, development of fetus or young and water balance (Webb *et al*., 1995). Physical characters such as the space, shape, thickness of the wall, orientation of the roosts alter the microclimate of roosts and in turn affect roost selection by bats (Kurta, 1985). Bats spend over half of their lives in their roosts, which provide them with protection and sites for resting, mating, rearing young and social interaction. Destruction of roosting and foraging habitats may have serious effects on population of insectivorous bats. Insectivorous bats use a variety of habitats for roosting such as caves, crevices and unused buildings etc. and their requirements may vary not only between species but also between seasons and geographical areas. For effective conservation planning, it is essential to clarify the type of habitat that each bat species uses for foraging and roosting over a period of year, so that provisions can be made to protect them. The feeding habits of bats as a whole are as varied as that of other mammals, and this dietary variation is proportional to much of the morphological, physiological and ecological diversity seen in bats (Altringham, 1996).

Actual diet is a heavily influenced by actual food supply availability, its seasonal fluctuation and the tactics with which a particular bat species responds to these changes. Significant seasonal change (Swift and Racey, 1983) in the diet composition of insectivorous bats may indicate flexible exploitation of available food resources (Fenton *et al.,* 1976). Seventy percent of all bats are insectivorous, they primarily feeds on insect as food and each bat can eat several hundred in one night (Adams, 2003). All the micro chiropterans used echolocation, with high frequency sound production and detection, to help them in their navigation are characterized by the series of specialization of middle and inner ear that are associated with echolocation (Folkman *et al.,* 1987).

The microchiroptera bats have ability to produce ultrasonic frequency or pulses by larynx which used to navigate and locate the pray (Vaughan and Vaughan, 1986). Little micro chiropteran locate their pray by the sound generated by passive listening (Marimuthu *et al.,* 1997). They caught prey from sound localization (Arlettaz *et al.,* 1995). Different species of bats makes use of different frequency of echolocation calls as an element of their environment (Neuweiler, 1983). Variation in calls frequency may have implication for resources partition (Jones, 1995). Higher call frequencies reflect more strongly from small prey then lowers frequencies (Pye, 1980).

Foraging behaviour has a vital role in evolutionary biology and ecology since which major contributing of survival, growth and reproductive success (Kramer, 2001). Bats are a group of nocturnal animals with many endangered and declining species throughout the world, in among most bats are important components of ecosystem acting as predators or seed dispersers agent (Kalka and Kalko, 2006; Tang *et al.,* 2008). Insectivorous bats are usually classified according to their foraging strategy such as aerial hawkers, foliage gleaners, uncluttered versus cluttered places (Findley, 1993; Patterson *et al.*, 2003). They have been known as the primary consumer of nocturnal insects (Kunz and Pierson, 1994). They prey on a number of major crops pests such as corn borers, planthoppers, tobacco budworms and oriental armyworms (Whitaker, 1993). Thus, large colonies of insectivorous bats may cause the large-scale depletion of pest insects in surrounding habitats as a result suppress pest population densities to levels lower than other habitats, therefore, known as biological pest control agents (Van Driesche and Bellows, 1996; Leelapaibul *et al.,* 2005). Several kinds of nocturnal insects, such as moths, mantids, lacewings, orthopterans and beetles, have evolved tympanic organs that are sensitive to the frequencies dominating the echolocation calls of most bats (Fenton *et al.,* 1998).

Most species of bats in the family's Emballonuridae, Mormoopidae, Noctilionidae, Vespertilionidae, Molossidae, Rhinolophidae, and Hipposideridae are aerial feeders, they emits frequency about > 110 dB SPL to detect, track, and assess moving targets, usually flying insects (Bogdanowiez *et al.,* 1993). Recently studies in Europe indicate that most insect groups have declined, such as springtails, carabid beetles and several predatory insects (Aebischer, 1991; Luff and Woiworth, 1995; Sotherton and Self, 2000). In Britain have confirmed that increasing the agriculture practice caused declines the several nocturnal insect families' abundance and diversity which it is important in bat diets (*Liang et al.,* 2008). These type changes have reduced resource abundance for bats as well as the stability and predictability of such food resources (Wickramasinghe *et al.,* 2004).

Urbanization alters natural landscapes more dramatically than any other human agent of habitat change (McIntyre and Hobbs, 1999). Many factors such as; water resource, lighting, food availability, house density, vegetation and abstraction in urban, suburban and in rural influence change in behaviours for choosing roosts of bats (Altringham, 1996). High housing density areas support low bat species richness while low-density housing areas have been support high bat richness (Threlfall *et al.,* 2011). Bats may avoid sound pollution environments, presumably because the noise affects their ability to effectively forage, communicate and spatially orient themselves

(Arnett *et al.,* 2013). Bats may also avoid noisy areas for roost sites to reduce disruption during torpor or hibernation (Kunz, 1995). Reproductive females which need to maintain a higher body temperature to facilitate fetal growth or who are rearing young may take advantage of higher ambient temperature in roosts to reduce metabolic energy expenditure (McNab, 1982). In contrast, males or non-breeding females which do not have the pressure of maintaining a higher body temperature for fetal growth choose roosting sites with lower ambient temperature (Hamilton and Barclay, 1994). Microclimate is an important factor in only of buildings roost (Racey and Swift, 1981; Hamilton and Barclay, 1994). Many authors reported that water resource and lightings are vital for bats (Furlonger *et al.,* 1987; Gehrt and Chelsvig, 2003; Kurta and Teramino, 1992). Availability of water and roost temperature increased the reproductive success of female insectivorous bats (Adam and Hayes, 2008) which directly impact on bats population. Higher light intensity may reduce the foraging success of bats and most of bats distract their traveling routs (Downs *et al.*, 2003; Stone *et al.,* 2012). So its effect on wildlife is greater than expected. Approximately <1% of the Earths total area is occupied by urban area (Potere *et al.,* 2009) hence it is a major cause of species endangerment (Czech *et al*., 2000). Much scope has been made in the field of urban wildlife ecology, yet it retains few biases. The first one is geographic: most of the work carried out in forest regions directing less attention to other biomes including grasslands (Marzluff *et al*., 2001; Chace and Walsh, 2005).

The other one methodological the dominant perspective in wildlife ecology has been synecological (Adams, 2005). Work carried out by asking question about abundance and diversity differences between urban and nonurban wildlife communities. The last one is taxonomic, with most research devoted to birds (Adams, 2005; Garden *et al*., 2006) and less to other vertebrates including mammals. There are even biases in urban mammal studies focused on charismatic, conspicuous rather than less secretive ones, such as bats (Gehrt and Chelsvig, 2003; Garden *et al*., 2006).

Studying the urban ecology of bats is worthwhile, and not just because of their ecological importance as predators of nocturnal insects and as pollinators (Garden *et al.*, 2006). For their size, bats have the lowest life histories of all mammals (Dobson and Oli, 2007). Long lived, monoestrous bats, that is temperate zone verpertilionids, are ideal for urban out ecological studies because when environmental conditions are not conducive to successful breeding, they may forego reproduction in favour of somatic maintenance (Olson *et al*., 2004). Thus habitat change can profoundly affect their populations (Racey and Entwistle, 2003) making bats good indictors of habitat quality in general and responsive to urbanization. Temperate bats use daily torpor which saves energy but has reproductive costs (Lausen and Barclay, 2006; Entwistle *et al.*, 1998).

The reproductive period is a critical phase for most living organisms and has become an area of great interest for biologists. Monoestrous is observed in some Neotropical bats; most species show a polyestrous bimodal pattern (Fleming *et al.,* 1972). In mammals, Animal behaviour is performed by a variety of physiological, ecological and social interactions. The genetic structure of populations is largely determined by the breeding behaviour of the individuals within them. In certain, a high variance in the male reproductive success associated with polygyny can decrease the ejective population size, potentially rapidly genetic drift and selection (Chesser, 1991).

Several gregarious species from mammalian taxa including pinnipeds (Boness, 1991), rodents (Hayes, 2000), bovids (Berger, 1992) and bats (Kunz and Hood, 2000;

Tuttle and Stevenson, 1982) exposer of environmental factors and social conditions that enhance reproductive success during the breeding season. Which effect on seasonally and spatially fluctuation food supplies and climate conditions likely influence the timing and location of reproduction (Hoying and Kunz, 1998; Kunz, 1974), whereas intraspecific competition may reduce the advantages of group-living animals (Kunz, 1982) to the negative effect of reproduction. Thus, animal behaviours that enhance an individual's fitness in the context of the group are likely to be favored.

Reproductive behaviour of females can be determined by observation of parturition and maternal care, which is a good indicator of motherhood. Therefore, a female’s reproductive success is often determined by behavioural observations. In contrast, a male’s reproductive success is much more difficult to determine. It has been reported that even detailed observations on male mating success may resulted in inaccurate estimates of reproductive success (Pemberton *et al*., 1992). Seasonally and spatially variable food supplies and climate influence the timing and location of reproduction (Kunz, 1974). Seasonal variation also has been attributed to changes in energy demand during pregnancy and lactation (Kunz *et al*., 1995a).

Sexual dimorphism in size where female are larger than male may occur in adult bats and is well documented among the Vespertilionidae (Myere, 1974). Reproductive females which need to maintain a higher body temperature to facilitate fetal growth or who are rearing young may take advantage of higher ambient temperature in roosts to reduce metabolic energy expenditure (McNab, 1982). In contrast, males or non-breeding females which do not have the pressure of maintaining a higher body temperature for fetal growth choose roosting sites with lower ambient temperature (Hamilton and Barclay, 1994).

Vespertilionidae bats are known as evening bats, which alone provides 493 species from 54 genera throughout the world (Burgin *et al.*, 2018). A total of 21 species of genus *Scotophilus* currently recognized species ranging throughout Africa and Southeastern Asia, (Demos *et al.,* 2018). In Indian subcontinent, only *S. kuhlii* and *S. heathii* were reported, especially *S. kuhlii* found in most states in Indian subcontinent as reported by Bates and Harrison (1997) and also in Western Ghats (Vishakha *et al.,* 2015), Assam (Rahman and Chaudhary, 2017), and Delhi (Dookia and Mishra, 2018). *Scotophilus kuhlii* was first reported from the Pilibheet district of Uttar Pradesh by Wroughton (1914). A comparison between geometrically similar animals of different sizes shows that the power required for flying increases faster with increasing body mass (Pennycuick, 1975). Based on the morphological characters, it is medium-sized species with pelage colour of the dorsal region, soft and olive-brown and abdomen light-creamy (Bates and Harrison, 1997; Elangovan and Kumar, 2015; Dookia, 2018). The facial structure is similar to a dog like a mouth (Bates and Harrison, 1997). Ear length is smaller as compared to the head with a half-moon shaped and tragus is separated from the pinna by a clear cut groove (Elangovan and Kumar, 2015; Dookia, 2018). The Average ear length was 10mm to 13.5mm (Bates and Harrison, 1997; Javed, 2014; Elangovan and Kumar, 2015). The average of forearm length ranges from 44 to 49 mm in length (Bates and Harrison, 1997; Elangovan and Kumar, 2015; Rahman and Chaudhary, 2017; Dookia, 2018). Minimum body mass was 16gm and a maximum of 25gm (Zhu *et al.*, 2012; Rahman and Chaudhary, 2017). *S. kuhlii* frequently occupies different types of roost such as natural and man-made structures like monuments, renounce building, crevices, caves, old temples, palm fronds, hollow structure in palm trees and dried leaves on palm trees (Brosset, 1962; Sinha, 1986; Elangovan and Kumar, 2015). Anthropogenic pressure which gradually changes vegetative land into settlements (Grimm *et al.*, 2008) supports very few species and is having harmful impact on some other species (McKinney, 2002).

According to IUCN version 3.1 (IUCN, 2008), *S. kuhlii* is the least concerned among stable species. However, *S. kuhlii* has not been considered in the wildlife protection act 1972 and the convention on International Trade in Endangered Species of Wild Fauna and Flora appendices (Rahman and Chaudhary, 2017).

The Lesser Yellow House bat, *Scotophilus kuhlii* (Leach, 1821) is a widely distributed species and has been recorded from Pakistan to Taiwan, Sri Lanka, Western Malaysia to Philippines and Indonesia (Bates and Harrison, 1997). In Indian subcontinents, it is distributed in Uttar Pradesh, Andaman and Nicobar Islands, Andhra Pradesh, Bihar, Gujarat, Madhya Pradesh, Maharashtra, Meghalaya, Karnataka, Kerala, Orissa, Rajasthan, Tamil Nadu, Tripura, and West Bengal (Bates and Harrison, 1997).

The Asiatic Lesser Yellow house bat is frequently found in both the rural and urban areas in association with man. Individuals of *S. kuhlii* roost under roofs, crevices and holes in walls of huts and old buildings, caves, temples, palm fronds, hollows in palm trees and dried leaves on trees (Elangovan and Kumar, 2015). Thus, the study was carried out on the following objectives: 1) Roost characteristics of Asiatic Lesser Yellow bat, *Scotophilus kuhlii* (Leach, 1821), 2) Effect of urbanization on roost selection of Asiatic Lesser Yellow bat, *Scotophilus kuhlii* (Leach, 1821), 3) Seasonal food preference and diet composition of Asiatic Lesser Yellow bat, *Scotophilus kuhlii* (Leach, 1821), and 4) Reproductive behaviour of Asiatic Lesser Yellow Bat, *Scotophilus kuhlii*.

# Review of Literature

Jung and Threlfall (2018) conducted a global meta-analysis of 87 studies, including 180 bat species from urban areas in Asia, Australia, Europe, North and South America to understand the importance of functional traits and phylogeny in driving changes in urban bat assemblages and assess the capacity of traits for predicting sensitivity to urbanization. The results revealed that species-specific functional traits explained differences in the intensity of urban habitat use. Urban tolerance mainly occurred within the open and edge space foraging and trawling species as well as in bats with flexible roosting strategies. They suggested that the local extinction of bat species in urban areas was non-random, trait-based and predictable, allowing urban landscape managers to tailor local conservation actions to particular types of species.

Nuratiqah *et al.* (2017) conducted experiments to determine if the females used the same day roost as a maternity roost in buildings in an agricultural and suburban habitat. Their results revealed that the females were found to use the same day roost as a maternity roost as the buildings provided a higher temperature and more stable thermal conditions as compared to the ambient temperature. Whereas a positive relationship exists between roost microclimate and ambient microclimate. They suggested that the females were found to be seasonally mono-estrous. Therefore, useful for the conservation and management of these synanthropic bats where natural roost sites are lacking and in managing human-bat conflicts.

Froidevaux *et al.* (2017) used the greater horseshoe bat, *Rhinolophus ferrumequinum* as a case study for understanding the recovery of bat populations, as its north-western populations had increased substantially over the past two decades following severe population declines. Using summer roost count data from the UK National Bat Monitoring Programme spanning 18 years from 1997 to 2014. They investigated the effects of landscape characteristics associated with the implementation of the agri-environment schemes on colony trends and size and meteorological variables on the annual colony growth rate. Besides they also assessed the relationship between colony size and colony growth to investigate intrinsic factors such as an alee effect. Their results revealed that colony size was positively related to a range of landscape features such as the amount of broadleaf woodland and grassland, and density of linear features surrounding the roost, while the amount of artificial light at night had a significant negative effect. Whereas spring temperatures and precipitation were associated with annual colony growth. They also identified a negative density dependence effect within colonies. Though the conservation of essential landscape elements may have contributed to population increases in the long-term. It has been concluded that recent population recovery has also been driven by climate change.

Moretto and Francis (2017) examined five factors that contributed to the low diversity of bats in temperate, North American urban environments such as anthropogenic noise, road infrastructure, and traffic, ecological light pollution, plant roost availability and diversity and the distribution and diversity of prey. They found that anthropogenic noise and plant roost availability and diversity were more likely to influence only some species of bats, whereas road infrastructure and traffic, ecological light pollution and the distribution and diversity of prey were likely to influence most species of bats. Generally, the effects of these factors on bats are common among urban environments, but individual species' responses to these characteristics might differ slightly among urban environments.

Ruczynski *et al.* (2017) studied that the temporal and spatial activities of bats were species-specific and shaped by many factors such as energy requirements, climate conditions, and food distribution. Pregnancy and lactation are the most energy-demanding periods throughout the female life cycle. They aimed to test if they exhibited similar patterns concerning the time and duration of their nocturnal activity. In Białowieża forest they demonstrated that female nocturnal activity of both nocturnal and Leister’s bats was shaped mostly by the reproductive period and ambient temperature. They have suggested that physiological constraints connected with reproduction and environmental conditions similarly affect these species and outweigh the competition between species.

Wilcox and Willis (2016) studied that habitat modification could improve outcomes for imperiled wildlife. Insectivorous bats in North America face a range of conservation threats, including habitat loss and white-nose syndrome (WNS). Even healthy bats face energetic constraints during spring, but enhancement of roosting habitat could reduce energetic costs, increase survival and enhance recovery from WNS. They tested the potential of artificial heating of bat roosts as a management tool for threatened bat populations. They predicted that after hibernation, captive bats would be more likely to select a roost maintained at a temperature near their thermal - neutral zone, bats recovering from white-nose syndrome at the end of hibernation would show a stronger preference for heated roosts compared with healthy bats and heated roosts would result in biologically significant energy savings. They used a series of bioenergetics models to quantify thermoregulatory costs in each type of roost under several scenarios. Bats specially selected heated bat houses, but white-nose syndrome affected bats were much more likely to use the heated bat house compared with control animals. Their model predicted energy savings of up to 81.2% for bats in artificially heated roosts if roost temperature was allowed to cool at night to facilitate short bouts of torpor. Their results revealed that protection and enhancement of high-quality, natural roosting environments would be a priority response to a range of threats, including white-nose syndrome. They suggested that the potential of artificially heated bat houses help populations recover from white-nose syndrome.

Caryl *et al.* (2016) investigated how insectivorous bats responded to housing density (a measure of urbanization intensity) and a range of habitat variables by modeling the occupancy and activity of 12 species in Melbourne, Australia. The housing density was the dominant explanatory variable of occupancy and activity of most species. The site occupancy probabilities of patch and edge species were reduced by half at housing densities of just 11–45 DPH depending on species, while their activity was halved at housing densities of 26–103 DPH. The activity of two matrix species also declined, but at higher housing densities (reducing by half at 45–79 dph). Patch and edge species responded nonlinearly to tree cover at low housing densities, with peaks in occupancy and activity at 20–60%. This response broke down at medium housing densities, however, as most species were no longer present. They suggested the occupancy probability and activity of almost all bat species studied were substantially reduced even at very low housing densities. Increasing tree cover had no positive effect on the occupancy and activity of patch and edge species once medium housing densities were reached. For land-sharing strategies to provide good habitat for patch and edge bat species housing densities would need to be so low as to be impractical in most urban planning contexts. By contrast, land-sparing with forested habitat remaining in 20% or more of the landscape could provide positive conservation outcomes for the species modeled here.

Krauel and Lebuhn (2016) studied that the distribution and abundance of bat foraging activity in natural areas and characteristics of natural areas that influence the observed patterns of distribution and foraging activity. They performed acoustic surveys of twenty-two parks. They confirmed that the presence of four species of bats including *Tadarida brasiliensis*, *Myotis yumanensis*, *Lasiurus blossevillii*, and *M. lucifugus*. *T. brasiliensis* were found in all parks, while *M. yumanensis* occurred in 36% of parks. Their results revealed that proximity to water, park size, and amount of forest edge best explained overall foraging activity. The proximity to water best-explained species richness. *M. yumanensis activity* was best explained by the reduced proportion of native vegetation as well as proximity to water. While activity was year-round but diminished in December. They have suggested that although bats are present even in very densely populated urban centers, there is a large reduction in species richness compared to that of outlying areas and that most habitat factors explaining their community composition and activity patterns are similar to those documented in less urbanized environments.

Jung and Threlfall (2016) used as a meta-analysis approach to test if the general response of bats was dependent on the intensity of urbanization. Besides, they further investigated if phylogenetic relatedness or functional ecology determined the adaptability of species to urban landscapes and if determining factors for urban adaptability were consistent worldwide. Their meta-analysis revealed that, in general, habitat use of bats decreases in urban areas in comparison to natural areas. While a high degree of urbanization had a stronger negative effect on habitat use compared to an intermediate degree of urbanization. Neither phylogenetic relatedness nor functional ecology alone explained species persistence in urban environments; however, their analysis did indicate differences in the response of bats to urban development at the family level. Bats in the family’s Rhinolophidae and Mormoopidae exhibited a negative association with urban development, while responses in all other families were highly heterogeneous. Furthermore, their analysis of insectivorous bats revealed that the adaptability of individual families such as Emballonuridae and Vespertilionidae, to urbanization, is not consistent worldwide. They suggested that behavioural and morphological traits of individual species might better determine species' adaptability to urban areas, rather than phylogenetic or functional classifications, and that driving factors for species adaptability to urban areas might be regionally divergent.

Chen *et al.* (2016) investigated the postnatal growth and development of *Scotophilus kuhlii* in captivity. An empirical growth curve was established, and the postnatal growth rate was quantified to derive an age-predictive equation. Besides controlling the fostering conditions of twins, the differences in the development patterns between pups that received maternal care or were hand-reared were analyzed to determine whether the latter developed in the same manner as their maternally reared counterparts. Their results revealed that both forearm length and body mass increased rapidly and linearly during the first 4 weeks, after which the growth rate gradually decreased to reach a stable level. The first flight occurred at an average age of 39 days with a mean forearm length and body mass of 92.07% and 70.52% of the maternal size, respectively. They suggested that the developmental pattern of hand-reared pups, although similar to that of their maternally reared twin siblings, displayed a slightly faster growth rate in the 4th and 5th weeks. Whereas the heavier body mass of hand-reared pups during the pre-fledging period may cause higher wing loading, potentially influencing the flight performance and survival of the bats once independent.

Starburk (2015) studied to evaluate support for relationships of bat site occupancy with vegetation structure and management and landscape composition and structure across a gradient of savanna to the forest in the Missouri Ozark Highlands, USA. He selected study sites that were actively managed for savanna and woodland conditions and control areas on similar landforms that had succeeded in the closed-canopy forest. He used Anabat detectors to survey bats during the summers of 2010, 2011, and 2012. He was fit in single-species site-occupancy models to estimate detection probability and site occupancy. He performed priori hypotheses in an information-theoretic approach by evaluating support for candidate models that included habitat, landscape, and management effects. Site occupancy of evening bats, *Nycticeius humeralis* was negatively related to pole timber and sawtimber density and positively related to fire frequency, while northern long-eared bat, *Myotis septentrionalis* site occupancy was positively related to pole timber density and negatively related to understory stem densities. Whereas the site occupancy of big brown bats, *Eptesicus fuscus*, eastern red bats, *Lasiurus borealis*), and tri-colored bats, *Perimyotis subflavus* were mostly not related to local vegetation structure and site occupancy was high across the savanna, woodland, forest gradient.

Russo and Ancillotto (2015) have reviewed that the current knowledge of the effects of urban expansion on bats and assess the potential of these mammals as bio indicators of urbanization. They have proposed different hypothetical models of bat fitness along an urbanization gradient and discuss why bat population density may not be an effective fitness proxy to assess the reactions of these mammals to urban expansion. They have suggested that urban habitat may act as an ecological trap even for synurbic species. Overall, bat sensitivity to urbanization makes these mammals promising candidates to track the effects of this process of land-use change on the biota, but more studies, specifically tailored to explore this role are needed.

Barros *et al.* (2014) assessed the spatial and seasonal activity patterns of insectivorous bats in open areas of the southernmost region of Brazil. They tested the hypothesis that bat activity varied among habitats, among seasons, and was influenced by climate variables. They observed that the highest activity of bats at the edge of a eucalyptus stood (0.64 bat passes/min) and along an irrigation channel (0.54 bat passes/min). The second highest activity values (0.31 and 0.20 bat passes/min, respectively) were obtained at the edge of the riparian forest and the margin of a wetland. While in the grasslands it was found significantly less (0.05 bat passes/min) activity. Bat activity was significantly lower in the winter (0.21 bat passes/min) and autumn (0.33 bat passes/min), spring (0.26 bat passes/min), and summer (0.29 bat passes/min). They also correlated temperature with bat activity. They suggested that insectivorous bats were active throughout the year, and use mostly forest and watercourses habitats.

Villasenor *et al.* (2014) explored effects of high and low-density housing developments on forest-dwelling mammals. Based on habitat characteristics, they predicted a gradual decline in species abundance across forest-urban edges and an increased decline rate in higher contrast edges. They surveyed arboreal mammals in sites of high and low housing density along 600 m transects that spanned urban areas and areas turn on the adjacent native forest. They also surveyed forest controls to test whether edge effects extended beyond our edge transects. They used fitted models describing richness, total abundance, and individual species abundance. Low-density housing developments provided suitable habitat for most arboreal mammals. In contrast, high-density housing developments had lower species richness, total abundance, and individual species abundance, but supported the highest abundances of an urban adapter species *Trichosurus vulpecula*. Their results did not find the predicted gradual decline in species abundance of four species analyzed three exhibited no response to the proximity of urban boundaries but spilled over into adjacent urban habitat to differing extents. One species *Petaurus australis* had an extended negative response to urban boundaries, suggesting that urban development had impacts beyond 300m into the adjacent forest. They demonstrated that high-density housing developments had negative effects on both community and species-level responses, except for one urban adapter.

Threlfall *et al.* (2013) used radiotelemetry to locate day roosts of a species considered sensitive to urbanization, Gould's long-eared bat, *Nyctophilus gouldi*, in suburban bushland in Sydney, New South Wales, Australia. They compared roost selection data collected for nine individuals during the mating season (March–April) and 10 individuals during the maternity season (November–December). Their result revealed that 41 roosts of *N. gouldi* under decorticating bark and in tree hollows, which were all located in one suburban bush land reserve (~40 ha), with roosts rarely located elsewhere, despite the abundance of available trees in smaller patches outside of the reserve. While *N. gouldi* displayed a clear preference for trees with a greater amount of understory and canopy cover, and only roosted where the extent of forest cover in the local landscape was greatest. Whereas maternity roosts also were predominately located in gullies, and closer to creek lines than expected. Roost switching differed significantly between seasons, with lactating females switching roosts significantly more often than non- lactating females, where roost switching occurred after 1 day on 71% of occasions. Because competition with other fauna for hollows has been suggested as a potential threat, systematic observations of hollow-using bird species, including rainbow lorikeets *Trichoglossus haematodus*, has also been conducted. They observed that birds occupying bat roosts on days following bat occupancy, and bats roosted in trees where there were fewer hollow-using birds than randomly available trees.

Threlfall *et al.* (2012) have developed strategies that would alter the accumulation of roost odors and are hypothesized to reduce predation risk. They experimentally manipulated the amount and refresh rate of roosting odor cues at 90 artificial bat roosts in Sydney, Australia. They tested the hypothesis that odors increased predator visitation. Predators visited roosts with bat faeces significantly more often than untreated control roosts. Roosts with small amounts of faeces mimicking sites used by solitary bats had the greatest rate of visitation. Their results revealed that bats roosting alone, rather than in groups, had a greater likelihood of disturbance or predation. Roost switching probably decreases the predictability of finding occupied roosts; however, we show that all roosts were visited by predators, suggesting generalist urban predators readily investigate potential roosts. They suggested that bat odors are attractive to predators that use olfactory cues, showing that bats are at risk of predation in visually cryptic roosts.

Coleman and Barclay (2013) have investigated that urbanization benefits bats in the Canadian Prairies by increasing access to insect prey and foraging habitat from 2007 to 2008. They used sticky traps to sample availability of nocturnal insects, and echolocation detectors to record foraging activity by bats, in and around the city of Calgary, Alberta, Canada. Their data did not support his predictions. Insect biomass and diversity were greatest in rural areas, and foraging activity by bats was influenced more by temperature than by urbanization. Although urbanization does not seem to benefit insects or their bat predators, they found no evidence that it is detrimental to bats in prairie grasslands.

Shetty and Sreepada (2013) analyzed the seasonal variations in the food habit of a microchiropteran bat, *Megaderma lyra*, to determine the insects on which they fed and also to do a nutritional analysis that included the moisture, carbohydrates, proteins, lipids, ash, nitrogen, phosphorus and potassium content of their guano. Their results revealed that a total of the insect-orders identified including Coleopterans formed the major food items in all three seasons (Pre-monsoon, monsoon and post-monsoon) The Coleopterans formed major food items during monsoon and post-monsoon. Whereas, Hemipterans formed the constant food in all three seasons and Lepidopterans formed the constant food along with Hemipterans during monsoon and postmonsoon. Other insect-orders quantified included Dictyoptera, Trichoptera, Orthoptera, Diptera, Hymenoptera, Odonata, Ephemeroptera, Isoptera, Neuroptera, Dermaptera, Thysanoptera and spiders. The insect orders represented in the faecal pellets though not all indirectly reflect the occurrence of agricultural pests since their presence coincides with the type of vegetation surrounding the roosting site. Besides, where nutritional analysis of the guano revealed that the guano contained maximum carbohydrates (2.8%) during pre-monsoon, lipid content (9.3%) during post-monsoon and protein during pre-monsoon and post-monsoon (8.9%) period. N-P-K analysis revealed that the guano was rich in phosphorus. Also, phosphorus content was recorded highest in all the seasons (6-11%) and potassium during monsoon (1.3%) and post-monsoon (1.2%). However, no significant variation in the nitrogen content was recorded. They have suggested that the Indian false vampire bat preys substantially on several insects injurious to crops, gardens and lawns and also on rodents. Further study is needed on the potential impacts of this and other insectivorous bats on these economic pests and also on organic enrichment of bat guano in the study area.

Andreas *et al.* (2012) described the diet composition of western bat, *Barbastella barbastellus*, its seasonal changes and main factors determining the trophic niche of the species. Their results revealed that *B. barbastelle* bat fed predominantly on moths and had the narrowest trophic niche within the entire studied bat community. A comparison of the food supply and the diet composition showed selectivity for larger species of moths. An increase in absolute abundance of preferred larger moths within summer is accompanied by a narrowing of bat's trophic niche. This pattern corresponds well with the conclusions of optimal foraging theory. While larger moths are preferred even in a period of their low relative abundance within a peak of the abundance of smaller species. There are no abrupt seasonal changes in the bat's diet within a season, but the narrow pool of available food supply seems to determine the trophic niche breadth within low prey diversity periods in early spring and late autumn. Whereas the exception is a late autumn period such as most probably due to a change in the food supply, larger moths are preferred and replaced in the diet by smaller individuals. Most of the moths' species cease to fly and chiefly only smaller moth species are flying and attracted by UV light. Larger moths still occurred at the studied area at that time, but they displayed minimal flying activities and they were detected using vegetation beating and sweeping. Besides, syntopic moth eating foliage gleaner (*Plecotus auritus*) still fed on larger moths at that time. They suggested that the change in the diet of *B. barbastellus* is a consequence of poor or absent gleaning abilities of this species, which is not able to pick up the prey from the surface as *P. auritus*. Different hunting strategies are probably efficient trophic niche partitioning mechanisms reducing interspecific competition between these syntopic moth eating bats.

Graclik and Wasielewski (2012) studied the diet of greater mouse-eared bats, *Myotis myotis*. It was investigated by analysis of 900 droppings taken from 8 different bat colonies in western Poland. They found three taxonomic orders including Coleoptera, Lepidoptera, Diptera and representatives of two other groups of arthropods such as Chilopoda: Lithobiidae and Arachnida: Araneae were identified in the droppings. Coleoptera was the most abundant prey found in faecal samples in all seasons. They suggested that the composition of prey, which probably reflected the local foraging conditions for *M. myotis*.

Pillai and Sastry (2012) studied that the female reproductive pattern in the order *Chiroptera* was unique in different ways, one of which is reproductive asymmetry. Their results revealed that the female reproductive asymmetry pattern was an understanding of some of the types of asymmetries prevalent among microchiropteran bats. They suggested that the reproductive tract in *Hipposideros speoris* showed a sinistral dominance of the reproductive tract, in which the ovulation occurred in the left functional ovary and implantation occurred in the ipsilateral left uterine cornu, thus following the general hipposiderid pattern.

Cryan *et al.* (2012) studied the details and timing of reproductive events in species of bats that died most frequently at wind turbines in North America. Because such information can help inform conservation strategies. They examined the reproductive anatomy of hoary bats, *Lasiurus cinereus*, eastern red bats, *L. borealis*, and silver-haired bats. *Lasionycteris noctivagans* was found dead beneath industrial-scale wind turbines. Their results evaluated that the 103 *L. cinereus*, 18 *L. borealis*, and 47 *L. noctivagans* from wind energy facilities in the United States and Canada. Histological analysis revealed that most male *L. cinereus* and *L. borealis*, as well as over half the *L. noctivagans* examined, had sperm in the caudal epididymides by late August, indicating readiness to mate. Testes regression in male hoary bats coincided with the enlargement of seminal vesicles and the apparent growth of keratinized spines on the glans penis. The seasonality of these processes also suggests that mating could occur during August in *L. cinereus*. Spermatozoa were found in the uterus of an adult female hoary bat collected in September, but not in any other females. Ovaries of all female-sampled had growing secondary or tertiary follicles, indicating sexual maturity even in first-year females. *L. cinereus*, *L. borealis*, and *L. noctivagans* are the only North American temperate bats in which most first-year young ones of both sexes are known to sexually mature in their first autumn. They suggested that the seasonal timing of mating readiness in these species is most affected by wind turbines.

Zhu *et al.* (2012) studied the morphology, echolocation call structure, diet, and foraging areas of *S. kuhlii* on Hainan Island, south China from March to November 2006. Their data from 85 individuals indicate that *S. kuhlii* was a medium-sized bat with (50.41 ± 1.36mm) forearm length and (19.81 ± 3.47g) body mass. The wing morphology with high wing-loading (11.38 ± 1.95 $N/m^2$) and moderate aspect ratio (6.96 ± 0.75) indicates that *S. kuhlii* flies fast and forages in open habitat and at the edges of cluttered environments. Echolocation calls of *S. kuhlii* consist of a fundamental and up to four harmonics, with a dominant frequency of (45.72 ± 2.09) kHz. Call shape suggests that this species is adapted to forage in open environments. Whereas, nine insect orders were recorded in its diet, with Lepidoptera (97.46%, by frequency) and Coleoptera (64.72 ± 2.37%, by volume) constituting the main prey, together with Hemiptera (19.99 ± n1.25%) and Hymenoptera (9.43 ± 1.14%). They suggested that significant seasonal variation in the diet of *S. kuhlii*: Coleoptera increased from March to May and then decreased to August, while Hemiptera and Hymenoptera showed the inverse trend.

Moosman *et al.* (2012) examined the diet of the North American big brown bats, *Eptesicus fuscus* and little brown bats, *Myotis lucifugus* using published works and their data from New England to better understand intraspecific dietary variation. They tested whether the diet corresponded with climate (an indicator of the availability of prey) and species richness of bat communities (a measure of potential interspecific competition). Diet of both species of bat varied with the climate in a manner that generally corresponded with longitude. *E. fuscus* increased the use of moths in regions with cool arid summers in western North America, whereas both species of bat consumed more beetles in moisture summer climates associated with eastern North America. Besides, *E. fuscus* consumed little amount beetles and more moths and true flies in more diverse bat communities. However, the correlation between richness of bat communities and mean monthly precipitation limits interpretation of whether richness of bat communities influenced foraging beyond effects of climate alone. Results suggest that the diet is influenced indirectly by environmental factors that limit the availability of prey.

Rainho and Palmeirim (2011) evaluated how important distances to resources were in modelling foraging bat habitat suitability. They used radio-tracked two cave-dwelling species of conservation concern *Rhinolophus mehelyi* and *Miniopterus schreibersii* in a Mediterranean landscape. Whereas, habitat and distance variables were evaluated using logistic regression modeling. Their results revealed that distance variables greatly increased the performance of models, and distance to roost and to drinking water could alone explain 86 and 73% of the use of space by *M. schreibersii* and *R. mehelyi*, respectively. Land-cover and soil productivity also provided a significant contribution to the final models. Habitat suitability maps generated by models with and without distance variables differed substantially, confirming the shortcomings of maps generated without distance variables. Indeed, areas shown as highly suitable in maps generated without distance variables proved poorly suitable when distance variables were also considered. They suggested that distances to resources were determinant in the way bats foraged across the landscape and that using distance variables substantially improved the accuracy of suitability maps generated with spatially explicit models. Therefore, modeling with these variables is important to guide habitat management in bats and similarly mobile animals, particularly if they are central-place foragers or depend on spatially scarce resources.

Moussey (2011) studied and compared five internal and three landscape features of roosts in stone buildings with those of random and paired unoccupied buildings in Cornwall (UK) to determine the roost selectivity of the brown long-eared bat. He found that bats selected roosts mainly for their vicinity and connection, to foraging habitat. While the occupied buildings were thus more likely to be situated closer to deciduous woodland than random control buildings and were connected through tree lines. Roosts were also found to have a roof space divided into more compartments than paired and random controls and no insulation These characteristics influence the building microclimate. Their results suggested that *P. auritus* was selective of its roosts both at the building and the landscape levels.

Coleman and Barclay (2012) hypothesized that urbanization in the North American Prairies, by increasing habitat complexity such as the proliferation of vertical structures such as trees and buildings, thereby enhancing the availability of day-roosts, tree cover, and insects, would benefit synanthropic bats, resulting in increased fitness among urban individuals. They captured more than 1,600 little brown bats, *Myotis lucifugus* in urban and non-urban riparian sites in and around Calgary, Alberta, Canada. Their data did not support most of the specific predictions such as increased numbers of urban bats that did not reflect urbanization-related benefits such as enhanced body condition, reproductive rates, or successful production of juveniles. Instead, bats did best in the transition zone situated between strictly urban and rural areas. They rejected their hypothesis and explored various explanations. They suggested that one possibility was that urban and rural *M. lucifugus* exhibited increased use of anthropogenic roosts, as opposed to natural ones, leading to larger maternity colonies and higher population densities and, in turn, increased competition for insect prey. While other possibilities included increased stress, disease transmission and/or impacts of noise on urban bats. Whatever the proximate cause, the combination of greater bat population density with decreased body condition and production of juveniles indicates that Calgary does not represent a population source for Prairie bats.

Sophia (2010) examined the food items of *H. ater* were from culled parts of the prey insects collected from their feeding roosts as well as from faecal pellet analysis. Their results revealed that the foraging time of *H. ater* and the activity period of insect pests coincided in the study area. Moreover, this bat species controls major pests of stored grains such as *Tribolium* spp which constitutes 55.83% of coleopteran, and the rest includes Lepidopteran pests such as *Hippotion celerio* which is a pest of grapevine, *Nausinoe geometralis* a pest of jasmine, *Othreis meterna, Othreis fullonica* pests of citrus and grapevine and *Nelanitis leda ismene* a pest of rice whose larvae and adults are serious pests in South India. While during winter seasons, *H. ater* feeds on the dipteran insects, especially mosquitoes, which constitute 98.33% of the total intake. Comparison of food habit of *H. ater* roosting at different localities in Tirunelveli district indicates that they are selective but opportunistic in feeding their prey insects. The nocturnal foraging behaviour, echolocation capability, dentition and flight maneuverability of this bat species are the adaptations that enhance their ability to capture nocturnal prey insects in open space during their foraging flight.

Monadjem *et al.* (2010) studied the two sympatric species of *Scotophilus* which were fitted with transmitters and tracked to their respective roosts in a natural savanna site in Swaziland. Their results revealed that both species roosted exclusively in trees, speciously preferring *Combretum imberbe* trees with large girths. They have suggested that the conservation of such roosting trees may be critical to the continued persistence of cavity-nesting insectivorous bats in African savannas.

Ruczynski *et al.* (2009) studied that tree-dwelling bats selected cavities in large, old, dying or dead trees. They used GIS techniques to evaluate bats' spatial response to changes in forest structure and to test the hypotheses that the forest-dwelling bats *Nyctalus noctula* and *Nyctalus leisleri* prefer roost sites within old deciduous or wet woodlands over young and coniferous ones and that roost site preferences reflect the extent to which dead and dying trees are removed. It was found a significant difference in the selection of roosting habitat between the managed and pristine areas of the forest. Within the pristine forest, both species displayed a strong preference for roost trees located within old deciduous stands more than 100 years, whereas in the managed part of the forest old wet woodland was preferred while all medium and young forest stands were avoided.

Knight and Jones (2009) studied the roosting behaviour of the lesser horseshoe bat *Rhinolophus hipposideros*, a species that had declined over large areas of Europe, they used radio-tracked 54 bats from 3 maternity roosts in contrasting landscapes in Britain. The bats exhibited multimodal patterns of overnight activity. They found that more than 75% of bats used night roosts away from the maternity roost, typically in buildings. While up to five different night roosts were used by individual bats, with the number of night roosts correlated with home range and core area. Night roosts were significantly nearer to core foraging areas than were maternity roosts, with 64 to 86% contained within core nuclei. Whereas multimodal activity patterns and frequent use of night roosts are important aspects of *R. hipposideros* behaviour that need to be considered in management strategies. They suggested that minimization of distance to feeding sites might be the primary function of the night roosts, with roosts being used for resting and digestion between foraging bouts. Night roosts are therefore an integral part of core foraging areas and require protection.

Jacobs and Barclay (2009) investigated whether two sympatric sibling species of insectivorous bats, *Scotophilus dinganii* and *Scotophilus mhlanganii,* that were similar in morphology also occupied similar niches as predicted by the ecomorphological paradigm. Their results revealed that the between the two species *S.dingani and S.mhlanganii* a 10-kHz difference in their echolocation frequencies such as *S. mhlanganii* (42.6 ± 1.6 kHz) while *S. dinganii* (33.7 ± 1.8 kHz) and a higher wing loading in *S. mhlanganii* (15.5 ± 2.3 N/m$^2$) than *S. dinganii* (13.6 ± 1.5 N/m$^2$).Whereas, the much overlap in the wing parameters, including wing loading, of the tow species. While the ecomorphological paradigm, the similarity in their phenotypes were reflected in the absence of any detectable spatial or temporal differences in their habitat use. Besides, subtle differences in skull morphology were correlated with subtle differences in the size of dietary items eaten. *S. dinganii,* with its larger skull, fed a wider range of insect prey sizes such as (11.2–18.9mm) than *S. mhlanganii* (11.6–12.2mm). They suggested that the ecological difference between the two species was the use of different roosts. Whereas, *S. dinganii* often was found in building roosts, while *S. mhlanganii* always in trees. Therefore, the ecological similarities with their phenotypic correlates support the ecomorphological paradigm.

