Comparative Analysis of Population Dynamics and Roosting Preferences of selected Microchiropteran Bats in Tirunelveli District, Tamil Nadu

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Received: 08.10.2023, Accepted: 23.11.2023, Published: 09.12.2023

Abstract

Bats are the second most diverse group of mammals. The objective of this study was to conduct an investigative survey on distribution, roost preferences, and population dynamics of Microchiropteran bats in Tirunelveli District, Tamil Nadu, South India. The comparative analysis with an earlier and current survey of similar objective carried out in the same study area. A total of five species of Microchiropteran bats were selected for this survey. Bats were surveyed through roost identification techniques, which included visual searching, bat presence signs, and sunlight reflection techniques. Population values were analysed through Principal Component Analysis (PCA) and diversity values—Margalef's Index, Simpson's Index, and Shannon's Diversity Index—and Mean Absolute Deviation (MAD) for analysis of roost preference. The result indicates a decline in populations of *Hipposideros speoris, Hipposideros fulvus, Megaderma lyra,* while *Pipistrellus coromandra,* and *Taphozous melanopogon* have increased in their populations. Habitat utilisation, co-occurrence patterns, and threats like habitat destruction, pesticide applications, and restoration of temples were documented as contributing factors for population decline and variation in roost selection. The study reports dramatic variations in bat population and roost site preference with a focus on the implementation of conservation strategies to mitigate Microchiropteran bat threats.

Keywords:
Microchiropteran Bats, Population Dynamics, Species Diversity, Habitat Preference, Conservation Threats.

1. Introduction:

Bats (order Chiroptera) are the second most diverse group of mammals after Rodentia and currently contain approximately 1482 species worldwide. More than 130 bat species under nine families have been reported from the Indian mainland and islands (Simmons and Cirranello 2023; Burgin *et al.*, 2018). Bats play amazing ecological roles in maintaining ecosystem balance and can play a key role in various kinds of ecological processes, like pollination of plants, soil enrichment, and pest control (Calisher*etal.*,2006).

The insectivorous bats' ability to manage some of the insect pest population was considerably aided by the Microchiropteran (Molur *et al.,* 2002). A wide range of shelters, such as caves, tree cavities, foliage roosts, rocks and tree crevices, and man-made structures, have been effectively utilised by bats (Kunz, 1982a; Kunz and Lumsden 2003a). The selection of roost or nest sites is influenced by microclimatic parameters such as temperature, humidity, and light levels for most bat species (Hartman and Oring 2003; Kerth *et al.,* 2001). Bats are good indicators of environmental change, responding to several stresses including urbanisation, agricultural intensification, forest disturbances, habitat loss, climate change, and overhunting. Bats' responses to habitat disturbance typically overlap with those of other taxa (Bass *et al.,* 2010; Jones *et al.*, 2009 a). Many bat species' populations are declining globally, mostly as a result of widespread habitat loss and degradation. Nearly one-fourth of all bat species worldwide are regarded as threatened (Schipper *et al.*, 2008; Meyer*etal.*,2010). Thus, there is an urgent need to establish a global network for bat population monitoring, as many bat species require conservation efforts (Jones *et al.*, 2009 b). According to a previous investigation by Addline *et al.* (2004), renovations of older buildings kill a large number of Megachiropteran and Microchiropteran bats. Additionally, the bat fauna is threatened by the killing of bats for food and medicinal purposes. The present research reports the distribution, roost preference, and colony size of selected species of Microchiropteran bats in Tirunelveli District. The results were compared with an earlier survey data carried out in the same study area. This study will provide a valuable opportunity to assess the impact of anthropogenic and environmental changes on bat populations. The results can provide new insights into conservation and management strategies.

2. Materials and methods

Present Survey: The survey was carried out in the district of Tirunelveli, located in Tamil Nadu, India during the current study period .The district has an area of 3,907 square kilometers (1,509 square miles). It is located between 8°05' and 9°30' north latitude and 77°05' and 78°25' east longitude

Earlier Survey: The survey was carried out in the same study area during the previous study period, by Jeyapraba (2008). .

