

Editorial

Diversity Aspects in Bats: Genetics, Morphology, Community Structure

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Bats are the second largest order of mammals, with about 1400 known species [1]. Consequently, bats make a significant contribution to the diversity of the class as a whole, as well as the local mammalian faunas of the tropics and temperate zones. Despite the long-term study and close attention of specialists, especially in recent decades, the space for the research of chiropteran peculiarities remains extremely vast. Even the number of species and genera, as well as the boundaries between taxa, are still not entirely clear. The composition and structure of local communities (especially tropical ones) and the principles of their functioning have been insufficiently studied; the features of a significant part of species, including phylogeographic structures, the specificity of behavior, and roles in local ecosystems, are often not known at all. Recent events have shown that knowledge of bat diseases and their role as possible vectors of pathogens are also very fragmented. It is not surprising that research teams worldwide are paying attention to this group of animals, often finding unexpected and non-trivial approaches to understanding the diversity of bats.

The Diversity Special Issue, entitled “Diversity Aspects in Bats: Genetics, Morphology, Community Structure”, contributes to various aspects of bat diversity and different methods and approaches to their cognition. The articles posted here are devoted to topical problems of the coexistence of bats with humans and the impact (both direct and indirect) of human activity on the chiropteran population; problems of bat taxonomy, species boundaries, and the necessity for an integrated approach to clarify them; and the composition of local fauna and the role of landscapes in maintaining bat diversity.

The urban environment is perhaps the most human-modified type of landscape. Nevertheless, it also has its own fauna; ecologically flexible animal species (including bats) adapt to such uncharacteristic living conditions, populating not only park zones but also buildings and other urban developments [2,3]. At the same time, the attention of researchers, especially in the tropics, has been mainly focused on the inhabitants of primary natural habitats, while urban fauna remain “behind the scenes”. An article by Pham et al. [4] partially fills this gap. However, since the direct capture of bats in urban environments is highly problematic, the authors resorted to modern acoustic monitoring methods by collecting bat echolocation call parameters in Ho Chi Minh and Tra Vinh cities. This work became a pilot study for Indochina. Collected data revealed an expectedly low level of diversity for the studied bat assemblages, with only four main urban bat species found in the observed cities. The success in classifying urban bats based on their echolocation calls provides a promising baseline for monitoring the effect of urbanization on bat assemblages in Vietnam and Southeast Asia as a whole.

The growing network of motor roads around the world has had an inevitable impact on bat populations, both indirectly (through degradation and fragmentation of natural habitats) and directly (as a result of roadkill) [5]. However, counting bats that die on the roads is very difficult, and it is even more difficult to identify patterns regarding where and which bats die more often. This task is posed in the publication by Huang et al. [6] for the territory of Taiwan. With the help of citizen scientists, a vast collection of about 660 roadkilled bats belonging to 20 species (a valuable part of the Taiwanese bat fauna)



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was obtained. Such a significant material made it possible to identify certain patterns in the distribution of victim bats. Higher elevations and light pollution were found to negatively correlate with roadkills, whereas protected areas were found to positively correlate. At lower elevations, aerial hawking species are most at risk of roadkill. This study shows that the spatial distribution and behavior of bats, among other things, should be taken into account when planning road networks and conducting associated conservation activities. Expanding urbanization, the development of road networks, and other anthropogenic landscape transformations inevitably lead to the fragmentation of natural habitats. As a result, populations of sedentary species become increasingly isolated from one another, which can lead to decreases in their genetic diversity. This hypothesis was tested by López-Wilchis et al. [7] for the case of the Mexican greater funnel-eared bat (*Natalus mexicanus*). Its genetic structure and diversity were measured using the hypervariable domain of the mitochondrial control region and 10 microsatellite loci. The obtained results showed that the species' genetic diversity was recently historically high and is currently decreasing to moderate. No contemporary gene flow between the populations was observed, suggesting that their isolation is caused by habitat fragmentation. The results of this study can be widely extrapolated, clearly demonstrating the vulnerability of forest bats to the growing anthropogenic transformation of natural landscapes.

Knowledge of taxonomic diversity has formed the basis for much subsequent research, both basic and applied. The concept of chiropteran taxonomic diversity has undergone changes since the 1990s. Significant roles in this have been played by molecular genetic methods (the application of which has been steadily expanding in recent decades) and the widespread use of the genetic species concept [8], which has changed the understanding of boundaries between taxa.

The hybridization and DNA introgression processes distort taxonomic boundaries and lead to the inconsistency of phylogenetic constructions based on different markers. To date, several cases of interspecies hybridization in bats have been identified [9,10], but each case requires special consideration.

Méndez-Rodríguez et al. [11] discuss the first revealed case of hybridization in the family Mormoopidae. The existence of individuals with an intermediate phenotype in the sympatry zone of two sibling species (*Pteronotus fulvus* and *P. gymnonotus*) became an indication of the presence of such a process. To clarify the situation, the authors used multiple genetic markers of different inheritance: the mitochondrial COI gene, 3 nuclear markers, and 13 microsatellites. These markers were analyzed in sympatric and allopatric populations of the two species plus the closely related *Pteronotus davyi*. The species-level differentiation of all three lineages was confirmed, but nuclear and mitochondrial results were discordant due to the introgression of the *P. fulvus* mitochondrial DNA in *P. gymnonotus* populations. Microsatellite analyses showed contemporary genetic contact between the two species, and 3.0% of the studied specimens were identified as hybrids. It is noteworthy that no correlation was found between contemporary hybridization and animals with an intermediate phenotype.

The use of genetic markers of only one type, in this case, would create an incorrect picture of phylogenetic relationships and taxonomic boundaries. This is also reported by Yuzefovich et al. [12] regarding an example of another taxon, *Hipposideros gentilis*. Based only on mitochondrial data, this bat was supposed to represent a paraphyletic complex of putative cryptic species. However, the use of multiple nuclear markers demonstrated its monophyly. The observed discordance could be explained by the historical hybridization between ancestral populations of *H. gentilis* and *H. rotalis*/*H. khaokhouayensis* lineage. Obtained morphological data better corroborate nuclear results than either mitochondrial data or previously proposed subspecies delimitation.

Both works demonstrate that any single approach (mtDNA or morphology) can successfully identify a taxonomic problem, but its adequate solution requires complex measures.

The adequate understanding of the composition of the fauna and the structure of local communities requires studying the entire diversity of habitats. This is especially

important when it comes to unique areas such as isolated islands. Based on new data, Vu Dinh Thong et al. [13] provide an overview of the bat fauna of the Cat Ba archipelago. Previous surveys on these islands were conducted in the inner areas of Cat Ba Island. Between 2015 and 2020, the authors conducted a number of bat surveys, with special emphasis on the mangrove ecosystem. A total of 23 species belonging to 13 genera of 6 families were recorded. Fifteen bat species were captured in mangroves, showing the high importance of this habitat for bat conservation. This conclusion is of particular importance due to the high vulnerability and continuing decline of this ecosystem in Vietnam and Southeast Asia.

The Special Issue does not cover the full range of existing problems. However, it reflects the existing variety of directions in bat studies, and the works published in it raise extremely interesting subjects and give readers a fresh look at them.

Conflicts of Interest: The author declares no conflict of interest.

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