Reichard *et al.* (2009) studied that the flexible behaviours permitted gregarious animals to exploit spatially and temporally favourable conditions for reproduction. Evening emergences of Brazilian free-tailed bats, *Tadarida brasiliensis,* in south-central Texas were recorded to determine changes in colony dynamics and to evaluate hypotheses associated with predator avoidance and seasonal energy demands. Their results revealed that the median parturition date was 18 June and lactation lasted about 54 days. Juveniles commenced flight after 41 days and then continued to suckle for 2 weeks before being weaned. The onset of evening emergence was correlated with the sunset, beginning, on average, 11.8 min after sunset (95% confidence interval 5 7.1, 16.6). Whereas the pregnant females emerged later than their roost mates, consistent with a predator avoidance hypothesis.While lactating females emerged after sunset, but earlier than other bats, consistent with the hypothesis that this was a period of high energy demand. Juveniles emerged later than adult females while they continued to be suckled, but emerged earlier as they matured and were weaned, suggesting a trade-off between predator avoidance and energy demands. They suggested that evening emergence behavior of *T. brasiliensis* varies with environmental cues but is mediated by the energetic demands of reproduction.

Voigt *et al.* (2008) studies show that the *Saccopteryx bilineata* exhibits a polygynous mating system, in which each male defends a group of females called a harem. Colonies consist of several harems, and non-harem males roost adjacent to harems. Unlike most other mammals, females disperse from their natal colony and most juvenile males remain in it. Thus, colonies consist of patrilines, which promote intense local mate competition. Females were in estrus for a few weeks at the end of the rainy season. Mating was most likely initiated by females and preceded by intense courtship displays of males. Forty percent of colony males do not sire any offspring during their tenure in the colony, whereas a few males can sire up to 6 offspring in a single year. Males use olfactory, visual, and acoustic signals for courtship, and they demonstrate territory ownership by scent marks, low-frequency calls and visual displays. Harem males sire on average more offspring than do non-harem males but produce only 30% of the offspring within their harem territory, with 70% being sired by other harem males or non-harem males. The reproductive success of males increases with decreasing size, fluctuating asymmetry, and fundamental frequency of territorial calls. Besides, females that are closely related to the harem holder are more likely to mate with other males than with the harem holder. They have suggested that sexual selection in *S. bilineata* is most likely influenced by intense local mate competition caused by scarce roosts and the patrilineal organization of colonies.

Colin *et al.* (2008) studied that in summer, females of most temperate bat species aggregate at maternity roosts, during which time females gestate, give birth, and wean offspring. These activities make the presence of suitable roosts critical for population persistence. They have compared variation in roost tree and site selection by lactating northern long-eared bats to the pre- and post-lactation periods. There result has revealed that when managing for bat roost trees, within-season variation in roost tree use should be considered.

Adams and Hayes (2008) studied that the water-needy lactation hypotheses directly by tracking the drinking habitats of individual lactating and non-reproductive female fringed myotis at an artificial water source located near a maternity roost. They used a submerged passive integrative transponder (PIT) tag reader system designed to track fish to instead record numbers of water source visitations by tagged bats. A total of 24 PIT-tagged adult females, 16 (67%) were detected repeatedly by the plate antenna as they passed to drink. Their results revealed that the total number of drinking passes by lactating females (*n* = 255) were significantly higher than those of non-reproductive adult females (*n* = 22). While overall, lactating females visited 13 times more often to drink water than did non-reproductive females. Whereas on average, lactating females visited six times more often per night. They suggested that the drinking bouts occurred most frequently just after evening emergence and at dawn. While drinking patterns of non-reproductive females correlated significantly with fluctuating ambient temperature and relative humidity recorded at the water source, whereas lactating females drank extensively regardless of ambient conditions.

Neubaum *et al.* (2007) studied the roost selection by the big brown bat, *Eptesicus fuscus* to determine characteristics of roost selectivity by bats; they compared variables for known maternity roosts and randomly selected buildings at microhabitat and landscape scales using logistic regression. They used an information-theoretic approach to determine which variables were most important. They considered 44 and 100 buildings in the microhabitat and landscape-scale analyses respectively. Whereas at the microhabitat scale maternity roosts had exit points with larger areas that were higher from the ground and had warmer average temperatures than randomly selected buildings. While at the landscape scale distances to similarly categorized roosts were smaller, and urbanization variables such as lower building density, higher street density and lower traffic count density was most important. Their results revealed that the variables important to urban-roosting big brown bats were often analogous to studies that characterized maternity roosts found in tree snags and rock crevices. Besides, changes in the landscape, not only in the form of anthropogenic structures but also in water availability and vegetation structure such as riparian forests, may have led to population increases and range expansions of the big brown bat. Because big brown bats appear to selectively choose specific combinations of characteristics found at maternity roosts, not all available structures can be considered suitable and exclusion from established maternity roosts may negatively impact.

Liang *et al.* (2008) studied the diet of echo-locating, insectivorous bats that could provide important insights into their foraging behaviors and ecological constraints they are facing. They were examining an extensive data set covering two years, their results revealed that identified the dietary composition of three sympatric insectivorous bat species in rural areas of Beijing municipality. Each species has different preferences for particular food items. Greater horseshoe bats, *Rhinolophus ferrumequinum*, preferred to catch nocturnal, actively flying insects, mostly moths Lepidoptera, and to a lesser percentage flies Diptera, beetles Coleoptera, and flying ants and termites Hymenoptera. While other nocturnal insects that do not exhibit any perceptible wing movements, such as true bugs Homoptera, or strictly diurnal insects that hardly ever fly in the dark, such as grasshoppers, Orthoptera, dragonflies damselflies and Odonata, were never found in droppings of horseshoe bats. Large mouse-eared bats, *Myotis chinensis*, preferentially glean relatively large terrestrial prey of the order Coleoptera (mostly carabid beetles) and Orthoptera, whereas greater tube-nosed bats, *Murina leucogaster,* consume predominantly smaller, diurnal Coleoptera (mostly soldier beetles, Cantharidae, and ladybugs, Coccinellidae). They suggested that the dramatic differences in the dietary composition of these three bat species were mainly based upon differences in their foraging behaviors, including differences in their echolocation signal structure.

Encarnacao *et al.* (2006) analyzed the effects of age, season on body mass and reproductive condition in male Daubenton's bats, *Myotis daubentonii* from a study area in central Germany. They first captured the bats (n = 336), which were banded and classified as either young of the year or adults. Furthermore, recaptured animals were first caught as young of the year, could be assigned an exact age in years. Epididymal distension in young of the year indicated that some males had reached sexual maturity already in their year of birth, while others did so in their second summer. Body mass and epididymal distension showed pronounced variation related to age and season, with the highest values reached in late summer/early autumn. Almost, older males (>2 years of age) tended to be heavier and in better reproductive condition than younger ones. They suggested that the physical condition of male *Myotis daubentonii* bats, and their reproductive condition, both increased after the initial onset of fertility (start of spermatogenesis) until three years of age. This relatively late physical maturation is in line with other life-history traits characterizing long-lived bats as K-strategists among small mammals.

Perry *et al.* (2006) studied to identify landscape attributes that potentially affected roost placement, determine whether commonalities exist among species in their response to landscape attributes, and evaluated the effects of scale. They modeled roost selection at two spatial scales (250- and the 1,000m radius around each roost). For each species, parameters included in models differed between the two scales, and there were no shared parameters for two species. Their results revealed that average coefficients of determination (R2) for scale models were generally higher than for large-scale models. The abundance of certain forest habitat classes was included more often than patch configuration or topography in differentiating roost from random locations, regardless of scale, and most species were more likely to roost in areas containing abundant thinned forest. While among topographic metrics, big brown bats, *Eptesicus fuscus* were more likely to roost at higher elevations, roosts of big brown bats, northern long-eared bats, *Myotis septentrionalis* and Seminole bats, *Lasiurus seminolus* were influenced by slope and big brown bats, evening bats *Nycticeius humeralis*, and Seminole bats were more likely to roost closer to water than random. While Northern long-eared bats and red bats, *Lasiurus borealis* were more likely to roost closer to roads, whereas eastern pipistrelles *Perimyotis subflavus* were more likely to roost away from roads than random. They suggested that, in a completely forested landscape, a variety of stand types, seral stages and management conditions, varying in size and topographic location throughout the landscape.

Lausen and Barclay (2006) compared patterns of thermoregulation concerning microclimate and compared reproductive timing for maternity colonies of big brown bats *Eptesicus fuscus* roosting in natural and building roosts in the prairies of southeastern Alberta. They observed that predators and predation-in rock roosts, but not in building roosts, and suggest that bats roosting in rocks use shallower torpor to remain vigilant. Patterns of torpor use suggest that bats in buildings save more energy than rock-roosting individuals by roosting in the warmer microenvironments of buildings and by achieving lower body temperatures when ambient conditions are cold and foraging is not productive. While the warmer building roosts are also conducive to juvenile growth, and young building-roosting bats fledged 1–2 weeks before rock bats. They proposed that advantages for bats roosting in buildings such as lower predation risk, earlier births, faster juvenile growth rates, and increased energy savings lead to greater long-term reproductive success for building-roosting bats and make buildings preferred roosts.

Jacobs (2006) studied the genetic, morphological, and echolocation call data to show the existence of a cryptic species. He found that *S. dinganii* consisted of two forms, one that used a peak echolocation frequency of 44 kHz and the other a peak frequency of 33 kHz. Both forms have yellow venters. The 44-kHz phonic type is up to 15% smaller than the 33-kHz phonic type and differed genetically by an average cytochrome-b (Cytb) sequence divergence of 3.3%. Besides, combined phylogenetic analyses of Cytb and control region sequences indicate that the two phonic types are reciprocally monophyletic. He has suggested that they are sibling species.

Flores and Fenton (2005) analyzed the patterns of habitat use by insectivorous bats in Mexico City. They tested the hypotheses that richer patches of food, expected in more vegetated areas, had higher bat activity levels and that fast-flying species benefited most from urbanization. They compared the activity of insectivorous species and relative abundance of insects in five habitats including large parks, small parks, illuminated open areas, residential areas and natural forest. A sampling of bat activity and insects was conducted every 2 weeks in 12 sites per habitat during summer 2002. The results revealed that the average number of taxa per site was significantly higher in the natural forest than in urban habitats, but overall bat activity was significantly higher in large parks and illuminated open areas than in small parks, residential areas and natural forest. Vespertilionid bats *Eptesicus fuscus*, *Myotis* and an unidentified species, along with *Eumops perotis*, occurred almost exclusively in extensive green areas such as large parks or natural forests. While the molossid *Nyctinomops macrotis* made the broadest use of the urban–natural mosaic, whereas *Tadarida brasiliensis* used urban sites with illuminated areas and large parks more intensively. While insect abundance was higher in large parks and natural forests, and it was significantly correlated with overall bat activity and with the number of taxa recorded per site. They suggested that the patterns of habitat use and foraging could be explained by considering the flight and echolocation performance of species. Although some species successfully exploited highly urbanized sites, large areas with vegetation are needed to maintain the most diverse insectivorous bat fauna in Mexico City.

Goodman *et al.* (2005) reviewed that the bat genus *Scotophilus* was poorly known from islands in the western Indian Ocean. *S. borbonicus* was originally described in the early 19th century from La Réunion based on two specimens. Its presence on that island has not been subsequently documented. The holotype specimen has been lost and the lectotype is in a very poor state of preservation, further complicating a proper diagnosis of this taxon. *S. borbonicus* has also been reported from Madagascar, but these records are without clear documentation. Little information is available on *S. robustus*. Based on recently discovered old specimens and newly collected material from Madagascar, they reevaluated the species limits of members of this genus. Three species of *Scotophilus* are documented in Madagascar, one of which is new to science and described herein. This new species, *S. tandrefana,* is distinguished from the other species occurring in Madagascar and elsewhere in the world by pelage coloration and cranial and dental measurements.

Ruczynski and Boganowicz (2005) studied that the selection of roost cavities by *Nyctalus noctula* and *N. leisleri,* widespread species of mainly Eurasian distribution, was examined in Biaowieza Primeval Forest in eastern Poland Because *N. noctula* is one of the most common forest-dwelling bats in Europe, whereas the smaller *N. leisleri* is relatively rare across its range (except in Ireland) and more limited to ancient forests. They hypothesized that these two species might differ significantly in their tree-cavity selection. They selected twenty-five *N. noctula* and twenty six *N. leisleri* were radio-tracked to 52 and 50 roost trees, respectively. The result revealed both species were selective in roost choice and preferred cavities located higher roost height, in more open surroundings, with smaller entrances, and with greater safety distance than available cavities. The all roosts occupied by bats were dry inside. Both species slightly more frequently settled in cavities with entrances facing North East and southwest direction, but the differences were not statistically significant. They compared to the pool of available cavities, *N. noctula* was statistically more frequently found in cavities with a wider inside cross-section and with one entrance, unlike *N. leisleri,* which often used cavities with more than one entrance. They noticed that the differences between the two species were roosted origin. *N. leisleri* used natural cavities (90%) more often than woodpecker cavities (10%), whereas *N. noctula* showed the opposite tendency (woodpecker-made cavities accounted for just over half of roosts chosen by this species). The safety distance also was significantly larger in *N. leisleri* than in *N. noctula*. These differences suggest that the two species use different antipredator strategies that may have important consequences for their different survival rates in younger forests.

Galvan *et al.* (2005) studied that the morphological observations of male genital tracts obtained from wild, adult Mexican big-eared bats *Corynorhinus mexicanus* revealed only one but long annual reproductive cycle showing the existence of temporal asynchrony of its reproductive functions, as is characteristic of temperate-zone vespertilionid and rhinolophid chiropterans. The results revealed that testes were largest in August, whereas the maximum development of epididymis and accessory sex glands complex was observed 1 and 3 months later. The high value of relative body condition of individuals was observed from May to June when testicular enlargement commenced. They have suggested that the recrudescence of spermatogenesis in the adult bats is dependent on a good body condition.

Siemers *et al.* (2005) studied that the European *Rhinolophus* species. They investigated whether this CF component contained reliable information on species, sex, age class or quality (size and body condition) of the caller and could, therefore, had a communicative value. They performed the resting frequencies (RF), measured from stationary, handheld bats for the species *Rhinolophus blasii*, *R. euryale*, *R. mehelyi* and *R. hipposideros* (the latter with very low sample size) in Bulgaria, where they occurred sympatrycally. They recorded calls directly onto a laptop computer and used a specially designed analysis algorithm to achieve high and accurate frequency resolution. After silent periods, individuals 'tuned in' to their RFs always formed lower frequencies, corroborating the recent finding that frequency below RF might be used for auditory feedback control as well. Their results revealed that the *Rhinolophus blasii* could reliably be separated from its congeners by RF, while *R. mehelyi* overlapped strongly with both *R. euryale* and *R. Hipposideros*. Only *R. blasii* showed sex and age differences in RF, albeit the overlap was large. While adult female *R. blasii* had higher RFs than both adult males and juvenile females. In *R. blasii*, RF was positively correlated with forearm length, body mass and body condition index; in *R. mehelyi* with body mass and the body condition index. They suggested that there occurred no correlation between RF and the body size parameters within a sex or age class for any of the species, suggesting that RF was not a reliable honest signal for intraspecific communication that would indicate the quality of a potential mate or competitor.

Leelapaibul *et al.* (2005) established the diet of the guano bat, *Tadarida plicata*. The study was carried out at the Khao Chong Pran Cave, from January to December 2002. Their results revealed that *T. plicata* fed on at least nine insect orders including Homoptera (28.4%), Lepidoptera (20.8), Hemiptera (16.4), Coleoptera (14.4), Diptera (7.0), Hymenoptera (6.6), Odonata (6.0), Orthoptera (0.5) and Psocoptera (0.1). Light traps indicated that Coleoptera (41.2%), Homoptera (25.3), Hemiptera (18.8) and Diptera (12.7) were the most abundant insects in the study area. Homopterans, most of which were white-backed planthopper (*Sogatella* sp., Delphacidae) had the highest percentage frequency of occurrence in the bats' diet indicating that *T. plicata* potentially plays an important role in controlling this major crop pest. The presence of macropterous planthoppers and a large proportion of moths in its diet suggest that *T. plicata* feeds on windborne migrant insects at high altitude. Female bats fed significantly more on lepidopterans and coleopterans and less on damselflies than males. The diet diversity index of lactating females was higher than pregnant females. They suggested that the diet did not differ significantly between the dry and rainy seasons for either sex.

Pereira *et al.* (2002) studied seasonal variations in the diet composition and prey selection by *Myotis myotis*. They found that the diet and food abundance was determined by faecal analysis and pitfall trapping, respectively. Their results revealed that the diet (expressed as % frequency) was dominated by carabid beetles (Carabidae 52%), crickets (Gryllidae 43%), and spiders (Arachnida 34%). Food was far more abundant in the spring than in the summer and autumn. While the dietary composition varied significantly throughout the year. Whereas in the spring, it was dominated by carabids and crickets, and in the summer by spiders. These were then replaced by carabids, which became the most frequently eaten prey in autumn. While the spring-summer switch to spiders coincided with a marked drop in food abundance. Some of the temporal variations in bats' diet can be explained by parallel changes in prey abundance. They suggested Mediterranean colony of *M. myotis* consumed much more crickets and spiders, which was balanced with lower use of carabid beetles.

Pinheiro *et al.* (2002) studied the temporal distribution of insect abundance in the savanna-like vegetation of the central Brazilian cerrado (*sensu stricto*) in Distrito Federal. They used multiple linear regressions to analyze the relationship between the abundance of insects of each order and climate variables. Their result revealed that a total of 50 127 individuals from 15 orders was collected. The orders were Coleoptera (26%), Hymenoptera (23%), Diptera (20.5%), Isoptera (20%), Homoptera (4%), Lepidoptera (4%), Orthoptera (1.5%) and Hemiptera (1%). The abundance of Diptera, Homoptera, Lepidoptera, and Orthoptera was randomly distributed over time; Isoptera peaked in the first half of the wet season, Coleoptera and Hemiptera in the second half of the wet season and Hymenoptera in each season. A significant correlation was found only between Coleoptera and delayed climatic variables. There were no obvious trends that might help explain the abundance patterns observed. They suggested that the phenological patterns of insect abundance and permits evaluation of this group as a resource for various food chains and different trophic levels.

Martin *et al.* (2000) studied the roosting and foraging ecology of temperate insectivorous bats in forests. They assessed general patterns in North American bat use of roost in trees. They used a second series of meta-analyses incorporating more recent data to determine the best current synthesis of knowledge on bat use of forests for roosting. In a third and fourth series of meta-analyses, they separated studies done on bats roosting in tree cavities versus roosting in foliage. They found that the roost trees of bats were tall with large dbh in stands with an open canopy and high snag density. In contrast, roost trees of bats did not differ from random trees concerning live-tree density. The main differences in this study detected between foliagecavity-roosting bats were in percent canopy cover and distance to water. The roost trees of cavity-roosting species had more open canopies and were closer to water than random trees.

Rossiter *et al.* (2000) studied that the breeding behaviour and male reproductive success over five years in a population of bats in south-west Britain. Paternity was assigned with 80% condense to 44% of young born in five successive cohorts. While a small annual skew in male reproductive success was detected, the variance increased over five years due to the repeated success of a few individuals. Mating was polygamous, although some females gave birth to offspring sired by the same male in separate years. Such repeated partnerships probably result from fidelity for either mating sites or individuals or from sperm competition. While females mated with males born both within and outside their natal colony; however, relatedness between parents was no less than the average, recorded for male-female pairs. Gene flow between colonies is likely to be primarily mediated by both female and male dispersal during the mating period rather than more permanent movements.

Whitaker *et al.* (1999) analyzed of 597 faecal pellets collected throughout the year from *Tadarida brasiliensis antillularum* in Puerto Rico. Their results revealed that the diet, expressed as percent volume, differed from the Texan subspecies and consistedd largely of dipterans, Hymenopterans, Lepidopterans, and Homopterans, in decreasing order of importance. This species seemed to prey heavily on swarms of flies or ants, suggesting that it was an opportunist, and appeared to be roughly the ecological equivalent of species of *Myotis* in mainland North American communities. They have suggested that the seasonal variations in the diet are significant.

Sedgeley and O'Donnell (1999) studied that the selection of roost cavities by the threatened New Zealand long-tailed bats *Chalinolobus tuberculatus* in temperate southern beech Nothofagus rainforest in Fiordland, New Zealand. They used radio-tracked 73 bats during spring and autumn to 155-day roosts, all of which were in trees. One hundred and forty-nine roosts were in cavities including 84 in live trunks, 33 in dead trunks, 32 in large branches (seven in dead branches, 25 in life) and the remaining six were beneath loose bark. They compared characteristics of the 84 roost cavities in live trunks with 57 random available cavities also in live trunks. Cavities used by *C. tuberculatus* were not a random subset of available cavities. They found that bat roosts were all located in knothole cavities, which were at heights from the ground, and had little surrounding vegetation and that all roosts were dry inside. *C. tuberculatus* used a higher amount of cavities which had medium-sized entrances and internal cavities, and thicker cavity walls. They tested the prediction of invasion biology by analyzing data on the population density of breeding birds in their ancestral rural habitats and in matched nearby urban habitats that had been colonized recently across a continental latitudinal gradient. Their estimated population density in the two types of habitats using extensive point census bird counts, and they obtained information on the year of urbanization when population density in urban habitats reached levels higher than that of the ancestral rural habitat from published records and estimates by experienced ornithologists. The population density was on average 30 % higher in urban than in rural habitats, although density reached as much as 100-fold higher in urban habitats in some species. Invasive urban bird species that colonized urban environments over a long period achieved the largest increases in population density compared to their ancestral rural habitats. This was independent of whether species were anciently or recently urbanized, providing unique cross-validation of the timing of urban invasions. Their results suggested that successful invasion of urban habitats was associated with gradual adaptation to these habitats as shown by a significant increase in population density in urban habitats over time.

Kurta and Whitaker (1998) studied of dietary preferences of Indiana bats. Determination was done by analyzing 382 faecal pellets collected beneath roost trees in southern Michigan, over parts of 3 year. Although terrestrial insects including Lepidoptera and Coleoptera usually dominated the diet of Indiana bats in more southern states, those in Michigan consumed mostly insects associated with aquatic environments. Their results revealed that Indiana bats in Michigan ate primarily Trichoptera (55.1% of volume) and Diptera (25.5%), followed by Lepidoptera (14.2%) and Coleoptera (1.4%). Consumption of Diptera was highest during lactation (48.2%), whereas consumption of Lepidoptera was least during this time (7.7%). Although most insectivorous bats do not prey on mosquitoes (Culicidae), these insects were a consistent component of the diet of Indiana bats and were eaten most heavily during pregnancy (6.6%).

Bogdanowicz *et al.* (1998) focused on the predictions of the all tonic frequency hypothesis which states that some insectivorous bats increase their access to moths that can hear echolocation calls by shifting to frequencies to which the ears of these insects are less sensitive. They hypothesized that the frequencies dominating the echolocation calls of bats might be correlated with the incidence of moths in their diets. They collected data for 62 species of bats that took airborne prey, usually insects, 25 species of high duty cycle echolocating bats (Rhinolophidae and Hipposideridae) and 37 species that are low duty cycle echolocators (Vespertilionidae and Molossidae). Their results revealed that the bats whose echolocation calls were dominated by frequencies <100 kHz, a parabolic dependency between moth consumption (% volume or % frequency) and echolocation call frequency (kHz), supporting the allotonic frequency hypothesis. The use of echolocation calls dominated by frequencies outside the range of best hearing by moths may indeed increase the availability of these insects to the bats. However, when the same analysis was performed with only the bat species using echolocation calls dominated by sounds > 100 kHz, the relationship was not statistically significant and suggesting that morphological characteristics rather than echolocation call frequency might limit the range of potential prey items. They demonstrated the importance of jaw morphology as a predictor of the incidence of beetles or moths in the diets of bats, and revealed that generally bigger species used echolocation calls dominated by lower frequencies than smaller species. Whereas in both high duty and low duty cycle echolocating bats the relationship between body size and dominant call frequency was best described by a linear model.

Jenkins *et al.* (1998) studied on roost features of *Pipistrellus pipistrellus inbuilding*. *P. pipistrellus* did not select roosts with specific structural attributes. They compared with random buildings, roosts were closer to a tree over 10 m height and covered a greater percentage within a radius of 50 m height. Trees provide benefits to shelter and microclimate in adverse conditions. Also protect from predators therefore, bats can emerge earlier, thus increasing foraging time. They concluded that *P.*

*pipistrellus* emerged 11 min earlier from roosts with 29% cover and roosts with a 3% cover, possibly gaining as greater 10% of their daily energy needs in this extra time. These roost features may be crucial for navigation, foraging, and predator avoidance. The random buildings roosts were closer to deciduous woodland within a radius of 0.5 km, and a greater area of coniferous woodland within a radius of 0.5 km, while it was more likely to be found within 0.5 km of a major river. All these factors are likely to be important for foraging.

Fenton *et al.* (1993) studied on activity patterns and location of *Noctilio albiventris* bat at the Estacion Experimental Enrique Jimenez Nufiez Cafias, Costa Rica. They observed that captive and free-flying animals varied in both foraging time and numbers of foraging bouts per night varied of captive and free-flying animals, but total time away roost usually averaged 120 min/night. They concluded that bats with radio transmitters often used the same roost, few individuals changed their roost during the period.

Barclay (1985) studied the foraging behavior of *Scotophilus leucogaster* in Zimbabwe, Africa, during January and February (normally the wet season) 1982, using mist nets, faecal analysis, light tags and radiotelemetry. Their results revealed that both the diet and foraging behavior of *Scotophilus leucogaster* appeared to be variable. Individuals foraged mostly over floodplains for an average of less than one hour at sunset and spent the rest of the night in small tree-cavity roosts. Adults averaged shorter feeding periods and remained closer to the roost area than did-sub adults. Hemipterans and coleopterans were the primary prey items although several other insect orders were eaten to varying degrees by different individuals. He suggested that the diet varied between adults and sub-adults and from night tonight.

While both the varied diet and single feeding bout more resemble dry season characteristics of *S. leucogaster* than wet season characteristics.

Anthony and Kunz (1977) studied the feeding strategies of the little brown bat, *Myotis lucifugus*. The investigation was carried out in southern New Hampshire USA from early May through late August 1974. The faecal analysis revealed that the diets of individual bats varied. All available insects 3 to 10 mm in body length were accepted as food items. Whereas Nematoceran Diptera were by far the most common insects taken in light-trap samples and constituted a major portion of the diet throughout the summer. While Coleoptera, Trichoptera, Lepidoptera, Ephemeroptera, and Neuroptera were also consumed in appreciable numbers. Their results revealed that comparison of dietary composition with prey availability indicated that pregnant bats consumed 3-10 mm prey in approximate proportions encountered during June when insect availability was low and unpredictable. However, lactating, post-lactating and non-reproductive exhibited more selective feeding in July when insects were more abundant. This increase in selectivity reflected the exploitation of beetles and mayflies, which were uncommon in trap samples. In August, juveniles approximated random feeding patterns, as they learned to forage. They suggested that increased resource availability allowed selective feeding in adult bats during July, as predicted by prey selection models. However, reduced discriminatory abilities might prevent similar levels of prey selection in juveniles.

# Chapter-I

# Roost characteristics of Asiatic Lesser Yellow bat, *Scotophilus kuhlii* (Leach, 1821)

# CHAPTER I Roost characteristics of Asiatic Lesser Yellow bat, *Scotophilus kuhlii* (Leach, 1821)

## INTRODUCTION

Roost selection is a subset of habitat selection which influence the survival and fitness of a species. The roost selection of bats influenced by many factors such as microclimate, structural characteristics of roosts, surrounding habitats, disturbance by humans and risk of predation (Brigham and Fenton, 1986; Sedgeley and O'Donnel, 1999). Physical characteristics such as the space, shape, thickness of wall and orientation of roost entrance alter the microclimates of roosts and in turn affect the roost quality and roost selection of bats (Kurta, 1985; Sedgeley, 2001). Further, the shape, size and coverage of entrance and height of the tunnel or roost entrance influence the probability of predation (Medway and Marshall, 1972; Vonhof and Barclay, 1996; Jenkins *et al*., 1998). In case of nesting of birds, increase in nest height decreased the predation rate and increased the fitness (Nilsson, 1984; Rendell and Robertson, 1989; Elliott *et al*., 1996). Thus, the roost qualities directly influence the survival and reproductive success of animals, and particularly bats (Li and Martin, 1991). Roost plays vital role during reproduction, the female bats of temperate countries form maternity roosts since gestation and leave when the offspring weaned (Garroway and Broders, 2008). Roost offers safe site survival during harsh weather, the bats of temperate zone hibernate in roosts during winter (Kurta, 1986) while they aggregate in maternity colonies during breeding seasons (Henshaw, 1960; Betts, 1997; Entwistle *et al*., 1997; Williams and Brittingham, 1997). A few studies reported that the roosts selected adjacent to water bodies provide food and water (Entwistle *et al*., 1997; Williams and Brittingham, 1997).

Asiatic yellow house bats belong to genus *Scotophilus*, consist 15 species worldwide and ranging from Southeast Asia to Africa (Robert *et al.*, 2009). The Asiatic lesser yellow house bat, *Scotophilus heathii* and Asiatic grater yellow house bat, *S. khulii* live in monuments, abandoned buildings, fronds of palm tree and tree holes in Uttar Pradesh, India (Rickart *et al.*, 1989; Elangovan *et al*., 2018). *Scotophilus kuhlii* readily uses man-made structures as roosts and lives in the roofs of houses, old abandoned buildings (Kingston *et al*., 2009) and leaf fronds (Rickart *et al.*, 1989). The attics of buildings were used as day roost as well as maternity roost by females of *S. kuhlii* (Nuratiqah *et al*., 2017). A few studies had been carried out on seasonal roost selection of tree dwelling bats (e.g. Menzel *et al*., 2000; Kurta and Rice, 2002; Hein *et al*., 2005; Turbill and Geiser, 2008). Although, many studies had been carried out on roost selection of microchiropteran bats (e.g. Sedgeley, 2001; Miller *et al*., 2003; Kalcounis-Riippell *et al*., 2005; Lacki *et al*., 2009; Yanzhen *et al*., 2015), a very few studies been carried out on roost characteristics and roost selection of *S. kuhlii* (Rickart *et al.*, 1989; Kingston *et al*., 2009; Nuratiqah *et al*., 2017). The maternity roosts with higher exit points may provide bats, particularly young individuals inexperienced in flying, with added room to drop and obtain lift, therefore avoiding low-lying clutter or potential urban ground predators (Neubaum *et al.*, 2007). Larger exits may increase access to the roost, ease of access may be particularly important to maternity colonies where larger exits may facilitate ingress and egress rates (Neubaum *et al.*, 2007). Larger roosts entrance openings offer access by more than one individual at a time, and this may be crucial as juvenile bats mature and begin exiting the roost. When juvenile bats inexperienced in flying may take longer space to exit from an access point and therefore block other bats attempting to enter or exit (Neubaum *et al.*, 2007). Neubaum *et al.* (2006) reported that the height of the exit point of roost from the ground variable was also important in maternity-roost selection by big brown bats, as it was when selecting hibernacula. Reproductive female bats, often involved in the only direct parental care investment, are predicted to face intense selection pressure to roost in relatively warm sites. Coolest roost and the use of torpor cause slow the development of prenatal and juvenile bats (Racey and Swift, 1981; Tuttle and Stevenson, 1982; Wilde *et al.*, 1999), which has insinuation for overwinter survival and thus, the fitness of mother and offspring (Kunz, 1987; Thomas *et al.*, 1990).

Previously studied evidence demonstrates that female bats use torpor while raising young, but they are more likely to select the warmest possible roosts (Kerth *et al.*, 2001) and avoid torpor use (Chruszcz and Barclay, 2002; Hamilton and Barclay, 1994) during lactation period relative to pregnancy (Willis, in press). The energetic costs of the lactation period are high for bats (Kurta *et al.*, 1989, 1990), hence, the thermoregulatory benefit achieved through roost selection is likely important for balancing the energy budget. Therefore, the selection of roosts based on abiotic mostly microclimate should be more pronounced during lactation than during other times of year (Willis and Brigham, 2005).

Maternity roost sites are an important food resource for bats (Kunz, 1982). While bats have low reproductive rates and are susceptible to human disturbance at roost sites (Schorr, 2010). Therefore, the availability of suitable maternity roosts may characterize a major constraint on the population size and distribution of different bat species (Knight and Jones, 2009). The female bats aggregate at maternity roosts during gestation and leave when the offspring have been weaned (Garroway and Broders, 2008). Whereas, social interactions between individuals at maternity roosts may confer fitness benefits to the bats (Willis and Brigham, 2004; Garroway and

Broders, 2007s). Nevertheless, in selecting suitable maternity roosts, bats will choose suitable roost microclimate conditions (Neubaum *et al.*, 2007; Knight and Jones, 2009; Russo and Ancillotto, 2015). The female *S. kuhlii* to use the same day roost as a maternity roost as the attics several types of the hole in buildings provided a higher temperature and more stable thermal conditions as compared to the ambient temperature. Whereas buildings are generally used by female bats during the reproductive season to raise their offspring because of the energetic benefits and lower predation risk (Voight *et al.*, 2016). The female offspring that are raise in buildings would prefer man-made structures such as abandoned buildings for their reproduction (Voigt *et al.*, 2016). It provides a special situation, in that young are hidden in roosts until they can fly. Therefore, roost selection may affect reproductive success, either directly through the survival of juveniles, or indirectly through their subsequent growth and development (Lausen and Barclay, 2006).

Little studies have investigated seasonal changes in roost-site selection by bats. Miller *et al.* (2003) and Kalcounis-Riippell *et al.* (2005) reported that two Seasonal changes in roost-site selection for tree-roosting bats such as Indiana bats, *Myotis sodalis* select snags as summer roosts while hibernating in caves and mines during winter (Kurta and Rice, 2002). Another, southeastern foliage-roosting species such as Seminole bat *Lasiurus seminolus* and red *L. borealis* bats usually occupied roost in the canopy of overstory trees in summer season (Hutchinson and Lacki, 2000; Elmore *et al.*, 2004; Perry and Thill, 2007; Hein *et al.*, 2008). Whereas, these species perform to occupied alternate roosts in other seasons. Saugey *et al.* (1989) reported that red bats found in ground rooting during winter. Whereas confirmed by several authors have reported the use of leaf litter by lasiurine bats (Saugey *et al.*, 1989, Moorman *et al.*, 1999, Rodrique *et al.*, 2001, Hein *et al.*, 2005; Mormann and

Robbins, 2007). Leaf litter perhaps provides thermal benefits during chilled winter weather by dropping heat loss through convection and radiation (Whitaker and Stauffer, 2003). During winter bats activity levels decrease as several bat species migrate to warmer latitudes or hibernate in caves, crevices, or human-made structures (Fleming and Eby, 2003; Speakman and Thomas, 2003)

Bats are facing scarcity of roosts due to various reasons like climatic and anthropogenic changes, and habitat destructions, and thus species like *S. kuhlii* forced to choose different roost types like monuments, abandoned buildings, other man-made structures, caves, crevices and tree cavities at different seasons. Thus, a study was carried out to investigate the influence of roost characteristics such as roost height above the ground, tunnel length and width, roost shape, roost surface area, microclimatic conditions and degree of protection of roost at different seasons on roost selection of Asiatic lesser yellow house bat, *Scotophilus kuhlii*.

## MATERIALS AND METHODS

### Study area

The study was carried out in 24 districts of Uttar Pradesh, India. Uttar Pradesh consists of several monuments with distinct styles of architectures of Hindu, Buddhist, and Royal memorials of Indo-Islamic architectures situated in Agra, Banda, Mathura-Vrindavan, Ayodhya, Varanasi, Prayagraj, Kaushambi, Kapilvastu, Kushinagar, Sankisa, Shravasti, Sarnath, Chitrakoot, Lucknow, Jhansi and other small towns (Figure 1.1).

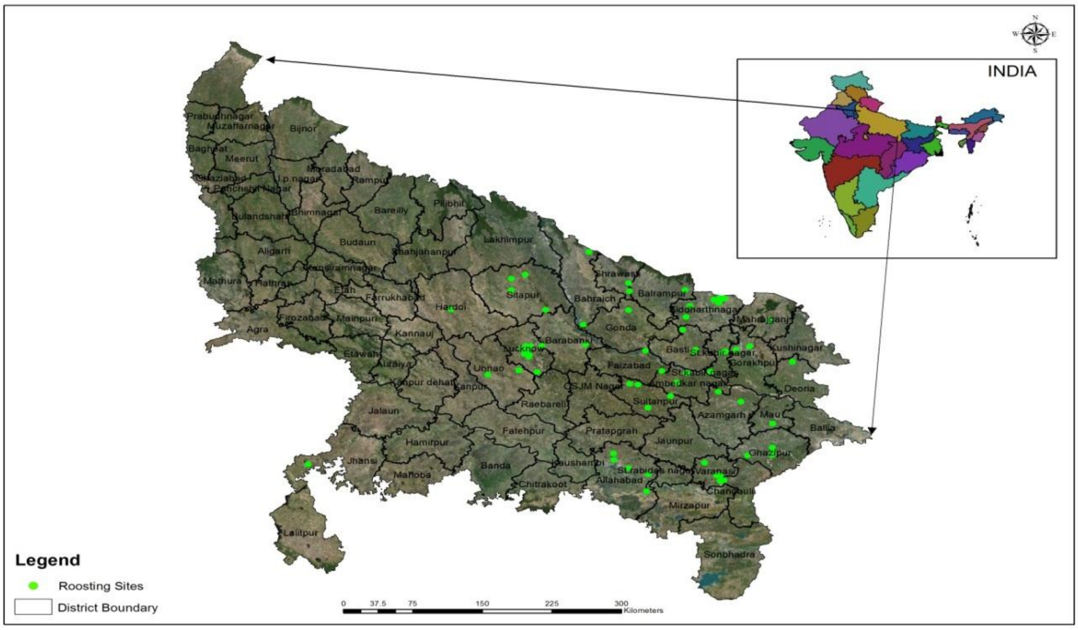

**Figure 1.1.** Map of the study area (Uttar Pradesh). The study sites were marked with circle using GPS Coordinates.

### Data collection

Roost search was carried out at monuments, abandoned buildings and larger trees in rural, semi-urban and urban areas at three distinct seasons such as summer (March–June), Monsoon (July–October) and winter (November–February). The active bat roost was located based on the availability of bat guano on the surface of roosts. Further, mist nets were erected adjacent to roost entrance at the time of emergence, the bats were captured, identified and released at the site of capture. The roost sites of *S. kuhlii* were categorized into abandoned building (ruined building not used by human being and not listed as monument by Archaeological Survey of India), monument (historical buildings and palaces protected and listed as monuments by Archaeological Survey of India, Govt. of India) and tree holes (cleft and holes used by bats as roost in large trees like *Ficus religiosa*, *F. virens* and *F. bengalensis*). Every roost was given an unique roost ID for recognition. The roost characteristics such as roost height above the ground (m), length of tunnel (cm), roost surface area ($m^2$), roost temperature (°C), humidity (%), and colony size were recorded at different roost types. The number of individuals in a harem at the time of observation was considered as colony size and sum of all individuals of colonies considered as populations. Roost height in monuments and abandoned buildings were measured using a measuring tape (m) and tree height was measured using clinometer method. Tunnel length was measured using a ruler (cm). The characteristics such as height (m) and diameter at breast height (dbh, cm) of roost trees were also assessed. Roost temperature and relative humidity were recorded using a Thermo-hygrometer (103-CTH). Since, *S. kuhlii* roosts primarily in tunnel or holes in walls and trees, the shapes of their roosts were categorized as i) branched tunnel or ‘T’ shape (Figure 1.2 a,e), ii) Gamma or ‘┐/┌’ shape (Figure 1.2 b,f), iii) unbranched tunnel(Figure 1.2 c,g) and iv) crevice or cleft(Figure 1.2 d,h). In addition the roost occupancy of bats, i.e. the bat occupied at periphery of roost or interior part of roost was also recorded. Degree of protection (DP) was calculated by using the following formula:

$$\text{DP (\%)} = \frac{\text{No. of occupied roosts observed at T0-No. of abandoned roosts at T1}}{\text{Number of occupied roosts observed at T0}} \text{ x } 100$$

Where T0 was the number of occupied roost observed initially and T1 was the number of abandoned roost observed after 1 year.

In addition, the characteristics of unoccupied tunnels located adjacent to occupied tunnels were also measured for comparison. The characteristics of unoccupied tunnels were measured as described above in occupied roosts characteristics. All those parameters of unoccupied tunnels which showed larger value than the minimum values of occupied tunnels were considered for comparison. Furthermore, maternity roost was also observed in the breeding season. A total of 10 roosts were selected and given a roost ID number to access the reproductive behabiour in Siddharthanagar district, whereas behaboiur was carryout fifteen days interval from February to June 2018. Whereas only a roost has become maternity roost because it was never vacated by bats throughout the breeding season. Therefore, we had been a consideration as a maternity roost. Thus we assessed the population of bats throughout the breeding month and taken accessory data of characteristics of maternity roost. Furthermore, more detailed information about reproductive behaviour has been given chapter fourth.

