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# ECOLOGICAL PARTICULARITIES AND THE IMPORTANCE OF BATS (MAMMALIA: CHIROPTERA) IN THE URBAN AND RURAL ENVIRONMENT OF THE REPUBLIC OF MOLDOVA

**165.02. Zoology**

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## CONCEPTUAL GUIDELINES OF RESEARCH

**The actuality of the subject.** During the last decades, many species of bats have undergone an essential decline in the numerical strength of their populations, becoming an important object of biodiversity conservation at the local, European and global level.

Bats, together with some birds, represent a group of insectivorous vertebrates with a significant role in regulating the number of insect species mainly harmful to agricultural crops and with a negative impact on humans.

Anthropogenic habitat creates specific conditions of interaction between organisms within this system. Bats found favorable conditions for shelter and food in this changed environment. The presence of a large number of insects accompanying human activities serve as a food source, and the presence of human constructions, with many enclosed spaces, serve as a source of shelter and provide an essential advantage for existence. It should be noted that only some species of bats accept this opportunity, other species prefer natural ecosystems, located far from anthropized ones, to carry out their biological cycle. However, anthropogenic impact, habitat destruction, increasing urbanization, has a negative aspect on the distribution of chiroptera in different habitats.

Bats are reference species for assessing the health of ecosystems. Through the activities of bats, their ethological aspects, it is possible to obtain data with reference to the state of ecosystems at local or global level.

Over the decades, studies have been carried out in order to establish the life cycles of bats, their hibernation and reproduction characteristics in natural conditions. In general, bats are not synanthropic species, but their presence in urban habitats suggests that some species are able to adapt to the conditions of a highly anthropized environment and become an important link in the functioning of urban and rural ecosystems.

The city of Chisinau and its suburbs represent heavily anthropized areas where favorable conditions similar to the natural ones characteristic for the activity of bats are created (recreational areas, parks, forest belts, lakes, etc.). Intense anthropic activity, the presence of permanent lighting during the night, noise pollution are factors with a negative influence on the bats species that inhabit urban and rural areas.

An important aspect in the field of chiropterology consists in researching the biological and ecological peculiarities of bats in order to establish the mechanisms of their interaction with the environment.

In specialized research, special attention is paid to the influence of climatic and anthropogenic changes on chiroptera populations in various types of urban and rural ecosystems. Carrying out an original and complex study through the faunal prism of bat communities in order

to obtain updated ecological information about the faunal spectrum of bats in urban and rural areas, the degree of adaptation of chiroptera to the human environment, highlighting the limiting factors and the need to protect them in the heavily anthropized environment.

**Description of the situation in the field of research and identification of research problems.** The first in-depth scientific studies in chiropterology were carried out by Averin I. and Lozan M. (1965), Lozan M. and Scvorțov V. (1965), Doroșenco A. (1975), Averin et al. (1979). More recent research was carried out in the 1990s by Andreev S. and Vasiliev A. (1997, 1998) [20, 22, 23]. At the beginning of this century, the research was continued by Andreev S. and Bondarenco A. After 2013, the in-depth monitoring research and description of underground habitats in the north and centre of the republic was carried out [13]. Urban fauna is still a new topic of research and there is only one booklet: "Fauna of cities and its protection" [21], with a brief description of some bat species found in urban habitats. Thus, urban fauna remains an open subject for research and monitoring. Bats play an important role in the functioning of natural and anthropogenic ecosystems, but they are the least studied group of mammals. The present work is topical, since bats in urban and rural areas are constantly under strong pressure from the anthropic factor, the number of chiropterans in these regions is constantly changing and requires the updating of data. The in-depth research of the chiropterofauna allows the accumulation of data necessary for the elucidation and maintenance of the functionality of the anthropized ecosystems in the Republic of Moldova.

**Scientific research methodology.** The collection of data and of biological material was carried out by the following methods: manual collection of individuals from buildings and identification of species by ultrasonic detector. The determination took place visually after the flight mode, after external characters such as typical resting posture, body length, ear length and shape, and species that are more difficult to differentiate were determined with the help of additional morphological measurements after capture [7, 11]. The works of researchers Brauner A., Cuznețov B., Gassovskkii G., Saenko Ia., Averin Iu., Lozan M., Doroșenko A., Munteanu A., Andreev S., Vasiliev, A Pocora V. and Pocora E. [1, 17, 20, 21, 22, 23] served as methodological and theoretical-scientific support. The research in the field was carried out according to the accepted methodologies in chiropterology and reflected in the works of the authors Valenciuc N., Decu V., Buttersby A., Murariu D. et al. [3, 18].

**The aim of the thesis is** elucidating the ecological peculiarities and faunal diversity of bat communities in urban and rural areas of the Republic of Moldova, highlighting the importance of rehabilitation of bat species and elucidating the role of bats in nature and in human life.

The following **objectives** have been set: 1) Elucidation of the faunal and taxonomic

structure of chiropterans from the urban and rural environment of the Republic of Moldova; 2) Determining the structure of chiroptera communities in various types of urban and rural biotopes; 3) Highlighting the ecological peculiarities of bat communities in the urban and rural environment of the Republic of Moldova; 4) Elucidation of the importance of the rehabilitation of bats, their role in nature and the ways of conservation of chiropteran fauna in heavily anthropized areas.

**Scientific novelty and originality.** For the first time, complex researches of bat communities in the urban and rural environment of the Republic of Moldova were carried out. Bat species that have adapted to urban conditions and species that use anthropogenic rural sites for roosting were identified. The data on the distribution and composition of the urban bat fauna were updated and the ecological peculiarities of 15 bat species from 5 genera were highlighted. The current status of chiropteran species in urban and rural habitats and faunal composition in different heavily anthropized ecosystems was established. For the first time, the methodology for the rehabilitation of bats during the winter period was developed under the conditions of the Republic of Moldova. The role and ways of conservation of this important group of mammals in the context of anthropo-climatic changes were highlighted.

The solved scientific problem consists in highlighting the ecological and faunal peculiarities in the urban and rural environment, elucidating the preferences of the species towards certain sites for shelter and hunting.

**Theoretical significance.** The faunal and taxonomic diversity of urban and rural bats was elucidated. The ecological peculiarities of bat species and their adaptations in heavily anthropized ecosystems were elucidated. The study carried out falls within the priority scientific directions, national and international programs and strategies, regarding the protection and conservation of biodiversity, which constitutes a significant contribution to the achievement of international conventions, including those of Bern (1979), Bonn (1979), the Convention from Rio de Janeiro (1992) and others to which is joined the Republic of Moldova.

**The applicative value of the work.** The importance of bats in urban habitats was elucidated and the bat rehabilitation methodology during the winter period was elaborated. The results of the thesis can serve as support for the conservation methodology of bat populations in heavily anthropized regions. Practical recommendations were developed regarding the conservation of chiropterans and their habitats in the urban and rural environment, highlighting the need for ecological education and the involvement of the general public in the conservation of chiroptera fauna.

**Implementation of scientific results.** The obtained results were used as support for the elaboration of a methodical indication. The research results were applied in the process of

implementing an international project of the COST program, to the implementation of two cross-border projects with Romania. The information about the urban bat fauna is used and implemented in the didactic process, in the preparation of bachelor's and master's theses at educational institutions with a biological and ecological profile. The data will be used for the development and drafting of the 4th edition of the Red Book of the Republic of Moldova.

**Approval of scientific results.** The results obtained from the research were presented and approved at national and international conferences.

**Publications on the topic of the thesis.** The results obtained from the research and the conclusions were presented in 15 scientific papers.

**Keywords:** chiroptera, urban environment, rural environment, taxonomy, diversity, shelters, anthropization, ecological features, importance, rehabilitation.

## THE CONTENT OF THE THESIS

**Introduction.** The characteristic of the paper is briefly represented: the importance and actuality of the approached topic, the purpose of the paper and the research objectives, the scientific importance and the applicative value of the obtained results, the summary of the thesis compartments are described.

### 1. HISTORY OF BAT RESEARCH (MAMMALIA:CHIROPTERA)

**1.1. History of chiropterofauna research worldwide.** Since prehistoric times peoples has struggled to understand bats – unique creatures that shared caves with them. Scientific data on chiropterofauna appeared in the works of Linnaeus, the most important being "Sistemae Naturae" (1758), in which some species of bats described had already been known for about 300 years (for example: Vespertilio murinus, Plecotus auritus). The name of the order – CHIROPTERA, was given by Blumenbach in 1779 [14].

Currently the Chiroptera order includes: about 1449 taxonomically classified species in 235 genera and 21 families of mega- and microchiroptera worldwide. Microchiroptera is the largest suborder, which includes: 17 families, 133 genera and about 743 species. Among microchiroptera, the largest family is Vespertilionidae with a fairly large number - 520 species belonging to 59 genera [14].

**1.2. The current state of chiropterofauna research in the Republic of Moldova.**

The study of bats on the territory of the Republic of Moldova began as early as the 19th century, along with faunal research throughout Europe. The first illustrious naturalists who studied bats were Nordmann A. (1840) and Tardent H. (1841). Since the 1950s XX, in this study notorious

specialists were involved, who describe the presence of 13 species of bats (Rh. hipposideros, M. myotis, M. blythii, M. daubentonii, M. dasycneme, M. bechshteinii, M. mystacinus, Nyctalus noctula , Pipistrellus pipistrellus, Plecotus auritus, Barbastella barbastellus, and Eptesicus serotinus), for which a brief morphological description and some biological and ecological peculiarities are given [14]. In the 1970s XX, the research of the chiropteran fauna continues with the detailed description of 18 species of bats identified on the territory of the Republic of Moldova

In 2006, an important scientific-popular work was published on the chiropteran fauna - "Bats, remarkable creatures", in which 21 species registered on the territory of the Republic of Moldova are described, of which 3 new species have been identified: *Pipistrellus kuhlii*, *P. pygmaeus* and *Plecotus austriacus* [1]. Starting from 2013, underground hibernation, breeding and roosting sites of bats in the central and northern areas of the Republic of Moldova were investigated, where 11 species of bats were identified [13].