Field survey of Microchiropteran bats:

The study was conducted to report the distribution of five selected species of Microchiropteran bats – *Hipposideros speoris, Hipposideros fulvus, Megaderma lyra, Pipistrellus coromandra, and Taphozous melanopogon.* Bat roosts were identified, and roosting places were visited on a regular basis during the day based on local enquiries from the public. The presence of droppings, insect leftovers, urine scent, and marks/staining that had previously been used as roosts, and visual searches, were utilised to identify roosts (Kalko *et al.,* 1999). Every field trip included an attempt to estimate the number of bats present at different roosting locations. The guidelines of the American Society of Mammalogists for the use of wild mammals in research (Sikes, 2016) were strictly followed to conduct the survey.

Data analysis:

The data were collected and summarised using Microsoft Office Excel 2019 and PAST version 4.04. Each bat roost's geographic coordinates were obtained using a JK Fantasy GPS Map (version 1.8.2). Using GIS software (Spatial Reference ArcGIS 10.2: WGS1984 Datum: 1984 Map units (degrees), bat roosting sites and distribution were marked and reported. The variation between the bat populations of the old (earlier survey) and new (present survey) colonies to the species level was reported using principal component analysis (PCA)**.** Mean Absolute Deviation (MAD) for each type of roost was computed to deduce roost variation in bat populations between earlier and new survey**s**. The diversity indices can be grouped into three general categories: (a) species richness, (b) species dominance, and (c) speciesevenness.SpeciesrichnesswascalculatedusingMargalef'sindex(R), species dominance was calculated using Simpson's index (D), and species evenness was calculated using the Shannon-diversity index (H′). These were calculated using the following formulas provided below.

Margalef's Index:

A measure of species richness with respect to both the number of individuals and number of species present in a community.

$$R= \frac{S-1}{1n(N)}$$

Where,

R=Species richness according to Margalef's Index.

S=Number of species that are present in the community (species richness).

N = Number of individuals (abundance).

ln=natural logarithm.

Simpson's Index:

Approximates dominance, with greater values representing communities dominated by a few species and lesser values representing evenness of species.

$$D = \frac{\sum_{i=1}^{S} ni(ni-1)}{N(N-1)}$$

Where,

D =Simpson's Dominance Index.

Ni= The number of individuals in the species.

N= The number of organisms in the sample.

S= The number of species in the community.

 JournalUGCCAREListed(Group-I)Volume12,Issu01,2023

Shannon's Diversity Index:

A measure of biodiversity based on species richness and evenness with greater values where diversity is more.

$$H' = \sum_{i=1}^{S} Pi1n(Pi)$$

Where,

H′=Shannon-Wiener Diversity Index.

Pi=The ratio of members of the

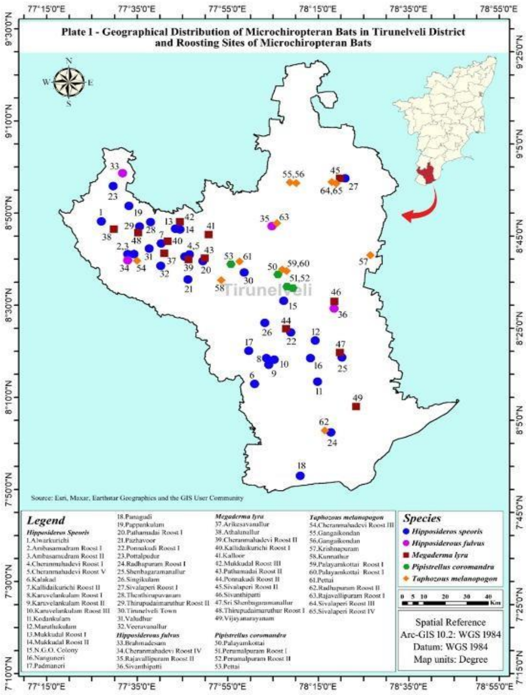
I=The species to the total number of members

S = The total number of species in the community.

ln=The natural log.