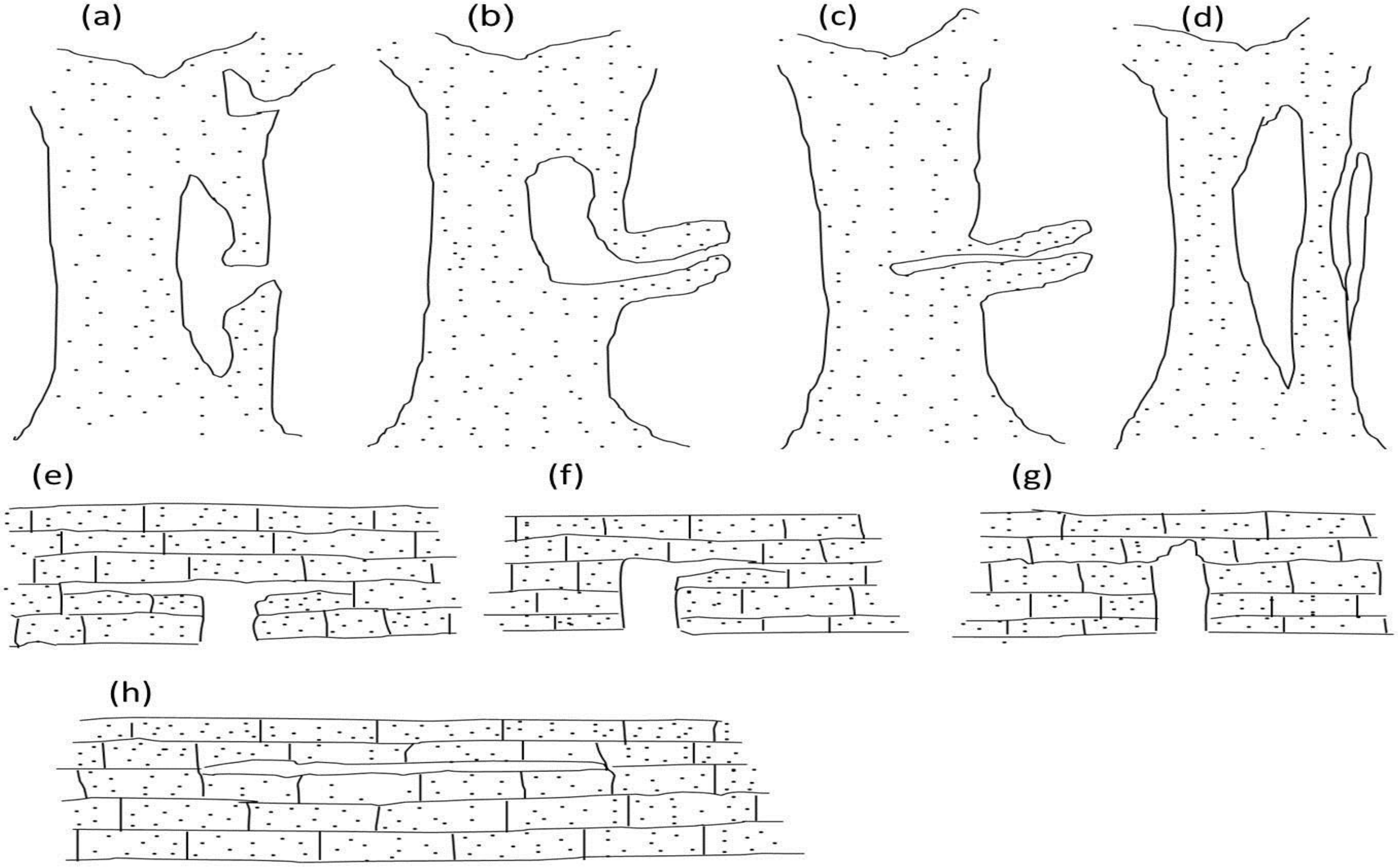

**Figure 1.2.** Various types or shapes of roosts selected by *S. kuhlii* in trees and manmade structure (a) T shape, (b) L shape, (c) Tunnel and (d) crevices in trees, remaining (e) to (h) same as above in manmade structure

## Statistical analysis

Multiple Linear regression analysis was used to determine the effect of roost height, tunnel length, roost surface area, roost temperature and humidity and dbh and height of roost trees with reference to colony size of *S. kuhlii*. The characteristics of occupied roosts and unoccupied tunnels and cavities listed in Table 1. 2 were evaluated using Kruskal Wallis-H test. We also compared the preferred shapes of roosts over seasons listed in (Table 1.3) using Kruskal Wallis-H test. The roost occupancy of *S. kuhlii* at different seasons was analyzed using Chi-square test. The level of statistical significance considered was $p < 0.05$. The average values were given as mean ± SD. All statistical analyses were performed using SPSS, ver. 21 and graphs were prepared using Prism Graph-Pad version-5.00.

## RESULTS

The roosts of *Scotophilus kuhlii* were observed in monuments, abandoned buildings and tree holes. On two occasions, the colonies of *S. kuhlii* were observed in palm fronds. The first colony was observed in Residency, campus of Archeological Survey of India, Lucknow and the second colony from Azad Nagar, Lucknow, and the colony sizes were 258 and 30 individuals, respectively. However, no bat was observed during our subsequent visit, thus this could be a temporary aggregation. They used naturally existing holes and tunnels in the walls of monuments and abandoned buildings as well as in the clefts of larger trees in urban, semi-urban and rural areas in Uttar Pradesh, India. A total of 199 roosts consist 702 individuals of *S. kuhlii* were observed from September 2015 to December 2018 in 23 districts of Uttar Pradesh, India (Figure 1.1). The colony size varied over seasons and type of roosts, and ranged from one to nine individuals per roost. A maximum percentage of roosts were observed in abandoned building (46.73%) followed by monuments (40.70%)

and tree holes (12.56%), while highest number of individuals was observed in monuments (323 individuals) followed by abandoned buildings (305 individuals) and tree holes (74). Akin to the number of individuals in each roost type, the average roost occupancy was higher in monuments (4.36 ± 2.19) than abandoned buildings (4.08 ± 2.03) and tree holes (2.64 ± 2.11), and the roost occupancy varied significantly among roost types ($\chi^2 = 99.47$, $P < 0.05$). Further, the average roost occupancy of *S. kuhlii* among roost types varied with seasons. The colony size of *S. kuhlii* varied among roost types and seasons (Figure 1.3). Highest level of protection was observed in monuments (96.29%) followed by abandoned building (78.50%) and tree holes (60%, Figure 1.4).

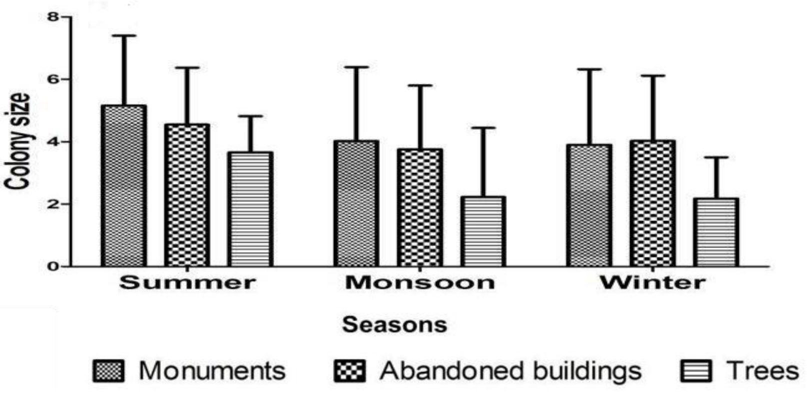

**Figure 1.3.** The colony size of *S. kuhlii* at Monuments, Abondoned buildings and Trees during summer, monsoon and winter.

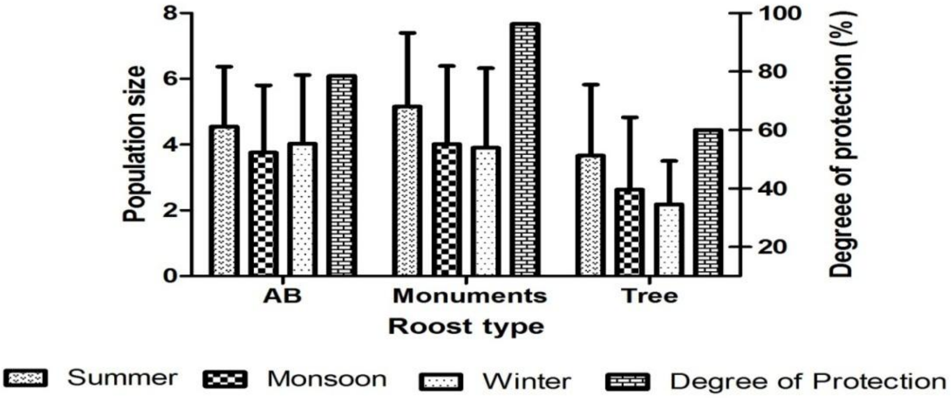

**Figure 1.4.** Degree of protection (%) and corresponding population size of AB, Monuments and Tree during summer, monsoon and winter dipend them only.

*Scotophilus kuhlii* preferred to roost at different heights across roost types and seasons (Figure 1.5). The highest roost height was observed in trees (4.68 ± 1.32m) followed by abandoned building (4.36 ± 1.42m) and monuments (4.06 ± 1.59m). Pearson correlation showed negative correlations between roost height and colony size at different seasons and roost types (Table 1.1).

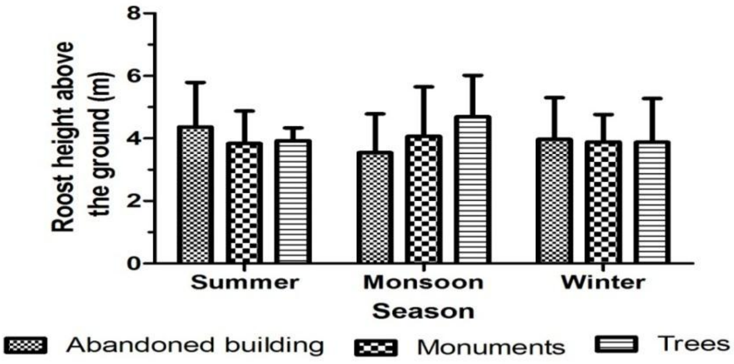

**Figure 1.5.** The height of the roost selection by *S. kuhlii* at abandoned buildings, Monuments and Tree during summer, monsoon and winter.

The tunnel length of roosts differed among seasons (Figure 1.6) and the highest tunnel length was observed in monuments (20.20 ± 6.60cm) followed by abandoned buildings (17.23 ± 8.699cm) and tree holes (13.818 ± 6.28cm). Pearson correlation showed positive correlations between tunnel length and corresponding colony size across roost types and seasons (Table 1.1).

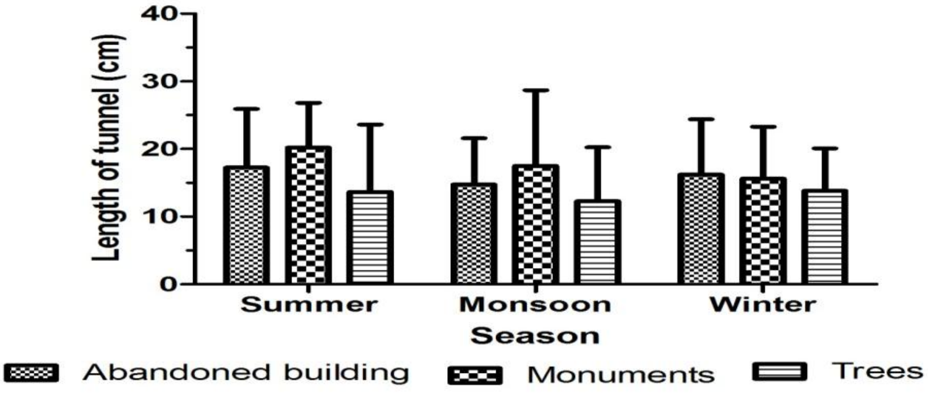

**Figure 1.6.** The length of tunnel selected by *S. kuhlii* at abandoned buildings, Monuments and Tree during summer, monsoon and winter.

*Scotophilus kuhlii* selected different quantum of roost surface areas at different seasons and roost types (Figure 1.7). The highest roost surface area was observed in monuments (3.03 ± 0.98m$^2$), followed by abandoned buildings (2.65 ± 1.82m$^2$) and tree holes (2.04 ± 2.45m$^2$). The bats were chosen highest roost area in monuments and trees during summer and least roost area during winter (Table 1.1). The roost area of monuments, abandoned building and tree holes among seasons showed significant difference ($P < 0.001$). Regression analysis on roost area and corresponding colony size showed positive correlations across roost types and seasons (Table 1.1).

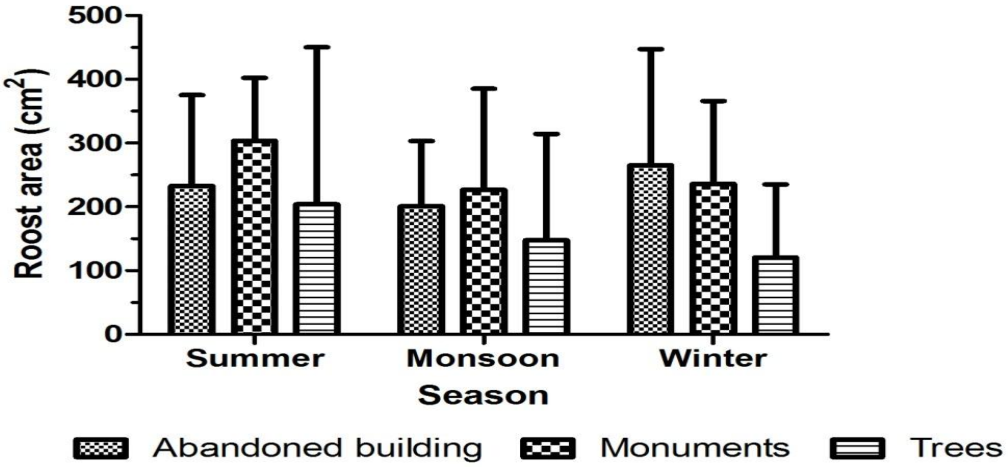

**Figure 1.7.** The area occupied by *S. kuhlii* at abandoned buildings, Monuments and Tree during summer, monsoon and winter.

*Scotophilus kuhlii* chosen various shapes of tunnels or holes as roosts, like ‘branched tunnel’ or ‘T’ shaped, Greek capital letter ‘Γ’ or mirror image of ‘Γ’ i.e. ‘┐ ’ shaped, unbranched tunnel and crevice or cleft. Out of 192 roosts observed, the most preferred roost type was ‘T’ shaped roosts (50.52%) followed by ‘┐ / ┌’ shaped (36.45%), unbranched tunnel (7.29%) and crevice or cleft (5.72%). However, there was no significant effect of roost shapes on different seasons and thus the colony size of *S. kuhlii* ($P > 0.05$; Table 1.2), except in crevice roosts ($H = 6.70$, $P < 0.05$) which shown high preference during summer.

**Table 1.1.** Roost characteristics of *Scotophilus kuhlii* at monuments, abandoned buildings and tree holes during summer, monsoon and winter seasons. The effect of roost characteristics of different roost types on colony size of *S. kuhlii* at different seasons are given in parentheses (regression values). The values of roost characteristics are given as mean ± SD.

| **Roost characteristic** | **Monument** | | | **Abandoned Building** | | | **Tree** | | |
|---|---|---|---|---|---|---|---|---|---|
| | **Summer** | **Monsoon** | **Winter** | **Summer** | **Monsoon** | **Winter** | **Summer** | **Monsoon** | **Winter** |
| **Roost height above the ground (m)** | 3.83 ±1.03 (-0.445) | 4.06 ±1.59 (-0.695) | 3.88 ± 0.87 (-0.911) | 4.36 ± 1.42 (-0.574) | 3.54 ± 1.23 (-0.652) | 3.96 ± 1.33 (-0.555) | 3.92 ± 0.41 (-0.675) | 4.68 ± 1.32 (-0.678) | 3.87 ± 1.40 (-0.555) |
| **Tunnel length (cm)** | 20.2 ± 6.60 (0.84) | 17.47 ± 11.20 (0.857) | 15.62 ± 7.66 (0.969) | 17.23 ± 8.69 (0.801) | 14.75 ± 6.82 (0.894) | 16.21 ± 8.16 (0.877) | 13.65 ± 9.97 (0.797) | 12.27 ± 9.97 (0.952) | 13.81 ± 6.28 (0.87) |
| **Roost temp ($^{o}$C)** | 34.0 ± 5.96 (0.11) | 31.44 ± 3.09 (0.415) | 27.63 ± 3.99 (0.588) | 31.02 ± 4.96 (-0.103) | 30.01 ± 3.25 (0.381) | 16.79 ± 5.30 (0.035) | 38.52 ± 2.09 (-0.06) | 31.15 ± 2.76 (0.125) | 17.68 ± 5.99 (0.28) |
| **Humidity (%)** | 79.5 ± 1.76 (0.067) | 84.03 ± 14.06 (-0.19) | 78.41 ± 7.42 (-0.129) | 80.72 ± 6.91 (0.089) | 78.80 ± 16.8 (0.101) | 72.65 ± 12.13 (0.437) | 90.31 ± 1.18 (0.201) | 70.33 ± 19.57 (0.078) | 64.21 ± 11.70 (0.157) |
| **Roost area ($m^2$)** | 3.03 ± 0.98 (0.848) | 2.26 ± 1.58 (0.836) | 2.36 ± 1.30 (0.961) | 2.32 ± 1.42 (0.754) | 2.01 ± 1.02 (0.721) | 2.65 ± 1.82 (0.755) | 2.04 ± 2.45 (0.743) | 1.47 ± 1.66 (0.834) | 1.20 ± 1.14 (0.90) |
| **DBH (cm)** | - | - | - | - | - | - | 31.90 ± 4.88 (0.457) | 35.07 ± 8.01 (0.624) | 31.75 ± 7.83 (0.569) |

The position of roost occupancy by bats varied over seasons, they occupied the interior region of tunnels during summer (5.33 ± 3.78cm) while they preferred to roost at the periphery of roosts during monsoon (3.00 ± 2.03cm). The bats preferred to roost amid of tunnel roosts during winter (3.93 ± 2.08cm). Roost temperature was fluctuated over the seasons (Figure 1.8), however, the temperature fluctuation was reasonably less in monuments (28.05 ± 7.68ºC) compared to abandoned buildings (21.96 ± 8.28ºC) and tree holes (23.76 ± 10.65ºC). Highest roost temperature was observed in tree holes (38.52 ± 2.09ºC) followed by monuments (34.00 ± 5.96ºC) and abandoned building (31.02 ± 4.96ºC). However, the roost temperature showed significant impact during monsoon and winter seasons in monuments, during monsoon in abandoned buildings and winter in tree holes (Table 1.1).

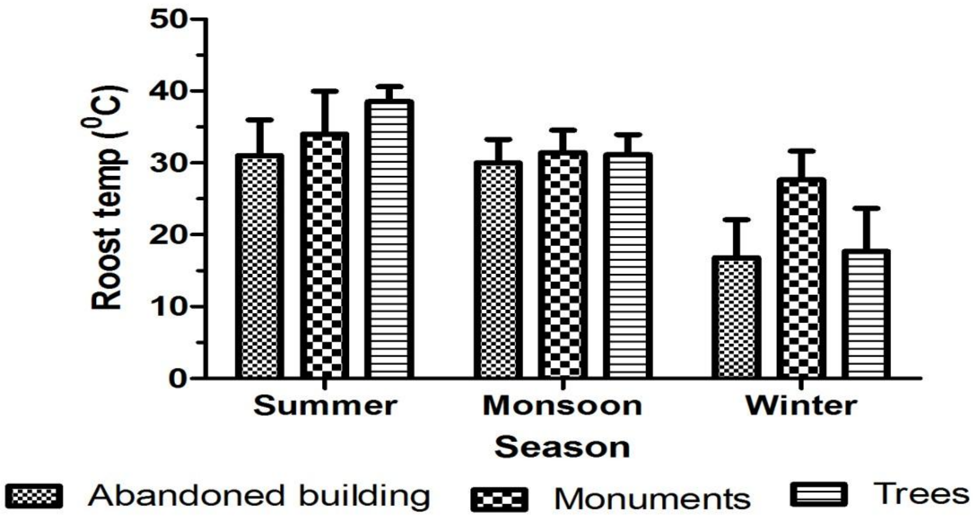

**Figure 1.8.** The roost temperature preferred by *S. kuhlii* in different habitats and in three distinct seasons.

The relative humidity was ranged from (90.31% to 64.21%) (Figure 1.9). A maximum humidity was recorded in tree holes (90.31 ± 1.18 %) followed by monuments (84.03 ± 14.06%) and abandoned buildings (80.72 ± 6.91%). There was no effect of humidity on colony size of *S. kuhlii*, except during winter in abandoned building (Table 1.1).

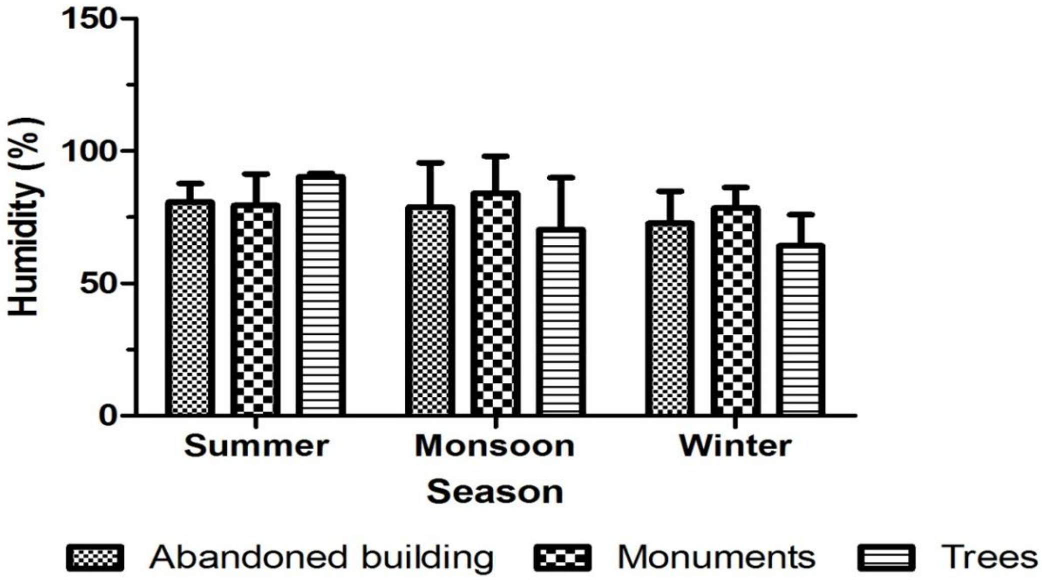

**Figure 1.9.** The roost humidity preferred by *S. kuhlii* in different habitats and in distinct season.

Roost height above the ground and length of tunnel were higher in occupied roosts compared to unoccupied tunnels available at abandoned buildings and monuments (Table 1.3). The height of occupied roost entrance was shorter in both abandoned buildings and monuments than the unoccupied tunnels. The roost height above ground, length of tunnel and height of tunnel entrance showed a significant difference ($P < 0.001$, Table 1.1). The widths of occupied roost entrance abandoned building and monuments were similar to unoccupied tunnels and did not show significant difference ($P > 0.05$, Table 1.3). The height of roost and non-roost trees was almost same and there was no significant difference among them (Table 1, $P > 0.05$) but dbh of occupied roost trees was higher than non-roost trees (Table 1.3) and differed significantly ($P < 0.001$).

**Table 1.2.** Selection of different roost shapes at different seasons and their effects on colony size of *Scotophilus kuhlii*. Values are given as mean ± SD.

| **Season/ Shape of roost** | **T-shaped** | **'┐ / ┌'- shaped** | **Tunnel** | **Crevice** |
|---|---|---|---|---|
| | **Mean±SD (cm)** | | | |
| Summer | 4.64 ± 20 | 3.57 ± 2.17 | 2.64 ± 1.78 | 4.71 ± 1.79 |
| Monsoon | 4.70 ± 2.39 | 3.07 ± 2.03 | 2.50 ± 1.77 | 1.00 ±0. 00 |
| Winter | 4.21 ± 2.02 | 3.78 ± 2.27 | 3.00 ± 1.00 | 2.00 ± 0.00 |
| $\chi^2$ | 2.508 | 3.91 | 0.540 | 6.70 |
| P | 0.285 | 0.141 | 0.763 | 0.034 |

There was found a maternity roost in rural which near the water and vegetative ground in a human-occupied building. The *S. kuhlii* used same-day roost as maternity roost in the building but not could be confirmed in trees. Whose roosting features such as roost height above the ground (2.43m), length of the tunnel (44cm) with single entrance whose entrance of roost (8cm) and width of the entrance (6cm). The direction of roost entrance was in the south with "T" or branched shaped. The roost surface area was (765cm). In building the maternity roost more than five individuals with one or two males make a tartery. It was observed that few individual bats immigrate and emigrate in maternity roost during the reproductive period. The average ambient temperature (32.68 ± 6.89°C) was significantly higher compared to the roosts temperature (31.36 ± 7.14°C). The linear regression showed a significantly positive correlation ($r^2$ = 994) between ambient and maternity roost temperature. Whereas maternity colony sizes were (5.33 ± 1.37) while average maternity roost temperature (33.36 ± 7.14°C) and relative humidity (60.85 ± 23.02%). Whereas linear regression showed a positive correlation between maternity colony size and humidity ($r^2 = 0.630$) (Fig1.11). While maternity roost temperature with linear regression has been not shown the correlation between colony size and ambient temperature ($P > 0.05$).While the colony size was frequently varied eache obsevartion month (Figure 1.10).

**Table 1.3.** Roost characteristics of occupied roosts and unoccupied tunnels in abandoned buildings, monuments and tree holes. Values are given as mean ± SD.

| | **Site** | **Height of roost / tunnel (m)** | **Length of tunnel (cm)** | **Height of roost / tunnel entrance (cm)** | **Width of roost / tunnel entrance (cm)** | **Height of tree** | **DBH** |
|---|---|---|---|---|---|---|---|
| Abandoned buildings | Occupied roost (n=93) | 3.96 ± 1.34 | 16.14 ± 7.99 | 6.54 ± 2.45 | 9.56 ± 4.42 | - | - |
| | Unoccupied roost (n=93) | 2.75 ± 1.11 | 5.90 ± 1.56 | 8.26 ± 3.10 | 9.65 ± 4.07 | - | - |
| | *H | 40.57 | 77.54 | 15.47 | 0.24 | - | - |
| | P | 0.001 | 0.001 | 0.001 | 0.62 | - | - |
| Monuments | Occupied roost (n=76) | 4.03 ±1.41 | 17.10 ± 9.47 | 7.32 ± 2.73 | 9.32 ± 3.70 | - | - |
| | Unoccupied roost(n=76) | 2.67 ± 1.05 | 5.80 ± 1.54 | 8.54 ± 2.74 | 9.05 ± 3.58 | - | - |
| | *H | 77.37 | 152.46 | 12.34 | 0.50 | - | - |
| | P | 0.001 | 0.001 | 0.001 | 0.47 | - | - |
| Tree holes | Roosting tree (n=34) | - | - | - | - | 15.02 ± 1.89 | 33.55 ± 7.62 |
| | Non roosting tree (n=34) | - | - | - | - | 14.63 ± 3.13 | 21.96 ± 0.68 |
| | *H | - | - | - | - | 1.15 | 14.72 |
| | P | - | - | - | - | 0.28 | 0.001 |

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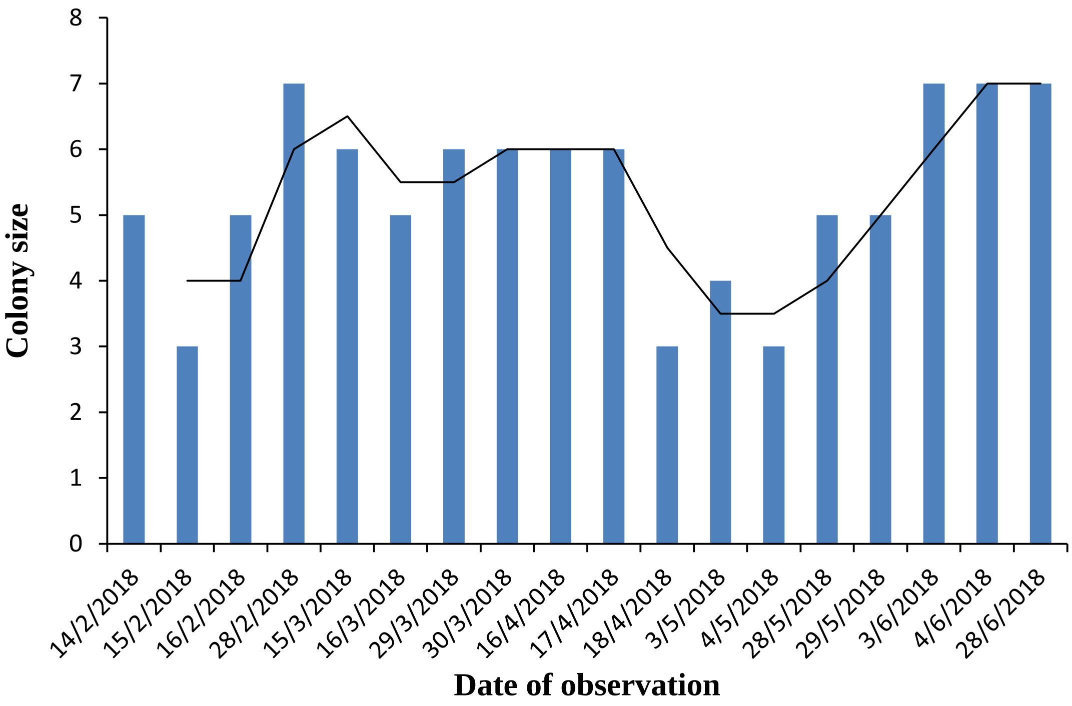

**Figure 1.10.** The colony size in maternity roost and line is showing average of bat, with date of observation during breeding season in Siddharth Nagar.

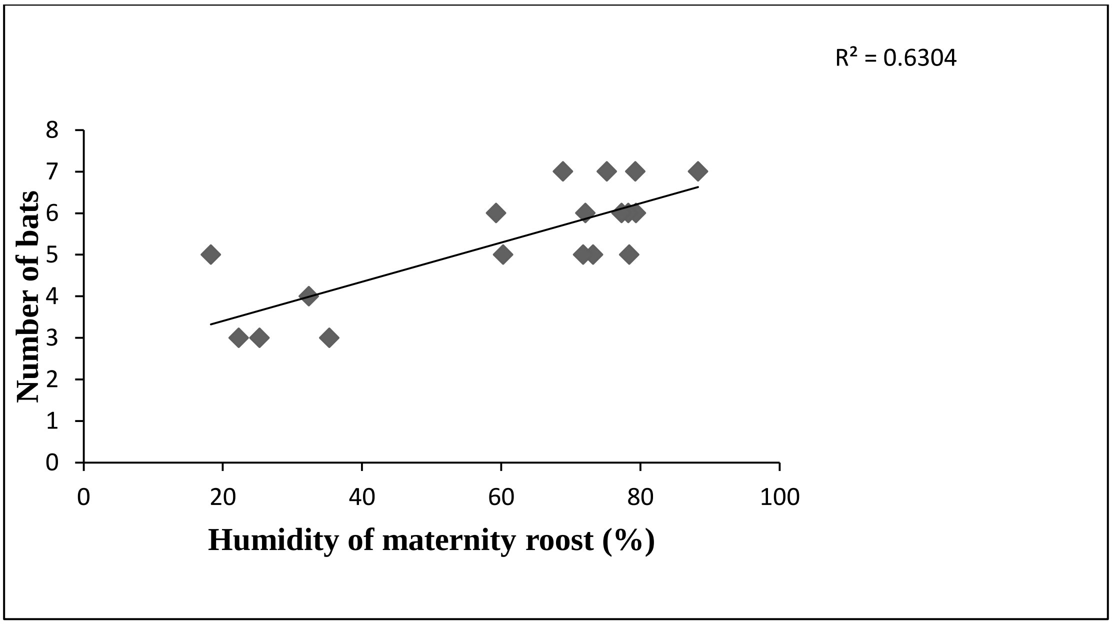

**Figure 1.11.** The relative humidity and colony size of maternity roost in Siddharth Nagar.

## DISCUSSION

The distribution of *Scotophilus kuhlii* in urban, semi-urban and rural areas in Uttar Pradesh, India shows its wide distribution in the region. Though *S. kuhlii* was commonly distributed, the observed colony size ranged from one to nine individuals across the seasons and roost types while an earlier study reported that the colony size could be from a few individuals to several hundred (Smith and Xie, 2008). The roosts of *S. kuhlii* were observed generally in abandoned buildings (46.73%), monuments (40.70%) and tree holes (12.56%) in the present study showed that the abandoned buildings and monuments could be the life-support to *S. kuhlii*. Though, abandoned buildings offered more roosts but the roost occupancy of monuments was higher (4.36 ± 2.19) which showed the highest suitability of monuments than rest of the roost types.

The results of present study showed the influence of roost characteristics on roost selection of *S. kuhlii*. Selection of high quality roosts influences on survival and fitness of bats while a poor quality roost invites predation. The present study shows that the degree of protection supported the claim that the high protection habitat could yield a maximum colony size, accordingly the monuments showed a high degree of protection and thus a maximum colony size was observed followed by abandoned buildings and tree holes. Monuments provide a stable climate and higher protection from predation throughout the year even in adverse conditions. This could be the reason why *S. kuhlii* preferred monuments for roosting over abandoned building and tree holes. In the present study, trees provided least level of protection and possibly stable climatic conditions compared to monuments and abandoned building. In unfavorable conditions such as heavy rain or low ambient temperatures roosts in monument provide warm and dry conditions suitable for the survival of *S. kuhlii*.

During the critical life stages such as reproduction building roosts may manifest energetic benefits to *S. kuhlii*. Many species of bats such as *Megaderma lyra* (Subbaraj and Balasingh, 1986), *Nycteris grandis* (Fenton *et al.,* 1990), *Nyctalusleisleri* (Shiel and Fairly, 1999) and *Antrozous pallidus* (Lewis, 1994) use building as a shelter for roosting. Kurta (1992) reported that building-roosting bats gave birth earlier than their conspecifics roosting in foliage or trees that are advantage of building-dwelling roost over tress dwelling roost. However, an earlier report on roosting ecology of *S. kuhlii* suggests that they modify the fronds of a fan palm, *Livistona rotundifolia* as tent roost and live (Rickart *et al.*, 1989). Many species of bats like greater sac-winged bat, *Saccopteryx bilineata* (Bradbury and Emmons, 1974; Bradbury and Vehrencamp, 1976), greater mouse-eared bat, *Myotis myotis* (Dietz *et al*., 2009), spear-nosed bat, *Phyllostomus hastatus* (Santos *et al*., 2003), and free-tailed bats such as *Tadarida brasiliensis* and *Mops condylurus* (Vivier and Vander Merwe, 2001) used building roosts. Trees provide very least stable temperature, humidity and protection from the predators; therefore the selection of tree roosts was less compared to monuments and abandoned buildings. Although, the roost height increases the protection, the results obtained in this study showed a decrease in colony size with increasing roost height in all three types of roosts which show an optimal height preference by *S. kuhlii*. *Scotophilus kuhlii* is a low flier which could be a possible reason for the preference of roosts at low to medium height. It has been suggested that high roosts also offer bats greater protection from predators (Rydell *et al*., 1996; Vonhof and Barclay, 1996).

The tunnel lengths of all roost types and across the seasons were positively correlated with colony size which show a significant role in roost selection. The length of tunnels varied among roost types and associated with protection. Further, larger size of tunnel length provides more space to *S. kuhlii* for roosting. The surface area of roosts varied among roost types and determined the fitness, i.e. roost occupancy. The roost surface area was positively correlated with the colony size. Veilleux and Veilleux (2004) reported that the roost area may be an important factor in maintaining healthy colony that helps in thermal maintenance during hibernation by social clustering. Social organization directly depends upon space inside roost used by bats, which limits the number and their ability to cluster together (Kunz, 1982). Willis *et al.* (2006) reported that female big brown bats (*Eptesicus fuscus*) preferring roost with larger cavities and cavity volume was positively correlated with roosting-group size. The shapes of roosts played a key role in roost selection of *S. kuhlii* as the shape of roosts associated with the protection level. Out of total roosts observed, the most preferred was ‘T’ shaped roost followed by ‘┐/┌’ shaped, unbranched tunnel and crevice. The area of ‘T’ shaped roost was always higher than ‘┐/┌’ shaped, unbranched tunnels and crevice, and thus the preference of ‘T’ shaped roost was higher than other types of roost. The shape and size of roost directly affects the microclimate of roost (Entwistle *et al.*, 1997; Vonhof and Barclay, 1997; Williams and Brittingham, 1997), which is directly related to survival of bats and developments of their offspring (Racey and Swift, 1981; McNab, 1982). There was no significant difference in the shapes of roost among three different seasons which shows the highest preference to ‘T’ shaped roosts.

Average humidity of roosts was 77% across the roost types, however there was no significant difference among the seasons. Stable microclimates such as humidity and temperature would be helpful for lowering the metabolic rate and energy expenditure of bats (Usman, 1988). For the successful reproduction, water as well as energy is important factor (Kurta *et al.*, 1990) and in small bats water balance is very sensitive to temperature and humidity (Herreid and Nielson, 1966). So many authors reported that bat roosts such as maternity roost, hibernacula roost with high humidity (Twente, 1955; Herreid, 1963; Clawson *et al*., 1979; Van Der Merwe., 1987; Churchill., 1991; Baudinette *et al*., 1994; Clark *et al*., 1996; Betts, 1997). High humidity reduces evaporative heat loss (Bakken and Kunz, 1988; Webb, 1995) and prevents dehydration (Vander Merwe, 1973). Webb *et al.* (1995) also reported that the high ambient temperatures and RHs would tend to slow down the evaporative water loss of active bats. Warm and stable temperature of maternity roosts allows breeding females to reduce their energy expenditure that remains them active and homeothermic for longer period. This, in turn results in an increased rate of gestation, postnatal growth and long survival rate (Racey, 1982; Kunz, 1987; Zahn, 1999). Our data also indicates that *S. kuhlii* selecting roosts with almost high and stable humidity and temperature without much change within the seasons. Harbusch and Racey (2006) reported that buildings offered suitable temperatures during gestation and lactation periods that are critical for the survival of their offspring. The results of present study support the earlier observation that *S. kuhlii* tolerated to high temperature (Shek and Chan, 2006).

The distinct characteristics between occupied roosts and unoccupied tunnels available adjacent to the occupied roost showed that *S. kuhlii* selects its roost wisely as the roosts influence the survival and fitness. This study revealed that the factors such as tunnel length and shape, roost surface area, roost height and associated protection influence the roost selection of *S. kuhlii*. The outcome of this study could be useful to understand the life history and future conservation of *S. kuhlii*.

The roost height above the ground, tunnel length and height of roost entrance differed significantly between occupied roost and available unoccupied tunnels.

However, the tunnel width did not differ significantly between occupied roost and unoccupied tunnel. It shows that the roost selection in *S. kuhlii* is influenced by various factors. Barclay *et al.* (1988) reported that roost of small to medium sized entrances may provide better insulation and protect the interior from extremes of weather. Although, a number of studies shown that several bat species (Tidemann and Flavel, 1987) and other cavity dwellers (McComb and Noble, 1981) uses cavities with entrance holes not much larger than themselves, thus excluding larger predators and competitors. In this study, the selection of roost by *S. kuhlii* was not random among available cavities. There were differences in roost height above the ground, length of tunnel, width of entrance, height of roost trees and dbh of occupied roost and unoccupied roost. The degree of protection plays a critical role in roost selection. The results showed that the degree of protection was driven principally by tunnel lengths, shape of roosts and optimum roost height at different roost habitats. Degree of protection was highest in monuments followed by abandoned buildings and tree holes. A maximum number of individuals of *S. kuhlii* found roosting in monuments followed by abandoned building and tree.

*S. kuhlii* used same-day roost as a maternity roost. Nuratiqah *et al.* (2017) reported that the maternity roost provides a higher temperature and more stable thermal conditions as compared to the ambient temperature. While cold roost temperatures reduce the development of prenatal and juvenile bats (Racey and Swift, 1981; Tuttle and Stevenson 1982; Wilde *et al.*, 1999). The present study showed that maternity roost temperature was higher than ambient temperature. Higher the maternity roost temperature may influence fetal growth and birth size. Buildings are mostly occupied by reproductively active female bats during the reproductive season to raise their pups because of the energetic benefits and less predation risk (Voight *et* *al.,* 2016). Roost surface area, the thickness of walls and amount of solar radiation will affect heat transfer by convection, radiation, conduction, and evaporation, and thus influence the microclimate and energy savings of bats roosting on these surfaces (Bakken and Kunz, 1988). The present study shows that relative humidity was significantly higher than relative ambient humidity. Willis And Brigham, 2005 reported that southeast orientation of the roost, reduced canopy closure, and reduced forest density in a southeast direction which could all increase sun exposure provide radiant heating mostly during the winter morning hours. The present study showed that orientation of maternity roost in the south direction which may reduce solar radiation and warm wind speed. Solar radiation does not directly expose to the roost tunnel, hence may increase the relative humidity to provide fast growth development of a fetus.

## CONCLUSION

A total of 199 colonies of *S. kuhlii* were observed and the colony size ranged from one to nine individuals. A maximum number of roosts was found in abandoned buildings (46.73%) followed by monuments (40.70%) and tree holes (12.56%) with mean colony size of (4.08 ± 2.03), (4.36 ± 2.19) and (2.64 ± 2.21) respectively. Increase in the roost height above the ground caused decrease in colony size across the roost types and seasons. Increase in the length of roost cavities and roost surface area shown an increase in colony size. The selection of roost surface area varied over seasons and roost types. *Scotophilus kuhlii* preferred ‘T’ shaped roosts followed by ‘┐’/‘┌’ shaped roosts, unbranched tunnels and crevices. The shape, length and surface area of roost cavities significantly influenced the protection level of roost and colony size. Roost heights and tunnel lengths of occupied roosts were higher than unoccupied cavities. The roost selection of *S. kuhlii* was influenced by roost height, length of roost cavity, roost surface area, shape of roost, tree dbh and level of protection.

**Plate 1.1.** Individuals of *S. kuhlii* roost in a crevice of abandoned building at Jaipur, Siddhrth Nagar.

**Plate 1.2.** A maternity roost of *S. kuhlii* or sub adult attached with mother located at village Jaipur, Siddhartha Nagar.