**1.3. Protection of bats in Europe.**

Most of the species recorded from different urban and rural sites are protected at national and international level. Some species, e.g. *Myotis myotis*, *M. bechsteinii*, *Vespertilio murinus*, mainly populate shelters in the central area of the republic, they are critically endangered and are detected in small numbers only in a few sites [1, 5, 8].

The species *Plecotus auritus, Rhinolophus hipposideros and Myotis dasycneme have the status of endangered species, Pipistrellus kuhlii, Myotis blythii, Myotis daubentonii, Myotis mystacinus, Plecotus austriacus* are vulnerable species and are protected by national legislation.

Practically all bat species in Europe are listed in Annex II of the Habitats Directive and in Annex II (strictly protected species) of the Bern Convention, with the exception of Pipistrellus pipistrellus, which is listed in Annex III (protected species). Bats are also included in the UN Convention on the Conservation of Migratory Species of Wild Animals (CMS). The Agreement on the Conservation of Bat Populations in Europe - "EUROBATS" - is dedicated exclusively to bats [14].

## 2. MATERIALS AND METHODS

**2.1. Geographical characterisation of Chisinau Municipality.** Urban ecosystems and the territories adjacent to them are of great importance for the conservation of biodiversity, being an essential component of the creation of an anthropised environment in the territory occupied by buildings. In recent decades, an intensive expansion of urban and rural settlements has been observed, resulting in an increase in population density in the city and suburbs. From an evolutionary point of view, cities are young habitats with a complex of constantly changing ecological conditions. In such conditions, there are changes in the structure of faunal communities

that induce the generation of strategies for the adaptation of animal species to the new living conditions. One of the aspects of these changes is synurbanisation, i.e. the adaptation of wild animals to the urban environment and to coexistence with humans. In total, the area of green spaces is 1883.03 ha, which represents 15% of the total area of the city of Chisinau (Fig. 2.1.2) [9].

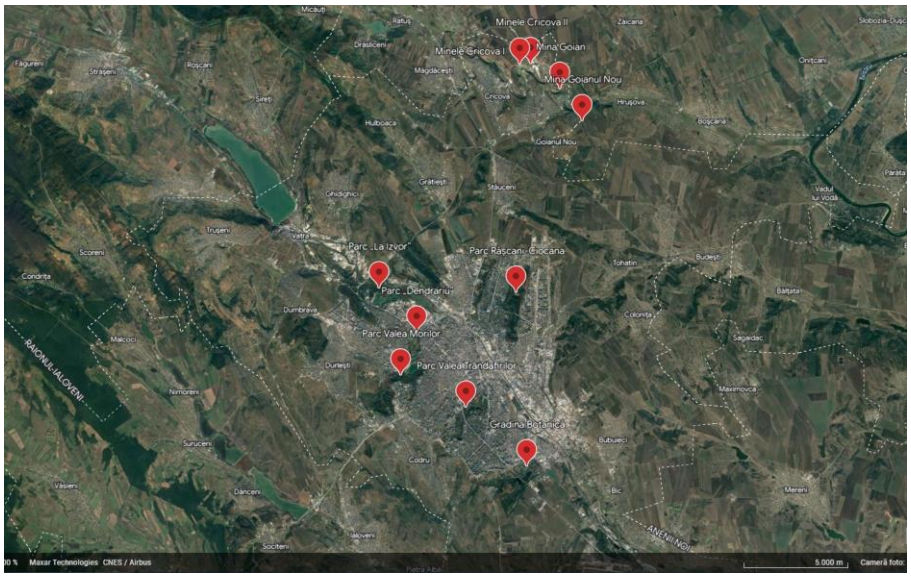



**Figure 2.1.2. Map of the city of Chisinau with sectors where research was conducted**

All the habitats examined were divided into two groups: rural habitats and urban habitats. Rural habitats are of anthropogenic origin but are similar to natural habitats and are not exposed to strong anthropogenic pressures.Urban habitats have specific conditions that are artificial but favourable to the presence of bats: vegetation and water sourses, a great variety of natural and artificial shelters, and an abundance of insects that accompany human activities and constitute the trophic base of bats.

**2.1.1 Description of the ecosystems of Chisinau city.** The natural and artificial ecosystems of the city of Chisinau and its surroundings were described, including: forest ecosystems, aquatic and wetland ecosystems (river basins, lakes, ponds, etc.), as well as adjacent areas, various types of agrocenoses (cereal fields, orchards, vineyards, fodder crops, etc.). Urban ecosystems are represented by the city parks: Botanical Garden, Valea Morilor, Valea Trandafirilor, Râscani-Ciocana forest area, Alunelul Park, Arboretum; neighbourhoods with blocks of flats, old and abandoned buildings, recreational sectors in the suburbs (Vadul-lui-Vodă, Durlești, Cricova, Dumbrava), etc. [9].

**2.1.2 The underground shelters of Chisinau municipality**. The underground habitats of bats in the central part of the Republic are, as a rule, of an artificial character, being represented by mines, caves, quarries left over from stone quarrying. Within the commune, there are 4

underground sites where a relatively high faunal diversity has been recorded: two mines in the town of Cricova (Cricova I and Cricova II), Goian and Goianul Nou [16].

**2.2. Chiroptera research methods.** In the research carried out in the territory of Chisinau Municipality, the following methods were used from the wide range of methods: bibliographic analysis, monitoring of bats in shelters, manual collection in various types of anthropogenic constructions, collection of dead individuals (for subsequent laboratory studies) and the acoustic method of determining bat species using the ultrasonic detector [3, 15].

For the identification of bat species in heavily anthropised urban areas, the classical methods were used: capture, morphological and morphometric study. In parallel, an indirect method of faunal research was possible during the flight: the determination of bat species using the heterodyne ultrasonic detector (Pettersson Electronic AB, D 200). The technique of using ultrasonic detectors together with the flight characteristics of bat species in a given habitat, as well as some behavioural characteristics, leads to a fairly accurate identification of species present in a given ecosystem [15].

A new acoustic method for the Republic of Moldova, used for the first time in September 2021, was achieved by placing the acoustic recorder "Audiomoth" in the parks. The recordings were analysed with the help of the "Kaleidoscope" program, which is a software for analysing the sounds of wild animals (birds, frogs, bats) with high precision without direct contact with them.

## 3. FAUNA AND ECOLOGY OF CHIROPTERA SPECIES IN URBAN AND URBAN AND RURAL ECOSYSTEMS OF CHISINAU MUN.

**3.1. The diversity of bats in Chisinau Municipality**. In the period 2018-2022, 15 species of bats from 2 families and 6 genera were recorded in different types of ecosystems of the Chisinau municipality by different research methods. The share of the commune's chiropterofauna is 71.4% of the republic's bat fauna [1].

I. Fam. Rhinolophidae, Gray, 1821
1. *Rhinolophus hipposideros* (Bechstein, 1800) – Lesser Horseshoe Bat

II. Fam. Vespertilionidae Gray, 1821
2. *Myotis myotis* (Borkhausen, 1797) – Greater Mouse-eared Bat
3. *M. blythii* (Tomes, 1857) - Lesser Mouse-eared Bat
4. *M. daubentonii* (Kuhl 1819) – Daubenton's Bat
5. *M. dasycneme* (Boie 1825) – Pond Bat
6. *M. mystacinus* (Kuhl, 1817) – Whiskered Bat
7. *M. bechsteinii* (Kuhl, 1817) – Bechstein's bat
8. *Plecotus auritus* (Fischer, 1829) – Brown Long-eared Bat
9. *P. austriacus* (Linnaeus, 1758) – Grey Long-eared Bat
10. *Pipistrellus pipistrellus* (Schreber 1774) – Common Pipistrelle
11. *Pipistrellus pygmaeus* (Leach, 1825) – Soprano Pipistrelle

12. *Pipistrellus kuhlii* (Kuhl 1819) – Kuhl's Pipistrelle Bat
13. *Nyctalus noctula* (Schreber, 1774) – Noctule bat
14. *Eptesicus serotinus* (Shreber, 1774) – Serotine Bat
15. *Vespertilio murinus* (Linnaeus, 1758) – Parti-coloured Bat.

**3.2. Structure of bat communities in urban and rural ecosystems.** On the territory of each district of Chisinau there are recreational green areas, parks, various types of water sources and a large number of buildings with structural defects. The conditions created by human activity in these ecosystems (microclimate, waste, artificial lighting, etc.) create a favourable environment for the reproduction of a large number of insects of different taxa, which also contributes to the increase in the number and diversity of chiroptera species in this area. In total, 10 species of bats have been recorded in the Chisinau area: *Rhinolophus hipposideros, Myotis daubentonii, M. dasycneme, Nyctalus noctula, Pipistrellus pipistrellus, P. pygmaeus, P. kuhlii, Plecotus austriacus, Eptesicus serotinus, Vespertilio murinus*. In urban ecosystems, the species *N. noctula, E. serotinus, P. pipistrellus* and *Plecotus austriacus* predominate and have been reported both in green areas and in buildings. Most of the species are listed in the Red Book of the Republic of Moldova, edition III, with critically endangered (*V. murinus*), endangered (*Rh. hipposideros, M. dasycneme*) and vulnerable (*M. daubentonii, P. kuhlii, Plecotus austriacus*) [5].

As most bat species are not able to build their own roosts, they are highly dependent on existing roost structures, either natural or man-made. In urban ecosystems, the following bat species have been collected from buildings at different times of the year: *Nyctalus noctula, Eptesicus serotinus, Plecotus auritus, P. austriacus, Pipistrellus kuhlii, P. pipistrellus, Vespertilio murinus*.

