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**BATS (CHIROPTERA, MAMMALIA) FROM THE UNDERGROUND SHELTERS  
OF THE REPUBLIC OF MOLDOVA**

**165. 02 – Zoology**

Summary of the doctoral thesis in biological sciences

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The doctoral thesis and the abstract can be consulted at the National Library of the Republic of Moldova, the “Andrei Lupan” Scientific Library (Institute), the USM Library, on the ANACEC website (<http://www.cnaa.md>) and on the USM website (<http://usm.md/>).

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## CONCEPTUAL GUIDELINES OF RESEARCH

**The actuality of the subject.** Biodiversity research and protection are currently the most current fundamental directions in the study of population ecology. In the current conditions of anthropization and climate change, bats are a less studied group of animals in our region whose biological and ecological features need more in-depth study. The adaptation to the conditions offered by different natural and artificial biotopes are vital for bats. Monitoring of these mammal species allows highlighting the ecological aspects of populations and limiting factors. The study of bats in different areas and their importance in the food chain as well as in the country's economy is especially important because most species are included in the Red Book of the Republic of Moldova and are protected at international level. Chiropterana, with a specific life cycle, with delimited periods of mating, reproduction and hibernation, are particularly susceptible to the action of environmental and anthropogenic factors, whose fluctuations affect the structure and viability of populations. The obtained results elucidate the current problems of bats and will contribute to the protection and conservation of bat species and their habitats, especially in the context of Moldova's accession to 18 international environmental conventions.

**Description of the situation in the field of research and identification of research problems.** Chiropterans have been known since antiquity and the studies on the identification, morphological description and elucidation of the way of life began in the eighteenth century. Along the way, 53 species were discovered and described in Europe and 21 species of bats in the Republic of Moldova. Although they play an important role in the functioning of natural and anthropized ecosystems, bats are the least studied group of mammals in the last decades. This work is very actual because the number of bats is constantly decreasing throughout the territory and completes the previous research, emphasizing the need to protect habitats. In-depth research will allow the accumulation of data needed to elucidate and maintain the functionality of bat sites in Moldova. It will be highlighted the need to preserve the sites where bats hibernate and reproduce.

**Scientific research methodology.** As methodological and theoretical-scientific support served the works of Averin I. and Lozan M., (1965), Doroşenko A., (1975), Lozan M., (1979). Fieldwork was carried out according to accepted methodologies in the field of chiropterology [2, 9, 11-13, 20-26].

**The aim of the thesis is** determining the structure of bat communities in the underground shelters of the Republic of Moldova, elucidating the bio-ecological features, the spread and importance of troglomorphic bat species on the territory of the republic.

The following objectives have been set: 1) Elucidation of the structure of bat communities in the underground shelters of the Republic of Moldova in different seasons of the year; 2) Highlighting the particularities of hibernation and reproduction of troglomorphic species of bats in underground shelters; 3) Determining the ecological features of bats in underground shelters; 4) Elucidate the importance of bats in

the trophic chains of the living world and develop recommendations for the conservation of bats and their habitats.

**Scientific novelty and originality.** For the first time, complex research was conducted elucidating the biological and ecological features of bats in the underground roosts of the Republic of Moldova. 6 new sites for hibernation and reproduction of certain bat species have been identified. Morphology data have been updated and maps of troglophilous bat species have been developed. The biological and ecological peculiarities of 11 species of bats from 5 genera, the qualitative and quantitative composition of the hibernation and reproduction colonies in various underground shelters were highlighted. The current status of populations of troglophilous bats has been established and limiting factors highlighted.

**The scientific problem solved** consists in highlighting the morphological, biological and ecological peculiarities, the structure of the bat communities during the hibernation and reproduction period, the elucidation of the species preferences towards a certain shelter. The factors that condition the decrease in the number of bat populations have been elucidated.

**Theoretical significance.** The morphological, biological and ecological features of troglophilous bat species have been elucidated. The seasonal and multiannual dynamics of the bat communities in underground shelters have been emphasized. The research conducted is part of the priority scientific directions and research, in national and international programs and strategies on the protection and conservation of biodiversity, which is a significant contribution to the implementation of international conventions, to which the Republic of Moldova has acceded.

**The applicative value of the paper.** The importance of bats in nature and the human economy has been elucidated. The results obtained serve as a support for the methodology of bat populations monitoring in underground shelters. Following the research, a series of recommendations were developed on the conservation of bats and their habitats, emphasizing the importance of educating and involving the general public in the protection of chiropteroфаuna.

**Implementation of scientific results.** The obtained results were used by specialists as support in the elaboration of a methodological guide. The research results were applied in the process of elaboration and establishment of protected areas within the Emerald Network, as well as in the implementation of a cross-border project with Romania. The information about this group of mammals is used and implemented in the teaching process, in the realization of bachelor's and master's theses at educational institutions with biological and ecological profile. The data will be used in the elaboration of the 4th edition of the Red Book of the Republic of Moldova.

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

**Thesis publications:** The results of the research and the conclusions were presented in 25 scientific papers.

**Keywords:** bats, underground sites, communities, colony, conditions, hibernation, reproduction, distribution, ecology, mines, rare species.

### **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. BIBLIOGRAPHICAL SYNTHESIS**

**1.1. The evolution and adaptations of bats.** When *Homo sapiens* did not yet exist, bats were already flying as insectivores. Because of this, the origin of chiroptera is thought to be older – from Paleocene, 70-100 million years ago. The oldest bats belonged to the genera *Palacochiropteryx*, *Aschaeonycteris* and *Hassianycteris* from the Lower Eocene. Current research suggests that bats evolved a long time ago compared to other mammals and have since undergone little change [12, 15].

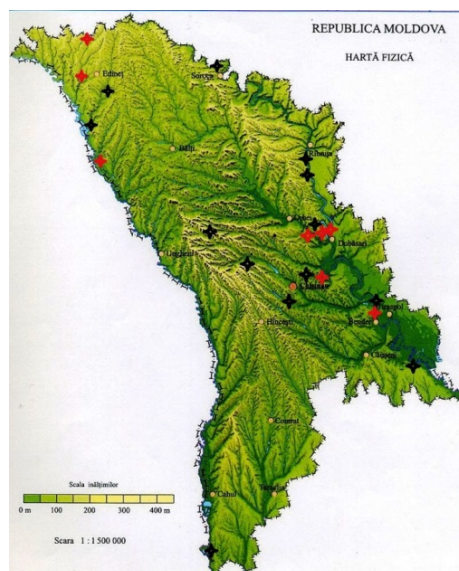
**1.2. Current status of chiropterological research in the Republic of Moldova.** This chapter presents the achievements of research since the 19th century, how many species of bats have been determined and the areas where they have been identified. There are citations of scientists who studied bats in Moldova in the 20th century and contributed to the knowledge and research of bat fauna. The first more in-depth scientific studies in chiroptera research were conducted by Averin I. and Lozan M. (1965), Lozan M. and Scvorțov V. (1965), Doroșenco A. (1975), Averin et al. (1979). More recent research were performed in the 1990s by Vasiliev A. and Andreev S. (1997, 1998). At the beginning of the century, the studies were continued by Andreev S. and Bondarenco A. (2006) [1, 20-26].

**1.3. Current state of research in adjacent countries.** On the Romanian territory there are 32 species of bats that belong to 2 families and most of them are found in underground shelters and forests. Compared to the chiroptera on the territory of the Republic of Moldova, in Romania there are large colonies that can count hundreds of individuals, even thousands and tens of thousands. The Red Book of Vertebrates in Romania includes 28 species of bats out of the 32 existing ones [3, 6, 9, 11].

On the territory of Ukraine 30 species of bats were registered that belong to 2 families and are found mostly in the rocky and mountainous areas of the country, in underground shelters such as caves, grottoes, mines, but also in forests and in urban areas, in various buildings, city parks. Although the number of species is relatively high, the issue of numerical decline persists and most species are vulnerable, 24 bat species out of 30 being included in the Red Book of Ukraine.

## 2. MATERIALS AND METHODS

**2.1. Description of bat habitats in the central and northern part of the country.** The research of the underground shelters in the north and central area of the Republic of Moldova was carried out systematically. From 2015 to 2020, various types of ecosystems were studied, especially the underground ones: rock (stone quarries from Cricova, Goianul Nou, Saharna, Bâcioc, Brânzeni, Cupcini, Vâșcăuți, Mașcăuți, Molovata, Molovata Nouă, Holercani, Trebujeni, Varnița).



- Situri noi cercetate
- Situri vechi cercetate

**Fig. 2.1.1. Spreading of troglophilous bat species on the territory of the Republic of Moldova**

**2.2. Climate conditions.** According to the State Hydrometeorological Service, in the years 2013-2020, on the territory of the Republic of Moldova was mostly warmer than usual and with a significant deficit of precipitation between June and September, except the summer of 2014. These conditions have contributed to maintaining a very strong atmospheric and pedological drought during this period.