**Plate 1.3.** A monument roost in a dilapidated state located at Lanka city, Ghazipur.

**Plate 1.4.** Atypical roost trees of *S. kuhlii* located at Shravasti, Balrampur.

**Plate 1.5.** *S. kuhlii* in cavity roost of Pakar tree (*Ficus virens*) at Newghat, Ayodhya.

**Plate 1.6.** *S. kuhlii* occupied roost in non-plaster building at village Ashoha, Unnao.

**Plate 1.7.** *S. kuhlii* occupied roost in Crivieces in Monuments at residency, Lucknow.

**Plate 1.8.** *S. kuhlii* selected L shape roost in monument at residency, Lucknow.

**Plate 1.9.** *S. kuhlii* occupied in crivieces in wooden door at Mehmoodabad, Sitapur.

**Plate 1.10.** *S. kuhlii* occupied roost in dry frond of plam leaves at residensy, Lucknow**.**

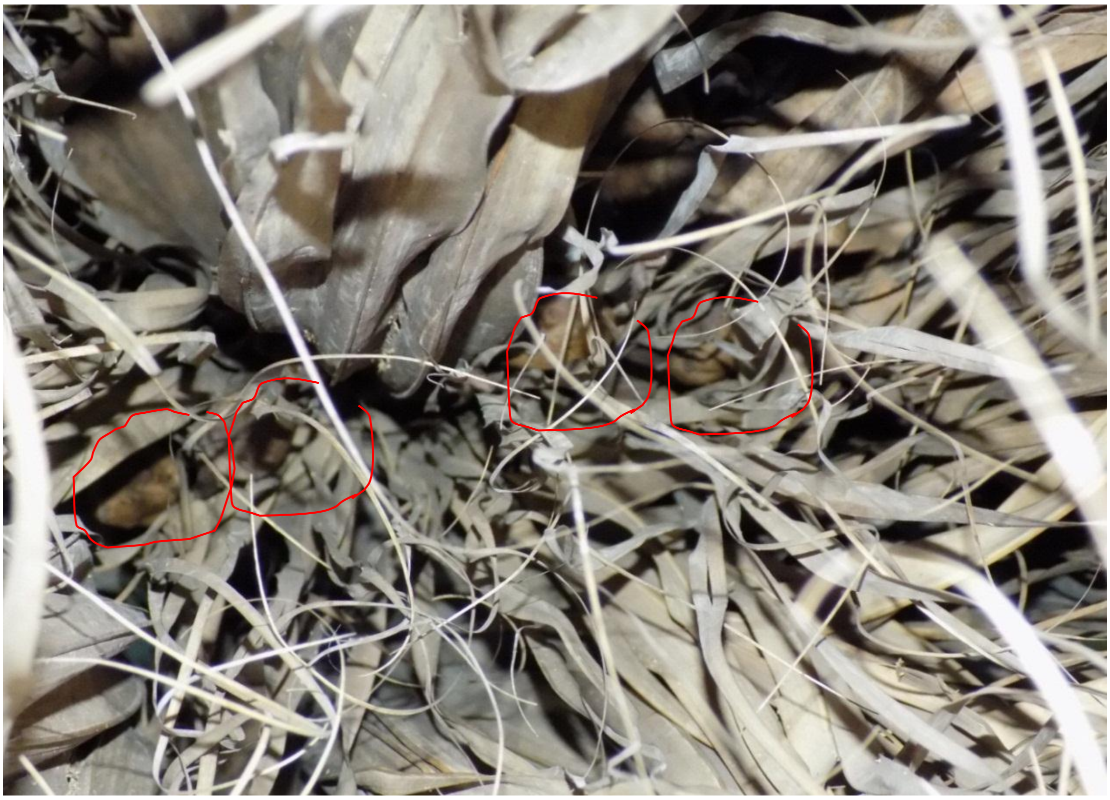

**Plate 1.11.** *S. kuhlii* occupiedroost in dry frond of plam leaves at residensy, Lucknow.

# Chapter-II

# Effect of urbanization on roost selection of Asiatic Lesser Yellow bat, *Scotophilus kuhlii* (Leach, 1821)

# Chapter II Effect of urbanization on roost selection of Asiatic Lesser Yellow bat, Scotophilus kuhlii (Leach, 1821)

## INTRODUCTION

The roost structure is one of the most important features of a bat's environment and the selections made by bats with respect to the type and location of roost sites are likely to have a decisive impact on their survival and fitness (Vonhof and Barclay, 1997), such as social interactions, protection from predators and suitable thermoregulatory conditions (Fenton *et al.*, 1983) can be influenced directly by the quality of a roost habitats (Li and Martin, 1991; Zahn, 1999). Earlier reports high quality roost cavities are generally higher from the ground, allowing for easy detection of and escape from, predators (Sedgeley, 2001). Some colonies of bats occupied the same roosts throughout the years, while other bats frequently change their roosts. Sometimes changes occur because roosts change structure (Findley and Wilson, 1974).

Bats spend over half their lives in several kinds of roost structure in different environment (Kunz, 1982) such as caves, rock crevices, tree cavities, foliage and man-made structures (Kunz and Fenton, 2003). Urbanization is anthropogenic pressure that gradually change vegetative landscapes into settlements (Grimm *et al.,* 2008) such kind of changes supports few species but could have harmful impact on some other species (McKinney, 2002; Shochat *et al.,* 2006). Moderated level of urbanization, including suburban areas, may excess on amount of foods available at roosting sites (Blair and Launer, 1997) supporting heterogeneity biodiversity (Mooney, 2011). As compared to urban, the suburban and rural areas may have higher biodiversity (Merotto and Francis, 2017). That provide favorable roosting sits and spaces such as building, bridges, tunnel etc.(Bennett *et al.,* 2013) for some invasive species (McKinney, 2002) to more able to adjust to urban environments (Marzluff, 2001). Many studies reports lower biodiversity in urban environments; insects (Blair and Launer, 1997), amphibians (Scheffers and Paszkowski, 2012), birds (Marzluff, 2001) and few mammals (Villasenor *et al.*, 2014). Urban areas also play negative effects such as additional stress (Isaksson, 2010), increasing infections and parasitisms rates (Giraudeau *et al.,* 2014). Low availability and diversity of urban plant roosts, which could contribute to their reduced abundance and hence lower bat diversity, in urban environments (Moretto and Francis, 2017). Many factors such as; water resource, lighting, food availability, house density, vegetation and abstraction in urban, suburban and in rural, may influence changes on bats in choosing roost sites (Altringham, 1996). High density of dwellings supports low bat species richness while low-density settlements may support high bat richness (Threlfall *et al.,* 2011). Bats may avoid sound pollution environments, presumably because the noise affects their ability to effectively forage, communicate and spatially orient themselves (Mackey and Barclay, 1989; Schaub *et al.,* 2008; Arnett *et al.,* 2013).

Microclimate is an important factor in only of buildings roost (Racey and Swift, 1981; Hamilton and Barclay, 1994). Many authors reported that water resource and lightings are vital for bats (Furlonger *et al.,* 1987; Gehrt and Chelsvig, 2003; Kurta and Teramino, 1992). Availability of water and roost temperature increases the reproductive success of female insectivorous bats (Adam and Hayes, 2008) which directly impact on their population. Higher light intensity may reduce the foraging success of bats and most of them could get distracted while traveling (Downs *et al.*, 2003; Stone *et al.,* 2012). For urban sites, it is known that insectivorous bats mostly forage near the high density of insects found near the bright lamps (Furlonger *et al.,* 1987). In rural areas lighting also play important role on some bats by attracting insect as food resources (Fenton *et al.,* 1983; Rydell, 1992; Van Langevelde *et al.*, 2011). *Lasiurus cinereus*, *L. borealis* roost among the foliage of trees, whereas *Lasionycteris noctivagans* roosts in cavities of tree's bark (Kunz and Lumsden, 2003). Deforestation for urban development, may damage roosting sites, but it could be advantageous for roosting in urban habitats (Duchamp and Swihart, 2008; Dixon, 2012).

Anthropogenic fragmentation may leads to loss of foraging as well as roosting sites as a result of declining bat populations (Mickleburgh *et al.,* 2002). Several disturbances near urban habitats may reduce the bats abundance and diversity (Russell *et al.,* 2009; Kitzes and Merenlender, 2014). Earlier studies reported that *Scotophilus dinganii* and *Scotophilus mhenhanii* occupied two different roosts, where *S. dinganii* is often present in building while *S. mhlanganii* is at trees (Jacobs and Robert, 2009). For other part, *S. viridis* and *S. dinganii* selected their similar roosts types of tree species and size (Monadjem *et al.,* 2010). *S. leucogaster* select tree roost based on the larger trunk (Fenton *et. al.,* 1998). *Scotophilus kuhlii* is a highly gregarious bat that thrives in anthropogenic fragmented habitats roosting in man-made structures (Nuratiqah *et al.,* 2017). Insectivorous bats are capable of flight and more mobile than other vertebrate groups, so permit some species to move between habitat patches, allowing them to be more tolerant of habitat fragmentation (Law *et al.,* 1999).

The *S. kuhlii* is frequently found in both rural and urban areas in association with humans (Elangovan and Kumar, 2018). They spend over half of their lives in several kinds of roosting structure in different environments (Kunz, 1982). These roosts are structures such as caves, rock crevices, tree cavities, foliage and man-made structures (Kunz and Fenton, 2003). Previous studied reports the *S. kuhlii* is a highly gregarious bat that thrives in anthropogenically altered habitats readily roosting in man-made structures (Nuratiqah *et al.*, 2017). The lack of roosting information of *S. kihlii* in Uttar Pradesh (U.P.). The U.P. located in the northern part of India, is the most populated state with 199,812,341 human populations (Tiwari, 2015), where about 72.2% of the total population of the state lives in rural areas. Geographical areas of the state are 240,928km$^2$ which constitutes 7.3% of the total areas of the country. The U.P. is humid subtropical with dry winter type with parts of Western U.P. as semi-arid type, temperature ranging from 0°C in winter to 50ºC in summer annual rainfall to vary from 1000mm to 1200mm. however the uniformity of the vast Indo-Gangetic forming bulk of the state gives a predominantly single climatic pattern to the state with minor regional variations (Mathur, 2011). Villasenor *et al.* (2014) reported that the species richness declined with higher level of urbanization while Blewett *et al.* (2005) reported that in moderate level of urbanization the species richness increases. Thus, we predicted that *S. kuhlii* is known as house bat therefore it should select roost near more house density. Therefore, the aim of this study was to understand the influence of house densities, roost height, insect's abundance, light source, obstruction, abandoned building, distance of adjacent water and vegetation resources, age of building and to correlates the story of building on the roost selection of *S. kuhlii* in urban, suburban and rural conditions.

## MATERIALS AND METHODS

### Study area

The field surveys were carried out at 24 different districts in Uttar Pradesh (26°50'48.16"N, 80°56'46.17"E). Roost search were made by visual observation of bats guano beneath at the roost and by acoustic survey (Peterson D230, bat detector). The whole study was divided in to three habitats based on the level of urbanization

(Mostly house density and agriculture lands) such as urban, suburban and rural. In urban, (> 30 dwellings 0.1km$^2$ and agriculture lands > 5km away from roosting sites); in suburban, (>20 to < 30 dwellings 0.1km$^2$and agriculture land < 5km away from roosting sites) and rural, (< 20 dwellings 0.1km$^2$ and agriculture land 200m away from roosting sites). To estimate the house density, light, abandoned building and type of abstraction, we used line transect method within 250m$^2$ from roosting site.

The water bodies and vegetative areas adjacent to roost sites were measured within 1km by mobile phone GPS tracker. The whole distance in this study was measured by mobile phone GPS tracker. The roost abstractions have been classified into; fire (set on fire of roost by a human), renovation (roost building) and constructions (roost building) based on the observed by local people information. Street light poles were classified: high mast light (Street light pole > 20m height), white-street light (Bright and white light colure or LED) and Yellow Street light (Yellow light colure). The roost building height was measured by a metal scale tape and the clinometer was used wherever possible (Stanley tough case tape). Building age was measured (because bats often prefer old building) by two methods first one construction date on the building and second by local people information. Abandoned buildings were classified in plasters building (both sides in/out) and non-plaster building (both side in/out). The insects were collected surrounding street lights (High Mast Light, White Street Light, and Yellow Street Light) within one km$^2$ by insect hoop net (r =10cm). And also separated them by morphology types based on phenotype characters such as colour antenna, and legs. The colony sizes were observed in urban, suburban and rural through visual at the time of emergence from roost. Temperature and humidity were measured by probe inserting thermo-hygrometer (HTC-103CTH). All line transects were surveyed on foot following Villasenor *et al.* (2014).

**Statistical analysis**

The determined to relationship between independent variable such as roost height, house density, insect abundance, street lamp post, abandoned building, numbers of obstruction, distance to adjacent water and vegetation source, building ages and number of stories with dependent variable colony size of *S. kuhlii* using Multiple Linear Regression (MLR) (SPSS, 21) because data was non-parametric. Krushkal Wallish H test (KW) using to determine to compared between colony size of *S. kuhlii* and habitats. Furthermore, Mann-Whitney U test was using to determine to compare between colony size between plaster and non-plaster abandoned building. All graphs were made using GraphPad Prism software (Ver. 5).

## RESULTS

A total of 82 roosts were observed from three different habitats including urban, suburban and rural sites. Highest numbers of roosts were found in suburban (n = 45) followed by urban (n = 23) and in rural (n = 14). Whereas the percentage of roosts was following, Suburban (54.87%) was significantly selected above all other habitat categories, followed by urban (28.04%) and rural (17.07%). Multiple linear regression (MLR) showed negative effect with colony size on roost height and distance from adjacent water source in urban followed by house density, number of obstruction and distance from adjacent vegetative sources in suburban (Table 2.1). While insects abundance (type of insects) and age of building in urban followed by abandoned buildings (no. of abandoned building) in rural and street light pole in suburban showed positive effect on colony size (Table 2.1). Whereas Kruskal Wallish

H test (KW) showed significantly different among the habitats such as urban, sub-urban and rural at $p < 0.05$ level of significant except roost height (Table 2.1). Whereas insects abundance were significantly higher around the high mast light than white-street light, had significantly more than yellow street light in among the habitat (Figure 2.1), KW test showed significant differences between insect abundance and colony size respectively (Table 2.1) in three different habitats such as urban, suburban and in rural.

**Table 2.1.** The effect of urbanization factors on roost selection and colony size of *S. kuhlii* in different habitats. The values of roost characteristics are given as mean ± SD. MLR and Kruskal Wallis H test significant at the 0.05 level.

| **Variable** | **Urban** | **Suburban** | **Rural** | **H** | **P** |
|---|---|---|---|---|---|
| | **Mean ± SD(r)** | **Mean ± SD(r)** | **Mean ± SD(r)** | | |
| **Roost height(m)** | 3.67 ± 1.09 (-0.745) | 4.15 ± 1.36 (-0.103) | 3.97 ± 1.47 (-0.744) | 3.216 | 0.2 |
| **House density** | 38.15 ± 14.00 (-0.759) | 25.55 ± 2.85 (-0.804) | 18.70 ± 4.70 (-0.016) | 37.576 | 0.001 |
| **No. of insect** | 8.60 ± 4.44 (0.643) | 12.48 ± 4.58 (0.621) | 15.42 ± 6.99 (0.462) | 11.34 | 0.003 |
| **No. of light pole** | 17.74 ± 3.15 (0.563) | 10.17 ± 3.22 (0.848) | 5.5 ± 2.27 (0.761) | 51.194 | 0.001 |
| **No.of abandoned building** | 9.56 ± 4.23 (0.591) | 13 ± 4.16 (0.862) | 12.28 ± 3.70 (0.876) | 8.514 | 0.01 |
| **No.of obstruction** | 14.08 ± 9.17 (-0.473) | 7.97 ± 3.37 (-0.881) | 6.07 ± 3.97 (-0.693) | 8.441 | 0.001 |
| **Distance from adjacent water source (km$^2$)** | 1.48 ± 1.43 (-0.343) | 0.34 ±0.22 (-0.143) | 0.30 ± 0.22 (-0.138) | 19.824 | 0.001 |
| **Distance from vegetation sources (km$^2$)** | 0.26 ± 0.18 (-0.124) | 0.29 ± 0.25 (-0.267) | 0.27 ± 0.20 (-0.000) | 26.719 | 0.001 |
| **Age of building** | 52.96 ± 42.94 (0.231) | 57.62 ± 36.37 (0.018) | 18.70 ± 4.70 (0.157) | 14.881 | 0.001 |
| **Population** | 4.60 ± 2.29 | 5.44 ± 2.07 | 3.71 ± 1.81 | 6.799 | 0.033 |

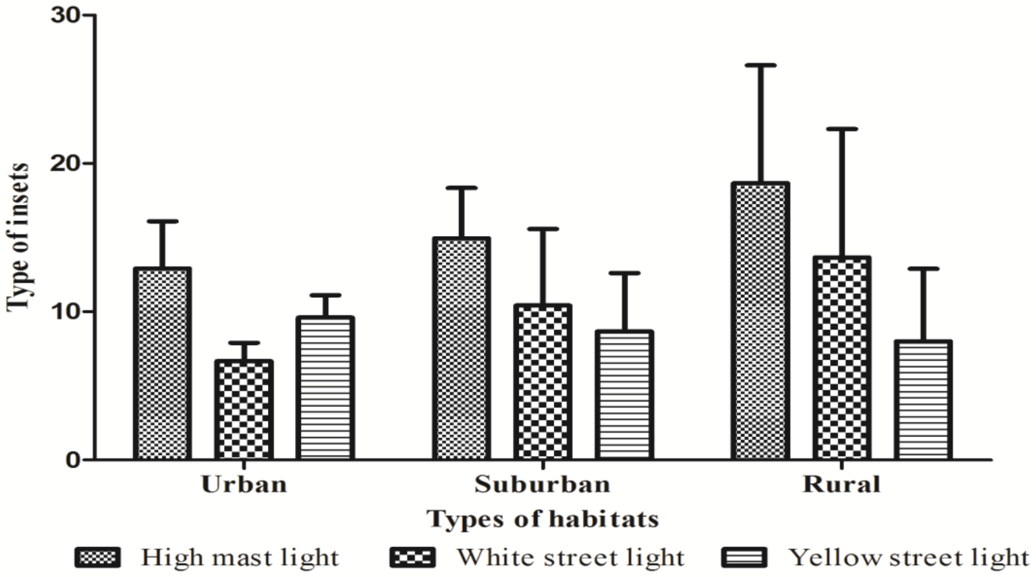

**Figure 2.1.** Insect collected from different streets light pole in urban,suburban and rural.

Obstruction was one of the important factors that play a very important role in roost selection that effect of *S. kuhlii* for roosting. The height of roosts was highest in the fire-sensitive building (Set of fire on roosts by a human) in suburban and rural among three habitats, while roost heights were highest in renovation in urban area whereas KW showed significant different between height and level of obstruction (Fire, renovation and construction) (H = 10.177, P = 0.0006) and colony size was significant (H = 36.55, P = 0.0001) (Figure 2.2). In an abandoned building, it was observed that the population size of *S. kuhlii* was highest in the non-plastered building compared to plastered buildings in all three habitats whereas Mann-Whitney U test showed significant different (U = 163.50, P = 0.0001) (Figure 2.3).

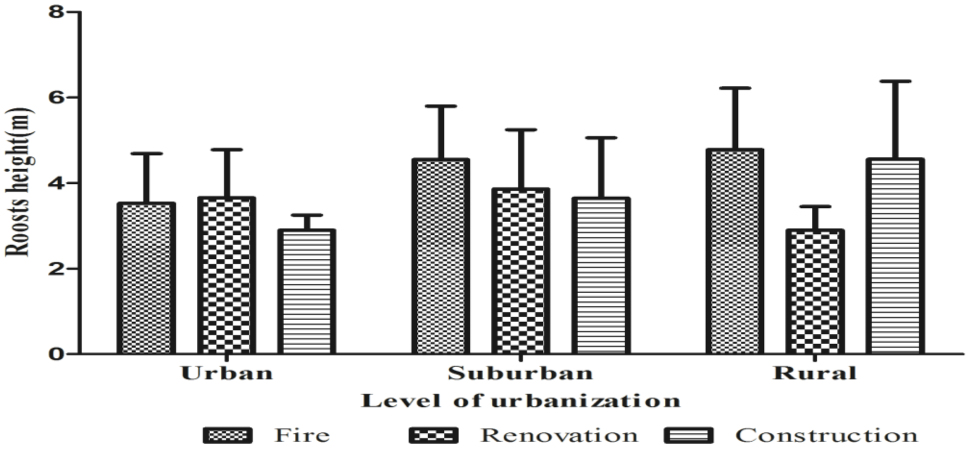

**Figure 2.2.** Roost height preferred by *S. kuhlii* in types of obstruction in three different habitats.

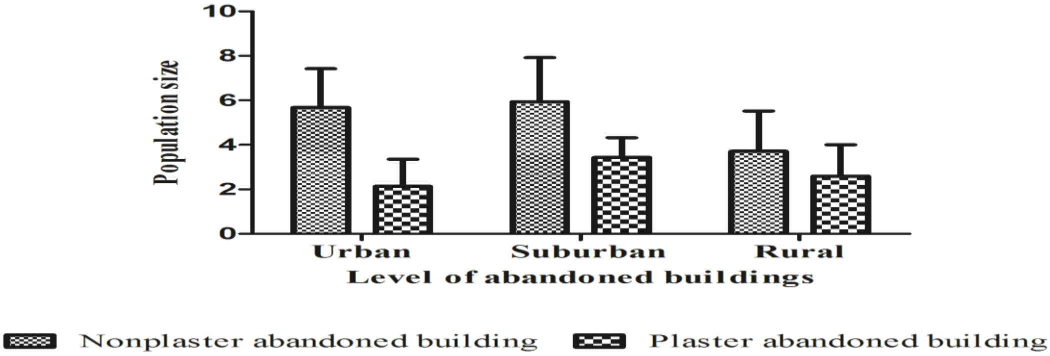

**Figure 2.3.** The population size of *S. kuhlii* in an abandoned building in three habitats.

**Microclimate**

MLR showed positive effect with colony size on ambient temperature in urban, followed by suburban and rural, and roost temperature, and among habitats such as urban, suburban and rural respectively. While MLR showed negative effect on humidity and in suburban and rural habitats except urban. Whereas KW showed significantly different among habitats at $p < 0.05$ level of significant except urban (Table 2.2)

**Table 2.2.** The effect of microclimate on roost selection and colony size of *S. kuhlii* in different habitats. The values of microclimate are given as mean ± SD. MLR and Kruskal Wallis H test significant at the 0.05 level.

| **Variable** | **Urban** | **Suburban** | **Rural** | **H** | **P** |
|---|---|---|---|---|---|
| | **Mean ± SD** | **Mean ± SD** | **Mean ± SD** | | |
| **Ambient temperature ($^o$C)** | 29.14 ± 12.46 (0.302) | 26.15 ± 5.56 (0.047) | 18.95 ± 9.16 (10.076) | 9.91 | 0.007 |
| **Humidity (%)** | 77.20 ± 19.95 (0.123) | 74.06 ± 16.57 (-0.062) | 72.8 ± 18.29 (-0.289) | 2.46 | 0.29 |
| **Roost tem ($^o$C)** | 32.18 ± 10.08 (0.482) | 29.53 ± 4.88 (0.402) | 28.07 ± 8.24 (0.637) | 4.79 | 0.09 |
| **Population** | 4.60 ± 2.29 | 5.02 ± 2.07 | 3.71 ± 1.81 | 3.9 | 0.14 |

## DISCUSSION

Urbanization factors influence the roost selection of *S. kuhlii* in their different habitats, at the time when the serious distraction of natural habitats surrounding us (Garden *et al.,* 2010). *S. kuhlii* selects several types of habitats areas to complete their life cycle. The present study shows that *S. kuhlii* prefers the highest roosts in suburban followed by urban and rural. The significant differences in urbanization factors among habitats. Presence and absences of roosts depend on the feature of the building but its selection for roosting depends on bats. Entwistle *et al.* (1997) reported that roost selection depends on the feature of the buildings, often occupied by female bats during the reproductive season to raise offspring and lower predation risk (Voight *et al.,* 2016). The present study shows that the colony size and number of a roost of *S. kuhlii* were significantly higher in non-plaster abandoned buildings that closed to a human-occupied building than isolated plaster building in among habitats. Non-plaster buildings provided different kinds of space such as a hole, crevices and cavities which important for roost selection compared to plaster building. Roost closed to a human-occupied building which radiuses the nocturnal predator. Roosting in buildings may expose bats to opportunistic predators (Threlfall *et al.,* 2013). Which reach mainly high bulks in urban habitats, including crows, kestrels, seagulls, rats, possums, dogs and especially domestic cats (Ancillotto *et al.,* 2013). Then these factors play a crucial role in the survival of bats in adverse conditions. Bats might accept a compromise between suitable features such as microclimate and roost location, and level of disturbance. However, some bats are known to be sensitive to human disturbance and can switch their roost when frequently disturbed (Tuttle, 1979; Kunz, 1982; Speakman *et al.,* 1991; Lewis, 1995; Thomas, 1995). Previous works reported that the reduction of roosts fidelity depends on roost disturbance (Lewis, 1995). In the previous study found that *Myotis nattereri*, *P. auritus*, *Pipistrellus* species and *Eptesicus serotinus* are never returned to the same building for roosting when once buildings are renovated (Briggs, 2004). In the present study, shows that among the habitats obstruction were one of the main negative factors that affected on roosts selection of *S kuhlii* in three habitats. Whereas increases the obstruction decreasing the colony size and number of the roost. *S. kuhlii* never occupied the same roost when once disturbed by fire. Similar work was found in the previous study on *P. auritus* (Briggs, 2004).

The level of obstruction such as fire was frequently higher in urban habitats, followed by sub-urban and rural because often human set on fire in front of the roost entrance for removing roost. Generally, bat not switch their roost frequently without any disturbance (Findley and Wilson, 1974) They spoil food and make ceilings, walls, and floors dirty with the accumulation of guano and urine and offensive odors to cause a serious public health problem (Greenhall, 1964). Process of renovation was higher in urban habitats, followed by the sub-urban and rural ones, while constructions were higher in suburban in among the habitats. The previous studies found that older buildings are more susceptible to roost loss and more prone to renovation (Entwistle *et al.*, 1997). However, it provides a different kind of space. In the present study, *S. kuhlii* selected old buildings for roosting which important for roost selection because a large number of unwanted spaces. It often occurred in suburban, urban compared to rural. Several studdies reports that bats can occupy a several kind of roosts including natural structures such as caves (*Rhinolophus ferrumequinum* and *R. hipposideros*), rock crevices (*Eptesicus fuscus*) and man-made structures such as churches, houses and farm buildings (*Pipistrellus pipi strellus* and

*Plecotus auritus*) and bridges (*Eptesicus fuscus*) (Kunz, 1982; Altringham, 1996; Kunz and Lumsden, 2003). Therefore, human constructions may simulate the structural and functional properties found in cliffs, caves or trees, all important natural roosts, so bats may have easily learnt to exploit the new artificial roosting habitats (Russoa and Ancillotto, 2014) to maintained the ecosystem balance. Previous studies reports bats have long been postulated to play crucial ecological roles in prey and predator, arthropod suppression, material and nutrient distribution, and recycle (Kunz *et al.,* 2011).

The height of roost negative effect on colony size of *S. kuhlii* in among the habitats while selecting the highest height for roosting relative to the availability of potential level of obstruction and roost cavities. Several previous studies found roost height increases predation rates decrease and productivity increases (Nilsson, 1984; Rendell and Robertson, 1989; Elliott *et al.,* 1996). While few reports have been suggested that high height roosts also offer bats greater protection from predators (Rydell *et al.,* 1995; Vonhof and Barclay, 1996). High levels of urbanization can negatively affect biodiversity (McKinney, 2002). Several authors have been reported that high house density negative effects on species richness and low house density support high species richness compared to natural habitats (Reside and Lumsden, 2012; Threlfall *et al.,* 2012; 2013; Soga *et al.,* 2014). In present study shows that increases the house-density decrease the colony size among the habitats. Dense house density areas cause their lake of a suitable sites such as an unwanted hole, crevices, and cavities which important for roosting. While the intermediate house density area provided suitable space for roosting and least house density area also provides space but less number of the house cause less space. Hence, an intermediate level of house density may play a crucial role in the selection of the roost site. Similar studies found in previous work on *Austronomus australis* species Fiona *et al.* (2016). The previous study reported that increase predation risk in high house density areas such as crows, kestrels, seagulls, rats, possums, dogs and especially domestic cats for preferring in urban environments (Ancillotto *et al.,* 2013; Mikula *et al.,* 2013; Threlfall *et al.,* 2013). The abundance of light in surrounding roost increases the light intensity creates a problem from their flight causes easily hunt by a predator. Insect availability less around high light intensity. Geggie and Fenton (1985) were reported that the abundance of artificial light sources dilutes the concentration of insects near each light source in urban habitats. Increases light intensity increases the predation risk (Avila-Flores and Fenton, 2005; Stone *et al.,* 2009; Threlfall *et al.,* 2013; Hale *et al.*, 2015).

Previous studies reports increases in the light intensity increase the insect's diversity (Threlfall *et al.,* 2013; Hale *et al.,* 2015). The least number of a light pole in habitats site insect abundance more on each light pole compared to the high and intermediate light pole. High mast light focuses long distance cause easily locate at night from a long distance so several insects pull to light while other two white and yellow streets light focus to less distance (Chu *et al.,* 2003). Hence insect abundance is low. A similar study found on *Nyctalus* and *Pipistrellus* was attracted to artificial light because its short-wavelength light attracts more insects as a result increases their foraging efficiency (Voigt *et al.,* 2016). Furlonger *et al.* (1987) and Gaisler *et al.* (1998) were reported that white-light lamps are strongly preferred by some species bats. Rainho (2011) was reported street lamp post may play a crucial role in the roost selection of bats. Geggie and Fenton (1985) were suggested that no strong correlation possible insects abundance around each light pole where artificial lights are higher in urban habitats. In thee present study shows that colony size was significantly higher around the moderate level of light intensity such as in suburban followed by urban and rural. Several species occupied their habitats in a moderate level of urbanization such as suburban i.e. mammals (Racey and Euler, 1982), lizards (Germaine and Wakeling, 2001)**,** avian and butterfly (Blair, 2001), bumblebees (Pawlikowski and Pokorniecka, 1990), ants (Nuhn and Wright, 1979).

Previous work has been reported that water sources may affect on bats population and community. The present study shows that adjacent water source distance was negatively affected by colony size among the habitats i.e. increases the water distance decrease the colony size. Food resources would long distance from roost may bat spent more energy on foraging and would increase the predation risk. Roosting sites near the water resources for maintaining the daily torpor and avoid the predation risk. Our results of suburban support of previous work of Rainho *et al.* (2012) on *Rhinolophus mehelyi* select roosts closer distance from opened foraging and water source than *Myotis schreibersii*. Maternity roost of *N. gouildi* near the watering points and ditches sites (Lunney *et al.,* 1988; Webala *et al.,* 2010). Artificial water sources, such as pits, swimming pools and water reservoirs were essential components for an urban living animal which provided drinking opportunity Russo (2012) and Rainho and palmeirim (2011) were suggested. Bruun (2003) reported that mobile species such as bat and bird cover a long distance to reach their resources destination. While the vegetation distance was also a negative impact on colony size among the habitats i.e. increases the distance while decreasing the colony size. Hence *S. kuhlii* prefers roosts near the vegetation sources to decline energy cost for foraging. Because of prey concentration higher nears the vegetative sources. Optimal foraging theory predicts limit the forager's ability to maximize energy (Pyke, 1984). Willis and Brigham (2004) and Whitaker (1995) suggested that deciduous trees, agriculture fields, and open area provided potential food sources for big brown bats. The maternity roosts of *Nyctophilus gauldi* roosted near the dance bushy area but the way from the semiurban area (Threlfall *et al.,* 2013). The big brown bat was selected as their maternity roost near the trees (Vonhof and Barclay, 1997; Rabe *et al.,* 1998; Cryan *et al.,* 2001). Marques *et al.* (2004) were reported on *T. teniotis* forage five kilometers away from their won day roost. *T. teniotis* most of the foraging areas were within 5 km from the roost (Marques *et al.,* 2004).

Stable microclimates such as humidity and temperature would help lower the metabolic rate and energy expenditure of bats (Usman, 1988). For successful reproduction, water, as well as energy, is an important factor (Kurta *et al*., 1990) and in small bats, water balance is very sensitive to temperature and humidity (Herreid and Schmidt-Nielson, 1966). The *S. kuhlii* selecting roosts with almost high and stable humidity and temperature without much change within the habitats. Harbusch and Racey (2006) reported that buildings offered suitable temperatures during gestation and lactation periods that are critical for the survival of their offspring. The results of the present study support the earlier observation that *S. kuhlii* tolerated to high temperature (Shek and Chan, 2006). Therefore, microclimate such as ambient temperature, humidity, and roost temperature was influencing for selection of roost of *S. kuhlii*in among habitats.

## CONCLUSION

The order Chiroptera is the second most diverse among mammalian orders, which exhibits great physiological and ecological diversity (Hutson *et al.,* 2001). They have evolved into an extremely rich diversity of roosting and feeding habits. Whereas insectivorous bats roost during the day time occupied several types of natural and artificial roost structures (Kunz and Fenton, 2003). They become active during the night and forage on diverse food items like insects, nectar, frogs, fish, small mammals, and even blood (Kunz *et al*., 2011). *Scotophilus kuhlii* is a highly gregarious bat that thrives in anthropogenically altered habitats readily roosting in man-made structures (Nuratiqah *et al.,* 2017). They emit an average dominant frequency of 45 kHz (Zhu *et al*., 2012) and fed several insect orders in a night bats are an essential natural resource that plays a great role in providing many ecological and economic services (Fujita and Tuttle, 1991). Several factors are important for survival in adverse conditions, such as abandoned buildings have a lot of cavities, crevices, and hole, etc., to provide space for resting, mating and protect from predators. Street light, attracts a mass of nocturnal insects preys during foraging. Whereas, water-body and vegetative resources close to roost, save the extra expenditure energy, and avoid a natural predator and long-distance forage. Therefore, bats are provided extremely ecosystem services provided directly to the production of goods and services consumed by humans (Fujita and Tuttle, 1991; Kunz *et al.,* 2011). Urbanization is causing serious damage to natural habitats and heritage as a result unbalancing ecosystem. A variety of factors are limiting bat abundance and diversity in Uttar Pradesh in urban habitats. though, by successfully handling existing habitat patches, correcting community misconceptions about bats, and advancing research about urban bat ecology, then may possible to increase the suitability of urban environments for bat species.

# Chapter-III

# Seasonal food preference and diet composition of Asiatic lesser yellow bat, *Scotophilus kuhlii* (Leach, 1821)

# Chapter III Seasonal food preference and diet composition of Asiatic Lesser Yellow bat, Scotophilus kuhlii (Leach, 1821)

## INTRODUCTION

Foraging behavior has a vital role in evolutionary biology and ecology with major contribution to survival, growth, and reproductive success (Kramer, 2001). Bats are a group of nocturnal animals with many endangered and declining species throughout the world (Voigt *et al.*, 2016). Bats are important components of the ecosystem acting as predators or seed dispersering agent (Kalka and Kalko, 2006; Tang *et al.*, 2008). Insectivorous bats are usually classified according to their foraging strategy as aerial hawkers, foliage gleaners such as *Myotis nattereri. Barbastella barbastellus* (Findley, 1993; Patterson *et al.*, 2003). Several kinds of nocturnal insects, such as moths, mantids, lacewings, Orthopterans and beetles, have evolved tympanic organs that are sensitive to the frequencies of echolocation calls of most bats (Fenton *et al.*, 1998).

One of the important factors in understanding bat ecology and conservation is information about their diet. Insect abundance can change over the year due to many reasons such as macroclimatic and microclimatic changes and variation in the availability of food resources in surrounding habitats (Wolda, 1988) according to seasons (Swift and Racey, 1983; Shiel *et al.*, 1991; Catto *et al.*, 1994). Which ultimately effect on diversity and abundance of food resources (Hails, 1982; Janzen and Pond, 1975; Kingslover, 1989; Tulp and Schekkerman, 2008). Several studies have reported that tropical insects undergo seasonal changes in abundance, at least for those parts of the tropics where seasons are alternate (Dobzhansky and Pavan, 1950;

Owen and Chanter, 1970, 1972; Janzen and Pond, 1975; Wolda, 1978a). Whitaker (1995) suggested that insectivorous bats generally selected among available food but becomes more opportunistic when food was limited. Michal *et al.* (2012) reported that *Myotis nattereri* consumed food highest in late summer and early autumn and lowest in cold and peak in summer.

The most common insect orders consumed by bats are Coleoptera, Lepidoptera, Diptera, Hymenoptera, and Isoptera (Verts *et al.*, 1999; Pavey *et al.*, 2001). Bats have several morphological adaptations that allow them to capture and handle prey in flight and their teeth are also a more important component for chewing (Evans and Samson, 1998). Whereas wing morphology helps the bats to do various manoeuvres during flight (Norberg and Rayner, 1987). Direct observation of foraging behaviour of insectivorous bats typically is not possible hence most authors have necessarily used fecal analyses to quantify diet compositions (Whitaker *et al.*, 1977). However, a thorough understanding of prey use among insectivorous bats requires knowledge of prey availability in surrounding habitats. Understanding the foraging ecology of insectivorous bats is further hindered by limited knowledge of how diet varies within species.

Actual diet composition is influenced by actual food supply availability, seasonal variations and strategies with which a particular bat species responds to these changes (Swift and Racey, 1983; Shiel *et al.*, 1991; Catto *et al.*, 1994). Insectivorous bats may indicate flexible exploitation of available food resources in the diet composition, foraging occasionally and less selective feeding (Belwood and Fenton, 1976; Fenton and Morris, 1976; Swift *et al.*, 1985; Rydell, 1986; Hoare, 1991). Among the food they consume large quantities of lepidopterans (moths), coleopterans (beetles), dipterans (flies), homopterans (cicadas, leafhoppers), and hemipterans (true bugs) (Anthony and Kunz, 1977; Ross, 1961; Leelapaibul *et al.*, 2005) which are mostly pests of agro crops (Harris, 1970). Therefore, bats are known as ravenous feeders of nocturnal insects which damage a large number of crops annually (Harris, 1970).

Previous studied reports the *S. kuhlii* consumed primarily the order of Hemiptera, Coleoptera, Odonata, Homoptera and Trichoptera (Zhu *et al.*, 2012). Lepidoptera, Hymenoptera, Coleoptera and Hemiptera in the diet approach 80% every month (Zhu *et al.*, 2012). Previous studies reports *S. kuhlii* fed the family like Anisopodiae, Chironomidae Culicidae and Seatophagidae belonging form the order Diptera and also fed the coleopteran such as Carabidae and Searabaeidae followed by Hymnopterans were included lychnumonidae (Srinivasulu *et al.*, 2010) Several earlier studies reported that *S. kuhlii* foraged predominately in open environments as well as at the edge of the cluttered environments, such as the crowns of trees within the urban environment, around street lights , agriculture fields, and over waterbodies (Zhu *et al.*, 2012). It is emitted low frequency 45.72 kHz can detect prey over long distances in open habitats and may catch relatively large prey (Zhu *et al.*, 2012). It also emitted echolocation calls with relatively broadband frequency-modulated with the fourth harmonic up to 200 kHz during the flight (Neuweiler, 1984). Thus, the predicted the diet composition of *S. kuhlii* was varies with season. Therefore, the main aim of this study was to assess the seasonal food preference and diet composition of *S.kuhlii* in Uttar Pradesh.

## MATERIALS AND METHODS

### Study area

The study was carried out in various districts of Uttar Pradesh. Geographical areas of the state are 240,928 $km^2$ which constitutes 7.3% of the total areas of the country. The climate of Uttar Pradesh is characterized by temperature ranging from $5^{\circ}C$ in winter to $45^{\circ}C$ in summer. Annual rainfall varies from 1000mm to 1200mm of which about 90% occurs from June to September which is the southwest monsoon. India is home to an extraordinary variety of climatic regions, ranging from tropical in the south to temperate and alpine in the Himalayan north, where elevated regions receive sustained winter snowfall.

### Sample collection

The fecal materials were collected seasonally by spreading polythene sheets (10x14cm) on the attic floor and front of the roost entrance from the various roosting places (Figure1.1). Fecal pellets from these roosts were collected in the summer months (March, April, May, and June), monsoon (July, August, September and October) and winter (November, December, January and February). Sampling was performed in the morning after the bats returned to the roost, at about one-month interval at various roosting sites of Uttar Pradesh, which is the biggest a state of Indian sub-continents. In this state a large number of historical places and also a rich diversity of living organisms including mostly bats. Simultaneously, collected insects from foraging grounds surrounding roosting sites using sweep nets (r = 20cm) from 18:00 PM to 19:00 PM in the evenings where possible. All investigated roosts were located near man-made structures including monuments, abandoned buildings, temples, and trees where bats hunted for prey. From each location, average one gram pellets approximately 25 to 50 pellets collected, and among each location, only 20 pellets were taken at random and analyzed monthly (Plate 3.1).

**Pellet analysis**

The collected fresh guano pellets only and thus the date of collection reflected recent diets. Fecal pellets were soaked in distilled water, then completely dissected with a needle, forceps and tweezers and searched for taxonomically recognizable remnants. The analysis was done using a light microscope (BR BIOCHAM, 1402923) with 10x magnification (Plate 3.3). The identification of remnants was done examining legs, antennae, and wings or elytra (Figure 3.9 to 3.11). Members of Arthropoda were identified to the order as well as family level using published identification guides and keys (Mroczkowski 1955; Smreczyński 1976; Stebnicka 1978; Trautner and Gaigenmuller 1987; Trojan 1957; Pławilszczikow 1972; Prashad 2010). The made permanent slides of identified insect parts and matched the remnants for confirming order and families. The remaining pellets were kept at - $4^{o}$C for further analysis. Results are expressed in terms of relative frequency of occurrence;

Percentage frequency (%f): This is the number of occurrences of the category, divided by the number of samples analyzed, multiplied by 100. Whereas for percentage volume (%Vol): Sum of individual volume divide by total volume of the sample multiply by 100. The using the formulae given by Whitaker (1988). The food items were categorized into three classes based on the frequency of remnants: basic food (>20%), constant food (5-20%), chance food (<5%) as described by Verzhutskii and Ramanujam (2002). Insect availability was categorized based on the total captured insects a month, namely, absent (0), rare (<5), common (5 to 10) and abundant (>10). Kruskal Wallis H test (KW) was applied to determine diet variation and seasonal variation based on the frequency of each dietary item, at 0.05 significance level (SPSS, 21). Because data was non parametric.