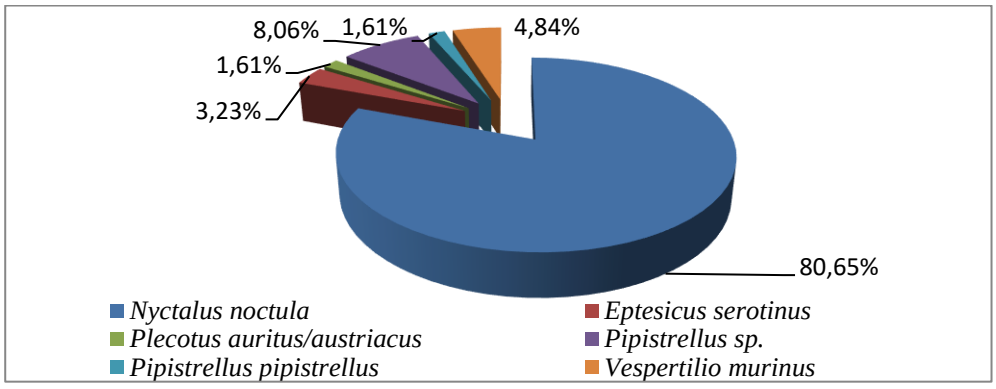



**Figure 3.2.2. The structure of the bat communities obtained by the method of collecting from buildings in 2021-2022.**

Most individuals belonged to the species *Nyctalus noctula* - the most anthropophilic and abundant bat species in urban areas. The other species were observed much less often with low

abundance, and the least collected species were *Plecotus auritus, P. austriacus* and *Pipistrellus pipistrellus* [6].

### 3.3. Ecological peculiarities of bat species in urban and rural environments

A total of 15 species of bats with a total population of 1837 individuals were identified in the urban area of Chisinau and in the mines of the rural localities of the commune (tab. 3.3.1).

The beginning of the hunting activity differs according to the species: *Nyctalus noctula, Eptesicus serotinus* start hunting early, often before sunset, while it is still daylight; *Myotis daubentonii, M. dasycneme, M. mystacinus, Pipistrellus pipistrellus* and *P. pygmaeus* start hunting at dusk, shortly after sunset; the species: *Pipistrellus kuhlii, Plecotus* sp., *Vespertilio murinus* start hunting after nightfall. Individuals were recorded at the beginning of the period of trophic activity, when it is possible to identify species not only by ultrasound, but also visually: by flight mode and by morphological characteristics observed during flight. Therefore, the number of individuals recorded does not represent the total number of individuals in a given ecosystem.

**Table 3.3.1. Number of bat species recorded in Chisinau Municipality**

| № | Species \ Habitat | Buildings | „La izvor"Park | „Dendrarium" | „Valea Morilor" | „Valea Trandafirilor" | Botanical Garden | Râșcani- Ciocana Park | Cricova I | Cricova II | Goian | Goianul Nou | In total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | *Rhinolophus hipposideros* | - | 1 | 2 | 4 | 6 | 3 | 5 | 47 | - | - | 2 | 70 |
| 2 | *Pipistrellus kuhlii* | 7 | 10 | 8 | 3 | 3 | 5 | 2 | - | - | - | - | 38 |
| 3 | *Pipistrellus pipistrellus* | 1 | 7 | 16 | 12 | 9 | 7 | 8 | - | - | - | - | 60 |
| 4 | *Pipistrellus pygmaeus* | - | 8 | 6 | - | - | 5 | 2 | - | - | - | - | 21 |
| 5 | *Myotis daubentonii* | - | 9 | 18 | 21 | 12 | 2 | 9 | 273 | 22 | - | 27 | 393 |
| 6 | *Myotis dasycneme* | - | 2 | - | 1 | 3 | - | 1 | 60 | - | - | 2 | 69 |
| 7 | *Myotis mystacinus* | - | - | - | - | - | - | - | 16 | - | 1 | 1 | 18 |
| 8 | *Myotis bechsteinii* | - | - | - | - | - | - | - | 50 | 6 | - | 12 | 68 |
| 9 | *Myotis blythii* | - | - | - | - | - | - | - | 3 | - | - | 2 | 5 |
| 10 | *Myotis Myotis* | - | - | - | - | - | - | - | - | - | - | 9 | 9 |
| 11 | *Eptesicus serotinus* | 5 | 7 | 10 | 12 | 11 | 5 | 16 | 6 | - | - | 14 | 86 |
| 12 | *Plecotus auritus/austriacus* | 4 | 7 | 18 | 14 | 7 | 4 | 9 | 16 | 1 | 1 | 2 | 83 |
| 13 | *Plecotus auritus* | - | - | - | - | - | - | - | 11 | 1 | - | 2 | 14 |
| 14 | *Vespertilio murinus* | 3 | - | - | - | 3 | - | 1 | - | - | - | - | 7 |
| 15 | *Nyctalus noctula* | 654 | 12 | 68 | 59 | 55 | 10 | 38 | - | - | - | - | 896 |
| **Total individuals** | | 674 | 63 | 146 | 126 | 109 | 41 | 91 | 482 | 30 | 2 | 73 | **1837** |
| **Total species** | | 6 | 9 | 8 | 8 | 9 | 8 | 10 | 9 | 4 | 2 | 10 | |

The most numerous species in the whole territory of Chisinau Municipality was *Nyctalus noctula* - 896 individuals, followed by *Myotis daubentonii* - 393 individuals, *Eptesicus serotinus* - 86 individuals and *Plecotus auritus/austriacus* - 83 individuals. The other species have a numerical population that does not exceed 50 individuals, and the endangered and critically endangered species *Myotis myotis, M. blythii, M. bechsteinii, Plecotus auritus, Vespertilio murinus* were represented by a small number - up to 20 individuals.

On the basis of the collected data, the biotope predilection was evaluated for each species of bats registered in Chisinau Municipality, the preference of a certain species for a certain habitat or biotope, depending on its characteristics.

All species have a negative preference for buildings, except for *Vespertilio murinus,* which is indifferent, and *Nyctalus noctula*, which has a significant preference for various buildings. Noctule Bat *N. noctula* is a common urban species, often using human structures as shelters, where it can be found in groups ranging from a few individuals to several hundred. *Rhinolophus hipposideros* has a significant preference only for the Cricova I mines and the Botanical Garden, being indifferent to other urban ecosystems. *Pipistrellus kuhlii* and *P. pygmaeus* have a significant preference for most urban parks, and *P. pipistrellus* for all forest areas. The species gen. *Myotis* have a significant preference for underground shelters similar to natural ones, represented by limestone mines. *Eptesicus serotinus* has a significant preference for the forest areas of the city and the mines of Goianul Nou. *Plecotus austriacus* and *P. auritus* have a marked preference for most urban parks and suburban mines. *Vespertilio murinus* is a critically endangered species with a strong preference for some large urban parks.

The species *Pipistrellus pipistrellus, P. kuhlii, P. pygmaeus, Vespertilio murinus* have been recorded in parks, prefer forest habitats and often use human structures for temporary shelter, but do not use mines for shelter. The species *Rhinolophus hipposideros, Myotis mystacinus, M. bechsteinii, M. Myotis, M. blythii* are troglophil species that shelter in mines, rarely occur in the heavily anthropised area, are sensitive to anthropogenic factors and choose habitats similar to natural ones on the edge of the municipality. The species *M. bechsteinii* and *M. myotis* are critically endangered [5] and only occur in a few locations in the central part of the country.

The most abundant species in urban ecosystems was *Nyctalus noctula* with 48.78% and a frequency of 63.64%. The highest abundance of this species was found in anthropogenic shelters (buildings) and was not identified in rural shelters. The next species found in all ecosystems with a relatively high abundance was *Myotis daubentonii* with an abundance of 21.39% and a frequency of 81.82%. This species also had a high abundance: *Eptesicus serotinus* 4.68% with a frequency of 81.82%, found in 9 of the 11 research sites, and *Plecotus* sp. with an abundance of 4.52% and

a frequency of 100%, this genus is present in a small number of sites, but in all the ecosystems studied. It should be noted that species of this genus cannot be distinguished visually at a distance, nor by ultrasound with the heterodyne detector. In the mines, where it was possible to determine the morphological characteristics, the exact identification of the species was also carried out. The other species have a lower abundance, between 0.27% and 3.81%, but with a relatively high frequency, such as species: *Rh. hipposideros* with a frequency of 72.73%, *Pipistrellus pipistrellus* and *P. kuhlii* 63.64%, *Myotis dasycneme* 54.55%. The endangered and critically endangered species *M. myotis*, *M. blythii* and *M. bechsteinii* recorded the lowest frequencies, ranging from 9.09% to 27.27%, and were only reported in some underground shelters similar to natural ones.

Practically all the habitats used by bats in Chisinau Municipality are anthropogenic or of anthropogenic origin. The intensity and frequency of use of these habitats by bats indicates the degree of adaptation of bats to anthropogenic environmental changes. According to the anthropogenic adaptation index, all bat species in urban and suburban areas were divided into 5 groups, indicating different degrees of adaptation to the highly anthropised environment (fig. 3.3.1).