**2.3. Research methods.** The capture of bats took place very accurately and predominantly during hibernation when bats are fast asleep and can be collected without trauma. Numerical estimates were made by the method of counting each individual in the shelter who is clearly visible. The identification took place through collection and measurements as well as the determination through the coloration, the size of the individual, the classic posture ect. [2].

**2.3.1. Indirect observation methods.** The ultrasonic detector or acoustic detection (PETTERSSON D220) was used. This method was performed in open places where the bats fly during foraging activity. Acoustic detection is a non-invasive method that does not affect bat species in any way [2, 15].

**2.3.2. Direct observation methods.** The captures were made with chiropterological nets (15x15 mm mesh) inside and at the entrance area of the shelter. Once captured, the time of identification and

morphological measurements of individuals was reduced to a minimum in order to diminish the level of animal disturbance. Pregnant and lactating females were released immediately without the necessary measurements. The most convenient and frequently used method of capture in caves/mines with low heights was the manual collecting during hibernation [9, 15].

**2.3.3. Identification of bat species.** The following classical characters were used to identify the species: appearance, fur color, body length and weight. Electronic caliper and electronic balance were used in the morphological measurements. All indicated measurements are only valid for adults who are already fully formed. At the time of the first flight, the bones of the juveniles are not completely ossified, and the phalanges can be best seen when the joints are positioned against a bright background.

### **3. TAXONOMIC AND ECOLOGICAL STUDY OF TROGLOPHIC SPECIES OF BATS IN THE CENTRAL AND NORTHERN AREA OF THE REPUBLIC OF MOLDOVA**

**3.1. Taxonomy and description of bat species.** Bats in Moldova belong to the class Mammalia, order Chiroptera, 2 families Rhinolophidae and Vespertilionidae. In our research, 11 species of bats were captured, identified and subjected to morphological study:

1. The genus *Rhinolophus* Lacepede 1799. *Rhinolophus hipposideros* (Bechstein 1800), the small horseshoe bat - in our fauna it is the smallest species of the genus.

2. Genus *Myotis* Kaup, 1829. *Myotis myotis* (Borkhausen, 1797), the greater mouse-eared bat – the largest species of the genus in the fauna of the Republic of Moldova; 3. *Myotis blythii* (Tomes, 1857), the lesser mouse-eared bat; 4. *Myotis bechsteinii* (Kuhl, 1817) the Bechstein's bat; 5. *Myotis daubentonii* Daubenton's bat (Kuhl, 1819); 6. *Myotis dasycneme*, the pond bat (Boie, 1825); 7. *Myotis mystacinus* (Kuhl, 1817) the whiskered bat - is one of the smallest species in the fauna of our country;

8. Genus *Barbastella* Gray, 1821. The species has a small stature, slender body, large, broad, overgrown ears at the base of the inner edges. *Barbastella barbastellus* (Schreber 1774), the western barbastelle;

9. Genus *Eptesicus* Rafinesque 1820. *Eptesicus serotinus* (Schreber 1774), heavier than representatives of the genus *Myotis*;

10. Genus *Plecotus* Geoffroy 1818. The species are medium-sized, with a slender body. *Plecotus auritus* (Linnaeus, 1758), the brown long-eared bat;

11. *Plecotus austriacus* (Fischer 1829), the gray long-eared bat - differs from the species presented above in color and some dimensional characters.

The morphology data of the studied troglophilous bat species have been updated. The distribution maps of the 11 studied species on the territory of the Republic of Moldova were elaborated, with the indication of the geographical coordinates of the recording places.



### 3.2. Biological features of bats

**Shelters.** Chiropterans do not have the capacity to build their own shelters. They use any type of natural and artificial shelter that meets the requirements of their changing metabolism [15].

The habitats of the bats of the central area are of 2 types – natural and artificial:

- natural are represented by different types of forests, shrub associations, meadows, caves, grottoes, underground caverns;

- artificial are the mines, caves, quarries left after the stone extraction.

For bats, a shelter meets the necessary conditions if it has a constant temperature; during the reproduction period the humidity of the shelter is of minimum 40%; the area occupied by bats must be free of air flows; bats need tranquility, not to be disturbed; lack of light.

**Reproductive intensity and duration of the reproductive period.** The determination of the sex of the species from the fauna of Moldova is made simply by the classical method, according to the characters of the external genitalia. In the fauna of our country, all species of bats are monoestrous and have a single birth in May-June. Bats mate predominantly in the fall, but ovulation occurs in the spring in some cases with only small time deviations. In most bat species, sexual maturity occurs in the second year of life [9, 15].

The female usually gives birth to one young, but in some species two youngs are born, the mother carries the young with her in flight even when hunting. Some species leave their young alone or with other ones together. The female feed it for 1.5-2 months after birth.

**Circadian rhythms.** The bats' internal clock is a perfect mechanism that allows them to wake up daily at a certain time and stay in the shelter until it's time to fly out of the shelter. Climate is the dominant factor that influences the life cycle of bats. The activity hours of the bats begin after sunset and depending on the weather, nebulosity and precipitation [12]. It was found that bats have two periods of maximum activity: the first and most important is at the beginning of the evening; the second occurs in the morning at the end of the night. The first bats come out of the shelters at 10-30 minutes after sunset. Returning to shelters usually takes place at dawn.

**Diet and feeding.** The bats coming out from shelters go to the places where they can satisfy their hunger and thirst. Large bats, such as *Myotis myotis* and *M. blythii* consume relatively large insects with chitinized bodies, while small species such as *Rh. hipposideros* and *P. pipistrellus* - usually eat small insects with a soft body. Bats do not eat the wings and legs of insects.

**Types of sounds and ultrasound.** The sounds emitted by the bats are like squeaks, these are the beginning of an ultrasonic emission. The emitted frequencies differ greatly depending on the species and activity [6, 10]. The studied species in the underground shelters were also determined with the ultrasound in the open field: *Rhinolophus hipposideros* 105-111 kHz, *Myotis blythii* 26-29 kHz, *M. bechshteinii* 45-50

kHz, *M. daubentonii* 38-41 kHz, *M. myotis* 27-30 kHz, *M. dasycneme* 35 kHz, *M. mystacinus* 45-50 kHz, *Barbastella barbastellus* 32-35 kHz, *Eptesicus serotinus* 25-27 kHz [15].

**Bat lifespan.** It is considered that the lifespan of bats is shorter than the real one. An important method for identifying the approximate age was their ringing, marking and recapture [2, 9]. An individual was collected in the mines from Bîcioc in 2014 that has been ringed in 1996 in the same site, the collected male was at least 20 years old, because at the time of the ringing he was already adult.

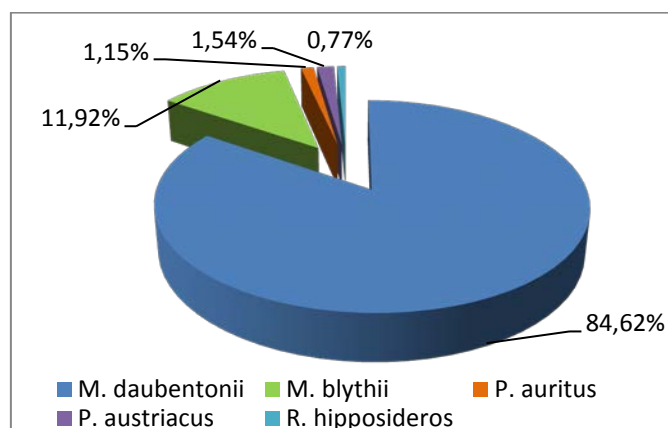
#### 4. STRUCTURE AND BIO-ECOLOGICAL PARTICULARITIES OF UNDERGROUND CHIROPTER COMMUNITIES

##### 4.1 The structure of chiroptera communities during hibernation

15 sites of mixed hibernation of several bat species in the central and northern part of the Republic of Moldova over several years were studied, usually in winter and spring-summer period, but also in autumn during 2013-2020.

1. The Gordinești mines are located in the northern part of the Republic of Moldova (48°09'89" N, 27°08'96" E). The first studies took place at the end of January 2015 [19]. 260 individuals from 5 species of bats were identified, the most numerous being individuals of *M. daubentonii* 84.62%, followed by *M. blythii* 11.92%, *P. austriacus* 1.54%, *P. auritus* 1.15 % and *Rh. hipposideros* 0.77 (figure 4.1.1.).

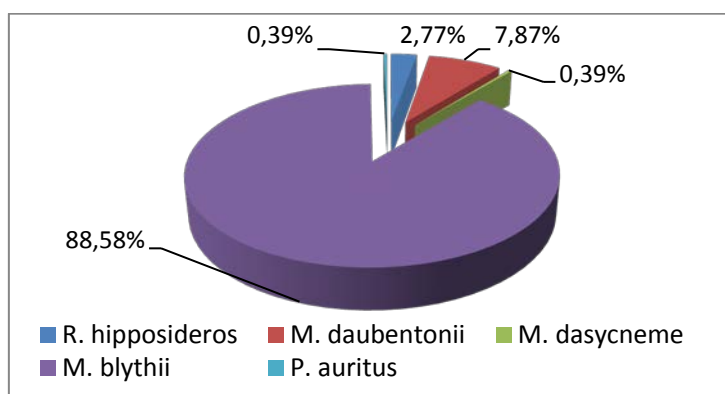
The diversity of bats was relatively large, no large hibernation colonies were found, only solitary or grouped individuals. Accumulations of guano have been identified in the places where breeding colonies were formed, during this study in the given area there were few bats.