3. Result

Figure1: Map showing the study area and the bat's roost locations of the present survey.



The present survey investigated the preferences for roosting sites, bat populations, and threats across old and new colony types to understand the factors that drive the success and sustainability of bat colonies in various habitats. Five species of bats were comparatively analysed in old and new population survey across (covering all 8 taluks) Tirunelveli district. The identified species were *Hipposideros speoris*, *Hipposideros fulvus*, *Megaderma lyra*, *Pipistrellus coromandra*, and *Taphozous melanopogon*. They belong to the Microchiroptera

Sub order and the families Hipposideros (leaf-nosed bats), Megadermatidae (false vampire bats), Vespertilionidae (evening bats), and Emballonuridae (sheath-tailed bats).The distribution of identified species as recorded in old (O) and new colonies (N) were as follows - *H. speoris* (O-59.87%, N- 45.64%), *H. fulvus* (O-3.73%, N-3.67%), and *M. lyra* (O-26.14%, N-7.81%). The population of all the above species have declined in new colonies compared to old colonies. However, *T. melanopogon* (O-24.5%, N-28.07%) and *P. coromandra* (O-0%, N-0.57%) have increased in their population when compared to old survey data. Figure 1 shows the roost locations of the all the identified bat species in the present survey.

Principal Component Analysis (PCA):

Principal component analysis based on eigen value showed cumulative values of principal components which is0.4017 (40.17%) for new colony represented as Principal Component 2 (PC2) and 0.9598 (95.98%) for old colony which is represented as Principal Component1(PC1).

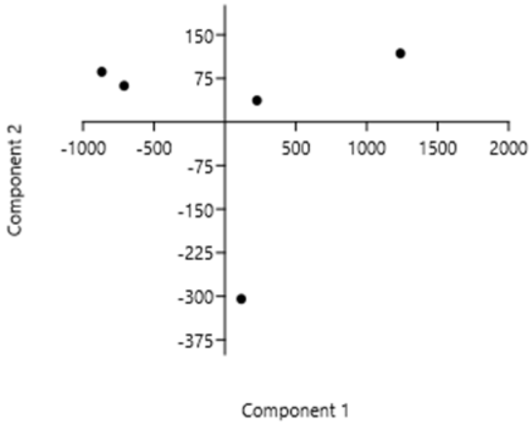


Figure 2: The graph of the score plot of distinguishing populations between the old and new colony sizes of bats found in the study according to the combination of Principal Component 1 and Principal Component 2

Figure 2 represent the scatter plot of principal components (PC1 vs. PC2), showing the relationship between old and new colonies of bat species. Among the bat species, the eigen value indicates that the new population is much lesser than the old populations in *H. speoris* [PC1(1237.4),PC2(118.22)],*H. fulvus* [PC1(-710.61),PC2(62.426)],and *M. Lyra* [PC 1 (115.46), PC 2 (-304.46)].This analysis also indicates increase in population variation among *P. coromandra*[PC 1 (-868.19), PC 2 (86.589)]and *T. melanopogon*[PC 1 (- 225.99), PC 2 (37.226)]. A variation of 1.887% was recorded for *T. melanopogon* among the old and new colony as indicated by Principal Component analysis.

Mean Absolute Deviation (MAD):

Mean Absolute Deviation (MAD) was calculated to compare the variation between the old and new roost preference. MAD determines how the roost preference behaviour of bats in various locations differs from both old and new surveys. The roost preference traits of Microchiropteran bats were caves, godowns, temples, abandoned buildings, and cracks in wooden boxes. Their preferences show more variation as evidenced by the Old Colony's larger absolute deviations across the majority of roost types. The Old Colony's temple roost displays a large deviation of 2292.83, while the New Colony's temple roost shows a smaller deviation of 1185.5. The significance of noticeable deviations is further highlighted by squaring the differences. In the Old Colony, the squared difference for the temple is remarkably high-5,257,849.23, while for the New Colony it is 1,405,410.25. The MAD values of observed roost preferences were shown in Table 1.