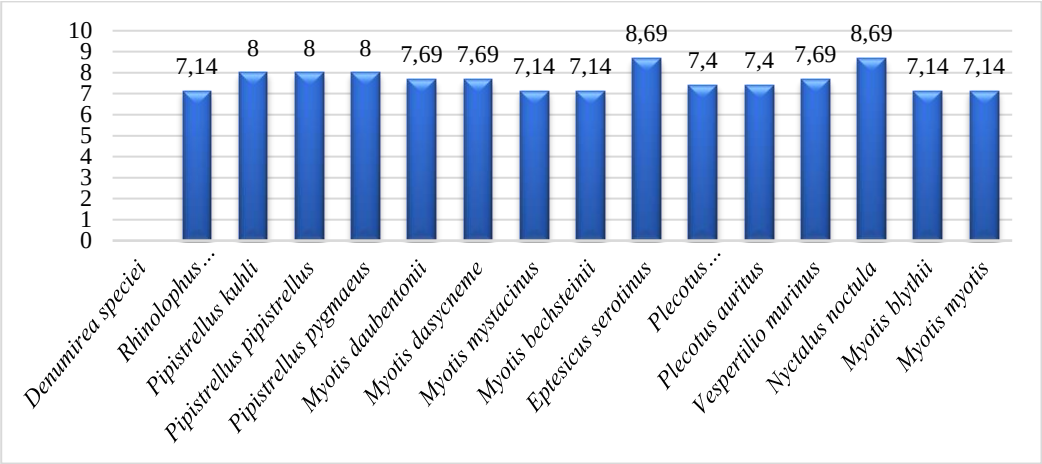



**Figure 3.3.1. Anthropic adaptation index of bat species in Chisinau Municipality (%)**

In the first group, the anthropogenic adaptation index is the highest, with a value of 8.69. This group includes 2 species, *Nyctalus noctula* and *Eptesicus serotinus*, the most abundant and widespread species, which often use urban shelters and are mainly found in buildings. The second group, with index values of 8.0, includes three species of the genus *Pipistrellus*: *P. pipistrellus*, *P. pygmaeus*, *P. kuhlii*. These species prefer human buildings for shelter, but are mainly forest species and are found solitary and occasionally in buildings. The third group has an index of 7.69 and includes 3 bat species: *Myotis daubentonii*, *M. dasycneme* and *Vespertilio murinus*. The 4$^{th}$ group, with an index of 7.4, includes the 2 species of the genus *Plecotus*: *P. auritus* and *P. austriacus*,

which are often recorded in flight in forest areas between trees and very rarely enter buildings. The 5th group has the lowest index of anthropic adaptation - 7.14 and includes the species: *Rh. hipposideros*, *M. myotis*, *M. blythii*, *M. mystacinus* and *M. bechsteinii*. Individuals of this group prefer a very hidden behaviour, avoid contact with people and are very sensitive to disturbance.

The species *Nyctalus noctula* and *Eptesicus serotinus* were classified as species with an anthropophilic tendency, the species of groups 2, 3 and 4 were considered as neutral species and the species of group 5 with the lowest index of anthropogenic adaptation were assigned to the anthropophobic category.

**Similarity of sites.** Based on the collected data, an analysis of the similarity of the bat communities in Chisinau Municipality was carried out, depending on the abundance of each species, the diversity and the total number of individuals identified in each ecosystem. The Bray-Curtis similarity index was used to group similar sites. The cluster analysis shows the degree of similarity between the studied sites from different regions of the commune, with different biotic and abiotic conditions that determine the number of chiroptera and their presence or absence (fig. 3.3.2).

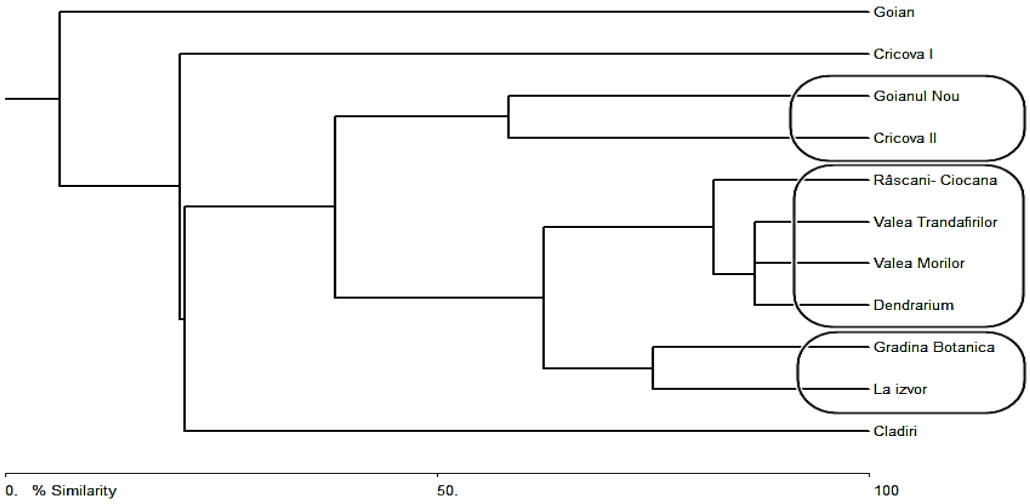



**Figure 3.3.2. Dendrogram of similarity of bat communities in the studied sites in Chisinau**

According to the hierarchical cluster analysis, we can observe that some shelters are similar in terms of the qualitative and quantitative structure of the chiropteran communities, due to the fact that the biotic and abiotic conditions, such as humidity, the presence of wooded areas, water bodies, disturbing factors, recreational activities, etc., are different in each individual site. Thus, the chiropteran communities in the urban parks have been grouped in 2 clusters: the first one is formed by the parks: „Râșcani-Ciocana", „Valea Morilor", „Valea Trandafirilor" and „Dendrarium", the second one by the Botanical Garden and „La Izvor" Park. These ecosystems

show a high similarity of bat communities, ranging from 63.04% to about 87%. The similarity between „Valea Morilor" and „Valea Trandafirilor" was 86.81%, between „Valea Trandafirilor" and „Dendrarium" - 86.76%, between „Dendrarium" and „Râscani-Ciocana" - 82%. In these areas, similar communities have been registered, consisting mainly of dendrophilous species, which work among the trees, and hydrophilic species, which hunt insects on the surface of the water basins created in the parks. The buildings are separated from the other urban sites, with which they have a similarity of only 21%, being specific by the quantitative and qualitative structure of the communities.

The underground shelters Cricova II and Goianul Nou formed a separate cluster with a similarity of 58.25%, because these sites are relatively small and had a low number of individuals during the study periods, with the same dominant species. The Cricova I and Goian mines are the least similar to the other sites in terms of community structure, with a similarity of less than 20%. Due to the presence of aquatic and forest ecosystems around the sites, the bat communities inhabiting them are troglophil, with common food and shelter preferences.

**Diversity of bat species.** Taking into account the small area of the Republic of Moldova and the permanent change of ecosystems under the influence of anthropogenic and climatic factors, the diversity of bat species on the territory of the country is quite large. Of the 21 species reported so far, 15 species have been recorded in the ecosystems of Chisinau municipality, which represents more than 70% of the chiropterofauna of the Republic. The diversity analysis was carried out according to the Shannon, Simpson, Margalef, Berger-Parker and Alpha indices. These indices have different values depending on the number of species, the number of individuals of each species, the proportion of dominant species, the proportion of rare species in each ecosystem (tab. 3.3.2).

Shannon's index shows the diversity of bat communities in relation to the number of individuals identified, which also depends on the distribution of the population of individuals by species. For example, in the Botanical Garden, the highest index was found (0.95), where 8 species were recorded in similar numbers, and in the buildings, although 6 species were recorded, the index is the lowest (0.099), because the relative abundance of the dominant species, Nyctalus noctula, is very high - around 97%.

The Simpson index indicates diversity by the high abundance of a single species in the community. As we can see, the highest index, 0.485, was recorded in the buildings, because the species Nyctalus noctula dominates with a high weight, and the lowest index, 0.278, was recorded in La Izvor Park, where the number of species is higher, but the individuals are relatively evenly distributed and there is no dominance.

**Table 3.3.2. Indices of diversity of bat communities in the Chisinau municipality**

| Index \ Habitat | Buildings | „La izvor” | „Dendrarium” | „Valea Morilor” | „Valea Trandafirilor” | Botanical Garden | „Râscani-Ciocana” Park | Cricova I | Cricova II | Goianul Nou |
|---|---|---|---|---|---|---|---|---|---|---|
| **Shannon J'** | 0,099 | 0,936 | 0,792 | 0,761 | 0,755 | **0,953** | 0,768 | 0,656 | 0,56 | 0,778 |
| **Simpsons Diversity** | **0,485** | 0,278 | 0,315 | 0,317 | 0,32 | 0,279 | 0,305 | 0,339 | 0,385 | 0,3 |
| **Margaleff** | 4,949 | 7,781 | 6,468 | 6,665 | 6,871 | 8,681 | 7,146 | 5,218 | **9,478** | 7,513 |
| **Berger-Parker** | **0,97** | 0,19 | 0,466 | 0,468 | 0,505 | 0,244 | 0,418 | 0,566 | 0,733 | 0,37 |
| **Alpha** | 0,91 | 2,874 | 1,82 | 1,902 | 2,328 | 2,967 | 2,867 | 1,572 | 1,24 | **3,136** |

The Margalef index is an index of species richness that indicates the even distribution of individuals of each species. The highest values of the index were recorded in the mines of Cricova II (9,478) and the Botanical Garden (8,681) - in these sites a small number of species were recorded with an even distribution of the number of individuals. This index is lowest in buildings, where only one species is significantly dominant.

According to the Berger-Parker index, which is based on the size and richness of the sample, the minimum values were recorded in the park "La izvor" (0.19), and the maximum index - in the buildings (0.97), where most individuals were collected.

The alpha index indicates the size of the dominant individuals of a species in relation to the size of other individuals of other species and sites. The index is highest in the Goianul Nou mines (3.136), where the highest number of species and 3-4 dominant species were recorded. The lowest index is recorded in the buildings, with 0.91, where the highest number of individuals was recorded, but only one dominant species.

The ecological importance of each species in urban ecosystems can be divided into four groups: constant, characteristic, accessory and accidental (fig. 3.3.3).