**Figure 4.1.1. The structure of the bat community during the hibernation period in Gordinești**

In 2018, the research took place in April at the end of hibernation, most bats were active. During this period, maternity colonies are created, females separate from males. Males of *M. blythii* were found alone, and females were already forming groups in different rooms. 254 individuals from 5 species were identified: *M. blythii* 88.58%, *M. daubentonii* 7.78%, *Rh. hipposideros* 2.77%, *M. dasycneme* and *P. auritus* with 0.39% each (figure 4.1.2.). There is a diversity similar to that of the hibernation period and a

relatively large number. Due to the lack of disturbance, the high ceilings and other optimal conditions, the *M. blythii* individuals remain in these mines and even form maternity colonies.



**Fig. 4.1.2. Structure of the bat community at the end of the hibernation period in Gordinești mines**

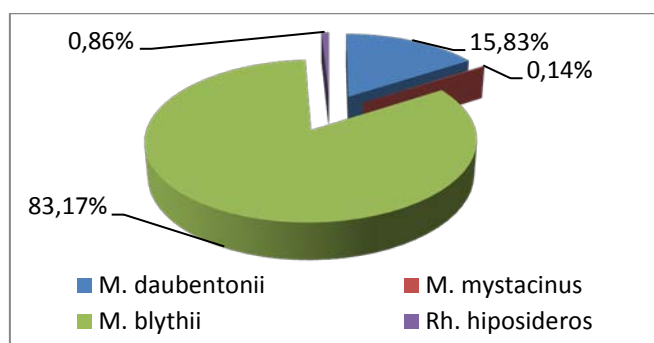
These mines have been studied for the first time and have not been mentioned before. This site is part of the landscape reserve "La Castel" and is of major importance for hibernation and breeding of bats in the northern part of the republic, being registered 5 protected species.

2. The abandoned mines from Cupcini are located in the northern part of the Republic of Moldova with the coordinates (47°41'79" N, 28° 7'85" E) at an altitude of 142 m. The entrances are located in the northern part, 2 entrances are abandoned and the rest are active. At 80 m from the entrance the temperature was + 8.4° C, humidity – 81%. At the end of February 2015, 461 individuals from 3 species were identified: *M. blythii* with 86.33%, *M. daubentonii* 12.58% and *M. mystacinus* 1.09%.

In 2018, the research took place in April, at the end of the hibernation period. During this period some species became active depending on climatic conditions. A rather high diversity was observed due to climatic conditions and migrations between shelters with the arrival of spring. 121 individuals from 4 species were identified: *M. blythii* with 88.42%, *M. daubentonii* with 9.92%, *M. mystacinus* and *Rh. hipposideros* with 0.83% each.

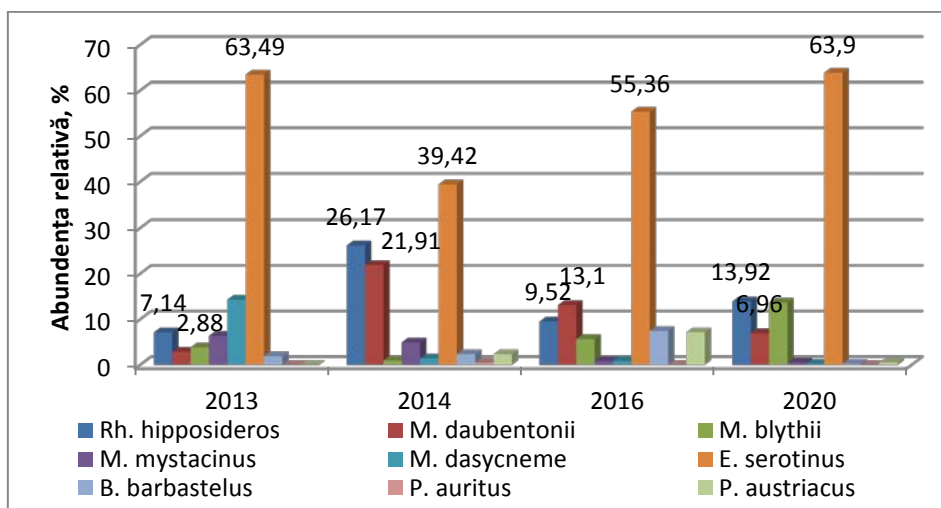
The 2020 research was conducted in early January during the hibernation period of bats. One of the mine was flooded and the access inside it was impossible. 3 species of bats with a number of 102 individuals were registered – a smaller diversity with a similar to 2018 number: *M. blythii* with 66.67%, *M. daubentonii* with 28.43% and *Rh. hipposideros* with 4.90%.

During the study years in the Cupcini mines 696 individuals from 4 species of bats were registered. The dominant species in all years was *M. blythii*, which constitutes over 80%, the lowest abundance had the species *M. mystacinus*, which in recent years has not been found. The maximum number of bats was registered in hibernation period of 2015. In all years of study of this site the dominant species was *M. blythii* with 83.17% followed by *M. daubentonii* 15.83%, *Rh. hipposideros* 0.86% and *M. mystacinus* 0.14% (figure 4.1.3.). In recent years, the Cupcini mines have undergone major changes due to flooding.



**Fig. 4.1.3. The total abundance of bat species in the Cupcini mines**

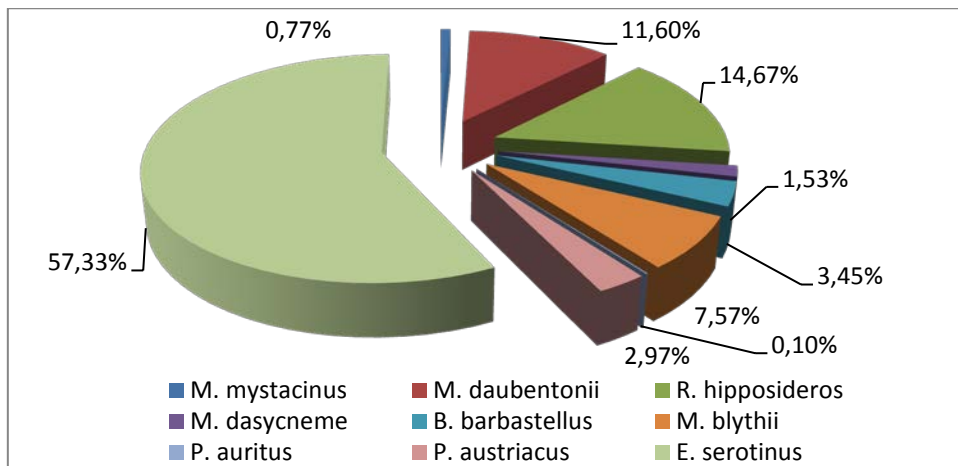
4. The abandoned Saharna mines are located in the north of the Republic of Moldova (47°41'79" N, 28°57'85" E) with several entrances located along the slope. The research took place in the winter of 2013, 2014, 2016 and 2020. 9 species of bats were identified: *Rhynolophus hipposideros*, *Myotis blythii*, *M. daubentonii*, *M. dasycneme*, *M. mystacinus*, *Plecotus auritus*, *P. austriacus*, *Eptesicus serotinus*. Here was registered the species *B. barbastellus* that has not been identified in any other site. A total of 1037 individuals of 9 bat species were identified in Saharna mines during all years of study (figure 4.1.4.).