Table 1: Summary of data showing the roosting preferences and population variability in Microchiropteran bat colonies in a comparison of old and new bat populations.

S. NO	Roost Type	Old Colony Size	Absolute Deviation (Old Colony)	Squared Difference (Old Colony)	New Colony Size	Absolute Deviation (New Colony)	Squared Difference (New Colony)
1.	**Abandoned Building**	50	620.17	384,410.03	132	158.5	25,140.25
2.	**Cave**	350	320.17	102,308.03	0	290.5	84,390.25
3.	**Godown**	50	620.17	384,410.03	0	290.5	84,390.25
4.	**Stone Building**	608	62.17	3,861.75	125	165.5	27,390.25
5.	**Temple**	2963	2292.83	5,257,849.23	1476	1185.5	1,405,410.25
6.	**Wooden Box Crevices**	0	670.17	448,900.03	10	280.5	78,680.25

Species diversity of bats in both new and old populations:

The species, *Hipposideros speoris* was dominant in both colonies, and Margalef's (R) index was noted as 1.996 (OC) and 3.222 (NC), which shows the species richness in New Colony. Simpson's (D) index of 0.8268 (OC) and 0.9038 (NC) shows overall moderate diversity with NC slightly being more diverse. Shannon's index of 2.14 (OC) and 2.66 (NC) shows overall high diversity with NC specifically being more diverse. *Pipistrellus coromandra* is not found in OC, so the value was given as 0 as compared to NC which shows R value as 1.303, D value as 0.7, and an H' value as 1.28 as shown in Table 2. *Hipposideros fulvus, Megaderma lyra,* and *Taphozous melanopogon* add low to moderate values for all the indices, with NC adding higher values than OC in most cases.

Table 2: Diversity Indices of Bat Species in Old and New Colonies

S. No	Bat species	Margalef's (R)		Simpson(D)		Shannon(H')	
		OC	**NC**	**OC**	**NC**	**OC**	**NC**
1.	*Hipposideros speoris*	1.996	3.222	0.8268	0.9038	2.14	2.66
2.	*Hipposideros fulvus*	0.1936	0.4809	0.2449	0.6138	0.41	1.02
3.	*Megaderma lyra*	0.8894	1.221	0.5846	0.8164	1.14	1.81
4.	*Pipistrellus coromandra*	0	1.303	0	0.7	0	1.28
5.	*Taphozous melanopogon*	0.8705	1.615	0.7714	0.8244	1.66	1.99

OC-Old Colony, **NC**-New colony

Habitat and Light Preference:

The majority of Microchiropteran bats select habitat such as agricultural areas, water bodies, human settlements, and hillocks. The propensity for roosting in temples was then noted for *H. fulvus*. The *P. coromandra* species favours the backs of picture frames, wooden boxes, and cracks as its preferred roosts. Figure 3 shows the percentage of bats' preferences for these habitat types. Bat preferences in the Agricultural Area (AA), Water Bodies (WB), Human Settlement (HS), Hillock (H) ranged from 28.79% to 33.33%. The roost had either bright, semi-dark, or dark lighting. When compared to roosts in semi-darkness (37.88%) and light environments (18.18%), Microchiropteran bats preferred dark environments (43.94%). *H. speoris* and *M. lyra* adapts all three-lighting pattern as their roosts.