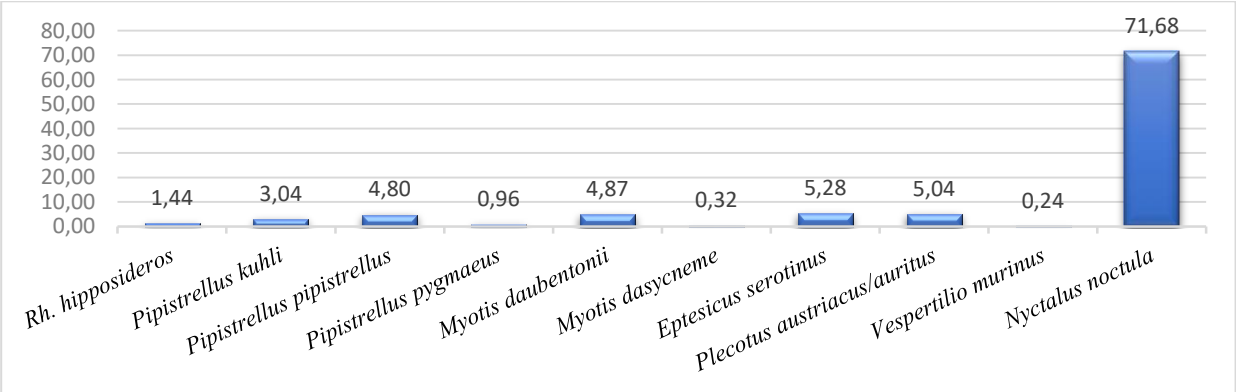



**Figure 3.3.3. The ecological significance of bat species in the city of Chisinau (%)**

In urban habitats, only the species *Nyctalus noctula* is of constant ecological importance, which means that it is a typical representative of habitats that are heavily anthropised or of anthropogenic origin. The species *Eptesicus serotinus* has a characteristic ecological importance and is also a typical representative of urban fauna, it is quite common, but in small numbers, and it also uses human constructions for shelter. It has been recorded hunting in parks, roosting on balconies, under roofs, in ventilation ducts and other parts of buildings, mostly solitary.

Accessory ecological importance have 5 bat groups: *Rh. hipposideros, Pipistrellus kuhlii, P. pipistrellus, M. daubentonii, Plecotus* sp. These species usually use abandoned human constructions and are sensitive to anthropic disturbances, therefore during hibernation they congregate alone or in small groups in buildings, and in summer they choose shelters as close as possible to foraging biotopes. There are 3 species of bats of accidental ecological importance in urban biotopes: *M. dasycneme, Pipistrellus pygmaeus, Vespertilio murinus*. For example, *Vespertilio murinus* is typical of urban shelters and has only been recorded in the city, in isolated buildings or in parks during hunting.

The most common species in urban habitats is *Nyctalus noctula* with 71.68% and 100% abundance. The highest number of individuals of this species was found in buildings, as it prefers to shelter in large groups of tens and hundreds of individuals. The next species with a relatively high abundance in all urban shelters is *Myotis daubentonii* with an abundance of 5.68% and a frequency of 85.71%, followed by *Eptesicus serotinus* with an abundance of 5.28% and a frequency of 100%. Lower abundances were recorded for *Plecotus* sp. and *Pipistrellus sp*., which have a frequency of 100%, but are present in smaller numbers in all the shelters studied. The other species have an abundance of up to 2%, but a relatively high frequency of around 50% (fig. 3.3.4).

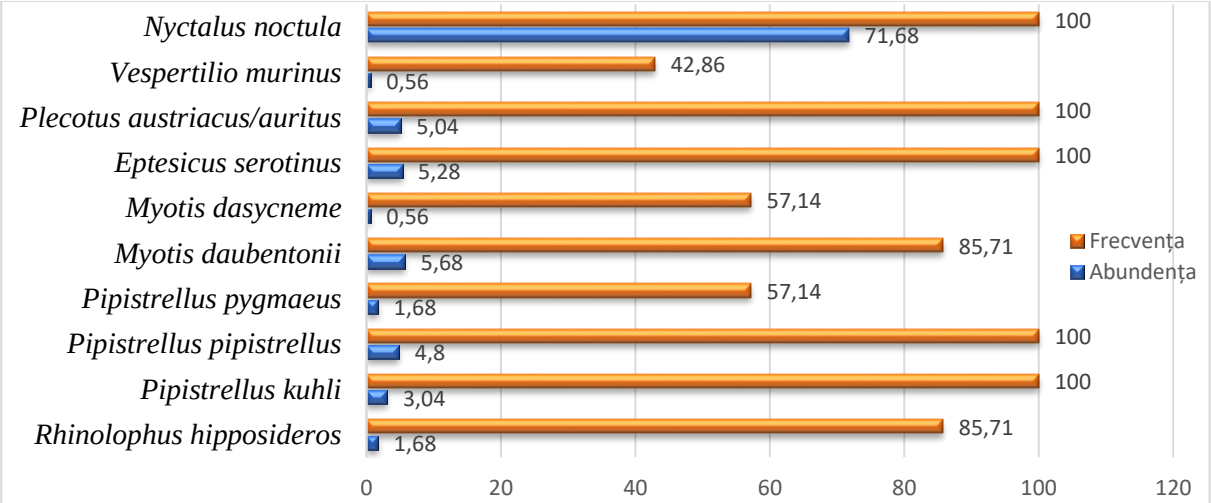



**Figure 3.3.4. Relative abundance and frequency of bat species in the urban habitats of the Chisinau city (%)**

All the rural sites studied are located in the suburbs, on the edge of the municipality, they are of anthropogenic origin, but because the mines have been abandoned for more than 80-100 years, the sites have acquired a microclimate and appearance similar to natural ones. These ecosystems are not completely free of anthropogenic disturbance, human presence is sporadic and bats can only be disturbed by uncontrolled tourism. These sites are spacious habitats with many cracks, crevices and holes, with stable temperature and humidity, without currents, preferred by troglophil species.

In rural underground shelters, represented by abandoned mines, the species *M. daubentonii* is of permanent ecological significance, being dominant in all underground shelters. 2 species of bats have a characteristic ecological significance: *M. dasycneme* and *M. bechsteinii*. 5 of the 10 identified bat species are of accessory ecological significance: *Rh. hipposideros, M. mystacinus, Eptesicus serotinus, Plecotus auritus, P. austriacus,* these species are usually typical representatives of underground shelters. 2 species of bats are of accidental importance: *M. blythii* and *M. myotis* in all 4 rural habitats studied. The representatives of these species were recorded in small numbers, by a few solitary individuals, and *M. blythii* is typical for mines in the northern region of the Republic of Moldova (fig. 3.3.5) [8, 13, 16].

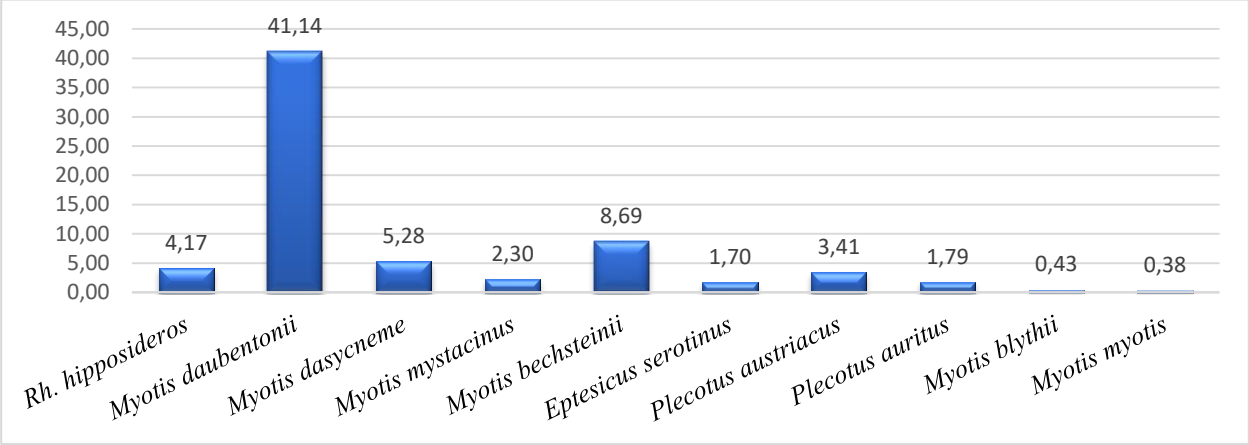



**Figure 3.3.5. The ecological significance of bat species from the rural area of the Chisinau municipality (%)**

The most abundant species is Myotis daubentonii with an index of 54.86% and a frequency of 75%. The highest abundance of this species was recorded in the Cricova I mines. The species had a relatively high frequency: M. bechsteinii with 11.58% abundance and 75% frequency, Myotis dasycneme with 10.56% abundance and 50% frequency, and Rh. hipposideros with 8.35% abundance and 50% frequency. The remaining species had a low frequency of up to 4% (fig. 3.3.6).

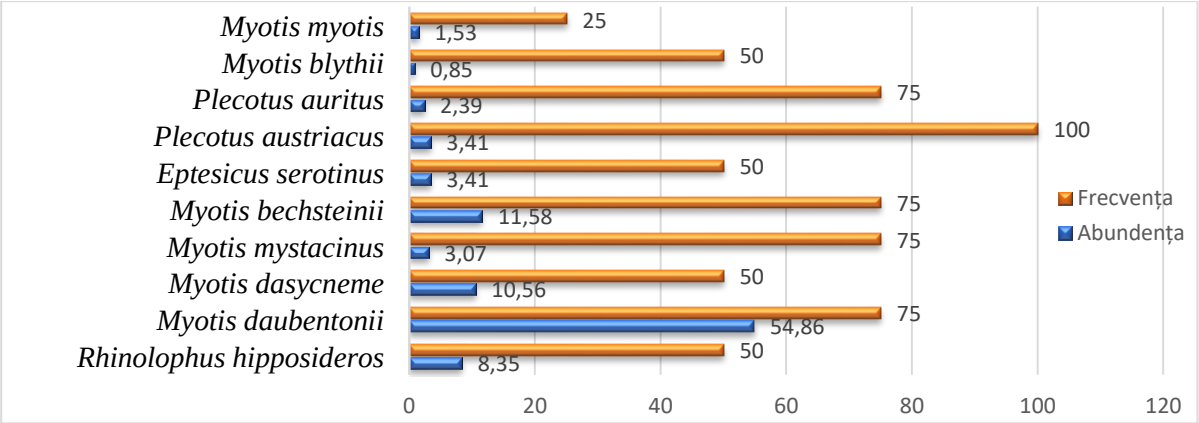



**Figure 3.3.6. The total abundance and frequency of bat species in the rural area of the Chisinau municipality**

The species *M. bechsteinii*, *Myotis dasycneme*, *Rh. hipposideros* are typical for underground roosts, preferring large sites that are used throughout the year. The rural shelters of Chisinau Municipality are very important for the species *Myotis bechsteinii*, which only uses underground shelters in the central part of the Republic [16].