**Fig. 4.1.4. Abundance (%) of bat species in Saharna mines during the study periods**

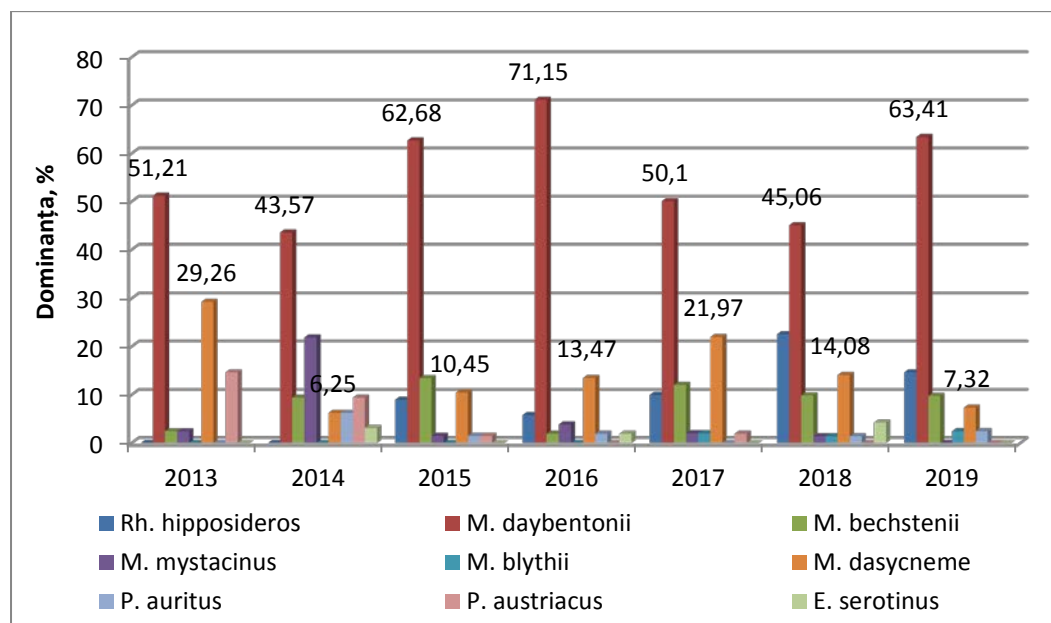
During the hibernation period, the most numerous species was *E. serotinus*, which constituted between 39.42% and 63.5% of the total identified chiroptera. In 2013, the second most abundant species was *M. dasycneme*, which accounted for about 15% of all bats, and the other species were recorded with less than 10% each. In 2014, the second most abundant species was *Rh. hipposideros* 26.76%, followed by *M. daubentonii* 21.59%, other species recorded less than 5% each [18]. In 2016 the same species were dominant (*M. daubentonii* 13%, *Rh. hipposideros* 9.52%). The number has grown over the years from 112 individuals in 2013 to 336 in 2016.

The total abundance of *E. serotinus* species for all years is 57.33%, followed by *Rh. hipposideros* 14.67% and *M. daubentonii* 11.60%, the other species have an abundance of less than 10% each (figure 4.1.5.).



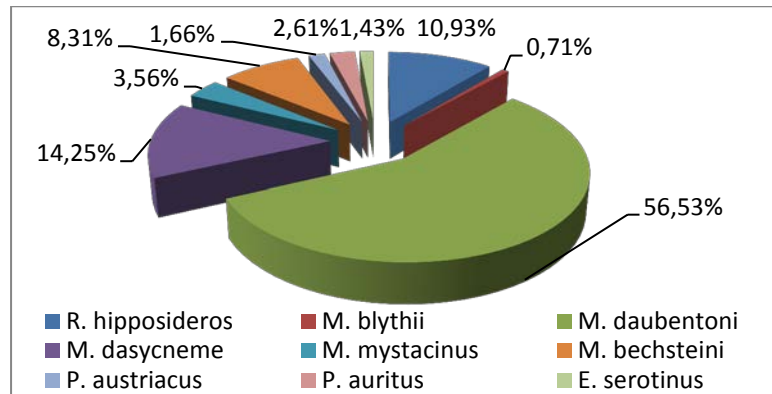
**Fig. 4.1.5. The total abundance of bat species in the Saharan quarries**

3. The abandoned mines from Cricova are located in the central part of the Republic of Moldova (47°09'04" N, 28°51'44"E) at an altitude of 87 m. The studies were performed from 2013 to 2019 mostly during the hibernation period. A total of 9 species of bats were identified: *Rhinolophus hipposideros*, *Myotis daubentonii*, *M. blythii*, *M. bechsteinii*, *M. dasycneme*, *M. mystacinus*, *Plecotus auritus*, *P. austriacus* and *Eptesicus serotinus* (Figure 4.1.6.).



**Fig. 4.1.6. Abundance of bat species in the Cricova mines in the studied years**

From 2013 to 2019 a significant dominance of the species *M. daubentonii* can be observed. The other species have a smaller number or only a few individuals of one species [17]. The total abundance of *M. daubentonii* constitutes 56.53% of the total number of individuals, followed by *M. dasycneme* 14.25%, which is rarely found in other shelters, *Rh. hipposideros* 10.93%, *M. bechsteinii* 8.31%, *M. mystacinus* 3.36%, *P. auritus* 2.61%, *P. austriacus* 1.66%, *E. serotinus* 1.43% and *M. blythii* 0.71% (figure 4.1.7.). In most cases, individuals were found alone, rarely in groups of 3-5 individuals.



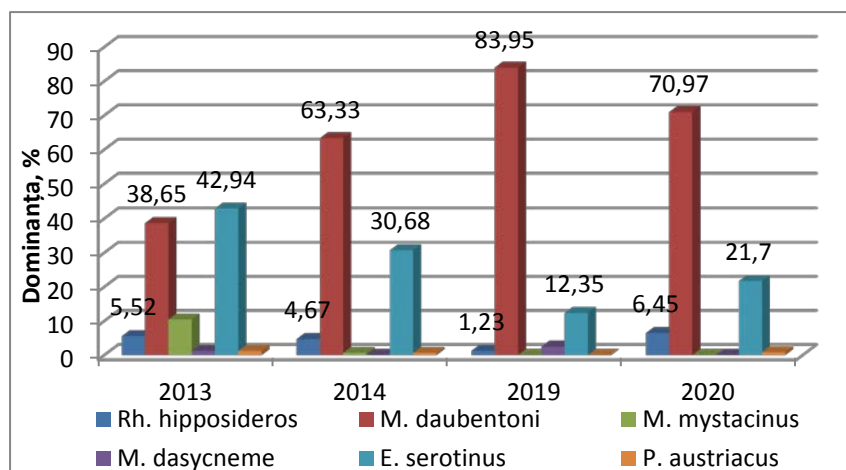
**Fig. 4.1.7. Total abundance of bat species in the mines of Cricova**

5. In the abandoned mines from Bîcioc (46°92'83" N, 29°48'43" E) the researches were carried out in the first half of December 2013, where 163 individuals from 6 species were registered: *E. serotinus* 42.94%, *M. daubentoni* 38.65%, *M. mystacinus* 10.43%, *Rh. hipposideros* 5.52%, *M. dasycneme* and *P. austriacus* with 1.23% each.

In the first half of March 2014, 150 individuals of 5 species were identified: *M. daubentoni* 63.33%, *E. serotinus* 30.68%, *Rh. hipposideros* 4.67%, *M. mystacinus* 0.66% and *P. austriacus* 0.66%. The most numerous were *M. daubentoni*.

The 2019 research took place towards the end of March [14]. 69 individuals from 4 species of bats were identified, the most numerous being individuals belonging to the species *M. daubentoni* 73%, followed by *E. serotinus* 21%, *M. dasycneme* 4%, *Rh. hipposideros* 2%.

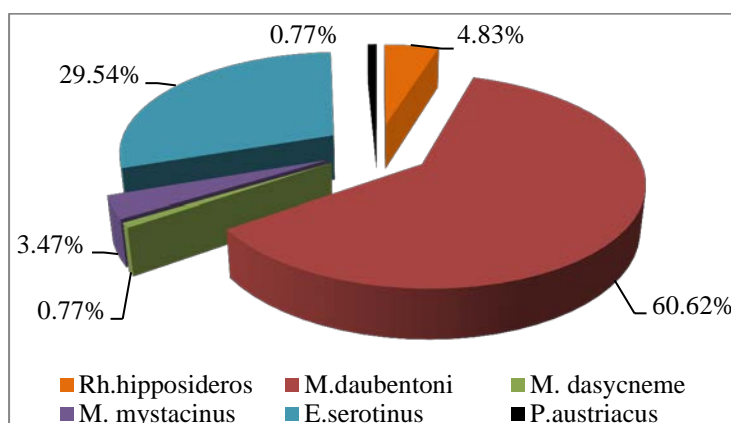
The next research in 2020 was carried out at the end of February, one month earlier than the previous year [10]. There were identified 124 individuals from 4 species of bats: *M. daubentoni* 71%, *E. serotinus* 22%, *Rh. hipposideros* 6%, *P. austriacus* 1%. A total of 518 bats of 6 species were identified in the mines from Bîcioc during the study years (figure 4.1.8.).



**Fig. 4.1.8. Abundance (%) of bat species in Bîcioc mines**

The dominant species was *M. daubentoni* except for 2013, the maximum abundance was 83,95% in 2019. As we can see, the abundance of the species is fluctuating during the years.

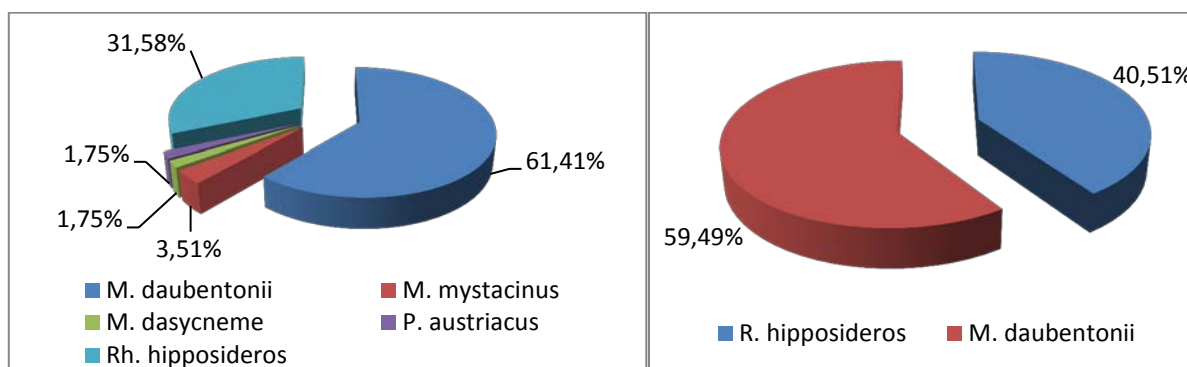
For all study years the dominant species was *M. daubentonii* with over 60%, followed by *E. serotinus* with about 30%, and the other species less than 5% each (figure 4.1.9).