**Plate 3.1.** The guano of *S. kuhlii* beneath the roost located at residency, Lucknow

**Plate 3.2.** Sweep net applied for collection of nocturnal insects at foraging ground.

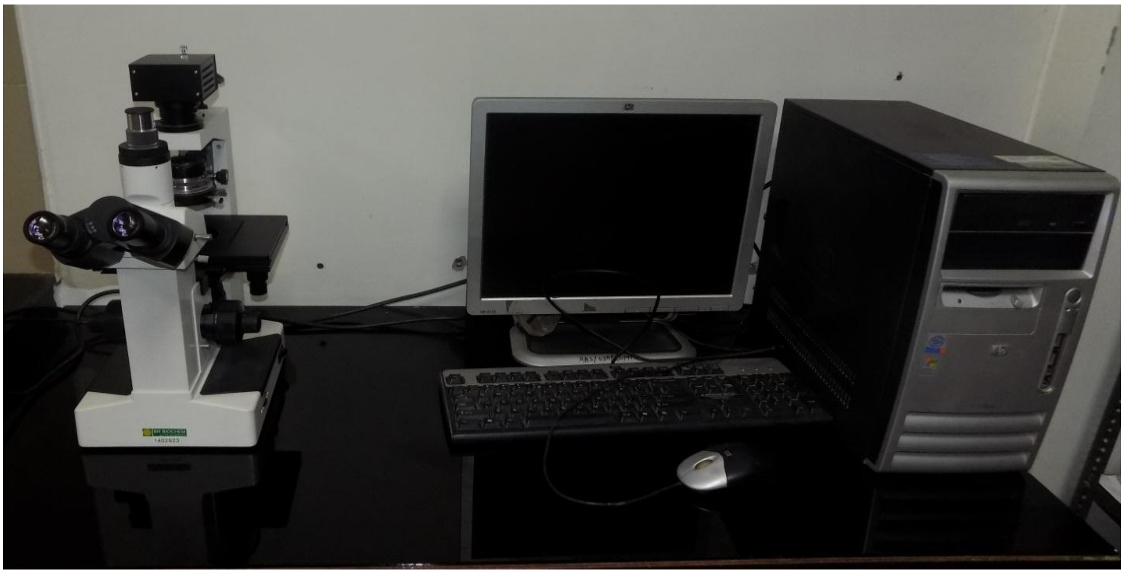

**Plate 3.3.** The complete set of light microscope with digital camara for identification of insect remnant.

## RESULTS

### Prey orders were consumed by *S. kuhlii*

In summer, 2016 Coleoptera (33.75%f), Lepidoptera (26.25%f) and Diptera (25%f) formed the basic food, Hymnoptera (9.16%f), Isoptera (16.66%f) Orthoptera (20.83%f), Hemiptera (12.91%f) and Blattodae (9.16%f) formed the constant food and Odonata (5.83%f), and formed the chance food in total frequency in sample (Figure 3.1). There was maximum percentage of volume occurred coleopteran (7.83%Vol) (Figure 3.2). Followed by monsoon, Lepidoptera (48.33%f) and Coleoptera (40.83%f) and Orthoptera (27.91%f) formed the basic food, Diptera (19.16%f), Hymnoptera (14.16%f), Isoptera (11.25%f) and Hemiptera (9.16%f) formed the constant food and Odonata (5.41%f), Blattdae (1.66%f) and formed the chance food (Figure 3.1), and maximum percentage of volume occurred Lepidoptera (11.21%Vol) (Figure 3.2), and winter Hemiptera (33.75%f) and Coleoptera (27.91%f) formed the basic food. Lepidoptera (11.25%f) Diptera (7.91%f), Orthoptera (6.25%f), formed the constant food and, Hynmoptera (3.33%f), Isoptera (1.66%f) and Odonata (1.25%f) formed the chance food in the total frequency of sample (Figure 3.1). While maximum percentage of volume occurred Hemiptera (7.83%Vol) (Figure 3.2).

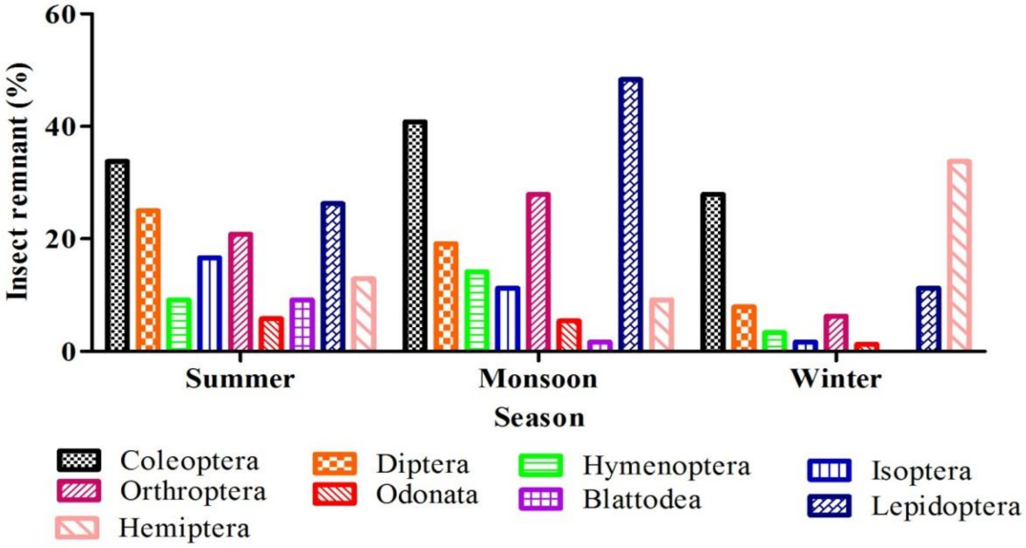

**Figure 3.1.** The percentage frequency of identified remnants of insect order consumed by *S. kuhlii* during 2016.

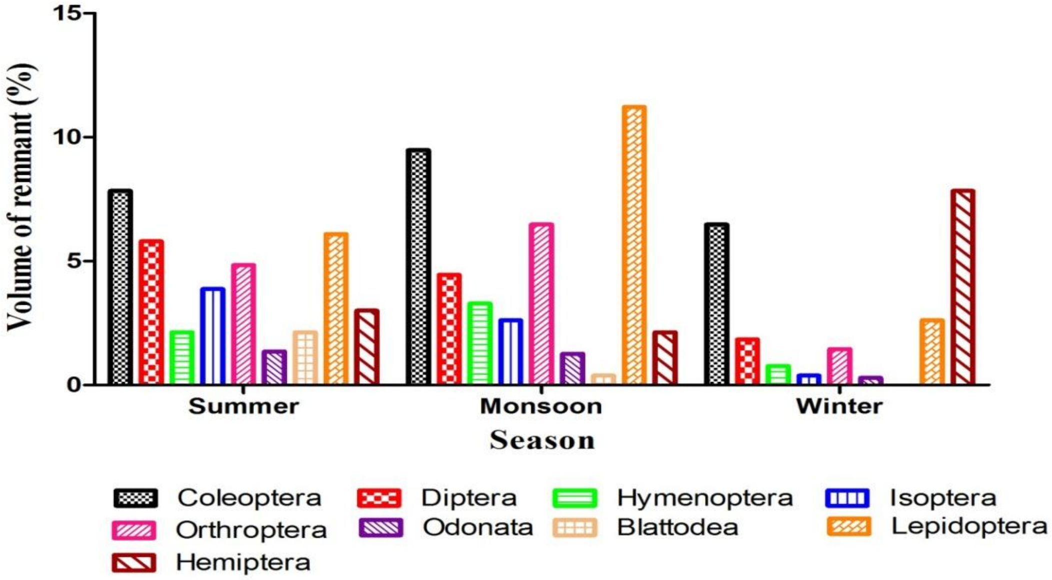

**Figure 3.2.** The percentage volume of identified remnants of insect order consumed by *S. kuhlii* during 2016.

In summer, 2017 only Coleoptera (48.83%f), Diptera (27.91%f), Lepidoptera (25%f) and Orthoptera (23.33%f) formed the basic food, Hymnoptera (11.25%f), Isoptera (15.41%f), Blattodae (10%f) and Hemiptera (12.25%f) formed the constant food and Odonata (4.95%f) formed the chance food (Figure 3.3). There was percentage of volume occurred coleopteran (10.88%Vol) (Figure 3.4). Followed by monsoon Coleoptera (45.41%f) and Lepidoptera (43.75%f), Orthoptera (26.25%f) and Diptera (22.5%f) formed the basic food, Hymnoptera (12.08%f), Isoptera (10.41%f), and Hemiptera (12.91%f) and Odonata (7.5%f) formed the constant food and Blattodea (1.25%f) formed the chance food (Figure 3.4). While maximum percentage of volume was occurred coleopteran (10.22%Vol) (Figure 3.3) and in winter Coleoptera (32.5%f) and Hemiptera (20.41%f) formed the basic food. Lepidoptera (12.91%f) and Orthoptera (7.71%f) formed the constant food and remaining order Diptera, Hymnoptera, Isoptera, Odonata and Blattdae formed the chance food (Figure 3.3), and maximum percentage of volume was occurred Coleoptera (7.31.%Vol) (Figure 3.4 ).

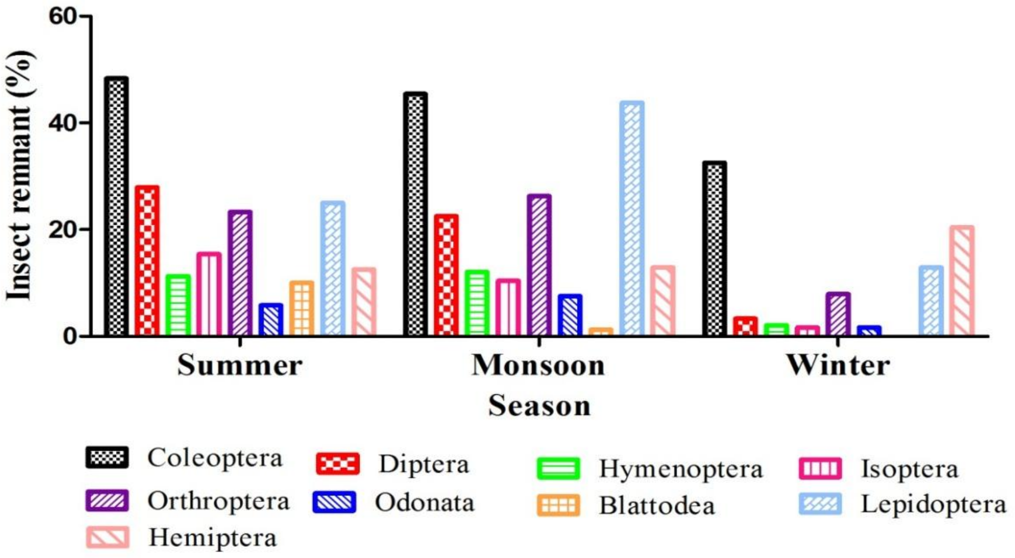

**Figure 3.3.** The percentage frequency of identified remnants of insect order consumed by *S. kuhlii* during 2017.

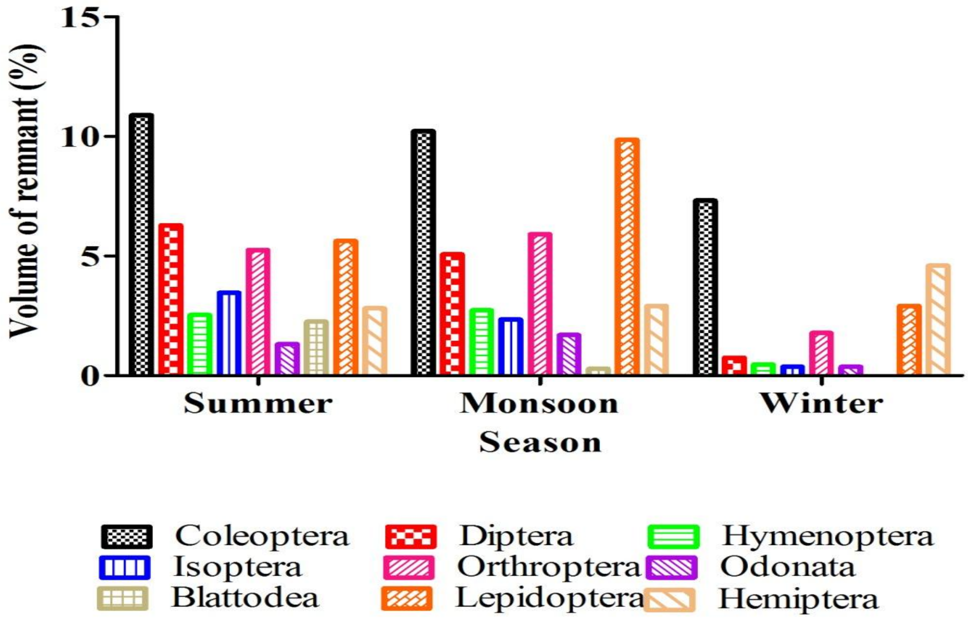

**Figure 3.4.** The percentage volume of identified remnants of insect order consumed by *S. kuhlii* during 2017.

In summer, 2018 there were found seasonal variation in diets and its composition of S. *kuhlii* which was following categories: coleopteran (35.83%f) and Diptera (22.08%f) formed the basic food, Hymnoptera (12.08%f), Isoptera (10%f), Orthoptera (12.5%f), Odonata (5.83%f) and Lepidoptera (18.33%f) formed the constant food. While Blattadea (4.16%f) and Hemiptera (1.25%f) formed chance of food in total percentage of frewuency, followed by monsoon, Coleoptera (42.5%f) and Lepidoptera (49.16%f), Orthoptera (26.25%f) and Diptera (20.41%f) the formed basic food. Hymnoptera (12.91%f), Isoptera (8.33%f), and Hemiptera (7.91%f) and Odonata (7.08%f) formed the constant food and Blattodae (1.6%f) formed the chance of food. Winter Coleoptera (30.83%f) and Hemiptera (21.66%f) formed the basic food. Lepidoptera (17.5%f) and Orthoptera (10.83%f) the formed the constant food and Hymnoptera (2.5%f), Isoptera (1.25%f), Diptera (4.16%f), Odonata (1.66%f) and formed the chance food (Figure 3.5). While maximum percentage of volume observed of Coleoptera (9.21%Vol) in summer followed by monsoon Lepidoptera (12.64%Vol) and winter Coleoptera (7.93%Vol) in total valume of sample (Figure 3.6).

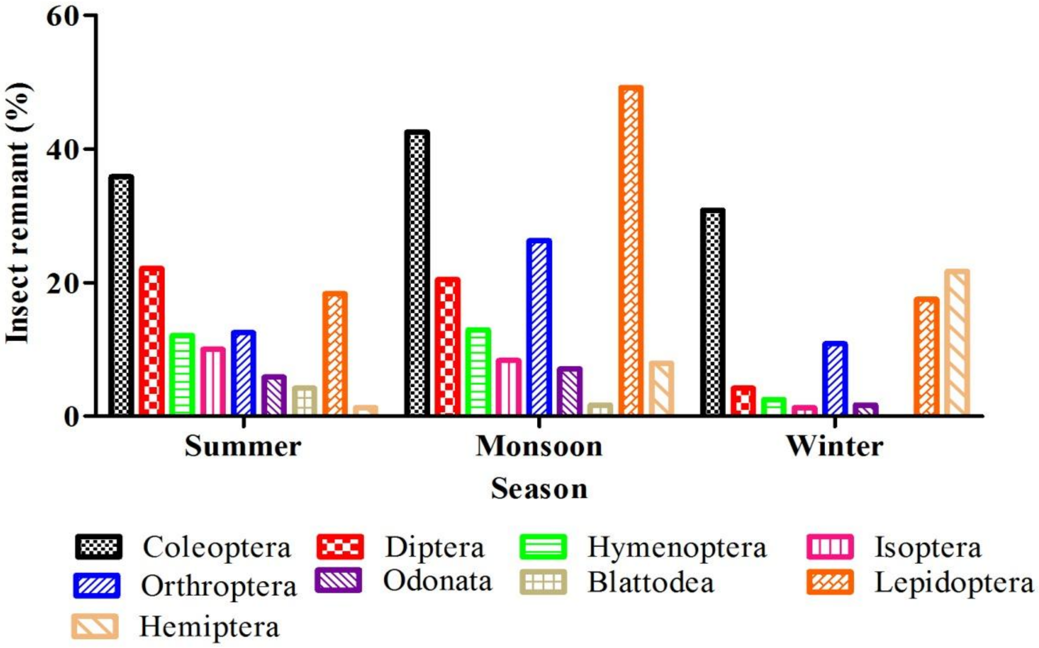

**Figure 3.5.** The percentage frequency of identified remnants of insect order consumed by *S. kuhlii* during 2018.

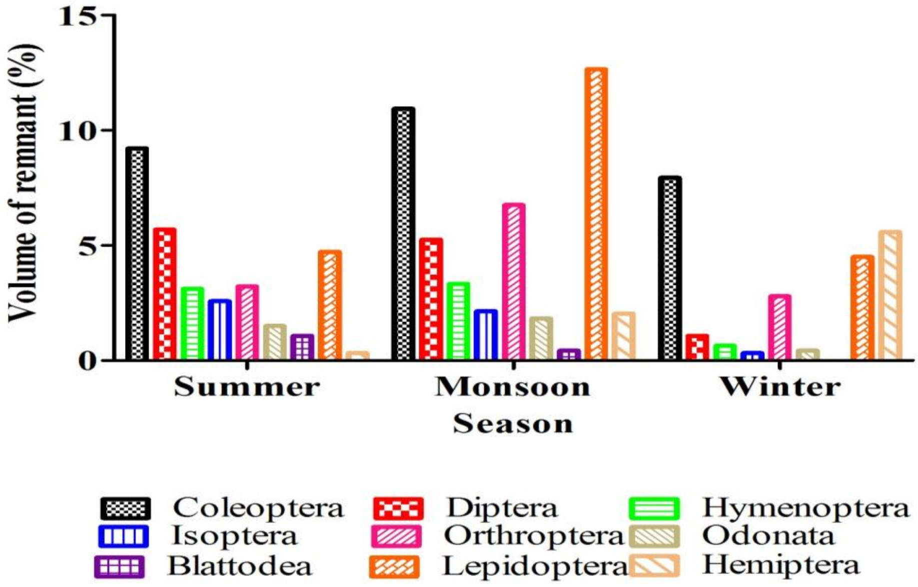

**Figure 3.6.** The percentage volume of remnants of various insect orders in the guano of *S. kuhlii*.

**Table 3.1.** The remnants of various insect orders found in the guano of *S. kuhlii* during summer, monsoon and winter seasons.

| | **Summer** | | | **Monsoon** | | | **Winter** | | |
|---|---|---|---|---|---|---|---|---|---|
| | **Wings** | **Antenna** | **Legs** | **Wings** | **Antenna** | **Legs** | **Wings** | **Antenna** | **Legs** |
| **Order** | **Mean ± SD** | **Mean ± SD** | **Mean ± SD** | **Mean ± SD** | **Mean ± SD** | **Mean ± SD** | **Mean ± SD** | **Mean ± SD** | **Mean ± SD** |
| **Col** | 15.8 ± 2.87 | 18.0 ± 9.12 | 2.5 ± 1.73 | 21.7 ± 2.08 | 19.7 ± 6.65 | 2.7 ± 3.78 | 10.2 ± 3.83 | 10.8 ± 5.93 | 0.6 ± 0.89 |
| **Dip** | 5.8 ± 2.21 | 6.5 ± 2.38 | 0.7 ± 0.95 | 16.7 ± 1.52 | 9.0 ± 3.46 | - | 5.8 ± 1.30 | 3.4 ± 0.54 | 0.8 ± 1.30 |
| **Hym** | 14.3 ± 3.77 | 12.0 ± 1.25 | 0.3 ± 0.50 | 11.3 ± 4.16 | 13.3 ± 3.21 | - | 6.6 ± 4.15 | 7.4 ± 2.88 | - |
| **Iso** | 3.0 ± 1.82 | 4.5 ± 1.20 | - | 5.0 ± 2.64 | 6.7 ± 1.52 | - | 5.0 ± 2.64 | 6.7 ± 1.52 | - |
| **Ort** | 10.3 ± 3.68 | 10.5 ± 1.91 | 2.5 ± 3.00 | 11.3 ± 5.68 | 14.3 ± 3.21 | 0.3 ± 0.577 | 5.4 ± 2.07 | 7.4 ± 2.70 | - |
| **Odo** | 8.5 ± 2.88 | 10.5 ± 3.31 | 1.5 ± 1.91 | 10.0 ± 3.00 | 12.0 ± 2.00 | 0.7 ± 0.577 | 3.8 ± 2.04 | 6.4 ± 2.70 | 0.4 ± 0.89 |
| **Bla** | 11.5 ± 30 | 3.8 ± 2.36 | 0.25 ± 0.50 | 6.7 ± 1.15 | 9.7 ± 6.42 | - | 3.8 ± 2.38 | 3.4 ± 1.14 | - |
| **Lep** | 7.3 ± 3.09 | 7.0 ± 2.94 | 0.5 ± 1.00 | 6.3 ± 1.52 | 10.3 ± 5.68 | - | 5.6 ± 1.51 | 5.2 ± 1.09 | 0.4 ± 0.54 |
| **Hem** | 10.0 ± 2.94 | 6.5 ± 0.57 | 0.75 ± 0.95 | 7.3 ± 4.04 | 7.3 ± 4.50 | - | 3.2 ± 0.44 | 4.4 ± 1.51 | - |

Note: **Col** = Coleoptera, **Dip** = Diptera, **Hym** = Hymenoptera, **Iso** = Isoptera, **Ort** = Othoptera, **Odo** = Odonata, **Bla** = Blatadae, **Lep** = Lepidoptera, **Hem** = Hemnoptera

## Seasonal food preference by *S. kuhlii*

A total of 11 families of insects were identified corresponding to 9 insect orders based on the leg, antenna, and wing or elytral fragments (Table 3.1) (Plate 3.10 to 3.12). About 3048 isolated remnants from a total of 720 pellets were analyzed. A total of 26.83% of remnants could be identified to order and family level; the remaining 73.5% remnants were unidentified.

## Order of Insects consumed by *S.kuhlii*

The percentage frequency of identified remnants of prey items consumed insects order by *S. kuhlii* during summer, showed that Order Coleoptera (39.30%f), Diptera (25%f) and Lepidoptera (23.19%f) have been formed basic food, followed by Orthoptera (18.88%f), Isoptera (14.02%f), Hemiptera (10.97%f), Hymenoptera (10.83%f), Odonata (5.83%f) and Blattodea (7.77%f) forming the constant food of total frequency in the sample, while there was no forming the chance of food in summer (Figure 3.7). Followed by monsoon, two most important insect order such as Lepidoptera (47.08%f). Coleoptera (42.91%f) Orthoptera (26.80%f) and Diptera (20.69%f) were forming the basic food of the total frequency in sample. While Hymenoptera (13.5%f), Isoptera (10%f) and Hemiptera (10%f) were forming the constant food and Odonata (6.66%f) and Blattdae (1.52%f) were forming the chance food of the total frequency in sample (Figure 3.7) and in winter Coleoptera (30.41%f) and Hemiptera (25.27%f) were forming the basic food of the total frequency of consumed diet in the sample. whereas Diptera (5.13%f), Orthoptera (8.33%f), and Lepidoptera (13.88%f) were forming the constant food, and Hymenoptera (2.63%f), Isoptera (1.52%f) and Odonata (1.52%f) formed the chance food of the total frequency of consumed diet in the sample (Figure 3.7).

**Insect family consumed by *S.kuhlii***

The percentage of frequency of insect families consumed by *S. kuhlii*, such as Gryllidae (25.18%f) form basic food, while Cerambycidae (7.03%f), Culicidae (8.88%f), Apidae (5.92%f), Termitidae (10.37%f), Acrididae (15.18%f), Erebidae (13.33%f) and Pentatomidae(5.55%f) formed constant food and Formicidae (4.07%f) and Crambidae (4.44%f) formed chance of food of the total frequency in the sample in summer (Figure 3.8). Followed by monsoon, Crambidae (21.70%f) form basic foods, Culicidae (9.75%f), Formicidae (11.95%f) Termitidae (10.24%f), Acrididae (7.07%f), Gryllidae (14.14%f), Erebidae (8.04%f) and Pentatomidae (9.02%f) formed constant food, and Cerambycidae (4.14%f), and Apidae (3.90%f) formed chance of food (Figure 3.8) of the total frequency in the sample, and winter Cerambycidae (15.52%f), Apidae (6.21%f), Acrididae (10.55%f), Erebidae (18.01%f), Crambidae (17.39%f), Lasiocampidae (11.80%f) and Pentatomidae (12.42%f) formed constant food, and Culicidae (3.72%f) and Termitidae (1.86%f) formed chance of food (Figure 3.8).

There was significantly different among the families in season such as Culicidae ($H = 19.16, P < 0.001$), formicidae ($H = 22.92, P < 0.001$), Termitidae ($H = 6.67, P < 0.035$), Acrididae ($H = 5.74, P < 0.05$), Gryllidae ($H = 24.51, P < 0.0001$), Crambidae ($H = 24.86, P < 0.0001$) and Lasioampidae ($H = 22.82, P < 0.0001$) and Pentatomidae ($H = 8.52, P < 0.014$) except Cerambycidae ($H = 1.38, P < 0.50$), Apidae ($H = 1.83, P > 0.399$) and Erebidae ($H = 1.74, P < 0.41$) (Figure 3.8).

## Seasonal prey availability at foraging ground

A total of twenty-three insect families corresponding to eight orders were captured from various foraging grounds. A statistically significant variation in insect abundance was observed with respect to seasons in the foraging grounds. Lepidopterans were the most dominant in at all locations with family Erebidae (H = 2.07, P > 0.35) being abundant in March, October and November and common in January months, followed by Crambidae (H = 1.32, P > 0.51) which was more abundant in October and November and common in February. Family Geometridae (H = 5.34, P > 0.69) was more abundant in April and October, while in the remaining months it was rare or absent, similarly, family Noctuidae (H = 0.29, P > 0.96) was more abundant in May and October while in remaining months, it was rare or absent. Family Limcadidae (H = 5.96, P < 0.05) was more abundant in October month and rare in September and November months. Family Lasiocampidae (H = 3.08, P > 0.21) was more abundant in December and common in March and September months (Table 3.2). Hemiptera, was second most captured in the whole sampling, with family Cicadellidae (H = 3.14, P > 0.200) being more abundant in October and common in December; family Reduviidae (H = 1.56, P > 0.45) was more abundant in March and September, and in remaining other months it was rare, followed by, Pentatomidae (H = 10.15, P > 0.006) was more abundant in April, July and August. Lygaeidae (H = 11.22, P < 0.004) was more abundant in August and common in September month, whereas Ischneumonidae (H = 0.58, P > 0.74) was more abundant only in September. Coleoptera, was the third most captured insect order during sampling, including family Elmidae (H = 10.30, P < 0.006) was more abundant in July and rare in June, August, and September; Carambycidae (H = 8, P < 0.014) was common in November and December, and Carabidae (H = 1.32, P > 0.51) was more abundant in April and common in March. Among Dipterans, family Culicidae (H = 6.91, P < 0.031) was more common in April, June, and August, and abundant in July, whereas, Tipulidae (H = 13.61, P < 0.001) was more abundant in July and common in June and August (Table 3.2). Among Hymenopterans, Apidae (H = 10.71, P < 0.005) was more abundant in May and July and common in June, whereas Formicidae (H = 6.09, P < 0.047) was more common in June and abundant in July month (Table 2). Among Isoptera, Termitidae (H = 4.94, P > 0.08) was more abundant in June and July while rare in May and August than any other month (Table 3.2). Among Orthopterans, Acrididae (H = 11.38, P < 0.003) was more abundant in March to May and September, while it was common in June, July and February. Family Gryllidae (H = 12.03, P < 0.002) was abundant in April to July and September than any other month (Table 3.2). Among Odonata, Anisoptera (H = 19.02, P < 0.001) was more common n July and August while more abundant in September. Among Mantodea, family Mantidae (H = 5.14, P > 0.76) was more abundant in February and rare in March than any other month (Table 3.2).

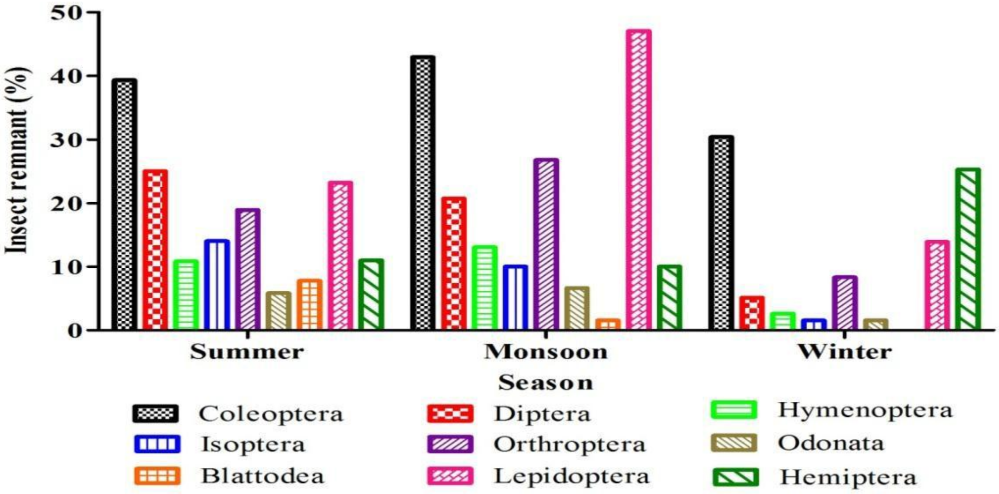

**Figure 3.7.** The percentage frequency of insects order consumed by *Scotophilus kuhlii.*

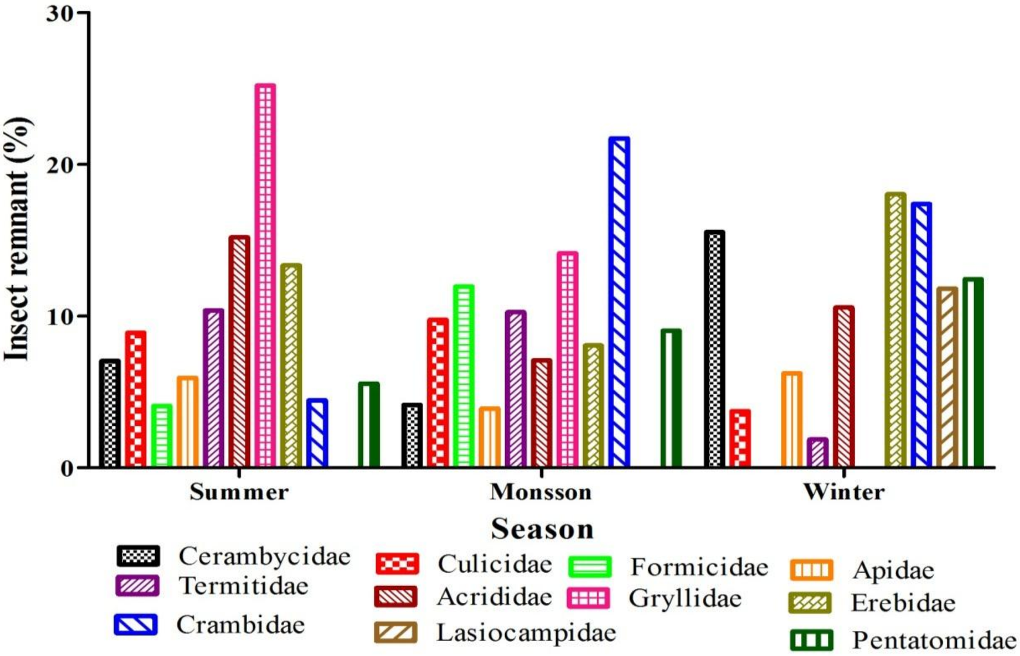

**Figure 3.8.** The percentage frequency of insect families consumed by *Scotophilus kuhlii*.

**Table 3.2.** Estimate quantitative of insect collected at various study sites. The insect abundance were classified following categories: Absent (0), Rare (*), Common (**), Abundance (***) and insect families by *S. kuhlii* (#).

| **Taxon** | | **Summer** | | | | **Monsoon** | | | | **Winter** | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Order** | **Family** | **Mar** | **Apr** | **May** | **Jun** | **Jul** | **Aug** | **Sept** | **Oct** | **Nov** | **Dec** | **Jan** | **Feb** |
| Coleoptera | Elmidae | 0 | 0 | 0 | * | *** | * | * | 0 | 0 | 0 | 0 | 0 |
| Coleoptera | Cerambycidae# | 0 | 0 | 0 | 0 | 0 | 0 | 0 | * | ** | ** | 0 | 0 |
| Coleoptera | Carabidae | ** | *** | * | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Diptera | Culicidae# | * | ** | 0 | ** | *** | ** | 0 | 0 | 0 | 0 | 0 | 0 |
| Diptera | Tipulidae | 0 | 0 | * | ** | *** | ** | * | * | * | 0 | 0 | 0 |
| Hymenoptera | Apidae# | 0 | * | *** | ** | *** | * | 0 | 0 | 0 | 0 | 0 | 0 |
| Hymenoptera | Formicidae# | 0 | 0 | * | ** | *** | * | 0 | 0 | 0 | 0 | 0 | 0 |
| Isoptera | Termitidae# | 0 | 0 | * | *** | *** | * | 0 | 0 | 0 | 0 | 0 | 0 |
| Orthoptera | Acrididae# | *** | *** | *** | ** | ** | 0 | *** | 0 | 0 | 0 | 0 | ** |
| Orthoptera | Gryllidae# | 0 | *** | *** | *** | *** | 0 | *** | 0 | 0 | 0 | 0 | 0 |
| Odonata | Anisoptera | 0 | 0 | 0 | * | ** | ** | *** | 0 | 0 | 0 | 0 | 0 |

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Lepidoptera | Erebidae# | *** | * | 0 | 0 | 0 | 0 | 0 | *** | *** | 0 | ** | * |
| Lepidotera | Crambidae# | * | * | * | 0 | 0 | 0 | 0 | *** | *** | 0 | 0 | ** |
| Lepidotera | Geometridae | * | *** | * | 0 | 0 | 0 | 0 | *** | 0 | 0 | 0 | 0 |
| Lepidotera | Noctuidae | 0 | * | *** | * | 0 | 0 | 0 | *** | * | * | 0 | 0 |
| Lepidotera | Limcadidae | 0 | 0 | 0 | 0 | 0 | 0 | * | *** | * | 0 | 0 | 0 |
| Lepidotera | Cicadillidae | 0 | 0 | 0 | 0 | 0 | 0 | 0 | *** | * | ** | 0 | 0 |
| Lepidotera | Lasiocampidae# | ** | 0 | 0 | 0 | 0 | 0 | ** | 0 | * | *** | 0 | 0 |
| Hemiptera | Reduviidae | *** | * | * | 0 | * | 0 | *** | * | * | * | 0 | 0 |
| Hemiptera | Pentatomidae# | 0 | *** | 0 | 0 | *** | * | *** | 0 | 0 | 0 | 0 | 0 |
| Hemiptera | Lygacidae | 0 | 0 | 0 | 0 | 0 | *** | ** | * | 0 | 0 | 0 | 0 |
| Hemiptera | Ischneumonidae | * | 0 | 0 | 0 | 0 | 0 | *** | 0 | 0 | 0 | * | * |
| Mantoda | Manteodae | * | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | * | *** |

## DISCUSSION

In the present study, a clear seasonal variation was observed in the diet of *S. kuhlii*. Barclay (1985) reported that primariy foods item of *S. kuhlii* was Hemiptera and Coleoptera. Our results indicate that *S. kuhlii* fed mainly on Coleoptera, followed Lepidoptera, Orthoptera, Diptera, Hemiptera, and Hymenoptera in all seasons. The results of present study are agreement with that reported by Zhu *et al.* (2012) and Pereira et al. (2002). Ramanujam and Verzhuskii (2004) reported that coleopterans were most frequently consumed by bats throughout the season because coleopterans are the most abundant order found in the world. Feldman *et al.* (2000) reported that Diptera, Lepidoptera, and Coleoptera were the main prey in diets of *P. kuhlii.* The present study shows that Gryllidae and Acrididae were major foods in the diet of *S. kuhlii*, while, Erebidae, Termitidae and Culicidae were second major foods in summer. Whereas, family Acrididae (Grasshopper) was maximum captured in March to September and disappeared August and October to January while Gryllidae (Crickets) was maximum captured in April to September and disappeared in August and October to March, and Culicidae was maximum captured in July, June, and April. Some small insect groups are not consumed by bats even if they are very abundant in their habitats (Pereira *et al.*, 2002; Jaskuła and Hejduk, 2005) because they have lower biomass, provide lower energy content, compared to larger prey items. The present study shows that Apidae, Formicidae were very preferred by *S. kuhlii* in summer. Andreas *et al.* (2012) reported low diversity and abundance of the food supply during the winter is among the season, with diversity and abundance peaking in the summer season. *Barbastellus barbastellus* is a highly specialized species, feeding predominantly on Lepidoptera, especially medium-sized and larger insects (Andreas *et al.*, 2012). In the present study, the Crambidae, Gryllidae, Formicidae were major food items in the diet of *S. kuhlii* in the monsoon season. While Crambidae (Grass-moths) was maximum captured in October and November and totally absent in December and January and again appeared in February to May but there was rare, Gryllidae (Crickets) was maximum captured in April to July and September, Formicidae (Fly ants) was captured maximum in July, while it totally disappeared in September to April and again appeared in May, hence, was the third major food item in the diet of *S. kuhlii* in the monsoon. Lynch *et al.* (1988) reported that Formicidae (ants) peak in June, but species richness was nearly as high in May, July and August. Whitaker *et al.* (1994) reported that ants (Hymenoptera) were the most consumed prey, followed by Coleoptera and Lepidoptera.

The present study shows that Erebidae, Crambidae, and Lasiocampidae, Cerambycidae, Pentatomidae and Acrididae was major food item in their diet in winter when other prey was limited. Kunz *et al.* (1995) reported that moths have highly fatty body and provide more energy-rich sources therefore bats feed maximum on them. More moths were fed on by *S. kuhlii* in winter which helps during breeding when more energy is required.

Insectivorous bats deliver economically valuable ecological services and decrease health risks to humans by reducing dependence on pesticides. Leelapaibul *et al.* (2005) reported that insectivorous bats act as biological pest control agents in the agricultural field, feeding on pests belonging to Homoptera, Lepidoptera, Hemiptera, and coleoptera in farms. In the present study, the *S. kuhlii* consumed several types of insects belonging to Coleoptera, Diptera, Isoptera, Hymenoptera, Orthoptera, Odonata, Blattodae, Lepidoptera, and Hemiptera and may be a good pest control agent. A study on *Scotophilus leucogaster* by Barclay (1984) showed that it had a varied diet from throughout the year as well as from season to season and night to night. These changes in diet and dietary diversity likely correspond to changes in insect abundance and distribution. The diet of *S. kuhii* and collected insect abundance showed a correlation in the seasonal variation which occurred due to choice of prey related to habitat use by *S. kuhlii* and climatic conditions.

## CONCLUSION

*Scotophilus kuhlii* is a medium size insectivorous bat. It feds on 11 families of insects corresponding from nine orders. Although, twenty-three families of insects belonging to eight orders were collected from the foraging grounds. it was observed that this species consumed a few families among the captured insect family at the foraging grounds. The diet of *S. kuhii* and collected insects abundance showed a correlation between seasonal variations in diet choice related to habitat use by *S. kuhlii*. The results revealed that *S. kuhlii* is an opportunistic feeder, and its diet varied from season to season.

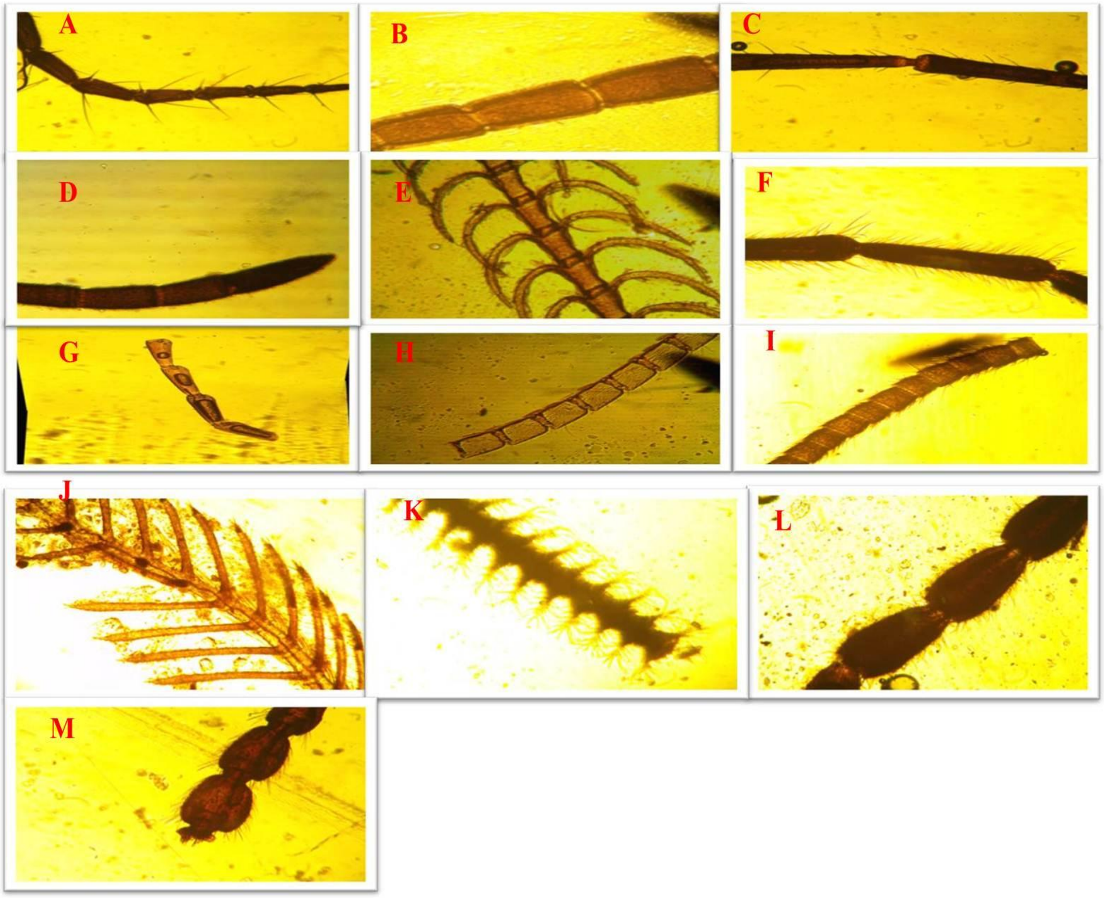

**Figure 3.9.** Deferent types of antennae isolated from guano of S. kuhlii such as (A ) Tipulidae family of Diptera, (B) Lepidoptera, (C) Reuvidae family of Hemiptera, (D) Formicidae family of Hynemoptera, (E ) Erebidae family of Lepidoptera, (F) Pentatomidae family of hemiptera, (G) Carambycidae family of Coleoptera, (H) Erebidae familyof Lepidoptera, (I) Blattodae family of Blattoda, (J) Crambidae family of Lepidoptera, (K) Gelechiidae family of Lepidoptera, (L) Carabidae, (M) Common beetle.