There is a significant difference in the share of bat species in urban and suburban roosts. In the urban area, *Nyctalus noctula* predominates, but in the suburban caves this species was not recorded, and the dominance belongs to the species *Myotis daubentoni*, which was recorded in practically all the caves. The species *Rhinolophus hipposideros*, *Plecotus* sp., *Eptesicus serotinus* and *Myotis dasycneme* were recorded in different proportions in both underground and urban shelters. The species *Pipistrellus* sp. and *Vespertilio murinus* are also typical in forested urban areas and were not recorded in underground shelters. The typical species for rural areas are *Myotis myotis* and *Myotis blythii*, which were found in small numbers in the surveyed sites; they are exclusively troglophilous species that use the edge habitats for hunting and for shelter, hibernation and reproduction in different types of underground habitats [16].

## 4. THE IMPORTANCE AND REHABILITATION OF BATS IN THE COLD PERIOD OF THE YEAR IN THE CONDITIONS OF THE REPUBLIC OF MOLDOVA

### 4.1. The importance of bats in highly anthropised ecosystems

Bats from the Republic of Moldova play an important role in controlling and regulating the number of insects, mostly harmful to agricultural and forestry crops, during the period of intensive activity. The body weight of the *Nyctalus noctula* individuals varies between 20-33 grams and that an individual consumes about 30% of its own weight, the approximate biomass of insects consumed by a colony of *N. noctula* located in the Buiucani sector, which numbers about 300

individuals, was calculated. The biomass of insects consumed was estimated at 2.4 kg of insects of different taxa, hunted in a single evening during the spring-summer-autumn period. The active period of the bats is between 180-220 days, depending on the climatic conditions. Thus, a colony of about 300 individuals consumes about 72 kg of insects in one month, and about 500 kg of insects in 6-7 months, depending on climatic factors, during the trophic period, providing an enormous benefit in regulating the insect herd of urban ecosystems.

Another example is the case of a colony of *Nyctalus noctula* in a number of 50 individuals collected from a school building in the Centre sector. If we take the average weight of an individual - about 26 grams - which consumes 8-9 g of food per night (at dusk and before dawn), a colony of 50 individuals consumes about 400 grams of insects per day, which represents 12-14 kg of trophic biomass per month. During the summer, this colony consumes about 45 kg of insects. If we consider that the preferred food of the species is moths and mosquitoes in a proportion of more than 70% [4, 11, 14], and that the average weight of a trophic object is up to 2 mg, it follows that a colony of 50 individuals of *Nyctalus noctula* consumes about 15-16 million moths and mosquitoes during the summer. These calculations show the importance of bats in highly urbanised ecosystems, as well as their role in public health and control of insects number in urban green spaces.

In the Republic's ecosystems, bats consume the most diverse taxa of insects and their larvae of different sizes, according to the specific individual dietary preferences of the species and depending on the size of the individual. Depending on the species, bats have different trophic preferences that are related to the location of the roost, the size and morphology of the bat, the time and season of the year when hunting takes place, etc., but in general the groups of insects captured are: beetles (Coleoptera), butterflies and moths (Lepidoptera), flies and mosquitoes (Diptera), bees and ants (Hymenoptera), cockroaches (Blattoidea), termites (Isoptera), crickets and wasps (Orthoptera), cicadas (Homoptera) [14].

Preference for insects varies greatly depending on region, time of year, season, climatic conditions and the type of habitat in which the species is found. It has been estimated that bats consume very large quantities of insects of different species in the course of a single night, with a bat consuming an amount of insects equivalent to a quarter or half of its body weight, depending on the abundance of insects and the time of year. In some cases, when insect abundance is high, especially in August and September, which also coincides with the peak hunting activity of chiropterans, they can consume an amount of insects of different taxa that exceeds their own body weight in a single night. Some species are able to capture more than 13 insects per minute. The smallest bat in our country, *Pipistrellus pipistrellus*, can consume about 600 mosquitoes in an hour

[4, 11]. Bats have extremely large appetites in spring, summer and autumn because they are completely deprived of food during hibernation. This means that bats are considered to be natural insecticides and very effective at biologically controlling pests.

### 4.2. Methodology of care in captivity and rehabilitation of bats

Humans have shared buildings with bats for thousands of years, since the first human structures were built. Some bat species can be defined as anthropophilic, because they have a strong ecological association with human settlements; bats do not build their own shelters, but use various constructions as temporary roosts, for reproduction or hibernation [2, 19].

In winter, bats hibernate due to lack of food sources, as all bat species in Moldova and neighbouring countries are insectivores. Any disturbance of hibernation conditions reduces the animals' chances of surviving until spring. Usually, animals found in an active state in winter (if flying indoors) are weakened and cannot be released into the environment, as in these cases the animal is usually doomed. Sometimes, during repair work, cavities are opened in buildings where solitary individuals or even colonies of bats hibernate [4, 10, 19]. There are cases where bats hibernate near heating pipes, emerge from hibernation but the conditions of the external environment do not allow them to survive. Bats are often found in rooms or corridors because they have been disturbed and awoken at the wrong time of year. To release such a bat outside into the cold is to condemn it to death. In such cases, the bats have little chance of find a new hiding place, and in the case of severe frost, this chance disappears completely. In all these situations, it is necessary to keep the animals in artificial conditions, giving them the opportunity to continue hibernation in suitable conditions and to survive until the weather changes and the first insects appear.

Immediately after the bats were collected, their condition was assessed by visual inspection and weighing. For each animal, species, sex, location, type of roost and the exact position of the bat within the roost were recorded. Body mass is one of the key indicators of condition and shows the amount of stored fat needed for hibernation. Each species has its own body mass limits. For example, the optimum weight for *Plecotus austriacus* is 7-9 g and for *Nyctalus noctula* it is 20-30 g. Rescued individuals taken from different hibernation sites that fell within the norm were considered healthy and moved to a new site to continue hibernation [12].

The optimal weight for hibernation is different for different species. The Kuhl’s pipistrelle bat (*Pipistrellus kuhlii*) must weigh about 10 g to survive the winter, the Parti-coloured bat (*Vespertilio murinus*) - 16-18 g, the Serotine bat (*Eptesicus serotinus*) - 26-28 g.

If the animal's weight was insufficient and release into the wild was not possible, the bats

underwent a series of additional rehabilitation measures. Bats with insufficient fat reserves and therefore below normal weight had no chance of survival until spring and were kept in artificial conditions to rehabilitate their physical condition.

These animals must first be placed in special containers (terrariums). These can be made of plastic, glass or cardboard. A piece of cloth should be placed on the walls of the container so that the animals can cling to it and hang in the required position. Animals are placed individually or in groups, depending on the species, sex and general condition of the animals. During the 2018-2023 hibernation period, about 95 individuals of the species *Nyctalus noctula, Eptesicus serotinus* and *Pipistrellus kuhlii* were rehabilitated. By keeping the bats in captivity, they have a good chance of surviving until spring. They were transferred to artificial conditions, kept in an aquarium and plastic container, with limited light, and to create a more comfortable environment, pieces of clay pots and tree bark were placed on the walls, to which the animals attached their lower limbs and positioned themselves as they found most comfortable. Single individuals of *Pipistrellus kuhlii, Vespertilio murinus, Eptesicus serotinus,* collected from different parts of the buildings, were usually kept in containers or small boxes with ventilation holes, a strip of cloth on the wall and an obligatory water source [12]. Bats, like all animals, need water at room temperature to maintain a healthy metabolism. A simple syringe without a needle or a pipette can be used as an aid, and this object must be gently placed over the animal's mouth, after which it will begin to drink water.

The captive bats were intensively fed for one to two weeks until they reached the required weight. The artificial diet consisted of live insects or larvae: the speckled cockroach (*Nauphoeta cinerea*), larvae of the yellow mealworm beetle (*Tenebrio molitor*) and larvae of the Flesh fly (*Sarcophaga carnaria*). The most convenient food for bats is the larvae of the yellow mealworm beetle *Tenebrio molitor*, which is used in the maintenance of many insectivorous animals because it contains the necessary amount of protein and a certain amount of chitin necessary for digestion.

An individual *Nyctalus noctula* weighing ±19 g consumes on average ~ 10 speckled cockroach, or ~ 25 mealworm beetle larvae, or ~ 50 fly larvae. An individual of *Pipistrellus kuhlii* with a body mass of ~6 g consumes ~21 fly larvae per meal, corresponding to ~1.50 g (fig. 4.2.1). Animals accumulate weight at different rates. Individuals of *Nyctalus noctula* gained the most weight when feeding on speckled cockroach, reaching a weight of 15 g to 25 g in 5 days.

During the feeding period, containers with animals were kept at a temperature below room temperature - + 14 $^{o}$C - + 17 °C or slightly lower. At this temperature the animals sleep almost all the time, biological activity is reduced to a minimum and they need only sleep and food for maintenance. Before each feeding, the animals should be moved to an area with normal room temperature, where after about 20 minutes the bats will wake up and warm up. Once warmed up,

the already lonely animal will begin to forage for food and feeding the bat is not difficult. After feeding, it is necessary to keep the animal in the room temperature area for about 20 minutes, then move the animal back to a lower temperature area. All handling should be done with gloves or a piece of cloth.




**Figure 4.2.1. Specimens of *Pipistrellus kuhlii* collected from buildings (A); body weight of an individual (B); the amount of food needed for one meal (C) (original photo)**

For normal hibernation, bats need a stable temperature of +2 - +5°C. This temperature is available in rooms without heating. Consumption of fat reserves during hibernation is individual and if the animal is healthy, it loses 1/3 - 1/5 of its weight during hibernation. The inspection and weighing procedure must be repeated regularly.