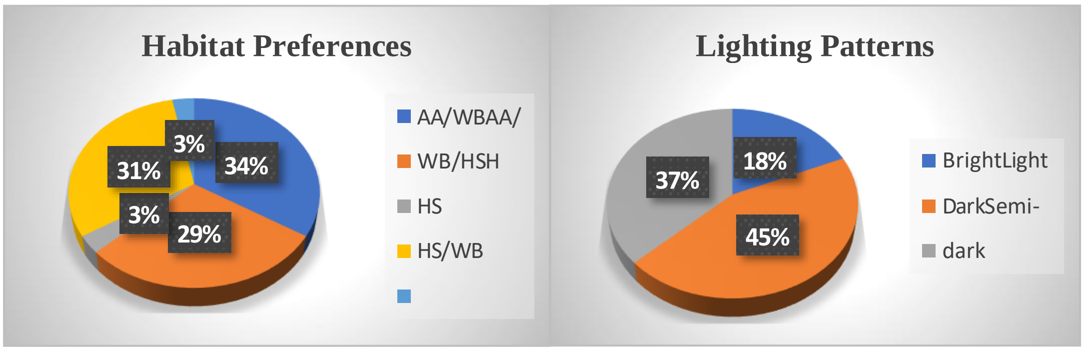


Figure 3: Represents the preferred habitat types of Microchiropteran bats, with percentages showing their selection across different environments. (AA–Agricultural Area, WB – Water Bodies, HS – Human Settlement, H – Hillock)

Co-existence:

Bats maintained an inter-individual distance ranging from 8 to 24 cm, and their roosting posture was consistently linear. It was discovered that *T. melanopogon and H. speoris* colonies coexisted. The space between individuals is approximately 7 to 12 cm. Colonies of *M. lyra* and *H. fulvus* also coexists with each other. The roosts of the three bat species (*H. speoris, T. melanopogon, and M. lyra*) were most often found in stone buildings, unused buildings, and temples.

4. Discussion

This study compared old and new roosting patterns across five bat species (*Hipposideros speoris*, *Hipposideros fulvus*, *Megaderma lyra*, *Pipistrellus coromandra*, and *Taphozous melanopogon*) at 65 sites in Tirunelveli district, revealing species-specific shifts in colony dynamics and habitat utilization. Roost selection emerged as a function of opportunistic exploitation of pre- existing structures (natural or anthropogenic), constrained by microclimatic requirements, predator avoidance, and foraging resource availability consistent with global patterns of chiropteran ecology (Balasingh *et al.*, 2023; Kunz, 1982 b). Notably, Hipposideridae dominated both old (50.86%) and new (47.5%) colonies, underscoring their tropical adaptability, though *H. speoris*, *H. fulvus*, and *M. lyra* exhibited declining populations in new surveys. However, *P.coromandra* and *T.melanopogon* showed significant increases in population, reflecting differential responses to anthropogenic human habitat modification. The dependence on anthropogenic roost (e.g., abandoned buildings) highlights bats' nature to exploit human-altered/abandoned landscapes, yet additional threats—particularly light pollution and habitat fragmentation which suggest that structural alternatives alone may insufficiently mitigate population declines. These findings align with Kunz and Lumsden's (2003b) framework of roost limitation, where even synanthropic species face compounding pressures from ecological degradation.

This comparative analysis of bat diversity between old (OC) and new colonies (NC) reveals distinct shifts in community structure, driven by differential species responses to anthropogenic and ecological pressures. Quantitative indices demonstrate NC's superior diversity: Margalef's index (R = 3.222 vs. OC's 1.996) highlights greater species richness, while Shannon (H' = 2.66 vs. 2.14) and Simpson (D = 0.9038 vs. 0.8268) indices reflect enhanced evenness and reduced dominance in NC. These trends align with Kunz (2003a) framework linking roost flexibility and foraging resource availability to synanthropic adaptation. *Hipposideros speoris* emerged as a keystone regulator in both colonies, though it was dominated in OC (50.86% population share) moderated in NC (47.5%) due to increased contributions from species like *Taphozous melanopogon* and the inclusion of *Pipistrellus coromandra*. The latter's preferential colonization of NC—despite minimal impact on diversity indices—suggests niche partitioning in response to microclimatic or structural roost features. Conversely, population declines in *Megaderma lyra* and *Taphozous melanopogon* may signal ecological stressors, such as light pollution or roost saturation, disproportionately affecting these taxa.