**Fig. 4.1.9. Total abundance of bat species in Bîcioc mines**

Some species were not observed in all years of the study, for example the whiskered bat was not reported in 2019 and 2020, and the pond bat – in 2014 and 2020. The studied sites are important places for hibernation of bats and are the largest underground shelters from the territory of the Republic of Moldova and we propose the designation of the status of protected area to these site.

6. In December 2016, a new site – the Varnița mines was studied (46°54'07" N, 29°27'47" E). The most numerous were the species *M. daubentonii* 61.41% and *Rh. hipposideros* 31.58%, followed by *M. mystacinus* 3.51%, *P. austriacus* and *M. dasycneme* 1.75%. The 2018 research was conducted in February. 79 individuals from 2 species of bats *M. daubentonii* 59.49% and *Rh. hipposideros* 40.51% were identified, and there is a significant decrease in the diversity from 5 species in December 2016 to 2 in February 2018 (figure 4.1.12).



**Fig. 4.1.10. Bat community structure in the mines from Varnița, December 2016 and February 2018**

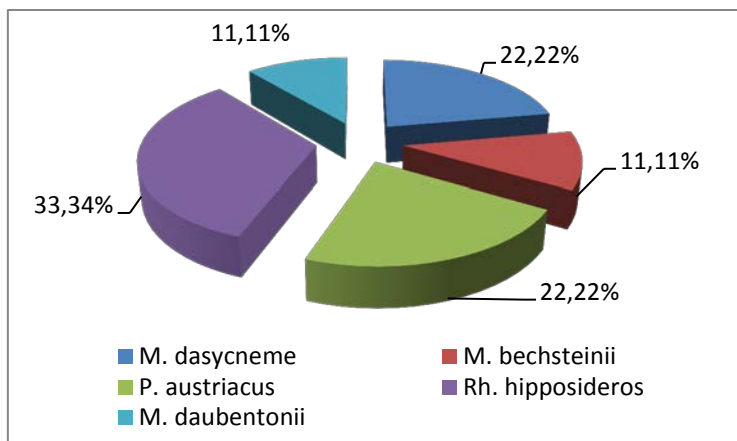
There is a negative dynamics of diversity for these shelters, despite the fact that the climatic conditions were similar[8].

7. In the abandoned mines from Mașcăuți (47°17'50" N 28°58'28" E) the research took place at the beginning of November 2016. The temperature at the entrance was 16° C and the humidity of 60%, there were strong air flow due to the existence of several enters, a factor that bothers bat individuals. A total of



63 individuals from 6 species of bats were identified. The dominant species was *E. serotinus* 50.79%, followed by *P. austriacus* 28.57%, *Rh. hipposideros* 9.52%, *M. daubentonii* 7.94%, *P. auritus* and *M. mystacinus* 1.59%. We can mention a great diversity of bat species but with a relatively small number of individuals.

8. The abandoned mines at Trebujeni are located on the left side of the river Răut (47° 18'21"N, 28°59'28" E). The research was carried out at the end of autumn in November 2016. Individuals from 4 species of bats were registered: *Rhinolophus hipposideros* 33,34%, *Plecotus auritus* 22,22%, *Myotis dasycneme* 22,22%, *M. daubentonii* 11,11%, *M. bechsteini* 11,11% (figure 4.1.12.).



**Fig. 4.1.12. Bat community structure in the Trebujeni mines in November 2016**

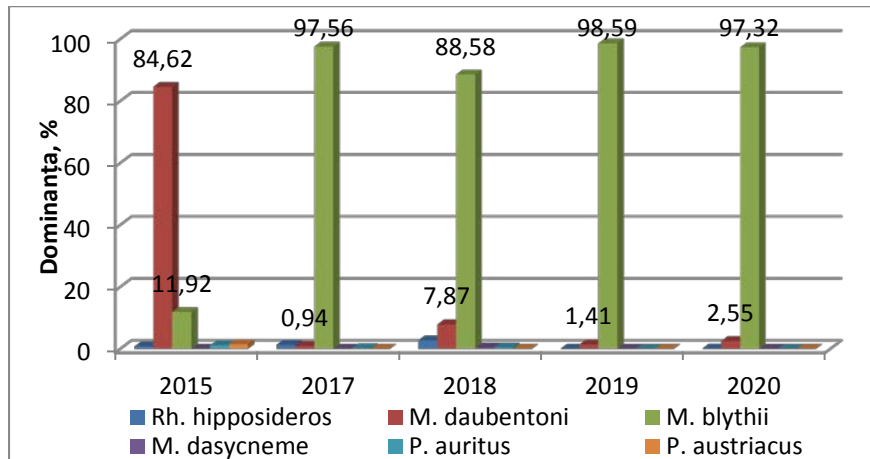
It has been found that in underground shelters in autumn, at the beginning of the hibernation period, most individuals are solitary, in winter they move and concentrate in groups, which can number tens or hundreds of individuals, and towards the end of hibernation large groups disperse and most bats were found alone.

#### **4.2. Reproduction of bat species in underground shelters**

The study took place during the breeding season of bats. In the mines from Gordinești the study was carried out in July 2017, April 2018, May 2019 and June 2020. In these mines during the pre-reproductive and reproductive periods, a maternity colony of the species *M. blythii* was identified, and every year the number of individuals in the colony was higher, which fact shows a positive number dynamics. The site was studied for the first time.

Pregnant females and young individuals were not collected in order to avoid their stress, the females showed increased activity and aggression during this period. The colony size was estimated by counting females and the youngs. The abundance of *M. blythii* species in the mines from Gordinești was high, between 88.58% and 98.59% due to the maternity colony and, during 4 years the dominant species remains *M. blythii* with a high number (figure 4.2.1)





**Fig. 4.2.1. Dynamics of the abundance (%) of bat species in Gordinești mines during the reproduction period**

The underground shelters in Vâșcăuți were studied for the first time. In July 2017, a maternity colony of the species *M. daubentoni* of 200 individuals was identified for the first time in Vâșcăuți mines (figure 4.2.2.). Because the youngs were born in the second half of June, all of them were well developed and were about  $\frac{1}{2}$  or  $\frac{3}{4}$  the size of adult animals. Juveniles were 3-4 weeks old and most of them were independent.

In June 2020, the maternity colony of *M. daubentoni* counted only 80 individuals, the youngs were hanging on to their mothers and were 1-2 weeks old.

The research in the Vâșcăuți cave took place in July 2017. A maternity colony of the species *Rh. hipposideros* was identified with 41 individuals. All the females had a juvenile attached to the ventral side, they were 2-3 weeks old, constituted about  $\frac{1}{3}$  the size of adults and did not fly independently (figure 4.2.2.).

The studies in 2020 took place in early June. The maternity colony of *Rh. hipposideros* counted 30 females, most with a juvenile attached to the ventral side, up to 2 weeks old, while some females were still pregnant. A negative dynamics in colony number were observed in both sites during the research period.



**Fig. 4.2.2. Maternity colonies of *M. daubentoni* and *Rh. hipposideros* (Vâșcăuți, 2017)**

The Red Book of the Republic of Moldova includes the three breeding species, protected at national and international level. The species are included in Annex II of the Berne Convention (strictly

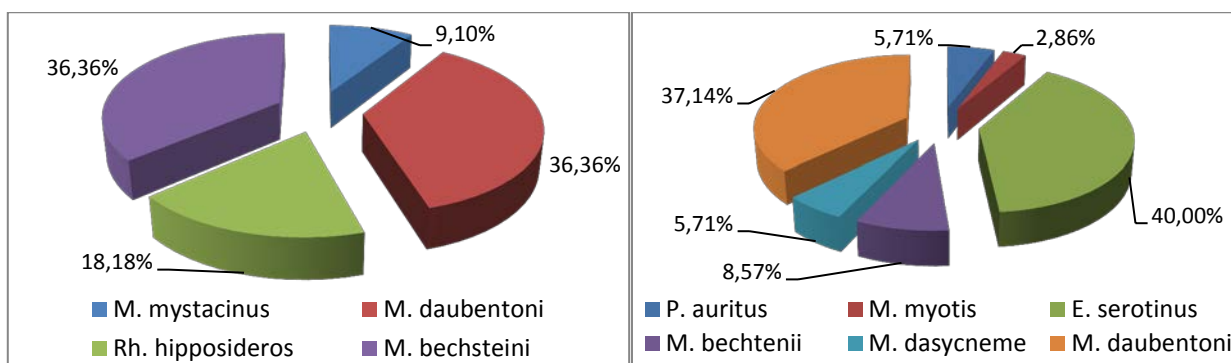
protected animal species), in Annex II of the Convention on the Conservation of Migratory Species and in (EUROBATS).