Bats that have reached the required body weight are transferred to an abandoned building for prolonged hibernation in the absence of human disturbance. When the temperature rises above +8 $^{o}$C - +15 $^{o}$C and is maintained for several weeks, it is a favourable time for the first insects to appear and the animals can be removed from the hibernaculum and prepared for release into the natural environment. Before the bats are released, it is necessary to weigh each individual so that the weight is in line with the norm. Some individuals collected at the end of hibernation are fed intensively for several weeks and then released directly into the wild as the time is favourable for their vital activity.

The release of animals into the wild depends on their body condition and weather conditions. Optimal conditions include a warm temperature (12-15°C), no rain and no strong wind, and in the evening the bats can be released.

## GENERAL CONCLUSIONS

The results obtained in relation to the purpose and objectives formulated in the doctoral thesis "Ecological particularities and the importance of bats (Mammalia: Chiroptera) in the urban and rural environment of the Republic of Moldova" led to the formulation of the following general conclusions:

1. As a result of the research carried out in the period 2016-2023 in the urban and rural ecosystems of the central area of the Republic of Moldova, 15 species of Chiroptera have been identified: *Rhinolophus hipposideros, Myotis myotis, M. blythii, M. daubentonii, M. dasycneme, M. mystacinus, M. bechsteinii, Plecotus auritus, P. austriacus, Pipistrellus pipistrellus, P. pygmaeus, P. kuhlii, Nyctalus noctula, Eptesicus serotinus, Vespertilio murinus*. The distribution data of synanthropic bat species and their roosts in urban and rural areas in the central part of the Republic of Moldova have been updated.

2. Was collected 7 species of bats from human constructions in the municipality of Chisinau: *Nyctalus noctula, Eptesicus serotinus, Plecotus auritus, P. austriacus, Pipistrellus kuhlii, P. Pipistrellus, Vespertilio murinus,* of which the critically endangered species *Vespertilio murinus* was represented by only a few individuals. Most individuals belonged to the species *Nyctalus noctula* - the most anthropophilic and abundant bat species in urban areas. The other species were much rarer and less abundant, the least observed species being *Plecotus auritus, P. austriacus* and *Pipistrellus pipistrellus*.

3. The highest activity in the urban area was recorded in parks-forests, near water sources. Buildings are used by bats as temporary shelters in summer and as hibernation shelters in winter.

4. In underground shelters of anthropogenic origin, 10 species have been identified: *Rhinolophus hipposideros, Myotis myotis, Myotis blythii, Myotis daubentonii, Myotis dasycneme, Myotis mystacinus, Myotis bechsteinii, Plecotus austriacus, Plecotus auritus, Eptesicus serotinus*, of which 9 species were recorded in the Cricova I limestone mines (*Rh. hipposideros, Myotis blythii, M. daubentonii, M. dasycneme, M. mystacinus, M. bechsteinii, Plecotus austriacus, P. auritus, Eptesicus serotinus*), 4 species in the Cricova II mines (*Myotis daubentonii, M. mystacinus, Plecotus austriacus, P. auritus*), all 10 species in the Goianul Nou mines and 2 species in the Goian mines (*M. mystacinus, Plecotus austriacus*). The Cricova II and Goian mines are new hibernation and roosting sites and were not previosly studied. Most of the species are listed in the Red Book of the Republic of Moldova, ed. III, including the critically endangered species: *Myotis myotis* and *M. bechsteinii*, identified with a small number, but as permanent residents of these underground sites. It was found that the presence of bats in underground shelters is conditioned by the presence of favourable ecosystems around the mines: water basins, proximity to forests.

5. In total 1837 of bats was identified taxonomically categorized into 15 species and 5 genera. According to the ecological analysis, the species *Nyctalus noctula* was dominant in the urban ecosystems with an abundance of about 48.78%, followed by the species *Myotis daubentoni* with an abundance of about 21.39%. There was also a high abundance of species: *Eptesicus serotinus* with about 4.68%, present in 9 of the 11 sites studied, and *Plecotus* sp. with an abundance of 4.52%, present in a small number but in all the sites studied. Lower abundances, between 0.27% and 3.81%, had the species: *Rh. hipposideros, Pipistrellus pipistrellus, P. kuhlii* and *Myotis dasycneme*.

6. The endangered and critically endangered species *Myotis myotis, M. blythii* and *M. bechsteinii* had a frequency ranging from 9.09% to 27.27% being reported only in some abandoned underground shelters, similar to natural ones.

7. The species *Pipistrellus pipistrellus, P. kuhlii, P. pygmaeus, Vespertilio murinus* are mainly forest species and were recorded in humanised habitats: parks, forest strips, often using human constructions as transit shelters. These species have not been recorded hibernating in underground shelters in the rural area of the municipality. *Rhinolophus hipposideros, Myotis mystacinus, M. bechsteinii, M. Myotis, M. blythii* are troglophilic species, that hibernate in underground habitats in the rural area of the municipality and are rarely found in the heavily anthropised area. These species are sensitive to anthropogenic factors and choose habitats similar to the natural ones at the edge of the municipality. The species *M. bechsteinii* and *M. myotis* are critically endangered, being recorded in low numbers in some underground refuges.

8. In the urban area, the species *Nyctalus noctula* dominates (over 90%), but in the underground shelters in the suburbs this species has not been recorded and the dominance belongs to *Myotis daubentoni* (about 60%), which was recorded in practically all the underground shelters studied.

9. The species *Nyctalus noctula* and *Eptesicus serotinus* were classified as species with an anthropophilic tendency with an anthropic adaptation index value of the around 8.69; the species *Pipistrellus pipistrellus, P. pygmaeus, P. kuhlii, Myotis daubentonii, M. dasycneme* and *Vespertilio murinus, Plecotus* sp. were considered as neutral species with a value of 8 - 7.4; and the species *Rh. hipposideros, M. myotis, M. blythii, M. mystacinus* and *M. bechsteinii* have the lowest index of anthropic adaptation equal to 7.14 and areattributed to the anthropophobic category.

10. According to the cluster analysis, the urban parks of Râșcani-Ciocana, Valea Morilor, Valea Trandafirilor and Dendrariu show a high degree of similarity of the bat communities - between 63.04% and about 87%. Similar communities have been recorded in these sites, consisting predominantly of dendrophilous species, which are active among the trees and hydrophilous

species which hunt insects around the water basins in the parks. The buildings form a separate cluster with only 21% similarity to the other urban sites, being specific in the quantitative and qualitative structure of the bat communities.

11. For the first time, a methodology for the rehabilitation of bats during the winter period has been developed and methods of bat care in artificial conditions have been applied. More than 200 individuals of different species: *Nyctalus noctula, Vespertilio murinus, Pipistrellus kuhli, Pipistrellus pipistrellus, Eptesicus serotinus,* were maintained during the years of study.

12. Research carried out during the hibernation period shows that keeping these vulnerable animals in artificial conditions is sometimes the only effective method of rescuing them. In total, around 95 individuals of the species *Nyctalus noctula, Eptesicus serotinus* and *Pipistrellus kuhlii* were rehabilitated during the hibernation period. By keeping the bats in captivity, they have a good chance of surviving until spring. Each species requires specific conditions and care in captivity, but in general bats need: water, insect food (larvae), low temperature and lack of disturbance.

## PRACTICAL RECOMMENDATIONS

1. Continuation of the study of bats communities in Chisinau municipality, using different research methods and ultrasound recordings in several locations. Monitoring of other sites in the municipality during different periods of the year in order to determine the effective populations of rare and anthropophilic species in highly anthropised areas;

2. Identification of anthropogenic and climatic factors and their impact on the state of faunal diversity. Under anthropogenic conditions, due to the strong influence of anthropogenic factors such as the use of pesticides, unregulated heavy logging of forest areas, dehydration of wetland habitats, increased tourism and recreational activities, it is recommended to monitor the dynamics of bat populations and their migrations between different areas in order to identify preferences, adaptations of bats and changes in conditions that lead to population changes;

3. To raise the awareness of the general public, especially children and young people, through lectures, projects, interviews on television and radio, articles in popular newspapers and magazines, participation in various events promoting nature conservation, involving amateur chiropterists and volunteer naturalists in the dissemination of knowledge about the importance of bats in nature and the human economy, the need for sustainable conservation of bats and their habitats. To disseminate information about bats and their importance by organising and participating in national and international scientific and popularisation events;

4. Conservation of faunal diversity by consulting the population when carrying out repair

work or following procedures in cases where bats use the building for shelter, informing about the benefits and consequences of different cases related to the appearance of bats;

5. Placement of information boards in important underground shelters, prohibition of excessive tourism, prohibition of access in cases where the shelter is of significant value for the conservation of fauna diversity and in cases where the shelter is used by rare species of bats;

6. Dissemination of information about contacts to which people can turn for advice, for the transfer of animals collected in houses, or for requests for help if the person cannot solve the situation and needs professional help.

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13. **DIBOLSCAIA, N.** Diversitatea chiropterelor din zona carierelor de piatră de la Cricova şi importanţa ocrotirii lor. În: „*Homo sapiens in raporturile dintre sistemele naturale şi factorii de mediu*", Materialele Conferinţei Ştiinţifice a Tineretului Studios, 13 noiembrie 2015, Chisinau, 2015, p. 46. ISBN 978-9975-56-447-2.

**5. Alte lucrări și realizări specifice diferitor domenii științifice** (recomandate spre editare/aprobate de o instituție abilitată în domeniu), cum ar fi:

1. NISTREANU, V., CALDARI, V., LARION, A., **DIBOLSCAIA, N.** *Liliecii – prietenii noștri neștiuți.* Chișinău, Republica Moldova: Centrul Editorial-Poligrafic al USM, 2022, 73 pp. ISBN 978-9975-159-98-2. https://doi.org/10.53937/9789975159982

## ADNOTARE

La teza cu titlul „**Particularitățile ecologice și importanța liliecilor (Mammalia: Chiroptera) în mediul urban și rural din Republica Moldova”,** înaintată de către candidatul – **Dibolscaia Natalia,** pentru conferirea titlului științific de doctor în științe biologice la specialitatea **- 165.02. Zoologie. Chișinau, 2024**

**Structura tezei:** teza este scrisă în limba română și constă din introducere, patru capitole, concluzii generale și recomandări, bibliografie 162 de titluri și 2 anexe. Teza conține 106 de pagini cu text de bază, 55 figuri și 12 tabele. Rezultatele obținute sunt publicate în 15 lucrări științifice.