Particularly, the expansion of roosting sites in NC shows contrast with OC's habitat availability, potentially facilitating *H. speoris* and *T. melanopogon* migrations to reduce environmental pressures. However, the inverse correlation between species richness and latitude (Findley, 1993) complicates the roost selection as localized habitat fragmentation may takeover broader biogeographically areas. These findings show the non-linear relationship between roost availability and population viability, emphasizing the need to adapt conservation strategies that address species-specific tolerance thresholds to anthropogenic/human indulgence change. The study reveals significant shifts in roost preferences among Microchiropteran bats between old and new surveys in the Tirunelveli district. A notable decline in cave roosting was observed, from 8.7% to 0%. This could indicate habitat loss, disturbance, or changes in local cave conditions. Temples remain the dominant roost preference, slight decrease from 84.68% (old survey) to 73.69% (new survey) was noted. This suggests temples remain to be crucial roosting sites, because of their more stable microclimates and complexity in structure. Godowns (1.24% to 0%) and stone buildings (15.12% to 7.17%) showed decreased utilization or complete abandonment. This highlights the importance of preserving diverse roost options for bat conservation. Bats favored older temples with specific features such as compartmentalized spaces, rough ceiling surfaces, dampness, and darkness. These characteristics likely provide optimal microclimatic conditions and protection. The findings support Kunz (2003 b) assertion that adaptive bat species can exploit urban environments for both foraging and roosting. Applying Arita's (1996) criteria, the changes in roost utilization underscore the need to assess and protect roosts based on species richness, abundance, and presence of species of special concern.

These results emphasize the critical role of diverse roosting options in bat conservation, particularly in human-modified landscapes. The decline in selection of natural roosts like caves and certain manmade structures (godowns) highlights the need for specific conservation efforts to maintain more suitable roosting habitats for Microchiropteran bats in the study region. Bats are nocturnal mammals that prefer natural roosting habitats such as caves, temples, stone buildings and many more (Kunz, 1982c; Kunz and Lumsden, 2003 c).In this study, *H. speoris*, *M. lyra*, and *T. melanopogon* preferred roosts with varying illumination levels, including bright light, dark, and semi-dark conditions. Conversely, *H. fulvus* and *P. coromandra* showed a preference for dark roosts. Synanthropic bats depend on the quality of their immediate surroundings for drinking and foraging, in addition to suitable roosting spaces. Urban areas with habitat parks and human settlements were identified as ideal habitats for species like *H. speoris* and *M. lyra*, which also find ample foraging opportunities in these environments.

Growth in Human population poses threats to bat diversity. Increased land use and resource demand contributes everely to species extinctions (Pimentel*etal.*,2007).While *H. speoris* showed resilience to temple disturbances, other species were negatively impacted by renovations and visitor numbers (Ganesh *et al.*, 2022). Artificial light had significantly impacted bat behaviour, especially with species like *Pipistrellus pipistrellus* which alters emergence patterns when exposed to differential light levels in daytime roosts (Down *et al.*, 2003).Detrimental effects on roosting preference can be seen if the roost entrances are well illuminated (Boldogh *et al.*, 2007).

Conservation priorities should focus on roost protection (Pierson, 1998), with legislation implemented to safeguard primary roosting habitats for bat species (Jeyapraba, 2016). These measures are crucial for mitigating the impacts of human activities on bat populations and preserving their diversity. Therefore, comparison of two studies that took place at the same study area at different period as improved our understanding towards mitigation strategies.

5. Conclusions

The findings of the study highlight the need for specific conservation strategies focussing to protect and preserve bat population and their habitat preferences. Human influenced threats which affect the viability of the bat roosting places must be severely monitored and mitigated with strong measures from the government and other law enforcing bodies. These kind of conservation and mitigation efforts will effectively conserve bat population in the future.

Author's Contribution: The first author conceived and designed the study, conducted field surveys, collected and analyzed data, and prepared the first draft of the manuscript. The second and third author contributed proportionately in providing overall supervision, study design, data interpretation, critical manuscript revision, and final approval for submission.

Acknowledgement: We would like to acknowledge the sincere efforts and assistance of S. Raja, D. Benifer Samraj, and R. Jeba Ruban and in Field work and data collection.

Funding statement: The authors received no financial support for the research, authorship, and/or publication of this article.

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