### 4.3. Structure of bat communities in underground sites during the summer-autumn period

In the Cupcini mines in 2017, the research took place in June, only 2 species of bats (*M. blythii* and *M. daubentonii*) were identified with a much smaller number compared to the hibernation period of the previous year.

In 2019, the studies was carried out in May, the period when the reproduction of bats begins. Only 3 individuals of 3 species were identified (*M. blythii* 33.3%, *M. daubentonii* 33.3%, *Rh. hipposideros* 33.3%) The low diversity and number is due to migrations to other warmer shelters for breeding, to flooding of the mine and collapse of the ceilings. In June of the same year, only one species *M. daubentonii* with 5 individuals was observed. This shows that bats flew to other shelters with optimal conditions, and frequent flooding and mine landslides are negative factors for bats.

The abandoned mines from Goianul Nou are located in the central area of the Republic of Moldova (47°07'18" N, 28°53'45" E). It is an underground roost for bats during the active and hibernation period of the year. It is an area with low influence of anthropogenic impact, away from localities surrounded by agrocenoses and forest belts. In April 2016, 4 species were identified in the mines from Goianul Nou: *M. daubentonii* 36.36%, *M. bechsteinii* 36.36%, *Rh. hipposideros* 18.18% and *M. mystacinus* 9.10%. In 2020, the research took place in mid-September. 35 bats from 6 species were registered: *E. serotinus* 40%, *M. daubentonii* 37%, *M. bechstenii* 8%, *M. dasycneme* and *P. auritus* with 6% and *M. myotis* 3% (figure 4.3.1.). All the bats were found at about 50 m from the entrance, except for a few individuals, located deeper, at 70-80 m. The most numerous were individuals of the species *E. serotinus*, which in 2016 were not identified. The highest diversity was observed in September.



**Fig. 4.3.1. Bat community structure in Goianul Nou mines in 2016 and 2020**

In the Saharna mines in 2020 the research took place in September. 376 individuals of 8 species were identified: *E. serotinus* 64%, *M. blythii* and *Rh. hipposideros* 14%, *M. daubentonii* 7%, *M. mystacinus* and *P. austriacus* 1%, while *M. dasycneme* and *B. barbastellus* were represented by a single

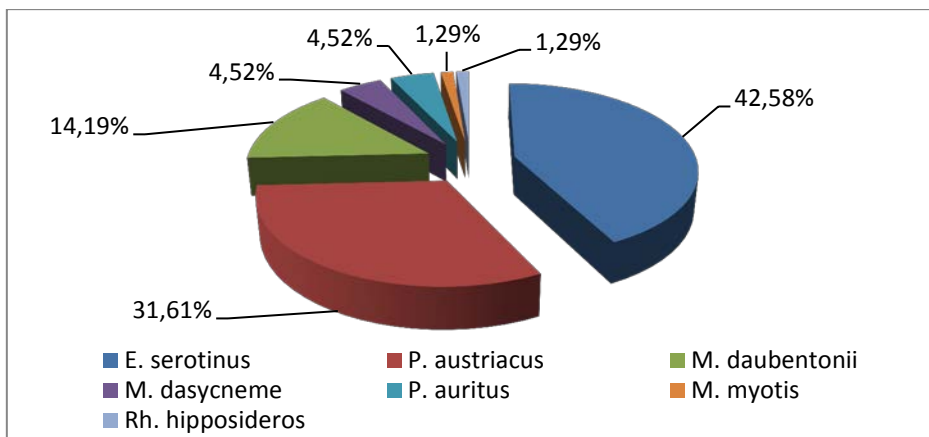
individual. The dominant species was *E. serotinus* followed by *Rh. hipposideros* and *M. daubentonii*, which is similar to the hibernation period situation.

Therefore, in September 2020, the highest number of bats in the Saharna mines was identified compared to the hibernation period, which indicates that the given site has all the optimal conditions for a high number of bat species at all times of the year.

In the mines from Mașcăuți in 2017, the researches were carried out in June. 32 individuals from 6 species of bats were identified. The dominant species was *P. austriacus* 71.85%, followed by *M. mystacinus* 12.5%, *E. serotinus* 6.25%, *M. myotis*, *M. dasycneme* and *Rh. hipposideros* with 3.13% each. The dominant species was *M. daubentonii* that in 2016 has not been identified.

In 2020, the studies took place in early June when the bats are active. 63 individuals were identified from 7 species of bats: *P. austriacus* dominated with 68%, followed by *M. dasycneme* 14%, *P. auritus* 7%, *M. myotis*, *M. mystacinus*, *Rh. hipposideros* with 3% each and *M. daubentonii* with 2%.

The dominant species was *P. austriacus* as in June 2017, the bat diversity and number were higher than in November 2016. The species *E. serotinus* was not identified during this period. In the same year, the studies continued in September, when bats began to look for hibernation shelters and have intense foraging activity. 155 individuals from 7 species were identified: *E. serotinus* 43%, *P. austriacus* 32%, *M. daubentonii* 14%, *M. dasycneme* 5%, *P. auritus* 4%, *M. myotis* and *Rh. hipposideros* 1% each (figure 4.3.2.).

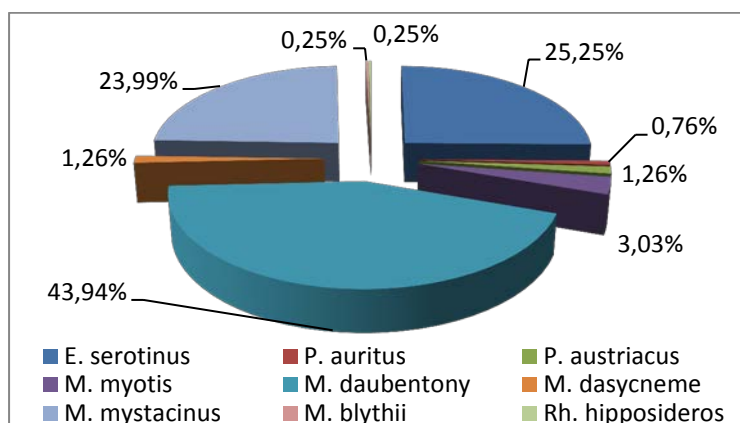


**Fig. 4.3.2. Structure of bat community in the mines from Mașcăuți**

The dominant species was *E. serotinus* as in the hibernation period, which proves that the given species only hibernates in these shelters from autumn until the beginning of the warm period. The same diversity has been identified as in spring with a larger number comparing to previous years, which is a positive dynamics for bats.

11. In the abandoned mines of Molovata (47°21'51" N, 29°04'5"6 E) the study took place in early September 2020. The studied mine has a small size and was studied for the first time. Only one species was identified – *M. daubentonii* with 24 individuals. The low diversity is due to the specific conditions of the mine and the high touristic activity.

12. The abandoned mines of Molovata Nouă are located on the left bank of the Dniester River (47° 19'53" N, 29°05'91" E) near the village. The studies were carried out at the beginning of September 2020. 8 entrances were studied, the temperature inside was 18°C at 40 m from the entrance and the humidity was 60%. The first bats were identified at 20 m from the entrance, a total of 396 individuals of 9 species were registered (figure 4.3.3.). The most numerous were *M. daubentonii* 43.94%, followed by *E. serotinus* 25.25%, *M. mystacinus* 23.29%, *M. myotis* 3.03%, *P. austriacus* and *M. dasycneme* with 1.26 each %, *P. auritus* 0.76%, *M. blythii* and *Rh. hipposideros* with 0.25% each.



**Fig. 4.3.3. The share of individuals identified in the Molovata Nouă mines**

In this site there was a great diversity of bats with a high number of individuals. This mine is located in a very favorable area with minimal disturbance and optimal conditions for many species of bats. This site has been studied for the first time.

13. The abandoned mines of Holercani are located on the right bank of the Dniester River (47°19'37" N, 29°04'22" E) near the village. The studie took place in early September of 2020. 3 species of bats were identified: *Rh. hipposideros* 66.657%, *M. daubentonii* and *M. bechstenii* with 16.7% each. The low number of individuals is due to the anthropogenic activities observed in the shelters, the collapse and flooding of the mine.

In Trebujeni mines in June 2017, only one species of bats was identified – *M. daubentonii* with 14 individuals. The low diversity is due to the warm period of the year, the existence of many suitable shelters nearby, as well as the sensitivity to tourist disturbance. In June 2020, only 2 species were identified in the Trebujeni mines: *M. daubentonii* and *P. austriacus* with a small number. The very presence of bats is an amazing fact for this site, taking into account the size and tourist activity.