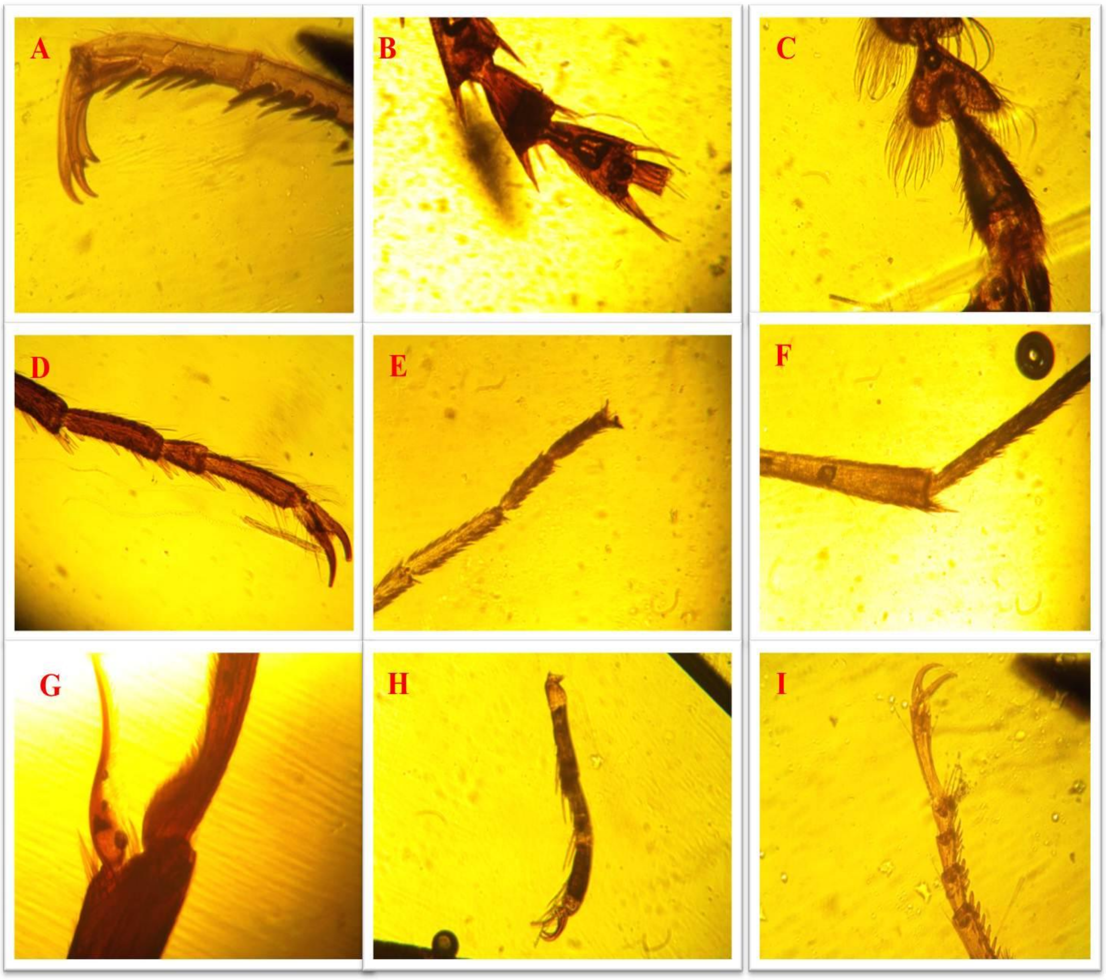

**Figure 3.10.** Different types of leg isolated from guano of *S.kuhlii* such as (A) Pentatomidae family of Hemiptera, (B) Coleoptera (C) Apidae family of Hymenoptera, (D) Coleoptera, (E) Erebidae Family of Lepidoptera, (F) Lepidptera, (G) Hymenoptera (H) and (I) Hemiptera.

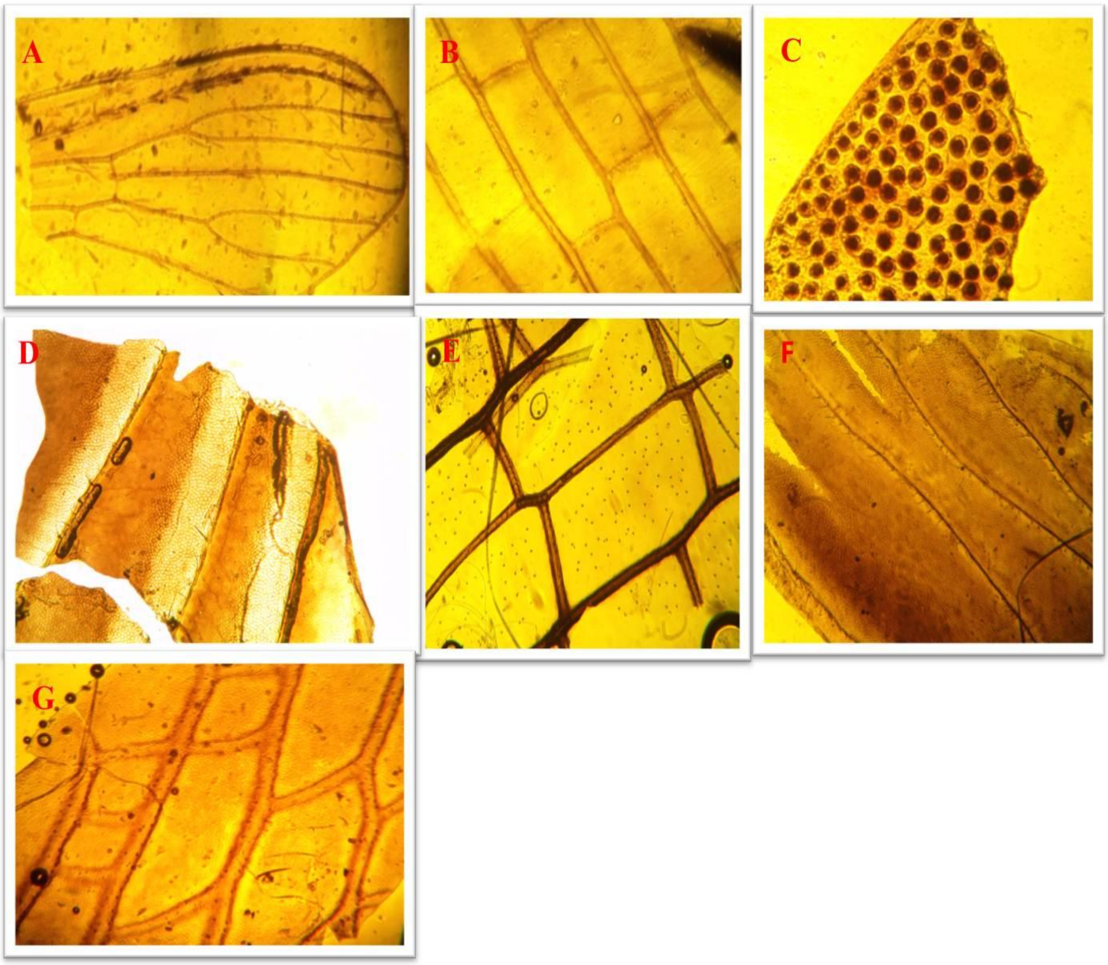

**Figure 3.11.** Different types of wings isolated from guano of *S. kuhlii* such as (A) Culicidae family of Diptera, (B) Acridinae family of Orthoptera, (C) Pentotomidae family of Hemiptera, (D) coleopteran, (E) Odonata (F) Carambycidae family of coleopteran, (G) Gryllidae family of Orthoptera.

# Chapter-IV

# Reproductive behaviour of Asiatic Lesser Yellow Bat, *Scotophilus kuhlii* (Leach, 1821)

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## INTRODUCTION

Reproductive behaviour is performed by a variety of physiological, ecological, and social interactions. The genetic structure of populations is largely determined by the breeding behaviour of the individuals within them. The high variance in the male reproductive success associated with polygyny can decrease the population size, potentially rapidly genetic drift and selection (Chesser, 1991). Several gregarious species from mammalian taxa including pinnipeds (Boness, 1991), rodents (Hayes, 2000), bovids (Berger, 1992), and bats (Kunz and Hood, 2000; Tuttle and Stevenson, 1982) exposer of environmental factors and social conditions that enhance reproductive success during the breeding season. The effect of seasonally and spatially fluctuation food supplies and climate conditions likely influence the timing and location of reproduction (Hoying and Kunz, 1998; Kunz, 1973). Thus, animal behaviours that enhance an individual's fitness in the context of the group are likely to be favored.

Previous studies has been shown that reproduction is more costly, required more energy and elements such as protein and calcium during pregnancy and lactation period (Seakman. 2008). Hence, in small mammals, during breeding period more energy required to generally influence the physical condition and complete the reproductive cycle (Thompson, 1992; Dammhahn, 2008). The energetic cost of reproductive effort such as gametogenesis, courtship, mating is probably sex-dependent and possibly high (Huchard, 2012), but overall poorly quantified (Kenagy, 1987). Even though, the critical importance of understanding the mating system function for establishing conservation strategies, unknown of detail mating system function in several animals (Lane *et al.,* 2011). Whereas, temperate-zone vespertilionid bats are unique among mammals because of the pronounced temporal asynchrony of primary and secondary sexual functions.

Sperm production by males begins during spring and continues through summer, while females are birthing and raising their offspring during breeding season (Wimsatt, 1960; Gustafson, 1979). This situation bats faced a particular challenge because their mating periods often extend into seasons when food resources become scarce or unavailable (Cryan *et al.,* 2012). Hence, mating systems of temperate insectivorous bats delay their reproductive system which both males and females capable of storing sperm for several months, especially seen among the Vespertilionidae bats (Crichton, 2000; Wimsatt *et al.,* 1966). These situations occur when food availability and necessary to fuel sperm production, is not available (Cryan *et al.,* 2012).

Copulation generally begins in autumn while few species continue mating occasionally through the winter and into spring (Racey and Entwistle, 2000; Barbour and Davis, 1969). The secondary sexual function in vespertilionid bats match with typical externally visible signs of primary sexual function such as maximum testes size which seasonal increases in resource availability, whereas common in other animals (Cryan *et al.,* 2012), however, these are specific seasonal timing and age at which mating initiates in vespertilionid bats can be difficult to determine, because mating might often occur more than half a year before (Cryan *et al.,* 2012). Previous studies reports in autumn, females visit males to mate, although copulation can also occur in winter and spring (Rossiter *et al.*, 2000). Therefore, breeding partnerships appear to be primarily determined by female choice. These can be up to more than one female who chose a single male (Ransome, 1991).

Mattings performed in territory sites occupied by single male, which may be small caves, mines or cellars and part of a larger underground system (Ransome, 1991). At the time of mating male reproductive success is determined by female choice (Rossiter *et al.,* 2000) then female dispersal during mating will influence spatial differentiation, while the male reproductive life span will affect the extent of temporal differentiation (Rossiter *et al.*, 2000). The vast majority of fatalities occur during late summer and autumn a period that matches both autumn migration and the beginning of accepted mating periods in many of the affected species (Arnett *et al.,* 2008; Cryan and Brown, 2007; Cryan and Barclay, 2009). Gestation and lactation are critical periods of energy expenditure (Gittleman, 1988) to require extra energy to fetal growth and the development of reproductive organs including the uterus, placenta and mammary gland, entail a drastic increase of energy expenditure. After that birth, lactation is even also more costly (Dammhahn and Kappeler, 2008; Loudon and Racey, 1987; Rogowitz, 1996). Kunkele (2000) reported that in the guinea pig *Cavia porcellus* the daily energy expenditure during gestation is 2.4 times the basal metabolic rate (BMR) and 3.7 times the BMR during lactation. The extent of such costs places reproductive decisions at the core of life-history trade-offs (Stearns, 1992; Williams and editor, 1966).

They exhibit unusual life histories for small-sized mammals in that they are long-lived develop more slowly and produce few offspring. The mating activity starts in late summer when the animals have increased their body mass or size and improved physical condition such as a genital organ. Although it is the seasonal variation in body mass and reproductive condition of an adult male seen Daubenton's bats and male young of the year were analyzed in previous studies (Encarnacao *et al.,* 2004).

Bairn size at birth and postnatal growth and development could be influenced by biotic and abiotic factors, including food availability, weather conditions, foraging success, metabolic rate, sex, litter size, colony size and social conditions (Tuttle, 1976; Tuttle and Stevenson, 1982; Kunz and Stern, 1995; Hoying and Kunz, 1998; Baptista *et al.,* 2000; Koehler and Barclay, 2000; Kunz *et al.*, 2010). Pup size at birth and post-delivery growth also reflects the parental effort during pregnancy and the postnatal period (Read and Harvey, 1989; Promislow and Harvey, 1990). Bats gave birth relatively large young one compared with other similarly sized terrestrial mammals (Chen *et al.,* 2016). In general, it's the body mass of offspring is higher in smaller mammal species compared to large species (Chen *et al.,* 2016). In terms of bairn mass, which is strongly associated with wing loading in pregnant females, vespertilionids bats that produce twins have the highest body mass as a percentage of maternal mass up to 50 percent (Kurta and Kunz, 1987). Hence, the energetic cost for bats to produce and raise young is relatively high, which may cause a depletion of nutrient reserves in females and constrain the litter size (Barclay, 1994, 1995; Kunz *et al.,* 2009). Female bats nurse their young one until the pups have nearly achieved the adult size and are capable of flight, foraging, and echolocation (Chen *et al.,* 2016).

The female short-nosed fruit bats lick their mate's penis often throughout copulation and that every second of licking outcomes in almost six extra seconds of copulation (Tan *et al.,* 2009). Several animals may lick their reproductively active mate's genitals before and after to judge whether she is in estrous (Koyama, 1988).

Grooming behaviour is a crucial and evolutionarily ancient behaviour observed across several animal taxa (Sachs, 1988; Terry, 1970). The main reason for hygiene and caring for the body surface, stimulation of the skin, thermoregulation, chemo-communication, social interaction, and stress reduction (Sachs, 1988; Terry, 1070; Colbern and Gispen, 1988). The behaviour of this type creates 15–50% of waking time and may be generated by swimming, pain, exposure to predators, and sexual behaviour (Kalueff *et al.,* 2007; Kalueff and Tuohimaa, 2004). The mice and hamsters raise their frequency of sniffing from "resting" frequencies near 2 Hz to 4–12 Hz when searching new odor sources during operant tasks (Welker 1964; Verhagen *et al.*, 2007; Wesson *et al.,* 2008). The dogs show various sniffing behaviours when tracking a scent in air versus on the ground (Thesen *et al.,* 1993), and water shrews change their sniffing behaviour depending on the shape of the objects during searching or hunting of the prey hunting (Catania *et al.,* 2008).

Based on the morphological characters, it is medium-sized species with pelage colour of the dorsal region soft and olive-brown and abdomen light-creams (Bates and Harrison, 1997; Elangovan and Kumar, 2015; Dookia, 2018). Ear length is smaller as compared to the head with a half-moon shaped and tragus is separated from the pinna by a clear cut groove (Elangovan and Kumar, 2015; Dookia, 2018). The Average ear length was 10 mm to 13.5 mm (Bates and Harrison, 1997; Javed, 2014; Elangovan and Kumar, 2015). The forearm length ranges 44mm to 49mm in length (Bates and Harrison, 1997; Elangovan and Kumar, 2015; Rahman and Chaudhary, 2017; Dokia, 2018). Minimum body mass was 16gm and a maximum of 25gm (Zhu *et al.,* 2012; Rahman and Chaudhary, 2017). *S. kuhlii* frequently occupied different types of roost such as natural and man-made structures like monuments, renounce building, crevices, caves, old temples, palm fronds, hollows in palm trees and dried leaves on palm trees (Brosset, 1962; Sinha, 1986; Elangovan and Kumar, 2015). Norberg and Rayner, 1987 reported that wing morphology may be used to predict flight behaviour which differences in flight and foraging behaviour and to species ecology. The wing shape of flying vertebrates animal influences both the energetic costs of flight and ecological and behavioural aspects, including flight pattern, foraging behaviour, habitat selection, and size of food items (Norberg, 1987). Previous studies have been shown that morphology variation occurred in of adult *S. kuhlii*, whereas length of forearm of male shorter than female (Zhu *et al.,* 2012; Goodman *et al.,* 2005). Similarly, Gao *et al.* (2017) reported that phenotypic plasticity is the ability for individuals to change their morphology in response to environmental changes, which Variation in external and cranial characters have been known in some small mammals. Therefore, our aim of this study to access to reproductive behaviour including genital grooming, sniff and licking and seasonal morphometric variation including scrotum length of male, body mass in reproductive and non-reproductive of Asiatic Lesser Yellow bat, *S. kuhlii*.

## MATERIALS AND METHODS

A total of 10 roosts were selected in Siddhartha Nagar district. Each roost was assigned by a roost ID number to assess the reproductive behaviour such as courtship, genital grooming, urogenital licking, urogenital sniff, tooth grooming approaching, yawn, copulation attempt and success. The study of behaviour was carried out at an interval of fifteen days from February to June 2018. Twenty individuals including 8 males and 12 females selected and tagged from the selected roosts. The tagged individuals were: (A) roost, two males and three females, (B) roost, a male two females, (C) roost, three female, (D) roost, a male and two female, (E) roost, two males, (F) roost, two males and two females. The tags were handmade metal collor tags of copper wire with coloured beads to identify male and female individuals. The tags were less than 0.5gm of body mass. A ‘T’ shaped maternity roost with higher tunnel length was never vacated by *S. kuhlii* throughout the breeding season. Remaining other roosts’ occupancy was fluctuating in the breeding season due to less tunnel length and larger size of roost entrance. Therefore, only such roosts which were never vacant were selected for behaviour observation. In June 2018, it was observed that only two tagged males and three females returned to the same roost after the breeding season. The behaviour was observed by CCTV camera during the breeding season (February to June).The CCTV camera was fixed by a metal hanger (self-made) in front of maternity roost. The recording was done for almost 24 hours from 6:00 am to 6:00 am. The whole recording was recorded in a single data card (32GB). The recorded videos were kept on transferring to the laptop from time to time so that it could be analysed. The 24 hours videos were trimmed off and single clips were composed having lengths below 40 minutes (average length being 22:16 minutes) and the total clips were 92, all of which forming 34 hours videos. The behaviours like courtship, genital grooming, urogenital licking, urogenital sniff, tooth grooming approaching, yawn copulation attempt and success of copulation were recorded. The successful mating with the tagged females could not be confirmed until they gave birth on May 28, 2018.

The bats were captured during emergence time by mist net (Avi net, Dryden, USA) to assess the morphometric variation of male and female, actual body status of reproductively active individuals during the breeding period. The mist net was erected at the exit point of roosts nearthe banks of the ponds because *S. kuhlii* often drunk water after emergence in summer when the temperature was high. The morphological characters such as body mass, head and body length, length of forearms and hind arms, body width, length and width of the ear, width, length and width of tragus, second, third, fourth and fifth metacarpals, maxillary and mandible length, wing-span, thumb, tail length were measured using a digital vernire caliper (Mitutoyo, 500-181,0003472, Japan). Reproductive status was assessed by the body condition of the female. Therefore, females were classified as either visibly pregnant, lactating, or post-lactating. Nipples remained visible after females gave birth, although they reduced markedly in size after lactation. Females without visible nipples or with nipples with hair grown over them were categorized as non-reproductive. If phalangeal epiphyses had not yet fused or if only one ring is visible, the bat is the young of the year; such bats were classified as juveniles.

The weight of the bat was measured by spring balance. Bats were released immediately after taking measurements at the site of capture. Morphological characters of male and female *S. kuhlii* were compared using the Kruskal Wallis H test, (SPSS, version 20) because data was nonparametric. The map was made by ArcGIS. Ambient temperature and humidity were measured by the thermohygrometer. The whole study was conducted monthly.

## RESULTS

### Morphometric variation of male and female

A total of 273 individuals were measured including 45.78% (n = 125) males and 53.84% (n = 147) females. Statistically significant differences were found in morphometric analysis of males and females of *S. kuhlii.* Females had significantly highr body masses (24.93 ± 2.86gm) as compared to males (22.39 ± 1.78gm) (H = 52.287, $P < 0.05$); The forearm length of females (49.03 ± 2.30mm) was longer than that of males (47.66 ± 1.56mm) showing significant differences (H = 18.53, $P < 0.05$). The average of 5th metacarpal was (43.69 ± 3.14mm) and (45.26 ± 7.59mm) of male and female respectively, with statistically significant differences (H = 14.038, $P < 0.05$). Average of 2nd metacarpal of males (45.65 ± 8.60mm) and female (47.34 ± 7.08mm) also showed statistically significant differences (H = 7.089, $P < 0.05$). The average wing-span of male (315.07 ± 8.39mm) and female (316.11 ± 7.51mm) showed statistically significant differences (H = 14.65, $P < 0.05$) (Table 4.1). Few morphological characters like lengths of various body parts such as head, ear, tragus, thumb, maxillary and mandible were not statistically different between males and females of *S. kuhlii* (Table 4.1)**.**

**Table 4.1.** Morphometric analysis of 273 *Scotophilus kuhlii* bats including male (n = 125) and female (n = 148). Mean ± SD is shown and compressions significant value (kruskal Wallis H test, $P < 0.05$) of male and female.

| **Parameter (mm)** | **Male** | **Female** | **Statistical value** | |
|---|---|---|---|---|
| | | | **H** | **P** |
| **Body mass(gm)** | 22.39 ± 1.78 | 24.93 ± 2.86 | 52.827 | **0.001** |
| **Body length** | 49.94 ± 7.32 | 50.71 ± 7.29 | 2.936 | 0.087 |
| **Head length** | 12.48±2.78 | 12.78 ± 3.07 | 0.237 | 0.627 |
| **Tail length** | 45.33 ± 2.83 | 45.63 ± 2.89 | 0.233 | 0.629 |
| **Ear length** | 11.29 ± 1.33 | 11.1 ± 1.42 | 0.653 | 0.419 |
| **Tragus** | 5.93 ± 0.82 | 6.13 ± 0.79 | 2.625 | 0.105 |
| **Forearm** | 48.02 ± 4.39 | 49.04 ± 2.80 | 18.532 | **0.001** |
| **5th Metacarpal** | 43.69 ± 3.14 | 45.26 ± 7.59 | 14.038 | **0.001** |
| **First phalanx** | 11.71 ± 5.09 | 11.03 ± 1.96 | 0.119 | 0.73 |
| **Second phalanx** | 9.72 ± 1.87 | 9.82 ± 2.00 | 0.192 | 0.661 |
| **4th Metacarpal** | 46.82 ± 2.26 | 47.13 ± 2.06 | 2.705 | 0.1 |
| **First phalanx** | 15.24 ± 1.95 | 15.578 ± 1.48 | 0.445 | 0.505 |
| **Second phalanx** | 10.96 ± 1.42 | 11.11 ± 1.59 | 1.009 | 0.315 |
| **3rd Metacarpal** | 47.94 ± 2.05 | 47.84 ± 5.85 | 3.784 | 0.052 |
| **First phalanx** | 12.19±1.75 | 12.39 ± 2.01 | 0.222 | 0.638 |
| **Second phalanx** | 11.22±1.36 | 11.25 ± 1.83 | 0.733 | 0.392 |
| **2nd Metacarpal** | 45.65 ± 8.60 | 47.34 ± 7.08 | 7.089 | **0.008** |
| **Wing span** | 315.07 ± 8.39 | 317.11 ± 7.22 | 14.65 | **0.001** |
| **Thumb length** | 6.1 ± 0.58 | 6.09 ± 0.64 | 0.014 | 0.905 |
| **Maxillary length** | 11.29 ± 1.28 | 11.59 ± 1.04 | 3.663 | 0.056 |
| **Mandible length** | 10.12 ± 1.34 | 10.24 ± 1.35 | 0.005 | 0.945 |
| **Hind arm** | 17.85 ± 2.43 | 18.52 ± 2.07 | 4.927 | **0.026** |

### Morphometric variation in reproductively active male and female *S.kuhlii*

A total of 20.87% (n = 57) adult males of *S. kuhlii* were analyzed for access in scrotum length. It was observed that seasonal variation occurred in male scrotum length, which maximum scrotum length in February (13.14 ± 0.51mm) and minimum in Nov (10.31 ± 0.49mm) (Figure 4.1).

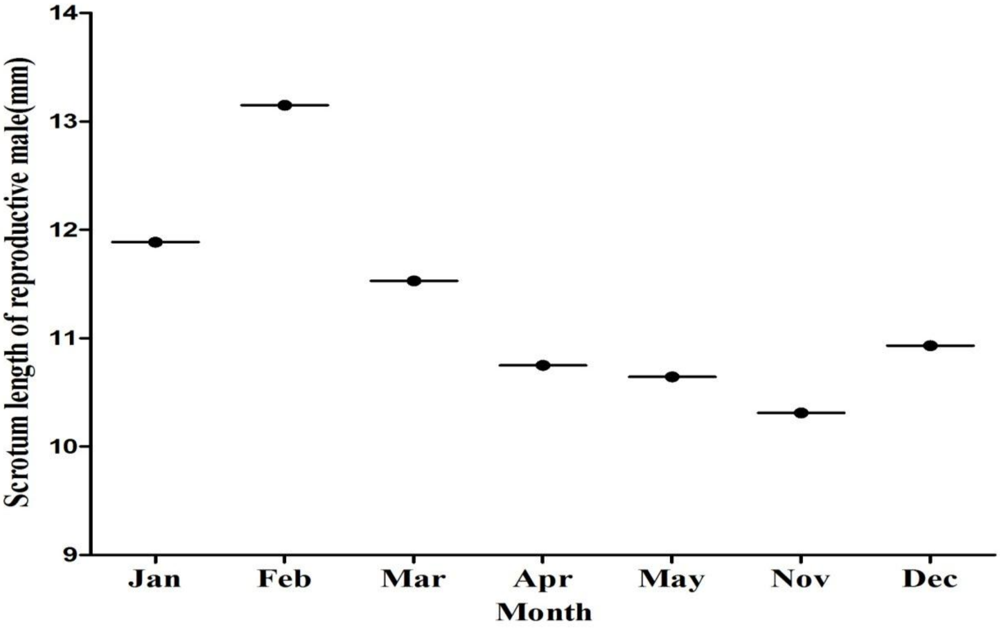

**Figure 4.1.** Scrotum length of reproductively active male measured during breeding season.

A total of 27.83% (n = 76) pregnant females were analyzed to assess variation in body mass and body width of pregnant females. Pregnant females of *S. kuhlii* gained body mass faster than males throughout the gestation period. The average body mass in January was (20.27 ± 0.46gm). Pregnant females were not found in January but the vaginal swab consideration indicated that such females were reproductively active. Females had greater body mass in May (26.33 ± 1.29gm) which decreased during June (Figure 4.2) June was observed being the lactation period.

Besides, the body width of pregnant females was increasing with increase in body mass (Figure 3.3). Pearson correlation analysis showed a significant difference between body mass and body width of pregnant females (r = 0.613**) (** correlation is significant at the 0.01 level). Body mass of non-reproductively males and females fluctuated throughout the season. The average body mass (21 ± 0gm) was observed in November and December while the maximum in October (23.85 ± 0.89gm) (Figure 3.4).Females' body mass was (21 ± 1gm) in December while maximum (22.4 ± 0.54gm) in November (Figure 3.8).

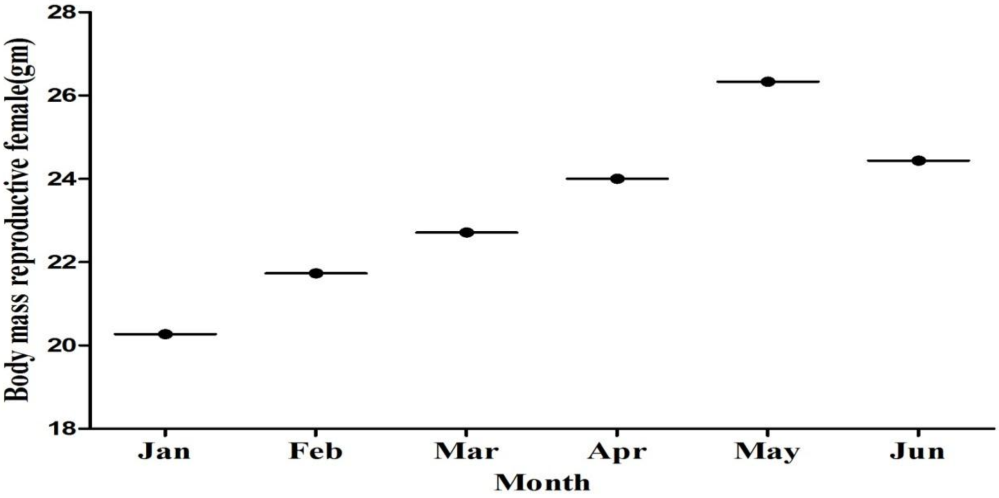

**Figure 4.2.** The body mass of pregnant female of *S. kuhlii* measured during breeding season.

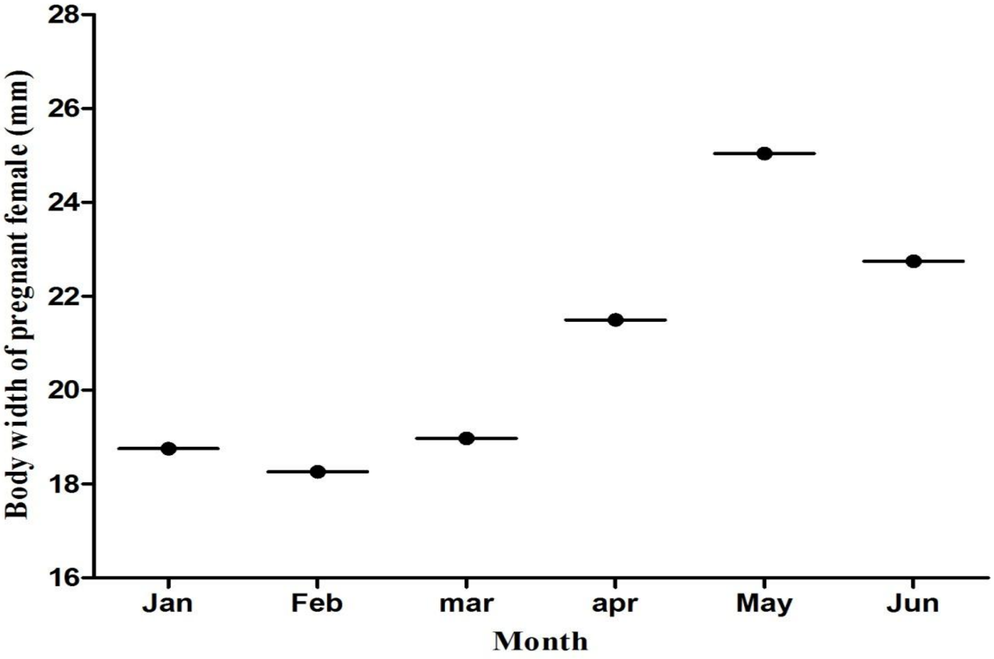

**Figure 4.3.** The body width of pregnant female of *S. kuhlii* measured during breeding season.

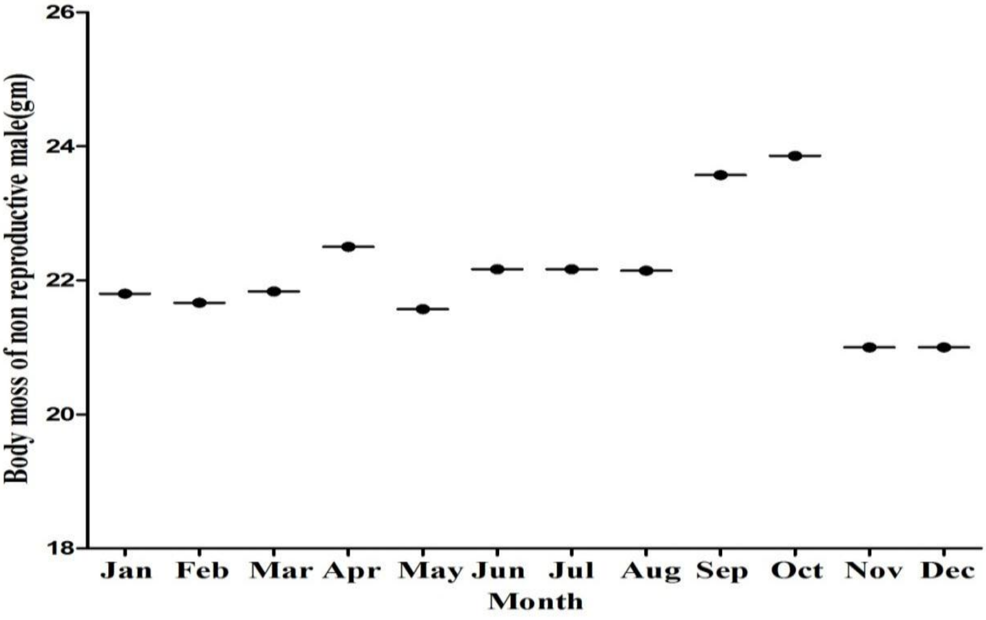

**Figure 4.4.** The body mass of non-reproductively active male of *S. kuhlii*.

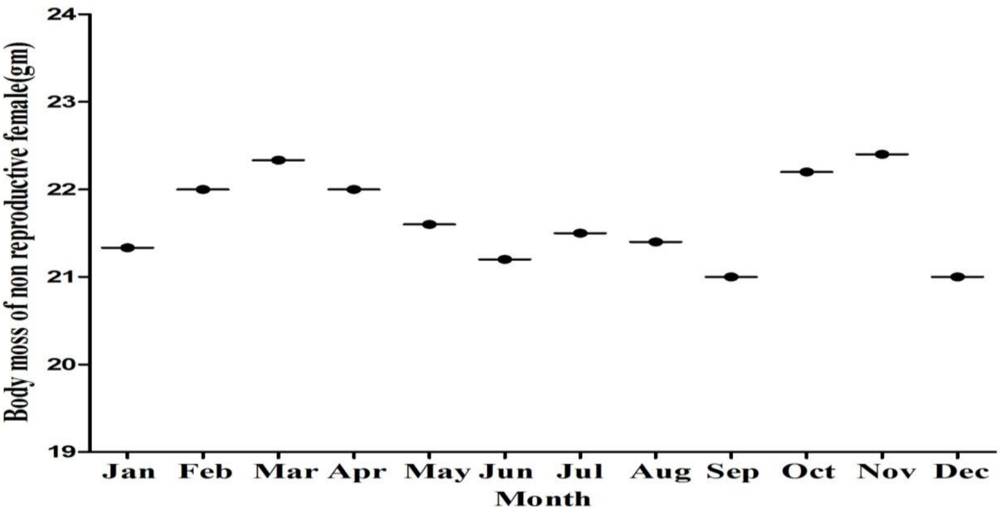

**Figure 4.5.** The body mass of non-reproductively active female of *S. kuhlii.*

**Reproductive behaviour of *Scotophilus kuhlii***

A total of 34 hours have been observed behaviour of *S. kuhlii* during breeding season from February to June. In February a total of 6:45:0 hours behaviour was observed, which only three reproductive behaviour such as male groom their genital organ (15.16 time/ hrs) was maximum behaviour observed (Figure 4.6).

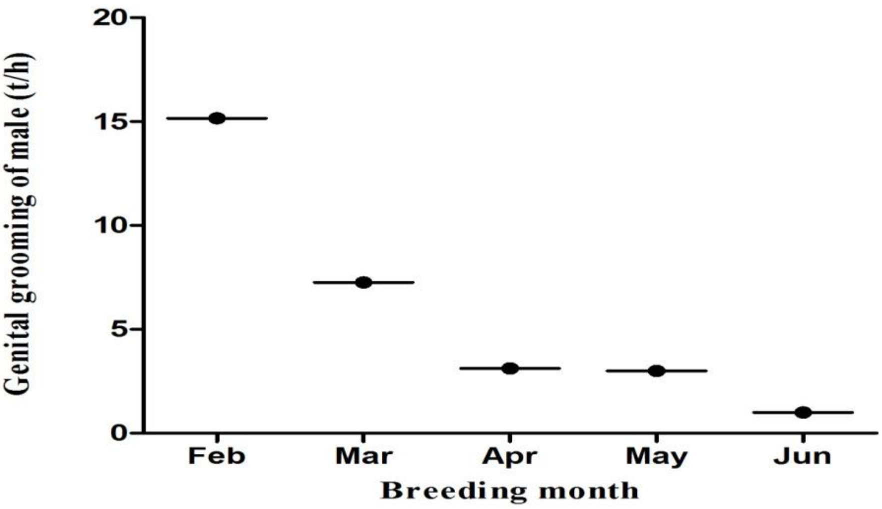

**Figure 4.6.** Genital grooming by male during breeding period.

While courting, male sniffs the female's vagina (9.13t/hrs) (Figure 4.7) and vagina licking number was (9.27t/hrs). The copulation attempt was (9.29t/hrs) by courting male was observed. The mating success was observed in the present study on February 15, 2018. In March, 2018 a total of 6:23:0 minutes behaviour was observed. The behaviours were gradually decrease such as genital grooming (7.25t/hrs) (Figure 4.6), urogenital licking (8.8t/hrs) (Figure 4.8), urogenital sniff (9.35t/hrs) (Figure 4.7) and copulation attempt (9.03t/hrs). Vagina licking by the pregnant female was seen for the first time in my studies (5.29t/hrs).

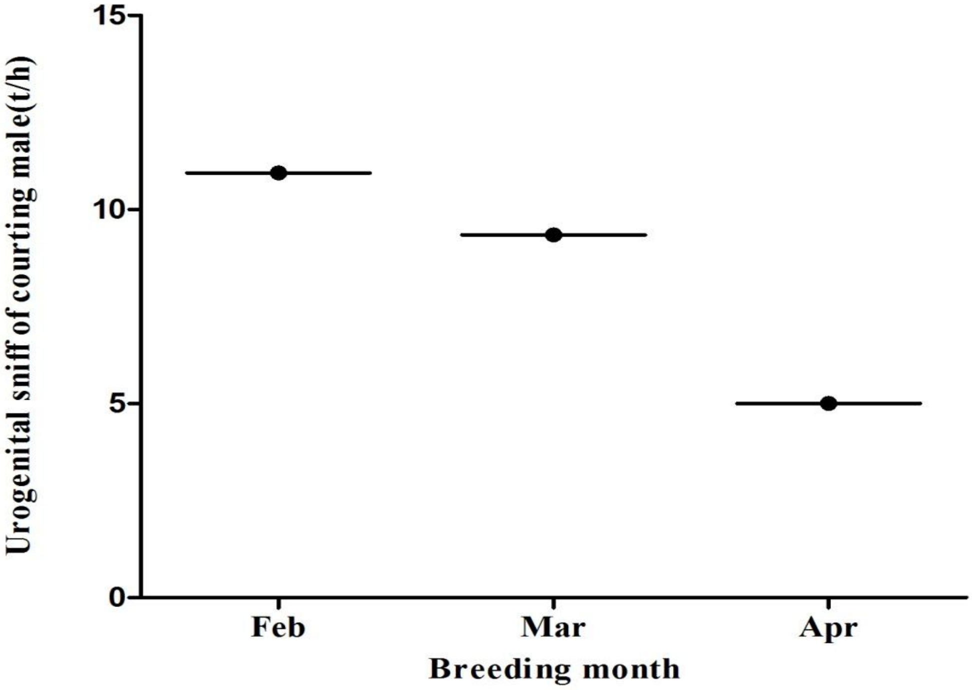

**Figure 4.7.** Urogenital sniff by male during breeding period

In April, 2018 a total of 8 hours 3 minutes behaviour was observed, A few behaviour like urogenital licking disappeared in April, 2018 while remaining behaviours gradually decreased in their frequency of occurrence. Vaginal licking (10.25t/hrs) gradually increased (Figure 4.8). In May, 2018, a total of 6 hours 21 minutes behaviour was observed and this time two behaviours: urogenital sniff and urogenital licking disappeared while vaginal licking by a pregnant female was on the peak (13.64t/hrs). Two pups were seen attached with their mother’s belly. First-time infant groom was seen by mother (9.78t/hrs).

In June, 2018, a total of 6 hours 33 minutes behaviour was observed, only genital grooming (2.63t/hrs) (Figure 4.6) was seen and all reproductive behaviours disappeared. Besides, few other behaviours were also observed in whole breeding month, such as general grooming (9.86t/hrs) tooth grooming of male and female(5.81t/hrs) and yawning of male and female was (50.65 t/hrs) seen.

**Morphometric Analysis of Pups of *S. kuhlii***

It was observed that *S. kuhlii* made a harem of one or two males with more than three females till the mating success. While at the time of birth pregnant, female lived alone or with two females in maternity roost. Courting males lived in adjacent roost until the pup flied away. The gestation period was approximately 112 days. Parturition occurred on June 28, 2018. A female gave birth to two pups. Newborn pups had red-brownish, back and light pink belly with closed eyes. The pups were almost hairless. The average forearm length of pups at birth was (19.41 ± 0.77mm) and the average body mass was (3.65 ± 0.49). Averages of 5th metacarpals (13.75 ± 1.26mm), 4th metacarpals (11.98 ± 1.33mm), 3rd metacarpals (13.81 ± 0.21mm) and 2nd metacarpals were (14.36 ± 0.001mm). While the average wing-span was (110.64 ± 0.14mm), average maxillary (4.57 ± 0.10) and mandibular (3.57 ± 0.010) (Table 4.2).