**Cuvinte-cheie:** lilieci, Chiropterele, importanță, diversitatea faunistică, conservare, reabilitare, repartizare biatomică, adăposturi, zona urbană, zona rurală, particularități ecologice.

**Scopul lucrării: e**lucidarea particularităților ecologice și diversității faunistice a comunităților de chiroptere în zonele urbane și rurale ale Republicii Moldova, evidențierea rolului liliecilor în natură și în viața omului și importanței conservării și reabilitării chiropterelor.

**Obiectivele cercetării:** elucidarea faunisticii și structurii taxonomice a chiropterelor din mediul urban și rural al Republicii Moldova; determinarea structurii comunităților de chiroptere în diverse tipuri de biotopuri din mediul urban și rural; evidențierea particularităților ecologice a comunităților de lilieci în mediul urban și rural al republicii; elucidarea importanței reabilitării liliecilor, rolului lor în natură și căilor de conservare a faunei de chiroptere în zonele puternic antropizate;

**Noutatea și originalitatea științifică:** pentru prima dată au fost realizate cercetări complexe ale comunităților de chiroptere din mediul urban și rural al Republicii Moldova. Au fost identificate speciile de lilieci care s-a adaptat la condiții urbane și speciile care utilizează siturile rurale de proveniența antropică în scopuri de adăpost. A fost stabilită starea actuală a speciilor de chiroptere în habitatele urbane și rurale și componența faunistică în diferite ecosisteme puternic antropizate. În premieră a fost elaborată metodologia reabilitării liliecilor în perioada de iarnă în condițiile Republicii Moldova. S-a evidențiat rolul și căile de conservare a acestui grup important de mamifere în contextul schimbărilor antropo-climatice.

**Problema științifică principală rezolvată:** problema științifică constă în evidențierea particularităților ecologice și faunistice în mediul urban și rural, elucidarea preferințelor speciilor față de anumite situri pentru adăpost și vânat.

**Semnificația teoretică:** a fost elucidată diversitatea faunistică și taxonomică a liliecilor din mediul urban și rural. Au fost elucidate particularitățile ecologice ale speciilor de lilieci și adaptările acestora în ecosistemele puternic antropizate. Studiul efectuat se încadrează în direcțiile științifice prioritare, în programele și strategiile naționale și internaționale, privind protecția și conservarea biodiversității, ceea ce constituie o contribuție semnificativă la realizarea convențiilor internaționale, inclusiv a celor de la Berna (1979), Bonn (1979), Convenția de la Rio de Janeiro (1992) și altele la care a aderat și Republica Moldova.

**Valoarea aplicativă:** a fost elucidată importanța liliecilor în habitatele urbane și elaborată metodologia de reabilitare a liliecilor în perioada de iarnă. Rezultatele tezei pot servi drept suport pentru metodologia de conservare a populațiilor de lilieci în regiuni puternic antropizate. Au fost elaborate recomandări practice privind conservarea chiropterelor și a habitatelor acestora în mediul urban și rural, evidențiată necesitatea educației ecologice și implicării publicului larg în conservarea chiropterofaunei.

**Implementarea rezultatelor științifice:** rezultatele obținute au fost utilizate ca suport la elaborarea unei indicații metodice. Rezultatele cercetărilor au fost aplicate în procesul implementării unui proiect internațional al programului COST, la implementarea a două proiecte transfrontaliere cu România. Informația despre fauna urbană de lilieci este utilizată și implementată în procesul didactic. Datele vor fi utilizate la elaborarea ediției a IV-a a Cărții Roșii a Republicii Moldova.

## ANNOTATION

Of the thesis entitled „**Ecological particularities and the importance of bats (Mammalia: Chiroptera) in the urban and rural environment of the Republic of Moldova**”, Presented by the candidate **Dibolscaia Natalia**, for obtaining the degree of Doctor in Biological Sciences with specialty – **165.02. Zoology**. **Chisinau, 2024**

**Structure of the thesis:** the thesis is written in Romanian and consists of an introduction, 4 chapters, general conclusions and recommendations, a bibliography of 162 titles and 2 appendices. The thesis contains 106 pages of basic text, 55 figures and 12 tables. The obtained results were published in 15 scientific papers.

**Keywords:** bats, Chiroptera, importance, faunal diversity, conservation, rehabilitation, biotope distribution, shelters, urban area, rural area, ecological particularities.

**Research purpose:** elucidating the ecological particularities and faunal diversity of chiropteran communities in urban and rural areas of the Republic of Moldova, highlighting the role of bats in nature and in human life and the importance of conserving and rehabilitating chiropteran species.

**Research objectives:** elucidation of the fauna and taxonomic structure of bats from the urban and rural environment of the Republic of Moldova; determining the structure of bat communities in various types of urban and rural biotopes; highlighting the ecological peculiarities of bat communities in the urban and rural environment of the republic; elucidating the importance of bat rehabilitation, their role in nature and ways to conserve chiropteran fauna in heavily anthropized areas.

**Scientific novelty and originality:** during the studies, complex researches of the chiropteran communities in the urban and rural shelters were carried out. Bat species that have adapted to urban conditions and species that use anthropogenic rural sites for roosting purposes have been identified. Data on the distribution and composition of the urban bat fauna have been updated. The current faunal status of the synanthropic chiropteran species and the ways to conserve this important group of mammals in the context of local ecological changes have been established.

**The result obtained:** The scientific problem consists in highlighting the ecological and faunal peculiarities in different regions of anthropogenic origin in urban and rural areas, elucidating the preferences of the species towards certain sites for shelter and hunting.

**The theoretical significance:** The ecological and biological particularities of bat species in urban and rural areas and their adaptive particularities were elucidated. The faunal diversity of bat communities in urban and rural areas was elucidated. The research carried out falls within the directions and priority scientific research, in the national and international programs and strategies, regarding the protection and conservation of biodiversity, which constitutes a significant contribution to the realization of the international conventions to which the Republic of Moldova has joined.

**The applicative value:** The importance of bats in nature and the human economy was elucidated. The obtained results serve as support for the methodology for the conservation of bat populations in regions of anthropogenic origin. Following the research, recommended methods were developed regarding the conservation of chiropterans and their habitats, emphasizing the importance of the involvement of the general public in the conservation of chiropteran fauna.

**Implementation of the results:** The research results were applied in the process of implementing an international project for research and innovation networks (COST). The data are used by the international agreement for the protection of bats (EUROBATS). The information about this group of mammals is used and implemented in the didactic process. The data will be used for the development and drafting of the 4th edition of the Red Book of the Republic of Moldova.

## АННОТАЦИЯ

Диссертация «**Экологические особенности и значение летучих мышей (Mammalia: Chiroptera) в городской и сельской среде Республики Молдова»**, представленная **Дибольской Натальей** на соискание степени доктора, биологических наук по специальности – **165. 02. Зоология. Кишинёв, 2024**

**Структура диссертации:** диссертация написана на румынском языке и состоит из введения, четырёх глав, общих выводов и рекомендаций, библиографии из 162 названий и 2 приложений. Диссертация содержит: 106 страниц основного текста, 12 таблиц, 55 рисунков. Полученные результаты опубликованы в 15-и научных работах.

**Ключевые слова:** летучие мыши, рукокрылые, значение, разнообразие фауны, охрана, реабилитация, биотопическое распространение, убежища, городская территория, сельская местность, экологические особенности, сохранение.

**Цель работы:** выявить экологические особенности и фаунистическое разнообразие сообществ рукокрылых в городских и сельских районах Республики Молдова, выделить роль летучих мышей в природе и жизни человека, а также их важность сохранения и защиты видов.

**Задачи исследования:** выяснение фауны и таксономической структуры видов рукокрылых городской и сельской среды Республики Молдова; определение структуры сообществ рукокрылых в различных типах городских и сельских биотопов; освещение экологических особенностей сообществ рукокрылых в городской и сельской среде республики; выяснение значения реабилитации рукокрылых, их роли в природе и путей сохранения фауны рукокрылых на сильно антропогенных территориях.

**Научная новизна и оригинальность:** впервые было проведено комплексное исследование сообществ рукокрылых в городской и сельской области. Выявлены виды летучих мышей, адаптировавшиеся к городским условиям, и виды, использующие антропогенные постройки в качестве убежища. Собраны данные о распространении и составе фауны рукокрылых в городской зоне. Выделены экологические особенности и состав фауны в разных регионах антропогенного происхождения. Установлен актуальный фаунистический статус видов рукокрылых и пути сохранения этой группы млекопитающих в условиях экологических изменений.

**Решенная научная проблема.** Научная задача состоит в выявлении эколого-фаунистических особенностей в различных регионах антропогенного происхождения, выяснении предпочтений вида в отношении тех или иных мест для убежища и охоты.

**Прикладная ценность:** Выяснено значение летучих мышей в природе и в хозяйственной деятельности человека. Полученные результаты служат информативной базой для сохранения популяций летучих мышей в регионах антропогенного происхождения. По итогам исследования был разработан ряд рекомендаций по сохранению рукокрылых и их среды обитания.

**Внедрение результатов**: Полученные результаты были при разработке методического пособия. Результаты исследований применены в рамках международного проекта COST. Собранные данные используются организацией - EUROBATS. Информация о рукокрылых используется в рамках дидактических процессов. Данные будут использованы для разработки и составления 4-го издания Красной книги Республики Молдова.

**DIBOLSCAIA Natalia**

**ECOLOGICAL PARTICULARITIES AND THE IMPORTANCE OF BATS (MAMMALIA: CHIROPTERA) IN THE URBAN AND RURAL ENVIRONMENT OF THE REPUBLIC OF MOLDOVA**

**165. 02. Zoology**

**Abstract of PhD Thesis in Biological Sciences**

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