As natural underground roosts 2 grottoes were studied at Brânzeni and Buzdugeni. These sites differ from the others, they have low depth and the cracks in the ceiling have several meters deep. The microclimate is different from the mines one due to the lack of air flow and the humidity is influenced by the weather outside. In both caves were found some individuals of the species *Rh. hipposideros* in the warm period of the year.

#### 4.4 Ecological analysis of bat communities

During 7 years of research, in the underground shelters from the north and center of the country 11 species of bats were identified with a total number of 6192 individuals (table 4.4.1). The most numerous were the representatives of the species *M. blythii* with 2666 individuals, *M. daubentonii* with 1592, *E. serotinus* 890 and *Rh. hipposideros* with 363 individuals. The other 7 species had a much smaller number that did not exceed 100-200 individuals.

**Table. 4.4.1. Number of bats registered in the underground sites of the Republic of Moldova in 2013-2020**

No.	Species	Bîcioc	Cricova	Varnița	Vășcăuți	Saharna	Mășcă-ufi	Trebujeni	Cupcini	Goianul Nou	Gordinești	Molovata	Molovata Nouă	Holercani	Total
1	<i>Rhinolophus hipposideros</i>	25	39	50	60	143	11	3	8	2	17	0	1	4	<b>363</b>
2	<i>Myotis myotis</i>	0	0	0	0	0	7	0	0	1	0	0	12	0	<b>20</b>
3	<i>Myotis blythii</i>	0	2	0	0	74	0	0	578	1	2010	0	1	0	<b>2666</b>
4	<i>Myotis dasycneme</i>	2	48	1	0	7	17	2	0	2	0	0	5	0	<b>84</b>
5	<i>Myotis daubentonii</i>	278	187	82	343	117	28	46	138	17	283	24	174	1	<b>1718</b>
6	<i>Myotis mystacinus</i>	18	16	2	0	15	7	0	12	2	0	0	95	0	<b>167</b>
7	<i>Myotis bechsteinii</i>	0	22	0	0	0	0	1	0	7	0	0	0	1	<b>31</b>
8	<i>Eptesicus serotinus</i>	153	5	0	0	518	100	0	0	14	0	0	100	0	<b>890</b>
9	<i>Plecotus austriacus</i>	4	4	1	0	31	135	2	0	3	4	0	5	0	<b>189</b>
10	<i>Plecotus auritus</i>	0	9	0	1	1	13	0	0	0	5	0	4	0	<b>33</b>
11	<i>Barbastella barbastellus</i>	0	0	0	0	31	0	0	0	0	0	0	0	0	<b>31</b>
	<b>Total</b>	<b>480</b>	<b>332</b>	<b>136</b>	<b>404</b>	<b>937</b>	<b>318</b>	<b>54</b>	<b>736</b>	<b>49</b>	<b>2319</b>	<b>24</b>	<b>397</b>	<b>6</b>	<b>6192</b>

The abundance of individuals of each species in the underground roosts and their frequency was different depending on the species vulnerability and the specific conditions of the shelter (tab. 4.4.2).

**Table. 4.4.2 Total abundance (%) and frequency (%) of bat species in underground shelters of the Republic of Moldova**

No.	Species	Bîcioc	Cricova	Varnița	Vășcăuți	Saharna	Mașcăuți	Trebujeni	Cupcini	Goianul Nou	Gordinești	Molovata Nouă	Holercani	Total abundance	Frequency
1	<i>Rhinolophus hipposideros</i>	5.21	11.75	36.77	14.85	15.26	3.46	5.56	1.09	4.08	0.73	0.25	66.66	<b>5.87</b>	<b>100</b>
2	<i>Myotis myotis</i>	0	0	0	0	0	2.2	0	0	2.04	0	3.02	0	<b>0.32</b>	<b>25.0</b>
3	<i>Myotis blythii</i>	0	0.6	0	0	7.9	0	0	78.53	2.04	86.68	0.25	0	<b>43.21</b>	<b>50.0</b>
4	<i>Myotis dasycneme</i>	0.41	14.56	0.73	0	0.75	5.35	3.7	0	4.08	0	1.26	0	<b>1.36</b>	<b>66.7</b>
5	<i>Myotis daubentonii</i>	57.91	56.33	60.29	84.9	12.49	8.81	85.19	18.75	34.69	12.2	43.83	16.67	<b>27.5</b>	<b>100</b>
6	<i>Myotis mystacinus</i>	3.75	4.82	1.47	0	1.6	2.2	0	1.63	4.08	0	23.93	0	<b>2.70</b>	<b>66.7</b>
7	<i>Myotis bechsteinii</i>	0	6.63	0	0	0	0	1.85	0	14.29	0	0	16.67	<b>0.50</b>	<b>33.3</b>
8	<i>Eptesicus serotinus</i>	31.8	1.51	0	0	55.28	31.55	0	0	28.57	0	25.19	0	<b>14.40</b>	<b>50.0</b>
9	<i>Plecotus austriacus</i>	0.83	1.2	0.73	0	3.31	42.45	3.7	0	6.12	0.17	1.26	0	<b>3.06</b>	<b>75.0</b>
10	<i>Plecotus auritus</i>	0	2.71	0	0.25	0.12	4.9	0	0	0	0.22	1.01	0	<b>0.53</b>	<b>50.0</b>
11	<i>Barbastella</i>	0	0	0	0	3.31	0	0	0	0	0	0	0	<b>0.50</b>	<b>8.33</b>

	<i>barbastelus</i>													
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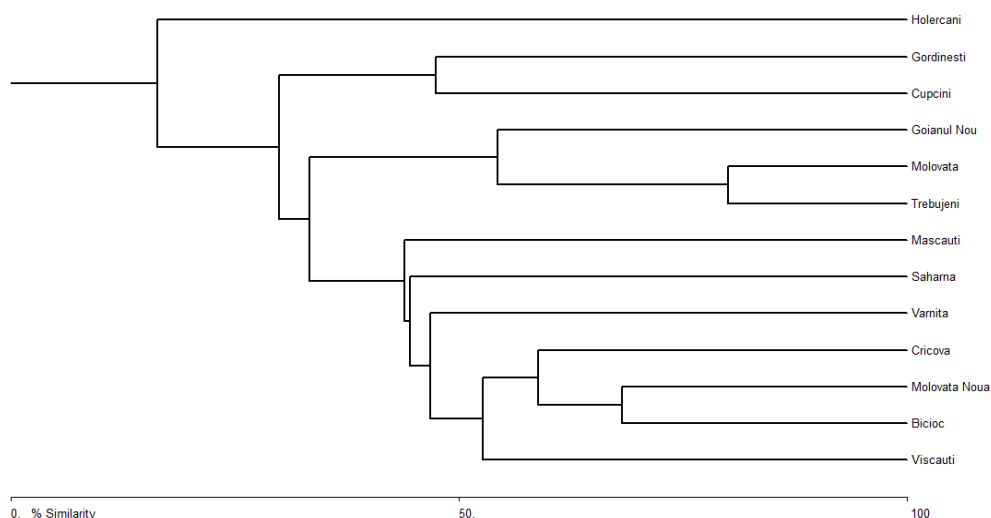
The most abundant species was *M. blythi* 43.21% which was dominant with a frequency of 50.0%. The next species that was found in all shelters in relatively large numbers was *M. daubentoni* with 27.5% and frequency of 100%. The lesser horseshoe bat was also found in all roosts, although its total abundance was about 6%.

**Diversity of bat species in underground shelters.** The bat diversity was assessed according to different indexes: Shannon. Simpson. Margalef, Berger-Parker and Alpha. The highest diversity was registered in Cricova, Saharna, Mășcăuți, Goianul Nou and Molovata Nouă mines. The index values depend on the total number of species, but also on the number of individuals and their distribution by species (tab. 4.4.3.).

**Table. 4.4.3 Diversity indexes of bat communities in underground roosts of Moldova**

No.	Index	Bîcioc	Cricova	Varnița	Vișcăuți	Saharna	Mășcăuți	Trebujeni	Cupcini	Goianul Nou	Gordinești	Molovata	Molovata Nouă	Holercani
1	Shannon	0.448	<b>0.621</b>	0.123	0.197	<b>0.619</b>	<b>0.664</b>	0.327	0.273	<b>0.754</b>	0.193	0.113	<b>0.585</b>	<b>0.596</b>
2	Simpsons	0.439	0.357	<b>0.893</b>	<b>0.739</b>	0.351	0.289	<b>0.68</b>	<b>0.651</b>	0.215	<b>0.766</b>	<b>0.918</b>	0.312	0.286
3	Margaleff	3.729	3.966	<b>5.802</b>	3.835	3.364	3.994	<b>7.482</b>	3.488	3.966	2.971	<b>7.15</b>	<b>12.01</b>	2.971
4	Berger-Parker	1.727	1.775	1.659	<b>1.178</b>	1.749	2.356	<b>1.174</b>	<b>1.273</b>	2.882	<b>1.154</b>	2.282	1.5	1.727
5	Alpha	0.967	<b>1.704</b>	1.337	0.275	<b>1.383</b>	<b>1.492</b>	<b>1.465</b>	0.558	<b>3.513</b>	0.608	0.211	1.64	0.967

**Similarity of bat communities in underground shelters.** Following the gathered data, the similarity of bat communities from different sites was performed, which depends on the abundance of the species, the diversity and the total number of registered individuals. Cluster analysis demonstrates the similarity degree between bat communities from different sites (Fig. 4.3.4).



