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

SUMMARY OF THESIS

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Summary

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 'ך / ר' 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 0.1km^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.*