**Table 4.2.** Morphometric analysis of pups of *Scotophilus kuhlii* bats including a male and a female. Mean ± SD is shown.

| **Parameter(mm)** | **Pup** | | |
|---|---|---|---|
| | **M** | **F** | **Mean ± SD** |
| **Body mass(gm)** | 3.3 | 4 | 3.65 ± 0.49 |
| **Body + head length** | 38.83 | 40.57 | 39.7 ± 1.23 |
| **Head length** | 15.54 | 15.54 | 15.54 ± 0 |
| **Tail length** | 33.32 | 32.96 | 33.14 ± 0.25 |
| **Ear length** | 4.65 | 4.5 | 4.575 ± 0.10 |
| **Ear width** | 3.65 | 3.86 | 3.755 ± 0.14 |
| **Targus** | 1.57 | 1.86 | 1.715 ± 0.20 |
| **Forearm** | 18.86 | 19.96 | 19.41 ± 0.77 |
| **5th Metacarpal** | 12.86 | 14.65 | 13.75 ± 1.26 |
| **First phalanx** | 3.86 | 4.65 | 4.25 ± 0.55 |
| **Second phalanx** | 2.54 | 2.65 | 2.59 ± 0.07 |
| **4th Metacarpal** | 11.04 | 12.93 | 11.98 ± 1.33 |
| **First phalanx** | 2.65 | 2.76 | 2.70 ± 0.07 |
| **Second phalanx** | 2.32 | 2.6 | 2.46 ± 0.19 |
| **3rd Metacarpal** | 13.96 | 13.66 | 13.81 ± 0.21 |
| **First phalanx** | 4.54 | 4.54 | 4.54 ± 0 |
| **Second phalanx** | 3.86 | 3.65 | 3.75 ± 0.14 |
| **2nd Metacarpal** | 14.86 | 14.87 | 14.36 ± 0.01 |
| **Wing span** | 110.54 | 110.75 | 110.64 ± 0.14 |
| **Thumb length** | 3.8 | 3.87 | 3.83 ± 0.04 |
| **Maxillary length** | 4.5 | 4.65 | 4.57 ± 0.10 |
| **Mandibular length** | 3.65 | 3.5 | 3.57 ± 0.10 |
| **Hind arm** | 12.4 | 10.95 | 11.67 ± 1.02 |
| **Foot** | 1.85 | 1.6 | 1.72 ± 0.176 |

## DISCUSSION

Based on the observations, mating in *S. kuhlii* involved a single with multiple females in territory sites occupied by single males. The territory sites included small caves, mines or cellars (Ransome, 1991). The present study is similar to previous work reported by Ransome, 1991. *S. kuhlii* roosts mostly in an abandoned buildings, monuments, tree cavities. The gestation is period approximately 112 days. Females gave birth to two pups once a year in the last week of May month, 2018. Chen *et al.* (2016) reported that parturition in *S. kuhlii* occurred on the first to the second week of June. Parturition of *S. kuhlii* may be varied according to a geographical area. Newborn pups had red-brownish back colour and light pink belly with closed eyes and hairless body. The present result is similar to previous work reported by Chen *et al.* (2016). Pups are always attached to their mother for one week. Gould (1975) reported that most of the newborn bats are not well furred, are weaned at a larger size and are completely dependent on their mothers. Mother left their pups in maternity roost during foraging. The mother foraged around the maternity roost to a short time. Just opposite result was reported by Hamilton and Watt (1970); Kunz (1974, 1982). Reproductively active male bats may shorten foraging time during the breeding period (Hamilton and Watt, 1970; Kunz, 1974, 1982). Males often live in roost adjacent to maternity roost until pups fly. It is speculated that males do not involve in parental care. Several previous studies reported that male parental care was occasional among mammals (Clutton-Brock, 1991), while almost absent among bats (Kunz and Hood, 2000). An adult individual of *S. kuhlii* is pelage coloured, the dorsal region olive-brown and creamy on ventral side. The ears are small and half-moon shaped which is an adaptation for conserving heat. The larger surface areas lose heat faster compared to the smaller surface areas (Kingston *et al.*, 2010; Rahman and Chaudhary, 2017). Our result is similar to previous work reported by Kingston *et al.* (2010). The average forearm length of females is longer than that of males. This helps in thermoregulation due to increase length of forearm simultaneously increase the wing area, which maintains the heat of the body. Similar results were also reported by Zhu *et al.* (2012) and Goodman *et al.* (2005) that forearm of males shorter than that of females.

Previous study-reports natural selection supports a wing shape which makes it easy for flight in a different situation, which reduces the extra load during the flight (Norberge and Rayner, 1987). Bats hawking high-flying insects have small, pointed wings that give good agility, high flight speeds and low cost of transport (Norberge and Rayner, 1987). Our result showed that the wingspan longer of females than males. The average wing-span of female of *S. kuhlii* is longer than that of males, was recorded by Goodwin, (1979). Longer wing-span provides resources by maintaining a territory for the un-matured females and young ones (Ralls, 1976). Body mass of females was higher than that of males because body fat content is more in females as compared to males. A similar study found that body mass of female *S. kuhlii* was higher as compared to males (Zhu *et al.*, 2012). Flux (1967) suggested that females were heavier compared to males according to seasonal variation in the body mass: females had more body mass and males had low body mass in spring. Previous studies conducted by Goodman *et al.* (2005) show that ear and hind arm lengths are shorter in males. Our result showed no differences in morphological characters like in length of head, tail and ear, between male and female.. Earlier studies by Elangovan and Kumar (2015) reported that the ears of this species (*S. kuhlii*) are small and half-moon shaped. Loss of roost occurs by several factors such as fire, decay, deforestation, tree fall and anthropogenic activities (Sedgwick and Knopf, 1992). Depletion of these sitesaffect the flora and fauna which largely threaten biodiversity globally (Henle *et al.,* 2004; Sala *et al.,* 2000).

The pregnant females' body mass increases one fourth from foetal mass alone during pregnancy (Kunz and Hood 2000; Kunz *et al.,* 1995b). Our results showed body mass of pregnant females continuously increases till parturition and again reduces to original body mass when lactation period starts. Parturition and lactation period are very costly. Therefore, more energy is required to maintain a basic metabolic rate. Lactation period is more costly (Dammhahn, 2008; Loudon, 1987; Rogowitz, 1996). Previous studies report that during lactation females frequently reduce their body weight (Canale *et al.,* 2012). Increasing the body mass of pregnant females simultaneously increases the breeding season length and gestation period. Pregnant females in early spring, adult males in late spring, juveniles, and post-lactating females in early summer, and adult females in late summer had the latest median emergence times (Reichard *et al.,* 2009). Seasonal variation in body mass of hibernating species (Ransome, 1990) requires high energy demands during this period. Hence, the animals build up body-fat reserves after the breeding season (Ewing *et al.,* 1970; Kunz *et al.,* 1998; Speakman and Rowland, 1999). After that, these fat reserves gradually decline, In consequence, bats are lightest when they leave their hibernation roosts. Our results showed that seasonal variation in body mass of non-reproductive male and female of *S.kuhlii* was a similar to the result reported by Encarnacao *et al.* (2006) and Kunz *et al.* (1998). The mating activity starts in late summer when the animals have again increased their body mass (Encarnacao *et al.,* 2006**).** Our results showed that non-reproductive bats gain body mass in summer and monsoon. Juvenile bats in temperate zone store fat in their body before going hibernation in winter (Grindal, 1992). Insect diversity and prey availability are high in summer and monsoon. Courting males lose their energy during mating time. Therefore more energy is required when males pause their mating in early summer. The scrotum length of *S. kuhlii* increased in February and gradually decreased with the end of the breeding season and disappeared in the non-breeding season. Scrotum size shows that males are reproductively active. During the breeding season, clearly visible signs of primary sexual organs such as testes size of Vespertilionidae bats (Cryan *et al.,* 2012). Krutzsch (2000) and Racey (1974) reported that, during spring, the accessory sex glands of males initiate to shrink, which empties the caudal epididymis, and sperm production begins again (Krutzsch, 2000; Racey, 1974).

### Genital grooming

Previous studies report that genital hair has been retained to improve the spread of pheromonal secretions, to increase attractiveness to the other sex (Ramsey *et al.,* 2009). Genital grooming is an innate behaviour which is common during the breeding period. It is played by courting males to attract the opposite sex seen in several mammals. The present study showed that courting males groom their genital organ continuously several second to minutes to stimulate scrotum size and erect penis to complete mating. These are frequently observed in February to the first week of March in the case of *S kuhlii.* While it may vary from species to species. Earlier studies have shown that the males often groom itself by licking the inner surface of the genitalia (Tan *et al.,* 2009). The females lick her mate's penis during copulation and influences the duration of copulation (Tan *et al.*, 2009).

## Urogenital sniff

The sniffing is a natural process in animals to respond to identification through the scent of the same or opposite sex. Roeder (1980) reported that estrus females might distinguish their partner scent marks. This determination of the physiological state of females by courting males is also possible by olfactory cues. Hence, scent marks perhaps allow identifying of estrus females by courting males. During the rutting period, the "hiccup" of the male appears after sniffing and urogenital region a place where an estrus female has just marked (Roeder, I978 a). The present study showed that urogenital sniff by the male was maximum observed before mating. It was often seen in the breeding season. Males often sniff the female’s genitalia to know the status of the sexual maturity of females. It may occur several times, lasting in minutes.

## Urogenital licking

Several mammals lick genitals before and after copulation. The present study showed that male bats lick their partner's vagina regularly during the breeding season. We speculate that males of *S. kuhlii* lick the female genital to increase the lubrication and stimulation to copulation. The male of *Lemur catta* species often licks the genital organ of the female to judge whether she is in estrous (Koyama, 1988). Previous studies report that female *C. sphinx* licks its courting male's penis regularly during copulation and that each second of licking results in influence approximately six extra seconds of copulation (Tan *et al.,* 2009). The female *C. sphinx* licks the male penis to increase penile stimulation, rigidness the penis and maintaining the male's erection (Tan *et al.*, 2009), at the same time, the female's saliva may increase lubrication, thus facilitating intromission and thrusting (Tan *et al.,* 2009). The present study showed that male *S. kuhlii* mating occurs in late winter. (Rossiter *et al.*, 2000) reported that, females visit males to mate in autumn, while copulation can also occur in winter and spring which is determined by female's choice.

## CONCLUSION

*S. kuhlii* was making a territory of one or two males with more than three females till mating success. While at the time of birth, pregnant female lives alone or two females in maternity roost. Courting male lives in the adjacent roost, until pups fly. The gestation period is approximately 112 days. Birth occurs from May to June. A female gives birth to two pups once a year. Newborn pups have red-brownish back and light pink belly with closed eyes and hair free skin. No differences in morphological characters between male and females pups at birth were observed. While in adults, males and females are different in morphological characters. Pregnant females gain body mass dramatically to parturition and lose their body mass during the lactation period. Body mass of non-reproductive individual fluctuates when food availability depending upon the availability of food; when food availability is more, the body mass increases. Mass gaining occurs in summer and monsoon when all insectivorous bats prepares for hibernation. The male sniffs and licks vagina of females before mating during the breeding period to assess the status of estrous. The male grooms its genitals for few seconds to minutes to attract and stimulate females for mating. The males try for copulation for several times to get the success of the mating. The females lick their vagina before birth to enhance cervix opening. Besides, yawing behaviour is common in the *S. kuhlii.*

# *Summary*

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Bats make a significant contribution to mammalian species richness in the tropics. About 1400 known species of bats distributed worldwide. A sum of 128 species of bats is reported from Indian subcontinents which belong to nine families, namely Pteropodidae, Rhinopomatidae, Megadermatidae, Rhinolophidae, Hipposideridae, Molossidae, Emballonuridae, Vespertilionidae and Miniopteridae. Insectivorous bats are indicators of habitat quality and occupy high trophic levels. Bats provide a unique set of challenges for conservation biologists because many species of conservation concern occur outside forests, in degraded or open habitats. Furthermore, many species aggregate in conspicuous and accessible roosts that are often accessible to people, successful conservation measures should include the protection of roost sites, as well as foraging habitats. The non-forest areas include human dwellings, palaces, old monuments; caves in urban and sub-urban areas constitute important habitats for bats.

Roosting ecology of bats is well studied in temperate zone species. Roost selection is a subset of habitat selection which influence the survival and fitness of a species. The roost selection of bats influenced by many factors such as microclimate, structural characteristics of roosts, surrounding habitats, disturbance by humans, and risk of predation. Thus, the study was carried out on the following objectives: 1) Roost characteristics of Asiatic lesser yellow bat, *Scotophilus kuhlii* (Leach, 1821), 2) Effect of urbanization on roost selection of *S. kuhlii*, 3) Seasonal food preference and diet composition of *S. kuhlii* and 4) Reproductive behaviour of *S. kuhlii*. Roost search was carried out at monuments, abandoned buildings and larger trees in rural, semi-urban and urban areas at three distinct seasons such as summer (March–June), monsoon (July–October) and winter (November–February). The active bat roost was located based on the availability of bat guano on the surface of roosts. Further, mist nets were erected adjacent to roost entrance at the time of emergence, the bats were captured, identified and released at the site of capture. The roost sites of *S. kuhlii* were categorized into the abandoned building (ruined building not used by a human being and not listed as a monument by Archaeological Survey of India), monument (historical buildings and palaces protected and listed as monuments by Archaeological Survey of India, Govt. of India) and tree holes (cleft and holes used by bats as a roost in large trees like *Ficus religiosa*, *F. virens* and *F. bengalensis*). Every roost was given a unique roost ID for recognition. The roost characteristics such as roost height above the ground (m), length of the tunnel (cm), roost surface area ($m^2$), roost temperature (ºC), humidity (%), and colony size were recorded at different roost types.

The number of individuals in a harem at the time of observation was considered as colony size and the sum of all individuals of colonies considered as populations. Roost height in monuments and abandoned buildings were measured using a measuring tape (m) and tree height was measured using the clinometer method. The tunnel length was measured using a ruler (cm). The characteristics such as height (m) and diameter at breast height (dbh cm) of roost trees were also assessed. Roost temperature and relative humidity were recorded using a Thermo-hygrometer. Since *S. kuhlii* roosts primarily in tunnel or hole in walls and trees, the shapes of their roosts were categorized as i) branched tunnel or 'T' shape, ii) Gamma or '┐/┌' shape, iii) unbranched tunnel and iv) crevice or cleft. In addition, the roost occupancy of bats, i.e. the bat occupied at the periphery of roost or interior part of the roost was also recorded. In addition, degree of protection (DP) was calculated. Also, the characteristics of unoccupied tunnels located adjacent to occupied tunnels were measured for comparison. The characteristics of unoccupied tunnels were measured as described in occupied roosts characteristics. All those parameters of unoccupied tunnels which showed larger value than the minimum values of occupied tunnels were considered for comparison. Furthermore, maternity roost was also observed in the breeding season.

The whole study was divided into three habitats based on the level of urbanization (mostly house density and agriculture land) such as urban, sub-urban, and rural. In urban, (> 30 dwellings 0.1 $km^2$ and agriculture land > 5 km away from roosting sites); in sub-urban (>20 to < 30 dwellings 0.1$km^2$and agriculture land < 5 km away from roosting sites) and rural, (< 20 dwellings 0.1$km^2$ and agriculture land 200 m away from roosting sites). To estimate the housing density, light, abandoned building, and type of obstruction, whereas used line transect method within 250 $m^2$ from the roosting site. The fecal materials were collected seasonally by spreading polythene sheets (10x14cm) on the attic floor and front of the roost entrance from the various roosting places. From each location, average one gram pellets approximately 25 to 50 pellets collected, and among each location, only 20 pellets were taken at random and analyzed them monthly wise. The express the results of diet analyses for percentage of frequency (%f) and percentage of volume (%Vol) based on the wing, legs, and antenna fragment. Percentage frequency (%f): This is the number of occurrences of the category, divided by the number of samples analyzed, multiplied by 100. Whereas for percentage volume (%Vol): Sum of individual volume divide by total volume of the sample multiply by 100.

A total of 10 roosts were selected to access reproductive behaviour such as courtship, genital grooming, urogenital licking, urogenital sniff, tooth grooming approaching, yawn, and copulation attempt, and success in Siddhartha Nagar district, whereas behaviour was carried out fifteen days interval from February to June 2018. The roosts of *Scotophilus kuhlii* were observed in monuments, abandoned buildings, and tree holes. A maximum percentage of roosts were observed in an abandoned building (46.73%) followed by monuments (40.70%) and tree holes (12.56%), while the highest number of individuals was observed in monuments (323 individuals) followed by abandoned buildings (305 individuals) and trees holes (74). The roosts of *S. kuhlii* were observed generally in abandoned buildings, monuments, and trees holes in which the abandoned buildings and monuments could be the life-support to *S. kuhlii*. The distinct characteristics between occupied roosts and unoccupied tunnels available adjacent to the occupied roost showed that *S. kuhlii* selects its roost wisely as the roosts influence the survival and fitness.

The roost height above the ground, tunnel length, and height of roost entrance differed significantly between occupied roost and available unoccupied tunnels. However, the tunnel width did not differ significantly between occupied roost and unoccupied tunnel. It shows that the roost selection in *S. kuhlii* is influenced by various factors. The selection of roost by *S. kuhlii* was not random among available cavities. There were differences in roost height above the ground, length of the tunnel, a width of the entrance, height of roost trees and dbh of occupied roost and unoccupied roost. The degree of protection plays a critical role in roost selection. The degree of protection was driven principally by tunnel lengths, the shape of roosts and optimum roost height at different roost habitats. The degree of protection was highest in monuments followed by abandoned buildings and tree holes. A maximum number of individuals of *S. kuhlii* found roosting in monuments followed by abandoned buildings and trees. *S. kuhlii* used same-day roost as a maternity roost.

The maternity roost provides a higher temperature and more stable thermal conditions as compared to the ambient temperature. While cold roost temperatures reduce the development of prenatal and juvenile bats. The present study showed that maternity roost temperature was higher than ambient temperature. Higher the maternity roost temperature may influence fetal growth and birth size. Buildings are mostly occupied by reproductively active female bats during the reproductive season to raise their pups because of the energetic benefits and less predation risk. The orientation of maternity roost in the south direction which may reduce solar radiation and warm wind speed.

A total of 82 roosts were observed from three different habitats including urban, sub-urban, and rural sites. Highest numbers of roosts were found in sub-urban (n = 45) followed by urban (n = 23) and in rural (n = 14). Whereas the percentage of roosts was following, sub-urban (54.87%) was significantly selected above all other habitat categories, followed by urban (28.04%) and rural (17.07%). Several factors are important for survival in adverse conditions, such as abandoned buildings have a lot of cavities, crevices, and hole, etc., to provide space for resting, mating and protect from predators. Street light, attracts a mass of nocturnal insects preys during foraging. Whereas, water-body and vegetative resources close to roost, save the extra expenditure energy, and avoid a natural predator and long-distance forage. Therefore, bats are provided extremely ecosystem services provided directly to the production of goods and services consumed by humans.

Urbanization is causing serious damage to natural habitats and heritage as a result unbalancing ecosystem. A variety of factors are limiting bat abundance and diversity in Uttar Pradesh urban habitats. though, by successfully handling existing habitat patches, correcting community misconceptions about bats, and advancing research about urban bat ecology, then may possible to increase the suitability of urban environments for bat species. The colony size and number of a roost of *S. kuhlii* were significantly higher in non-plaster abandoned buildings that closed to a human-occupied building than isolated plaster building in among habitats. Non-plaster buildings provided different kinds of space such as a hole, crevices and cavities which important for roost selection compared to plaster building, and also roost closed to a human-occupied building which radiuses the nocturnal predator.

The habitats obstruction was one of the main negative factors that affected on roosts selection of *S kuhlii* in three habitats. The process of renovation was higher in urban habitats, followed by the sub-urban and rural ones, while constructions were higher in sub-urban in among the habitats. The older buildings are more susceptible to roost loss and more prone to renovation. However, it provides a different kind of space. Hence, *S. kuhlii* selected old buildings for roosting which important for roost selection because of a large number of unwanted spaces. High levels of urbanization can negatively affect, which increases the house-density decreases the colony size among the habitats. Dense house density areas cause their lake of a suitable site such as an unwanted hole, crevices, and cavities which important for roosting. While the intermediate house density area provided suitable space for roosting and least house density area also provides space but less number of the house cause less space. Hence, an intermediate level of house density may play a crucial role in the selection of the roost site.

The adjacent water source distance was negatively affected by colony size among the habitats i.e. increases the water distance decrease the colony size. Food resources would long distance from roost may bat spent more energy on foraging and would increase the predation risk. The *S. kuhlii* select roosts closer distance from opened foraging and water source.

A total of 11 families of insects were identified corresponding to 9 insect orders based on the Leg, Antenna, and Wings or elytra, trough 3048 isolated remnants from a total of 720 pellets were analyzed. A total of 26.83% of remnants could be identified order and family level; the remaining 73.5% remnants were unidentified family level, the total frequency of prey item in the pellets. Whereas a total of 23 insect families corresponding eight orders were captured from various foraging grounds it was seen seasonal variation occurred in the diet of *S. kuhlii*. *S. kuhlii* fed mainly Coleoptera, Lepidoptera, Orthoptera, Diptera, Hemiptera, and Hymenoptera.

The order Coleoptera, Lepidoptera, Orthoptera, Diptera, and Hemiptera were major foods items in diets of *S. kehulii* throughout the season including summer, monsoon, and winter. The Gryllidae and Acrididae were major food items involve in their diet, while, Erebidae (Moth), Termitidae, and Culicidae (Flies) were the second major food item in summer. Whereas, family Acrididae (Grasshopper) was maximum captured in March to September and disappeared August and October to January while Gryllidae (Crickets) was maximum captured in April to September and disappeared August and October to March, and Culicidae (Flies) was maximum captured in July, June, and April. Some small insect groups are not consumed by the bat even if they are very abundant in the habitats area because they have lower biomass, as a result, lower energy content provided, compared to larger pray items.

The Apidae and Formicidae were very less fed by *S. kuhlii* in summer. Region behind it this family Apidae (Haney bee) maximum captured in May and July from foraging ground. While Crambidae, Gryllidae, and Formicidae were major food item in the diet of *S. kuhlii* in monsoon season. Whereas Crambidae (Grass-moths) was maximum captured in October and November and absent in June, July, August, September and again appeared in February to May but there was rare, Gryllidae (Crickets) was maximum captured in April to July and September, Formicidae (Fly ants) was maximum captured in July, while totally disappeared in September to April and again appeared in May. Therefore, the Formicidae (Fly ant,) was the third major food item in the diets of *S. kuhlii in* monsoon.

The family Erebidae, Crambidae, and Lasiocampidae, Cerambycidae, Pentatomidae, and Acrididae was a major food item in their diet in winter when another prey item was limited. Whereas, Lasiocampidae (Snout moths) maximum captured in December and it is disappeared in January to February and April to August and again appeared in March, Erebidae (Moth) was maximum captured in March, October, and November and disappeared in May to September and December, Crambidae (Grass-moths) was maximum captured in October and November and disappeared in December, January and June to September and again appeared in March, and Cerambycidae (Long-horned beetle) appeared in October which maximum captured in November and December and disappeared in January to September and Pentatomidae (Sting bug) was maximum captured in April, July, August, and September and disappeared in October to March, May, and June. The moth has a highly fatty body and provides more energy-rich sources therefore bat maximum feed them. Hence, *S. kuhlii* may be a good pest control agent, and delivers economically valuable ecological services and decrease health risks to humans by reducing dependence on pesticides.

A total of 34 hours have been observed reproductive behaviour of *S. kuhlii* during breeding season from February to June, 2018. *S. kuhlii* was making a territory of one or two males with more than three females till mating success. While at the time of birth, pregnant female lives alone or two females in maternity roost. Courting males lived in adjacent roost until the pup flied away. The gestation period was approximately 112 days. Parturition occurred on June 28, 2018. A female gave birth to two pups. Newborn pups had red-brownish back and light pink belly with closed eyes. The pups were almost hairless. The average forearm length of pups at birth was (19.41 ± 0.77mm) and the average body mass was (3.65 ± 0.49).

No differences in morphological characters between male and females pups at birth were observed. While in adults, males and females are different in morphological characters. Pregnant females gain body mass dramatically to parturition and lose their body mass during the lactation period. Body mass of non-reproductive individual fluctuates when food availability depending upon the availability of food; when food availability is more, the body mass increases. Mass gaining occurs in summer and monsoon when all insectivorous bats prepares for hibernation. The male sniffs and licks vagina of females before mating during the breeding period to assess the status of estrous. The male grooms its genitals for few seconds to minutes to attract and stimulate females for mating. The males try for copulation for several times to get the success of the mating. The females lick their vagina before birth to enhance cervix opening. Besides, yawing behaviour is common in the *S. kuhlii*.

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# REPRODUCTIVE BEHAVIOUR OF ASIATIC LESSER YELLOW BAT, *SCOTOPHILUS KUHLII* (CHIROPTERA : VESPERTILIONIDAE) IN UTTAR PRADEH, INDIA

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**ABSTRACT : Reproductive behaviours are crucial to the stimulation of genital. Aim of this study to access to reproductive behaviours of *Scotophilus kuhlii* including genital grooming, sniff, and licking in Siddharth Nagar. Furthermore, the morphometric variation including scrotum length of male, body mass was access in reproductively and non-reproductively active of Asiatic lesser Yellow bat, *S. kuhlii* at various districts from 2016 to 2018 in Uttar Pradesh, India. Video recorder used for access reproductive behaviour and Mist net used for captured for access the morphometric variation. Our result indicates that a total of 34hours have been observed behabiour of *S. kuhlii* such as genital grooming, urogenital sniffing, urogenital licking by a male were increased in February, after which gradually decreases. While vaginal licking by a pregnant female was maximum performed in April. The body mass of pregnant females was gradually increased until birth while scrotum length of a male maximum length size in February and minimum in November. The females gave birth to two pups in the last week of May. Newborn pups red-brownish in colour back and light pink belly which closed eyes and hairless. We conclude reproductive behaviour was important to make a success of the reproduction.**

***Key words :*** Genital grooming, genital sniffing, genital licking, morphometric characters, *S. kuhlii*.

## INTRODUCTION

Reproductive behaviour is performed by a variety of physiological, ecological and social interactions. The genetic structure of populations is largely determined by the breeding behaviour of the individuals within them. The high variance in the male reproductive success associated with polygyny can decrease the population size, potentially rapidly genetic drift and selection (Chesser, 1991). Several gregarious species from mammalian taxa including pinnipeds (Boness, 1991), rodents (Hayes, 2000), bovids (Berger, 1992) and bats (Tuttle and Stevenson, 1982; Kunz and Hood, 2000) exposer of environmental factors and social conditions that enhance reproductive success during the breeding season. The effect of seasonally and spatially fluctuation food supplies and climate conditions likely influence the timing and location of reproduction (Kunz, 1973; Hoying and Kunz, 1998). Thus, animal behaviors that enhance an individual's fitness in the context of the group are likely to be favored.

Speakman (2008) reported that reproduction is more costly, required more energy and elements such as protein and calciumduring pregnancy and lactation period.Hence, in small mammals, during breeding period more energy required to generally influence the physical condition and complete the reproductive cycle (Thompson, 1992; Dammhahn, 2008). The energetic cost of reproductive effort such as gametogenesis, courtship, mating is probably sex-dependent and possibly high (Huchard, 2012), but overall poorly quantified (Kenagy, 1987). Eventhough, the critical importance of understanding the mating system function for establishing conservation strategies, unknown of detail mating system function in several animals (Lane *et al*, 2011). Whereas, temperate-zone vespertilionid bats are unique among mammals because of the pronounced temporal asynchrony of primary and secondary sexual functions.

Sperm production by males begins during spring and continues through summer, while females are birthing and raising their offspring during breeding season (Wimsatt, 1960; Gustafson, 1979). This situation bats faced a particular challenge because their mating periods often extend into seasons when food resources become scarce or unavailable (Cryan *et al*, 2012). Hence, mating systems of temperate insectivorous bats delay their reproductive system which both males and females capable of storing sperm for several months, especially seen among the Vespertilionidae bats (Wimsatt *et al*, 1966; Crichton, 2000). These situations occur when food availability and necessary to fuel sperm production, is not available (Cryan *et al*, 2012).

Copulation generally begins in autumn while few species continue mating occasionally through the winter and into spring (Barbour and Davis, 1969; Racey and Entwistle, 2000). The secondary sexual function in vespertilionid bats match with typical externally visible signs of primary sexual function such as maximum testes size, which seasonal increases in resource availability, whereas common in other animals (Cryan *et al*, 2012), however, these are specific seasonal timing and age at which mating initiates in vespertilionid bats can be difficult to determine, because mating might often occur more than half a year before (Cryan *et al*, 2012). Rossiter *et al* (2000) reported that in autumn, females visit males to mate, although copulation can also occur in winter and spring. Therefore, breeding partnerships appear to be primarily determined by female choice. These can be up to more than one female who chose a single male (Ransome, 1991).

Mattings performed in territory sites occupied by single male, which may be small caves, mines or cellars and part of a larger underground system (Ransome, 1991). At the time of mating male reproductive success is determined by female choice (Rossiter *et al*, 2000) then female dispersal during mating will influence spatial differentiation, while the male reproductive life span will affect the extent of temporal differentiation (Rossiter *et al*, 2000). The vast majority of fatalities occur during late summer and autumn a period that matches both autumn migration and the beginning of accepted mating periods in many of the affected species (Arnett *et al*, 2008; Cryan and Brown, 2007; Cryan and Barclay, 2009). Gestation and lactation are critical periods of energy expenditure (Gittleman, 1988) to require extra energy to fetal growth and the development of reproductive organs including the uterus, placenta and mammary gland, entail a drastic increase of energy expenditure. After that birth, lactation is even also more costly (Loudon and Racey, 1987; Rogowitz, 1996; Dammhahn and Kappeler, 2008). Kunkele (2000) reported that in the guinea pig *Cavia porcellus* the daily energy expenditure during gestation is 2.4 times the basal metabolic rate (BMR) and 3.7 times the BMR during lactation. The extent of such costs places reproductive decisions at the core of life-history trade-offs (Stearns, 1992; Williams and Editor, 1966).

They exhibit unusual life histories for small-sized mammals in that they are long-lived develop more slowly and produce few offspring. The mating activity starts in late summer when the animals have increased their body mass or size and improved physical condition such as a genital organ. Although, it is the seasonal variation in body mass and reproductive condition of an adult male seen Daubenton's bats and male young of the year were analyzed in previous studies (Encarnacao *et al*, 2006).

Bairn size at birth and postnatal growth and development could be influenced by biotic and abiotic factors, including food availability, weather conditions, foraging success, metabolic rate, sex, litter size, colony size, and social conditions (Tuttle, 1976; Tuttle and Stevenson, 1982; Kunz and Stern, 1995; Hoying and Kunz, 1998; Baptista *et al*, 2000; Koehler and Barclay, 2000; Kunz *et al*, 2010). Pup size at birth and post-delivery growth also reflects the parental effort during pregnancy and the postnatal period (Read and Harvey, 1989; Promislow and Harvey, 1990). Bats gave birth relatively large young one compared with other similarly sized terrestrial mammals (Chen *et al*, 2016). In general, it's the body mass of offspring is higher in smaller mammal species compared to large species (Chen *et al*, 2016). In terms of bairn mass, which is strongly associated with wing loading in pregnant females, vespertilionids bats that produce twins have the highest body mass as a percentage of maternal mass up to 50 percent (Kurta and Kunz, 1987). Hence, the energetic cost for bats to produce and raise young is relatively high, which may cause a depletion of nutrient reserves in females and constrain the litter size (Barclay, 1994, 1995; Kunz *et al*, 2009). Female bats nurse their young one until the pups have nearly achieved the adult size and are capable of flight, foraging and echolocation (Chen *et al*, 2016).

The female short-nosed fruit bats lick their mate's penis often throughout copulation, and that every second of licking outcomes in almost six extra seconds of copulation (Tan *et al*, 2009). Several animals may lick their reproductively active mate's genitals before and after to judge whether she is in estrous (Koyama, 1988). Grooming behabiour is a crucial and evolutionarily ancient behavior observed across several animal taxa (Terry, 1970; Sachs, 1988). The main reason for hygiene and caring for the body surface, stimulation of the skin, thermoregulation, chemo-communication, social interaction and stress reduction (Terry, 1070; Sachs, 1988; Colbern and Gispen, 1988). The behavior of this type creates 15–50% of waking time and may be generated by swimming, pain, exposure to predators, and sexual behavior (Kalueff and Tuohimaa, 2004; Kalueff *et al*, 2007). The mice and hamsters raise their frequency of sniffing from ''resting'' frequencies near 2 Hz to 4–12 Hz when searching new odor sources during operant tasks (Welker, 1964; Verhagen *et al*, 2007; Wesson *et al*, 2008). The dogs show various sniffing behaviors when tracking a scent in air versus on the ground (Thesen *et al*, 1993) and water shrews change their sniffing behavior depending on the shape of the objects during searching or hunting of the prey hunting (Catania *et al*, 2008). Therefore, our aim of this study to access to reproductive behaviour including genital grooming, urogenital sniff and urogenital licking and morphometric variation including scrotum length of male, body mass in reproductive and non-reproductive of Asiatic lesser Yellow bat, *S. kuhlii*.

## MATERIALS AND METHODS

A total of ten roosts were selected and given a roost ID number to access the reproductive behabiour such as courtship, genital grooming, Urogenital licking, Urogenital sniff, Tooth grooming Approaching, Yawn and copulation attempt, and success in Siddharthanagar district, whereas behaboiur was carried out fifteen days interval from February to June 2018 (Fig. 1). The tagged 20 individuals including 8 males and 12 females from the selected roosts. The tagged individuals were following: (A) roost, two males and three females, (B) roost, a male two females, (C) roost, three female, (D) roost, a male and two female, (E) roost, two males, (F) roost, two males and two females. Self-made metal tags of copper wire with colored beads to identify male and female individuals. The tags were less than 0.5gm of body mass of bats. A maternity roost was never vacated by *S. kuhlii* throughout the breeding season, which was T (Single entrance which inward divide in to both side) shape and higher the cavity or tunnel length. Remaining other roosts occupancy were fluctuating in the breeding season due to less covity or tunnel length and larger size of roost entrance. Therefore, only we chose a roost for behavior observation. End of the breeding season only two tagged males and three females were returned to the same roost was observed in June last. The behviour was observed by CCTV Camera during the breeding season (February to June), the CCTV Camera was fixed by the metal hanger (Self-made) at front of maternity roost. The recording was performed 24 hours observation from 6:00 am to 6:00 am. The whole recording was recorded in a single data card (32GB). When completed 24hr recording, we transfer data in HP Laptop to could pull the behabiour related data. A total of 34 hours behaviour was recorded from 92 videos recording, which average recoding time was 22: 16 minutes.The several types of behaviour including courtship, genital grooming, Urogenital licking, Urogenital sniff, Tooth grooming Approaching, Yawn and copulation attempt and success have been recorded. The successful mating with the tagged female could not confirmed until it gave birth on 28th May 2018.

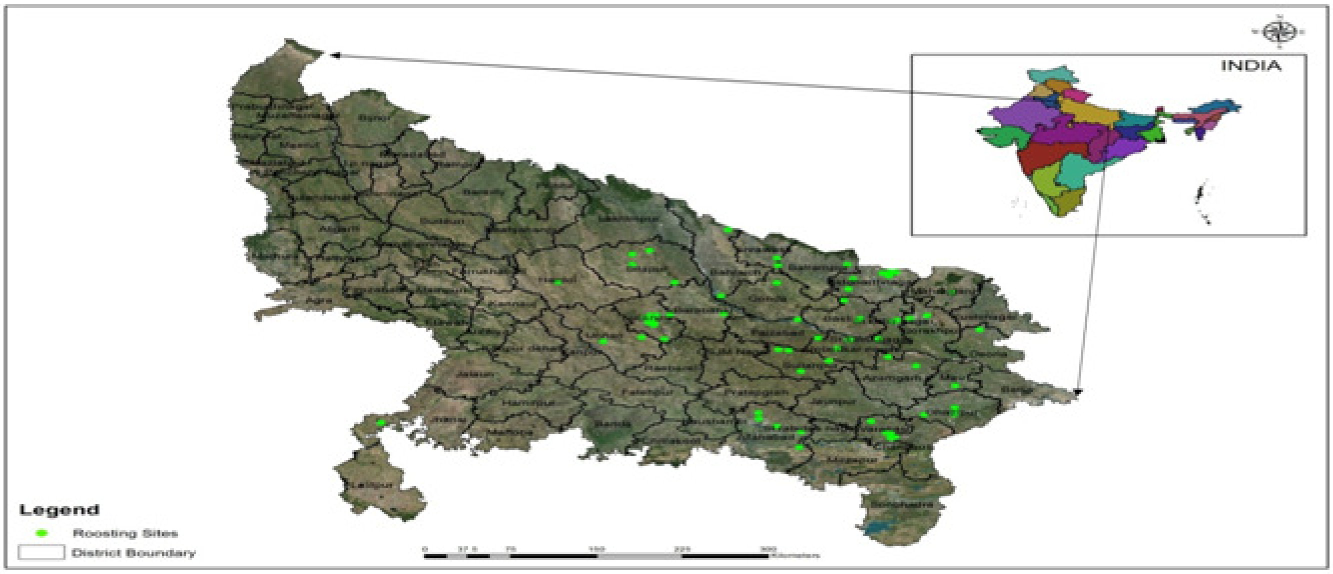

**Fig. 1 :** Map of study area (Uttar Pradesh). The capture or roosting locations were marked as green circles with the help of GPS.

The bats were captured during emergence time by mist net (Avi net, Dryden, USA) from various places to accesses the morphometric variation of male and female, actual body status of reproductively active individuals during the breeding period (Fig. 1). The mist net was erected exit point of roosts and bank of the pond because *S. kuhlii* often drunk water after emergence in summer when the temperature was high. The Morphological characters such as body mass, head and body length, length of forearms and hind arms, body width, length and width of the ear, tragus width, length and width of stratum, second, third, fourth and fifth metacarpals, maxillary and mandible length, wingspan, thumb, tail length have been measured by using digital venire caliper (Mitutoyo, 500-181,0003472, Japan). Simultaneously, Reproductive status was access by the body condition of the female. Therefore, females were classified as either-visibly pregnant, lactating, or post-lactating. Nipples remained visible after females gave birth, although they reduced markedly in size after lactation. Females without visible nipples or with nipples with hair grown over them were categorized as non-reproductive. If phalangeal epiphyses had not yet fused or if ringing date indicated they were young-of-the-year, the bats were classed as juveniles.

The weight of the bat has been taken by spring balance. Bats released immediately after taking measurements at the site of capture. The Pearson correlation used to determined of the body mass and body width of female *S. kuhlii* (SPSS, version 20) because data was nonparametric. The map was made by ArcGIS. The whole study was conducted monthly.

## RESULTS

A total of 20.87% (n = 57) adult males of *S. kuhlii* were analyzed for access in scrotum length. It was observed that seasonal variation occurred in male scrotum length, which was maximum scrotum length in February (13.14±0.51mm) and minimum in November (10.31±0.49mm) (Fig. 3a). A total of 27.83% (n=76) pregnant females were analyzed to access variation in body mass of pregnant females and body width. We found pregnant females of *S. kuhlii* gained body mass faster throughout the gestation period. The average body mass in January (20.27±0.46gm), pregnant female not found in January but the status of the vaginal swab, consideration reproductive active female and maximum body mass in May (26.33±1.29) which was decreasing in June (Fig. 2c), which begin lactation period. Beside the body width of pregnant females was increasing with increase body mass (Fig. 2d). Pearson correlation analysis showed a significant difference between body mass and body width of pregnant females (r= 0.613**) (** correlation is significant at the 0.01 level). Bodies, body mass of non-reproductively males and females fluctuated throughout the season. The average body mass (21±0gm) of non-reproductive males were observed in November and December, while the maximum in October (23.85±0.89gm) (Fig. 2a). Whereas non-reproductive female's body mass (21±1gm) were minimu in December while maximum (22.4±0.54) in November (Fig. 2b).

A total of 34 hours have been observed behabiour of *S. kuhlii* during breeding season from February to June. In February a total of 6 hours 45 minutes behavior was observed, which only three reproductive behabiour such as male groom their genital organ (15.16time/ hours) was maximum behavior observed (Fig. 3b). While, courting male sniff of the female's vagina (9.13t/hrs) (Fig. 3c) and vagina licks (9.27t/hrs) (Fig. 3d). The copulation attempt (9.29t/hrs) by a courting male was observed. A mating success has been observed in the present study on February 15th 2018. In March a total 6:23:0 minutes

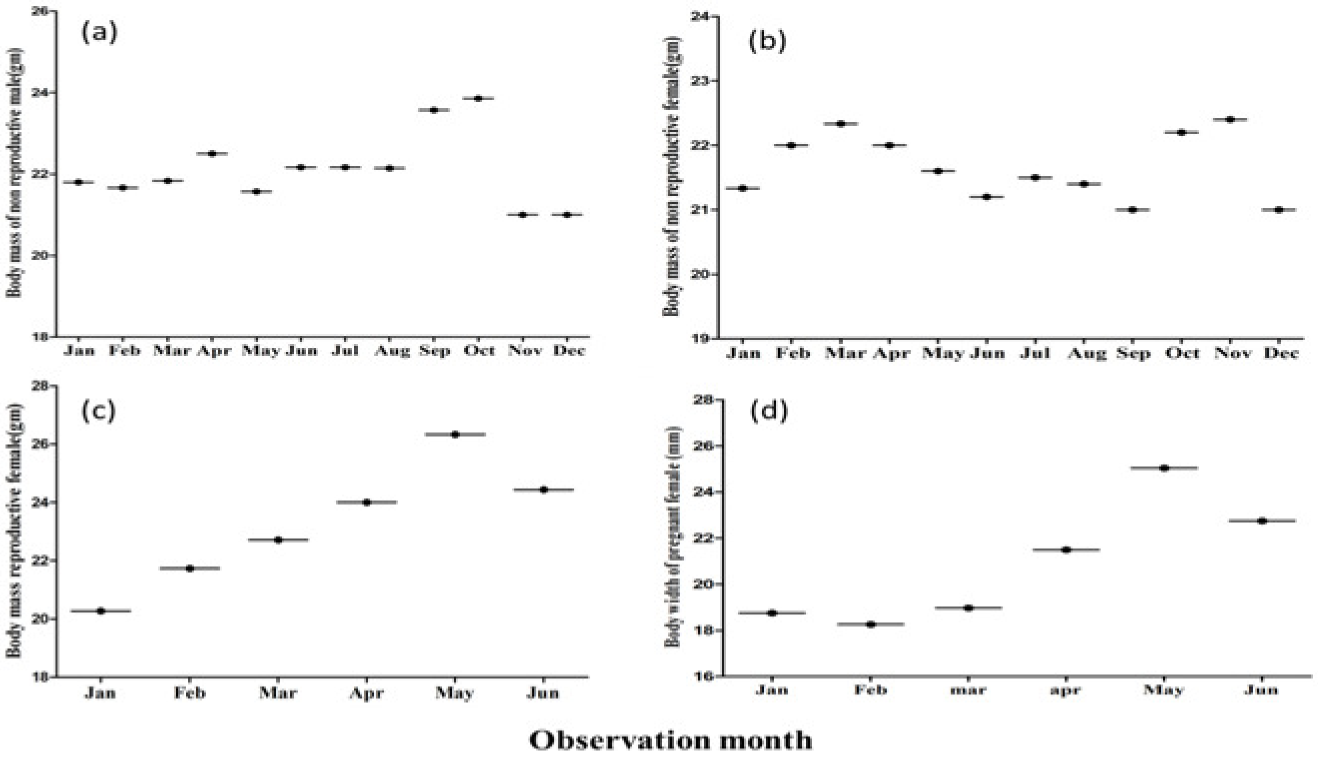

**Fig. 2 :** Morphomatric variation of non-reproductive and reproductive males and female of *Scotophilus kuhlii* in breeding and non breeding season:(a) body mass of non-reproductive male, (b) body mass of non-reproductive female, (c) body mass of reproductive (Pregnant) female, (d) Body width of pregnant female.

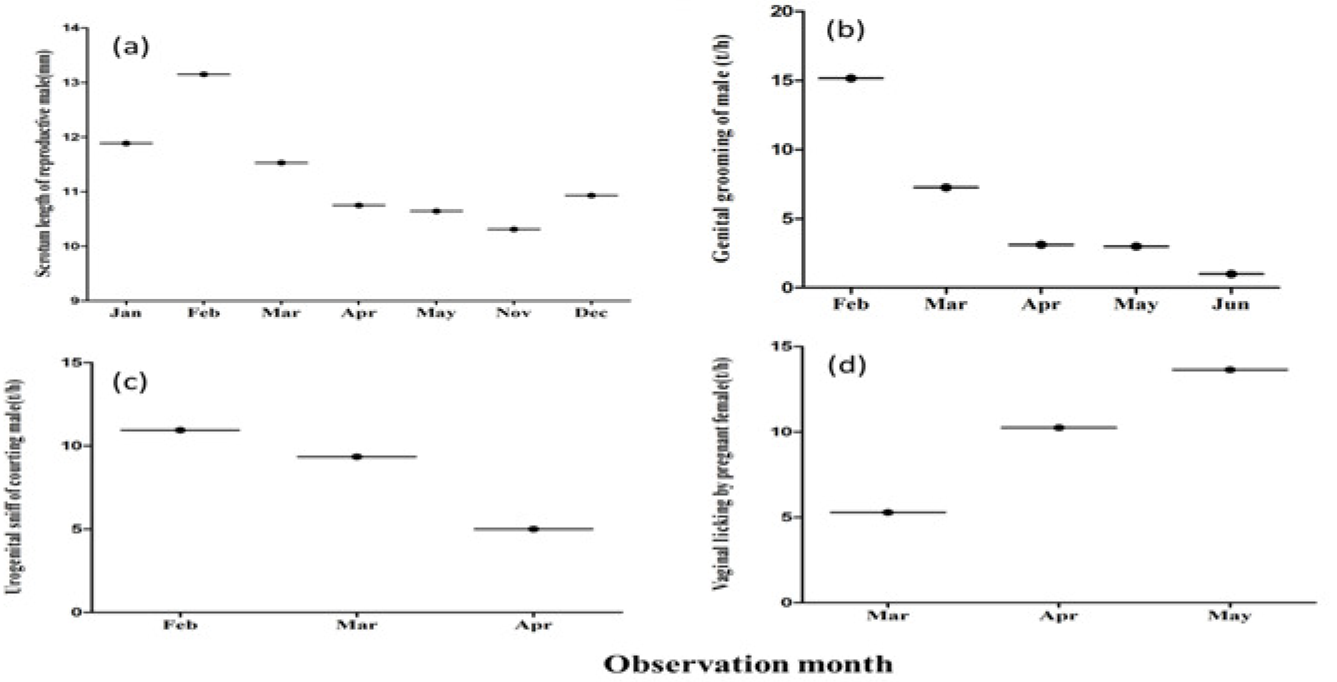

**Fig. 3 :** Reproductive bahaviour of *S. kuhlii* during breeding season (a) Scrotum length of reproductive male, (b) Genital grooming of male. (c) Urogental sniffing by reproductive male, (d) Vaginal licking by pregnant female.

behavior was observed, which was gradually decreasing such as genital grooming (7.25t/hrs) (Fig. 3b), urogenital licking (8.8t/hrs) (Fig. 3d), urogenital sniff (9.35t/hrs) (Fig. 3c) and copulation attempt (9.03t/hrs). While the first time another behavior was seen pregnant female licking their vagina (5.29t/hrs).

In April a total of 8 hours 3 minutes behavior was observed, which little behaviour was disappeared such as urogenital licking, while remaining behavior gradually decreasing. Whereas vaginal licking (10.25t/hrs) was gradual increases (Fig. 3d). In May a total of 6 hours 21 minutes behavior was observed including, urogenital sniff and urogenital licking were disappeared while vaginal licking by a pregnant female was on the peak (13.64t/hrs) (Fig. 3d). There was the first time observed two pups attached with their mother belly and which first-time infant groom was seen by mother (9.78t/hrs). In June, a total of 6 hours 33 minutes behabiour was observed, only genital grooming (2.63 t/hrs) (Fig. 3b) was seen and all reproductive behavior was disappeared. Besides, few other behavior was also observed in a whole breeding month, such as general grooming (9.86t/h) tooth grooming of male and female the average (5.81t/h) and yawning of male and female average (50.65 t/h) was seen.

We observed that one or two males with more the three females lives in single maternity roosts. While at the time of birth pregnant female lives alone or two females in maternity roost. Whereas courting male life

**Table 1 :** Morphometric analysis of pups of *Scotophilus kuhlii* bats including a male and a female. Mean ± SD is shown.

| Parameter (mm) | Pup | | |
|---|---|---|---|
| | M | F | Mean ± SD |
| **Body mass(gm)** | 3.3 | 4 | 3.65 ± 0.49 |
| **Body + head length** | 38.83 | 40.57 | 39.7 ± 1.23 |
| **Head length** | 15.54 | 15.54 | 15.54 ± 0 |
| **Tail length** | 33.32 | 32.96 | 33.14 ± 0.25 |
| **Ear length** | 4.65 | 4.5 | 4.575 ± 0.10 |
| **Ear width** | 3.65 | 3.86 | 3.755 ± 0.14 |
| **Targus** | 1.57 | 1.86 | 1.715 ± 0.20 |
| **Forearm** | 18.86 | 19.96 | 19.41 ± 0.77 |
| **5th Metacarpal** | 12.86 | 14.65 | 13.75 ± 1.26 |
| **First phalanx** | 3.86 | 4.65 | 4.25 ± 0.55 |
| **Second phalanx** | 2.54 | 2.65 | 2.59 ± 0.07 |
| **4th Metacarpal** | 11.04 | 12.93 | 11.98 ± 1.33 |
| **First phalanx** | 2.65 | 2.76 | 2.70 ± 0.07 |
| **Second phalanx** | 2.32 | 2.6 | 2.46 ± 0.19 |
| **3rd Metacarpal** | 13.96 | 13.66 | 13.81 ± 0.21 |
| **First phalanx** | 4.54 | 4.54 | 4.54 ± 0 |
| **Second phalanx** | 3.86 | 3.65 | 3.75 ± 0.14 |
| **2nd Metacarpal** | 14.86 | 14.87 | 14.36 ± 0.01 |
| **Wing span** | 110.54 | 110.75 | 110.64 ± 0.14 |
| **Thumb length** | 3.8 | 3.87 | 3.83 ± 0.04 |
| **Maxillary length** | 4.5 | 4.65 | 4.57 ± 0.10 |
| **Mandibular length** | 3.65 | 3.5 | 3.57 ± 0.10 |
| **Hind arm** | 12.4 | 10.95 | 11.67 ± 1.02 |
| **Foot** | 1.85 | 1.6 | 1.72 ± 0.176 |

in the adjacent roost, until pups fly. The gestation period approximately 112 days. Parturition occurred on 28th June 2018. A female gave birth to two pups. Newborn pups red-brownish in colour back and light pink belly which closed eyes and hairless. The average forearm length of pups at birth (19.41± 0.77mm mean ± SD) and body mass (3.65±0.49). Whereas average 5th metacarpals (13.75±1.26mm), 4th metacarpals (11.98±1.33mm), 3rd metacarpals (13.81±0.21mm) and 2nd metacarpals (14.36±0.001mm). While the average wingspan (110.64±0.14mm), maxillary (4.57±0.10) and mandibular (3.57±0.010) (Table 1).

## DISCUSSION

Based on the observation mattings performed in territory sites occupied by single males, which may be small caves, mines or cellars or a specie part of a larger underground system (Ransome, 1991). The present study similar to previous work reported by Ransome (1991). Whereas roost mostly in an abandoned building, monuments, tree cavity in the same roost. The gestation period approximately 112 days. Females gave birth to two pups once a year in the last week of May month. Chen *et al* (2016) reported that parturition occurred of *S. kuhlii* on the first to the second week of June. Parturition of *S. kuhlii* may be varied according to a geographical area and roosting sites. Newborn pups red-brownish in colour back and light pink belly, which closed eyes and hairless. A present result similar to previous work reported by Chen *et al* (2016). Pups are always attached to their mother until one week. Gould (1975) reported that mostly newborn bats are not well furred, are weaned at a larger size and completely dependent on their mothers. Mother left their pups in maternity roost during foraging, which forage around the maternity roost to a short time. A present study just opposite to those reported previous study by Hamilton and Watt (1970), Kunz (1974, 1982). Reproductively active male bats may shorten foraging time during the breeding period (Hamilton and Watt, 1970; Kunz 1974, 1982). Males often live in roost adjacent to maternity roost until pup fly. We speculate that males do not involve in parental care. Several previous studies reported that Male parental care is occasional among mammals (Clutton-Brock,1991), while almost absent among bats (Kunz and Hood, 2000).

Body mass of females was higher compare to males because body fat content is more compared to males. A similar study found body mass of female *S. kuhlii* higher compared to males recorded by Zhu *et al* (2012). According to Flux (1967) suggested that females were heavier compared to males according to seasonal variation in the body mass *i.e.* females more body mass and males have low in spring. The pregnant female's body mass increases one fourth from fetal mass alone during pregnancy (Kunz *et al*, 1995b; Kunz and Hood, 2000). Our results showed body mass of pregnant females continuously increases until parturition than again original or reduce their body mass during begging lactation period. Parturition and lactation period are very costly. Therefore, more energy required to maintain a basic metabolic rate. Lactation period is more costly (Loudon, 1987; Rogowitz, 1996; Dammhahn, 2008). Canale *et al* (2012) reported thatduring lactation females frequently reduce their body weight. Increasing the body moss of pregnant females simultaneously increases the breeding season length and gestation period. Pregnant females in early spring, adult males in late spring, juveniles, and postlactating females in early summer, and adult females in late summer had the latest median emergence times (Reichard *et al*, 2009). Our result showed pregnant females were frequently captured in February to May and after that lactation female was captured frequently in June.

Seasonal variation in body mass of Hibernating species (Ransome, 1991) required high energy demands during this period. Hence, the animals build up body-fat reserves after the breeding season (Ewing *et al*, 1970; Kunz *et al*, 1998; Speakman and Rowland, 1999). After these fat reserves gradually decline. In consequence, bats are lightest when they leave their hibernation roosts. Ourresults showed that seasonal variation in body mass of non-reproductive male and female of *S.kuhlii* whichwas a similar result reported by Kunz *et al* (1998), Encarnacao *et al* (2006). When a mating activity starts in late summer thus the animals have again increased their body mass (Encarnacao *et al*, 2006). Our result showed that non-reproductive bats gain body mass in summer and monsoon, when food abundance is more. Juvenile bats in temperate zone store fat in their body before going hibernation in winter (Grindal, 1992). Insect diversity and prey availability is high in summer and monsoon. While courting males lose their energy during mating time. Therefore, more energy required when males pause their mating in early summer.

Our result showed that the male scrotum length of *S. kuhlii* was increased in February and gradually decrease with the end of the breeding season. While disappeared in the non-breeding season. Scrotum size shows males are reproductively active. During the breeding season, clearing visible signs of a primary sexual organ such as testes size of Vespertilionid bats (Cryan *et al*, 2012). Racey (1974) and Krutzsch (2000) reported that, during spring, the accessory sex glands of males initiate to shrink, which the caudal epididymides empty, and sperm production begins again (Racey, 1974; Krutzsch, 2000).

Ramsey *et al* (2009) suggested that genital hair has been retained to improve the spread of pheromonal secretions, to increase attractiveness to the other sex. Genital grooming is innate behaviour which common during the breeding period. It is played by courting males to attract the opposite sex seen several mammals. The present study showed that, courting male groom their genital organ continuously several second to minutes to stimulation scrotum size and erect penis to complete mate. These are frequently observed in February to the first week of March in the case of *S. kuhlii.* While it may vary species to species. Tan *et al* (2009) reported that the male often groomed himself or licked the inner surface of the genital. The females licked her mate's penis during copulation influence the duration of copulation (Tan *et al*, 2009).

The sniffing is a natural process in animals to respond to identification through the scent of the same or opposite sex. Roeder (1980) reported that estrus females may distinguish their partner by scent marks. This determination of the physiological state of females by courting males is also possible by olfactory cues. Hence, scent marks perhaps allow identifying of estrus females by courting males. During the rutting period, the "hiccup" of the male appears after sniffing and urogenital region a place where an estrus female has just marked (Roeder, 1980). The present study showed that urogenital sniff by the male was maximum observed before mating. It was often seen in the breeding season. Male often sniff of the females genital to know the status of the sexual maturity of females. It may several times in minutes or to several seconds.

Several mammals lick genitals before and after copulation. The present study showed that male bats lick their partner's vagina regularly during the breeding season. We speculate that males of *S. kuhlii* lick the female genital to increase the lubrication and stimulation to copulation. The male of *Lemur catta*, species often licks the genitals organ of the female to judge whether she is in estrous (Koyama, 1988). Tan *et al* (2009) reported that female *Cynopterus sphinx* licks their courting male's penis regularly during copulation and that each second of licking results in influence approximately six extra seconds of copulation. The female *C. sphinx* licks the male penis to increase penile stimulation, rigidness the penis and maintaining the male's erection (Tan *et al*, 2009), at the same time, the female's saliva may increase lubrication, thus facilitating intromission and thrusting (Tan *et al*, 2009).The present study showed that male *S. kuhlii* mating occurs in late winter. Rossiter *et al* (2000) reported that, females visit males to mate in autumn, while copulation can also occur in winter and spring and which determined by female choice.

## CONCLUSION

Based on the observation few morphological characteristicsvary between males and female of *S. kuhlii.* While at the time of birth pregnant female lives alone or two females in maternity roost. Whereas courting male life in the adjacent roost, until pups fly. The gestation period approximately 112 days. Birth is occurring around May to June. A female gave birth to two pups once each year. Newborn pups red-brownish in colour back and light pink belly, which closed eyes and hairless. No difference morphological characters between male and females pups at birth. While in adults males and females are different in morphological characters. Pregnant females gain body mass dramatically to parturition than lose their body mass during the lactation period. While body mass of non-reproductively an individual fluctuates when food availability is more than body mass gain. It occurs in summer and monsoon when all insectivorous bat prepared for hibernation. The male sniff and lick vagina of females before mating during the breeding period to assess the status of estrous. The male groom their genital for few seconds to minutes to attract and stimulate females to mating. The males try to several copulation attempts to the success of the mating. The female lick their vagina before birth may enhance to cervix opening could be easily the birth. Besides yawing behaviour is common in the *S. kuhlii.*

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# DISTRIBUTION AND MORPHOMETRIC OF THE *SCOTOPHILLUS KUHLII* (LEACH, 1821), AT UTTAR PRADESH, INDIA

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## ABSTRACT

Family Vespertilionidae commonly known as evening bat and frequently found associated with human habitats. The present study carried out on the distribution and morphometric of the *S. kuhlii* in various districts at Uttar Pradesh, India from Aug 2016 to Dec 2018. It was observed that various habitats occupied by *S. kuhlii* in 23 districts. A total of 970 individuals counted from 216 roosts and 273 bats captured for morphometric analysis and comparison made between males and females. Results revealed that forearm length, wingspan, body moss 5th metacarpal, and 2nd metacarpal and hind arm of female was longer than males showed significantly different. Body, head, ear, maxillary and mandible length showed no significant differences. The present study signifies that body mass of females was higher than males. Roost was highly depleted by local people as they were scared due to a zoonotic disease. Hence, awareness programs should be a plan about bats.

**Keywords:** *Distribution, Morphological characteristics, Population, Roost depletion. S. kuhlii, Vespertiliniodae*

## INTRODUCTION

Vespertilionidae bats are known as evening bats, which alone provides 493 species from 54 genera out of total 1,386 species throughout the world (Burgin *et al.,* 2018). A total of fifteen species of *Scotophilus* found in different parts of the world including seven species distributed throughout sub-Saharan Africa, four across southern and southeastern Asia, three endemic to Madagascar, and one endemic to Reunion Island (Robert *et al.,* 2009). In the Indian subcontinent, only *S. kuhlii* and *S. heathii* were reported, especially *S. kuhlii* found in most states in Indian subcontinent as reported by Bates and Harrison (1997) and also in Western Ghats (Vishakha *et al.,* 2015), Assam (Rahman and Chaudhary, 2017), and Delhi (Dookia and Mishra, 2018). *S. kuhlii* was first reported from the Pilibheet district of Uttar Pradesh by Wroughton (1914). A comparison between geometrically similar animals of different sizes shows that the power required for flying increases faster with increasing body mass (Pennycuick, 1975). Based on the morphological characters, it is medium-sized species with pelage colour of the dorsal region, soft and olive-brown and abdomen light-creamy (Bates and Harrison, 1997; Elangovan and Kumar, 2015; Dookia, 2018). The facial structure is similar to a dog like a mouth (Bates and Harrison, 1997). Ear length is smaller as compared to the head with a half-moon shaped and tragus is separated from the pinna by a clear cut groove (Elangovan and Kumar, 2015; Dookia, 2018). The Average ear length was 10mm to 13.5mm (Bates and Harrison, 1997; Javed, 2014; Elangovan and Kumar, 2015). The average of forearm length ranges from 44 to 49 mm in length (Bates and Harrison, 1997; Elangovan and Kumar, 2015; Rahman and Chaudhary, 2017; Dookia, 2018). Minimum body mass was 16 grams and a maximum of 25g (Zhu *et al.,* 2012; Rahman and Chaudhary, 2017). *S. kuhlii* frequently occupies different types of roost such as natural and man-made structures like monuments, renounce building, crevices, caves, old temples, palm fronds, hollow structure in palm trees and dried leaves on palm trees (Brosset, 1962; Sinha, 1986; Elnagovan and Kumar, 2015). Anthropogenic pressure which gradually changes vegetative land into settlements (Grimm *et al.,* 2008) supports very few species and is having harmful impact on some species (McKinney, 2002).

According to IUCN version 3.1 (IUCN, 2008), *S. kuhlii* is the least concerned among stable species. However, *S. kuhlii* has not been considered in the wildlife protection act 1972 and the convention on

International Trade in Endangered Species of Wild Fauna and Flora appendices (Rahman and Chaudhary, 2017). Therefore, our aim in this study was to assess the distribution of *S. kuhlii* and its morphological characters at Uttar Pradesh.

## MATERIALS AND METHODS

### *Study area*

The field survey was carried out at various places of different districts (Fig. 1) from August 2015 to December 2018 in Uttar Pradesh (U.P.). UP is located in the northern part of India and the 4th largest area wise state in the India. The state boundary is surrounded by Rajasthan, Haryana and Delhi, Uttrakhand, Bihar, Jharkhand, Chhattisgarh, Madhya Pradesh, and the country of Nepal. The roost survey was conducted at various places such as monuments (Historical place, protected by Archeological Survey of India), old Temples, abandoned buildings (renounce building by a human), and old trees. This survey was conducted at once during the entire study. The roosting site was identified based on the guano dropping beneath the roost and pungent odor coming out from the roost. Roost ID was given for farther observation. Besides, roost depletion was confirmed by the questionnaire method i.e. fears of zoonotic disease, bush-meat, and medicine. The GPS coordination of the roosting site was taken by compass mobile application. The individuals were counted by visual observation during the emergence of a small colony and video recording (TV-Out Digital Video Recorder) was used for the big colony (more than hundreds of individuals in single roost). The bats were captured during emergence time by mist net (Avi net, Dryden, USA). The nets were erected at exit points of roosts and bank of the pond. The Morphological characters such as body mass, head and body length, length of forearms and hind arms, body width, length and width of the ear, tragus width, length and width of stratum, second, third, fourth and fifth metacarpals, maxillary and mandible length, wingspan, thumb, tail length have been measured by using digital vernier caliper (Mitutoyo, 500-181,0003472, Japan). Simultaneously, the status of sex such as male or female and a juvenile were identified based on the phalangeal joint. The weight of the bat has been taken by spring balance. Bats released immediately after taking measurements at the site of capture. Morphological characters of male and female *S. kuhlii* were compared using the Kruskal Wallis H test, (SPSS, version 20) because data was nonparametric. The map was made by ArcGIS software.

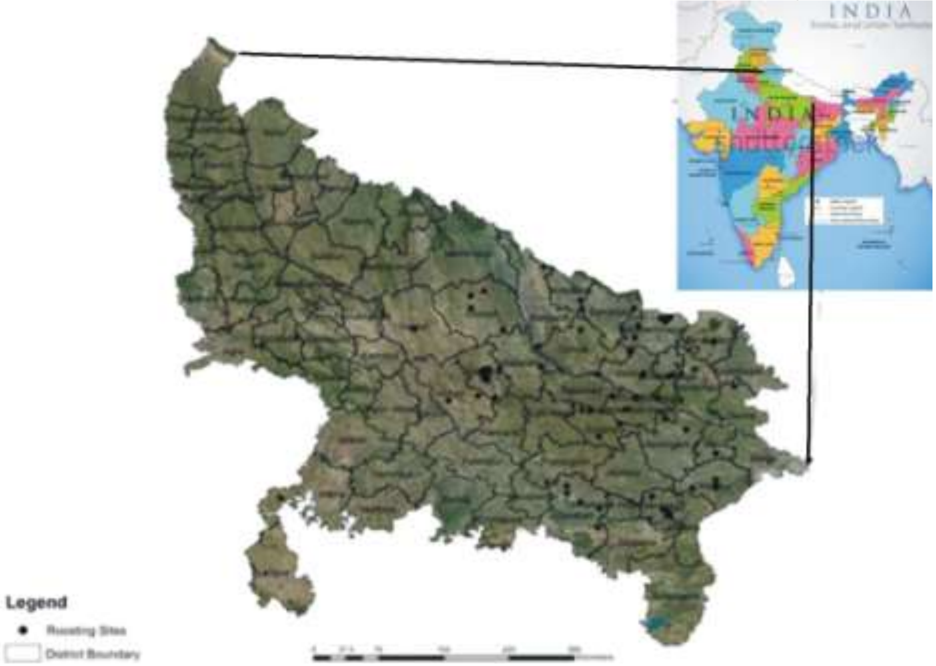

**Figure 1: Map of study area (Uttar Pradesh).**

The colony locations (roost sites) were marked as solid circles with the help of GPS.

## RESULTS

A total of 970 individuals of *S. kuhlii* were counted from 216 roosts during the study period from various places of the districts. The maximum 62 roosts, (39.69%) were observed in residency in which population size was having 105 bats found in Lucknow district, while there were occasionally two roosts found on palm trees (*Livistona*) with 258 individuals. A sum population of bats in monument and palm tree was 363. While only one individual was captured in village Ajgara, district in Varanasi (Table 1). Detail information about the distribution of roosting sites of *S. kuhlii* given table (Table 1).

**Table 1: Distribution, types of roosting habitats with GPS location and population of *S. kuhlii* in different habitats with geographical districts in Uttar Pradesh**

| Roosting site | GPS Coordination | No. of population | Type of roosting habitat |
|---|---|---|---|
| **Allahabad#** | | **7.4 ± 5.27** | |
| Shantipuram | 25°31'45.66"N<br>81°51'13.87"E | 5 | Abandoned building |
| Basupur | 25°21'26.39"N<br>82°13'15.51"E | 14 | Abandoned building |
| Ahopur | 25° 9'24.79"N<br>82°12'9.46"E | 12 | Abandoned building |
| Bahadurpur | 25°25'54.83"N<br>82° 0'23.94"E | 2 | Abandoned building |
| Soraon | 25°36'25.26"N<br>81°50'59.12"E | 4 | Abandoned building |
| **Faizabad#** | | **12.5 ± 3.53** | |
| Newghat | 26°48'38.99"N<br>82°12'19.29"E | 15 | Tree cavity |
| Kachahari | 26°48'38.99"N<br>82°12'19.29"E | 10 | Abandoned building |
| **Azamgarh#** | | **13.5 ± 2.12** | |
| Bilariya ganj | 26°12'1.51"N<br>83°13'43.39"E | 15 | Abandoned building |
| Tofa pur | 26° 9'18.67"N<br>83°11'20.45"E | 12 | Abandoned building |
| **Ambedkar nagar#** | | **8.5 ± 3.00** | |
| Tanda | 26°32'35.75"N<br>82°39'52.37"E | 6 | Abandoned building |
| Railway station Tanda | 26°32'36.83"N<br>82°38'43.71"E | 10 | Tree cavity |

| | | | |
|---|---|---|---|
| Akbarpur bus station | 26°26'2.99"N<br>82°32'27.47"E | 12 | Tree cavity |
| Railway station Akbarpur | 26°25'45.18"N<br>82°32'24.21"E | 6 | Abandoned building |
| **Barabanki**[#] | | **8.5 ± 2.12** | |
| Chauka ghat | 25°19'59.23"N<br>82°59'29.48"E | 10 | Abandoned building |
| Dariya bad | 26°53'18.72"N<br>81°33'24.84"E | 7 | Abandoned building |
| **Basti**[#] | | **13.25 ± 3.59** | |
| Gandhi nagar | 26°47'47.11"N<br>82°43'55.53"E | 11 | Abandoned building |
| Jhakarkatti | 26°47'40.95"N<br>82°43'45.32"E | 10 | Abandoned building |
| Rudhauli | 26°48'59.88"N<br>82°45'5.65"E | 14 | Abandoned building |
| Patkhauli | 27° 3'16.37"N<br>82°36'42.75"E | 18 | Abandoned building |
| **Bahraich**[#] | | **11.00 ± 0.00** | |
| Jarwal road | 27° 7'9.57"N<br>81°32'5.11"E | 11 | Abandoned building |
| **Ghazipur**[#] | | **6.5 ± 4.041** | |
| Zangi pur | 25°39'14.58"N<br>83°33'27.53"E | 12 | Abandoned building |
| Phullanpur | 25°35'19.49"N<br>83°33'49.11"E | 4 | Abandoned building |
| Lanka | 25°33'55.47"N<br>83°33'8.35"E | 3 | Abandoned building |
| Bhitari | 25°34'0.71"N<br>83°17'21.83"E | 7 | Abandoned building |
| **Gonda**[#] | | **6.00 ± 0.00** | |
| Ityathok | 27°17'23.62"N<br>82° 1'37.53"E | 6 | Abandoned building |
| **Gorakhpur**[#] | | **6.00 ± 0.00** | |
| Maniram | 26°50'56.94"N<br>83°20'19.90"E | 6 | Abandoned building |
| **Jhansi**[#] | | **4.00 ± 00** | |
| Fort | 25°27'28.44"N<br>78°34'32.25"E | 4 | Abandoned building |

| | | | |
|---|---|---|---|
| Kanpur | | **5.00 ± 0.00** | |
| Beethur | 26°36'20.65"N<br>80°16'11.16"E | 5 | Abandoned building |
| **Lucknow**[#] | | **5.12 ± 1.96** | |
| Residency | 26°51'38.29"N<br>80°55'36.43"E | 258**, 105* | Monuments, Plam tree |
| Jugganr | 26°52'25.80"N<br>81° 4'51.55"E | 3 | Abandoned building |
| Mohanlalganj | 26°45'59.80"N<br>80°56'41.87"E | 4 | Abandoned building |
| Nigohan | 26°33'44.45"N<br>81° 1'47.71"E | 3 | Abandoned building |
| Goshaiganj | 26°34'11.60"N<br>82°22'55.30"E | 6 | Abandoned building |
| Bani | 26°39'20.17"N<br>80°47'51.48"E | 7 | Abandoned building |
| Utratia birdge | 26°46'15.53"N<br>80°55'47.30"E | 7 | Abandoned building |
| Char bagh loco wherhouse | 26°49'58.03"N<br>80°55'23.72"E | 8 | Monuments |
| Bada Imambada | 26°52'8.17"N<br>80°54'45.70"E | 7 | Abandoned building |
| Chhota Imambada | 26°52'17.83"N<br>80°54'31.31"E | 3 | Monuments |
| Aminabad | 26°50'46.53"N<br>80°55'34.78"E | 4 | Abandoned building |
| Narhee | 26°50'48.02"N<br>80°57'9.24"E | 7 | Monuments |
| Badshah Nagar | 26°52'9.54"N<br>80°57'39.53"E | 6 | Abandoned building |
| Transport Nagar | 26°46'42.70"N<br>80°53'30.27"E | 3 | Abandoned building |
| Alam Nagar | 26°50'21.90"N<br>80°51'45.67"E | 7 | Abandoned building |
| Pushpendra Marg | 26°46'16.78"N<br>80°55'54.51"E | 2 | Abandoned building |
| Kallipushcim | 26°44'40.47"N<br>80°56'21.81"E | 5 | Abandoned building |
| **Mau**[#] | | **5 ± 0.00** | |
| Bus stop | 25°56'11.02"N | 5 | Tree cavity |

| | | | |
|---|---|---|---|
| | 83°34'4.39"E | | |
| **Maharaj Ganj**# | | **9.00 ± 0.00** | |
| Veer Bahadur Nagar | 27° 8'40.60"N<br>83°33'43.83"E | 9 | Abandoned building |
| **Santkabir nagar**# | | **12.5 ± 3.53** | |
| Fort Qazi khailil Urrahman | 26°47'41.16"N<br>83° 4'31.87"E | 15 | Monuments |
| KhaIilabad | 26°46'34.86"N<br>83° 2'2.97"E | 10 | Monuments |
| **Siddharth nagar**# | | **8.72 ± 7.77** | |
| Jaipur | 27°24'51.71"N<br>83° 1'4.96"E | 30 | Abandoned building |
| Bansi city | 28°54'3.32"N<br>77°18'13.40"E | 8 | Abandoned building |
| Mahala village | 27°26'14.93"N<br>83° 2'19.76"E | 11 | Abandoned building |
| Basantpur | 27°24'51.71"N<br>83° 1'4.96"E | 2 | Abandoned building |
| Babhani | 27°24'51.71"N<br>83° 1'4.96"E | 4 | Tree cavity |
| Dumariya ganj | 27°12'5.35"N<br>82°39'13.78"E | 5 | Abandoned building |
| Chilhiya | 27°21'57.62"N<br>83° 0'43.08"E | 2 | Abandoned building |
| Navgarh | 27°17'56.64"N<br>83° 5'34.02"E | 8 | Abandoned building |
| Shohrat garh | 27°24'9.11"N<br>82°57'34.88"E | 12 | Tree cavity |
| Itwa | 27°19'53.70"N<br>82°41'49.42"E | 8 | Abandoned building |
| Chandanpur | 27°24'7.74"N<br>83° 2'0.43"E | 6 | Abandoned building |
| **Shravashtee**# | | **3.5 ± 0.70** | |
| Jaitvan | 27°58'31.65"<br>81°36'2.76"E | 3 | Abandoned building |
| Hussain jat villege | 27°30'46.88"N<br>82° 2'19.21"E | 4 | Monuments |
| **Sitapur**# | | **5.75 ± 1.70** | |
| Mehmoodabad | 27°17'48.17"N<br>81° 7'30.44"E | 8 | Abandoned building |

| | | | |
|---|---|---|---|
| Laharpur | 27°42'36.32"N<br>80°54'5.06"E | 6 | Abandoned building |
| KhaIrabad | 27°31'42.35"N<br>80°44'56.98"E | 5 | Abandoned building |
| Biswan | 27°29'37.53"N<br>80°59'47.33"E | 4 | Abandoned building |
| **Sultanpur#** | | **5.75 ± 3.09** | |
| Kurebhar | 26°24'46.18"N<br>82° 7'17.43"E | 10 | Monuments |
| Lambhua | 26° 8'24.98"N<br>82°13'37.52"E | 4 | Tree cavity |
| Dostpur | 26°16'19.92"N<br>82°28'21.24"E | 3 | Tree cavity |
| Mayang | 26°25'22.14"N<br>82° 1'52.24"E | 6 | Tree cavity |
| **Unnao#** | | **9.33 ± 7.76** | |
| Kalukheda | 26°33'17.86"N<br>80°54'28.74"E | 7 | Abandoned building |
| Ashoha | 26°35'5.60"N<br>80°50'1.06"E | 18 | Abandoned building |
| Banthra | 26°31'49.77"N<br>80°29'42.73"E | 3 | Abandoned building |
| **Varanasi#** | | **4.6 ± 5.36** | |
| Kasi Vidyapith | 25°19'14.95"N<br>82°59'23.29"E | 14 | Abandoned building |
| Ram Nagar | 25°16'35.26"N<br>83° 2'0.43"E | 2 | Abandoned building |
| Pindra | 25°29'11.32"N<br>82°49'40.96"E | 4 | Abandoned building |
| Dhaunkal ganj | 25°20'14.92"E<br>82°57'10.24"E | 2 | Tree cavity |
| Ajagara | 25°16'9.71"N<br>82°59'32.96"E | 1 | Abandoned building |
| **Balrampur#** | | **10.5 ± 3.53** | |
| Pachperwa | 27°31'5.43"N<br>82°38'46.11"E | 13 | Abandoned building |
| Ganeshpur | 27°36'23.22"N<br>82° 1'42.52"E | 8 | Abandoned building |

*** indicate Tree population,* monument population and did not include in average, # indicate district with Mean± SD of population of S. kuhlii and # District*

A total of 273 individuals were measured out of 970 bats including 125 males and 147 females. There were found a statistically significant difference in morphometric analysis of male and female of *S. kuhlii*, such as Body mass of females (24.93 ± 2.86g) was significantly higher compared to males (22.39 ± 1.78mm) (H = 52.287, P < 0.05); The forearm length of females (49.03 ± 2.30mm) was longer than males (47.66 ± 1.56mm) and showed significant difference (H=18.53, P < 0.05), followed by an average of 5th metacarpal (43.69 ± 3.14mm) and (45.26 ± 7.59mm) of male and female respectively, which showed statistically significant difference (H = 14.038, P < 0.05), and average 2nd metacarpal of male (45.65 ± 8.60mm) and female (47.34 ± 7.08mm) also showed statistically significant difference (H = 7.089, P < 0.05). The average wingspan (315.07 ± 8.39mm) and (316.11 ± 7.51mm) of male and female respectively, showed statistically significant difference (H = 14.65, P < 0.05) (Table.2). Apart from, morphological characters few characters including body, head, ear, tragus, thumb, Maxillary, and Mandible, of length were not statistically different between males and females of *S. kuhlii* (Table 2).

**Table 2: Morphometric analysis of 273 *Scotophilus kuhlii* bats including male (n=125) and female (n=148). Mean ± SD is shown and compressions significant value (kruskal wallis H test, P < 0.05) of male and female.**

| **Parameter(mm)** | **Male** | **Female** | **Statistical value** | |
|---|---|---|---|---|
| | | | **H** | **P** |
| **Body mass (g)** | 22.39 ± 1.78 | 24.93 ± 2.86 | 52.827 | **0.001** |
| **Body length** | 49.94 ± 7.32 | 50.71 ± 7.29 | 2.936 | 0.087 |
| **Head length** | 12.48±2.78 | 12.78 ± 3.07 | 0.237 | 0.627 |
| **Tail length** | 45.33 ± 2.83 | 45.63 ± 2.89 | 0.233 | 0.629 |
| **Ear length** | 11.29 ± 1.33 | 11.1 ± 1.42 | 0.653 | 0.419 |
| **Tragus** | 5.93 ± 0.82 | 6.13 ± 0.79 | 2.625 | 0.105 |
| **Forearm** | 48.02 ± 4.39 | 49.04 ± 2.80 | 18.532 | **0.001** |
| **5th Metacarpal** | 43.69 ± 3.14 | 45.26 ± 7.59 | 14.038 | **0.001** |
| **First phalanx** | 11.71 ± 5.09 | 11.03 ± 1.96 | 0.119 | 0.73 |
| **Second phalanx** | 9.72 ± 1.87 | 9.82 ± 2.00 | 0.192 | 0.661 |
| **4th Metacarpal** | 46.82 ± 2.26 | 47.13 ± 2.06 | 2.705 | 0.1 |
| **First phalanx** | 15.24 ± 1.95 | 15.578 ± 1.48 | 0.445 | 0.505 |
| **Second phalanx** | 10.96 ± 1.42 | 11.11 ± 1.59 | 1.009 | 0.315 |
| **3rd Metacarpal** | 47.94 ± 2.05 | 47.84 ± 5.85 | 3.784 | 0.052 |
| **First phalanx** | 12.19±1.75 | 12.39 ± 2.01 | 0.222 | 0.638 |
| **Second phalanx** | 11.22±1.36 | 11.25 ± 1.83 | 0.733 | 0.392 |

| | | | | |
|---|---|---|---|---|
| **2nd Metacarpal** | 45.65 ± 8.60 | 47.34 ± 7.08 | 7.089 | **0.008** |
| **Wing span** | 315.07 ± 8.39 | 317.11 ± 7.22 | 14.65 | **0.001** |
| **Thumb length** | 6.1 ± 0.58 | 6.09 ± 0.64 | 0.014 | 0.905 |
| **Maxillary length** | 11.29 ± 1.28 | 11.59 ± 1.04 | 3.663 | 0.056 |
| **Mandible length** | 10.12 ± 1.34 | 10.24 ± 1.35 | 0.005 | 0.945 |
| **Hind arm** | 17.85 ± 2.43 | 18.52 ± 2.07 | 4.927 | **0.026** |

## DISCUSSION

The Asiatic lesser yellow house bat, *Scotophilus kuhlii* was rarely distributed in the study area and chosen different types of roost habitats such as monuments, abandoned buildings, temples, trees cavities, and mud walls. Our result showed similar, of an earlier report by Elangovan and Kumar (2015) that the state Uttar Pradesh has quite a good number of places, ancient temples, historical monuments, and natural forests for providing roosting sites for resting, breeding and protection in adverse conditions. Brosset (1962) and Sinha (1986) reported that *S. kuhlii* roost occurs in different kinds of habitats such as crevices and holes in walls of huts and old buildings, caves, old temples, palm fronds, dried leaves on trees and is found both in urban and rural landscapes. Our result showed that roost of *S. kuhlii* was widely distributed in different types of habitats including monuments, abandoned buildings, and old trees with one individual to a hundred individuals in the single roost. Its pelage colour of the dorsal region was soft and olive-brown and ventrally creamy. The ears of the *S. kuhlii* are small and half-moon shaped compared to the head, it helps in adaptation for retaining heat, because the large surface area will lose heat faster compared to the smaller surface area (Kingston *et al.*, 2010; Rahman and chaudhary, 2017). Our result was similar to previous work reported by Kingston *et al.* (2010). The average forearm length of females is longer compared to the male, may support thermoregulation due to increase length of forearm. This simultaneously increases the wing area, which maintains the heat of the body. Similar studies of Zhu *et al.* (2012) and Goodman *et al.* (2005) showed that forearm of male shorter than female.

Previous studies reports natural selection supports a wing shape which makes it easy for flight in a different situation, which reduced the extra load during the flight (Norberge and Rayner, 1987). Bats hawking high-flying insects have small, pointed wings that give good agility, high flight speeds, and low cost of transport (Norberge and Rayner, 1987). Our result showed that the wingspan longer of females than males. The average wingspan of female of *S. kuhlii* was longer than male recorded by Goodwin (1979). Longer wingspan provides better utilization of resources by maintaining a territory for the un-matured female and young ones (Ralls, 1976). Body mass of females was higher in comparison to the males because body fat content was more compared to males. A similar study found body mass of female *S. kuhlii* higher compared to males recorded by Zhu *et al.* (2012). According to Flux (1967) suggested that females were heavier compared to males according to seasonal variation in the body mass i.e. females more body mass and males have low in spring. Previous studies have shown that ear and hind arm lengths are shorter than females recorded by (Goodman *et al.*, 2005). Our result showed that no differences morphological characters including body, head, tail ear, the length between male and female of *S. kuhlii*. Earlier studies of Elangovan and Kumar (2015) reported that the ears of the species are small and half-moon shaped compared to the head. Loss of roost takes place by several factors such as fire, decay, and anthropogenic activities and deforestation and tree fall (Sedgwick and Knopf, 1992). The depletion of these sites affects fauna and flora which the largest threats to biodiversity globally (Henle *et al.,* 2004; Sala *et al.*, 2000). Our result showed that roost depletion was mostly caused by the zoonotic disease compared to bush-meat and medicine. The zoonotic disease often spread by interfering with an animal which affects health problems. We observed that *S. kuhlii* distributed throughout the districts in Uttar Pradesh with closed to human-occupied habitats. Based on the morphometric analysis, female *S. kuhlii* body mass was longer than male. During the study period, we found some myths about bats. Some local people used to kill bats for bush-meat, medicines. Some people killed bat and removed his roost, scared by zoonotic diseases such as Rabies, Nipha virus, Corona virus, and bloodsucking. It is also suggested that more and more awareness programs among the communities living adjoining to the roosting sites would be of immense help in conserving the chiropterans in the study area in particular and their entire range in general.

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## CONFLICT OF INTEREST

The authors declare no conflicts of interest.

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