**Figure 4.3.4 Dendrogram of bat communities similarity of underground shelters**

According to the Cluster analysis, some underground shelters are similar to each other in terms of the qualitative and quantitative structure of the bat communities. According to several indices that have common characteristics, the sites were grouped in clusters with a similarity between 45% and 70%. The sites from Saharna, Mașcăuți and Goianul Nou have the similarity of about 45%, having few common indices, being specific through the quantitative and qualitative structure of the communities. The mines in the northern area of Gordinești and Cupcini have a similarity of about 50% and are very different from the other underground shelters. The sites in Varnița and Trebujeni have a similarity of over 50%. The highest similarity (about 70%) was found between the mines from Cricova, Molovata Nouă and Bîcioc.

#### **4.5. Importance of bats in food chains and in human life**

The bats are insectivorous mammals that have the ability to fly, making them unique in the world of mammals. They are a natural insecticide of great importance, their presence in nature is irreplaceable in biological control of insects. Bats occupy a special trophic niche because they use as trophic resources insects that no other group of animals use. Observations have shown that bats begin their activity at dusk and are the only animals that hunt actively after sunset and in the morning, before sunrise.

The economic importance of bats lies in the consumption of pests insects for agriculture and forestry, which is a natural and healthy way pests control. The importance of bats for public health should be mentioned. For example, the smallest bat in our country (*Pipistrellus pipistrellus*) can consume about 600 mosquitoes in one hour. Guano is considered the best natural organic fertilizer for plantations and crops. Bats in our country's ecosystems consume a variety of insects, depending on the species: Coleoptera, Lepidoptera, Diptera, Orthoptera, Homoptera and other groups [15, 21].

#### **4.6. Limiting factors**

On the territory of the country are present the owls that seldom hunt some species of bats, especially small species from the genera *Pipistrellus* and *Vespertilio*. Among the Strigiformes, the barn owl (*Tyto alba*), the tawny owl (*Strix aluco*) and the long-eared (*Asio otus*) occasionally hunt bats, having the same trophic activity. In general, bats have a low percentage in the diet of nocturnal birds of prey. Only in the diet of the tawny owl (*Strix aluco*) the bats constitute a higher percentage, reaching up to 22% of the total eaten animals [9].

Significant anthropogenic changes and the intensive use of natural resources occurred in the last decades, which, along with climate change, have become key factors in the functioning of ecosystems and wildlife elements, including bats. Intense use of pesticides and insecticides reduces the trophic resources of bats, which can lead to a decrease in the intensity of reproduction and fertility, migration to other habitats and a decrease in the survival of species populations. One of the negative anthropogenic factors, specific to our republic, is the unauthorized storage of waste. Thus, at the entrance to the mines from

Bîcioc, Varnița, Saharna on a distance of 20-30 m, the local population started to deposit household waste and to visit the mines more often, which influenced upon the distribution and the number of individuals. This is especially evident for the mines near Bîcioc, where the number and diversity of bats during the hibernation period of 2019-2020 decreased considerably compared to the same period of 2014-2016 [10].

The climatic conditions during the study period were different every year and had a negative influence on the bat species: sudden melting snow, heavy rains, low temperatures and strong winds at the beginning and end of summer. All these factors negatively influence both the underground habitats of bats and the activity of individuals.

#### **4.7. Conservation of bat species in the Republic of Moldova**

Habitat degradation and pollution, as well as uncontrolled tourism and recreational activities are the main limiting factors leading to a decrease in the number and reduction of bat diversity. The protection of bats is necessary not only in the protection of the biodiversity of the fauna and the genofund we have - a real national treasure, but also for maintaining the ecological balance, the bats being natural regulators of the insect fund. In the Republic of Moldova at present there are only a few tens to several hundred individuals in an underground shelter except for the breeding season in May-June [14, 16, 19]. As example can serve the Saharna and Bâcioc mines, where 30-60 years ago the bat communities counted over 1000 individuals, while in the last 7 years the bat number was of several hundreds [24, 26].

The state of most bat species in Moldova is alarming due to human destruction of foraging habitats and shelters, reckless use of pesticides and human hostility. The importance of bat species for preserving the quality of the environment lies, first of all, in their predominantly insectivorous feeding regime, being a basic link in the food chain without which maintaining the balance of ecosystems would be impossible. Their contribution to maintaining the balance of ecosystems is enormous, without bat populations man is forced to use more and more pesticides.

Despite the benefits of bats and their role in ecosystems, many bat species are endangered and some species are very rare or disappearing. In the Bern Convention all bat species are protected. In the Habitats Directive 7 species that are found in the Republic of Moldova are under protection, and in the European Red List (IUCN) 7 species have the status of endangered (EN), vulnerable (VU) and critically endangered (CR). Only 6 species of bats were included in the second edition of the Red Book of the Republic of Moldova [18], while in the third edition of the Red Book [19] 16 species are listed. In the Law of the Animal Kingdom, 16 species of bats are protected by the State and considered monuments of nature. In the conducted studies, 10 of the 11 species recorded in underground sites are listed in the Red Book of the Republic of Moldova [19].



## GENERAL CONCLUSIONS

The results obtained in correlation with the purpose and objectives formulated in the doctoral thesis "Bats (Chiroptera, Mammalia) from the underground shelters of the Republic of Moldova", led to the formulation of the following general conclusions:

1. As a result of the research, 11 species of bats were identified in underground shelters of the Republic of Moldova: *Rhinolophus hipposideros*, *Myotis blythii*, *M. myotis*, *M. bechsteinii*, *M. daubentonii*, *M. dasycneme*, *M. mystacinus*, *Barbastella barbastellus*, *Plecotus auritus*, *P. austriacus* and *Eptesicus serotinus* which belong to 2 families: Rhinolophidae and Vespertilionidae. Morphology data have been updated and maps of the troglophilous species distribution on the territory of the republic have been developed.

2. The studies were carried out in 16 underground shelters, including abandoned mines in the central area of the republic: Cricova, Goianul Nou, Bîcioc, Vâșcăuți grotto and mine, Mașcăuți, Molovata, Molovata Nouă, Holercani, Trebujeni, Varnița and the northern part of the country: Saharna, Gordinești and Cupcini mines, Brânzeni and Buzdugeni caves. 7 new sites for hibernation, breeding and shelter of bats were found: Vâșcăuți, Molovata, Molovata Nouă, Varnița, Mașcăuți, Goianul Nou and Gordinești, which were not previously studied.

3. 6 very rare species of bats for the fauna of the Republic of Moldova were identified, such as *Barbastella barbastellus*, *M. dasycneme*, *M. bechsteinii*, *M. mystacinus* and *Plecotus auritus* included in the Red Book of the Republic of Moldova with the status of endangered and critically endangered. The critically endangered species *Myotis myotis* that has not been reported for over 40 years was registered. All these species were identified with a small number: *B. barbastellus* 31 individuals, *M. bechsteinii* 31, *M. dasycneme* 84, *Plecotus auritus* 33 individuals.

4. It was found that the area of distribution of most bat species in underground sites on the territory of the Republic of Moldova is relatively small, and some species were recorded in a single site: *Barbastella barbastellus* – in Saharna, *Myotis myotis* – in Molovata Nouă and Holercani, *M. bechsteinii* – in Cricova, Trebujeni, Goianul Nou and Holercani. The presence of bats has been found to be closely linked to the ecosystems around the mines. All the shelters are located near the water basins, on the banks of the rivers and near the forests.

5. In the mines of Saharna, Cricova, Mășcăuți and Molovata Nouă the greatest diversity of bats was found, where 8-9 species were registered. The smallest diversity was registered in the shelters from Molovata (1 species) and Vâșcăuți (3 species), which also have a small surface. The largest number was recorded in the mines of Gordinești, Molovata Nouă and Saharna.

6. For the first time, 3 new maternity colonies were identified, in new research shelters, of the species *M. blythii*, *M. daubentonii* and *Rh. hipposideros*. The colonies were monitored and a positive

dynamics of the *M. blythii* colony in the mines from Gordinești was observed, while in the other 2 colonies from Vâșcăuți a negative dynamics was registered.

7. In the period 2013-2020 more than 6,000 bats were identified in the underground shelters. Following the ecological analysis, it was found that the species *M. blythii* is dominant with a total abundance of 44.05% and a frequency of 53.8%, followed by *M. daubentonii* with an abundance of 27.5% and a frequency of 100% and *E. serotinus* with 14.40% and 50%, respectively, while the other species have an abundance of less than 10%. The species *Rh. hipposideros* and *M. daubentonii* had the highest frequency of 100%, *M. mystacinus*, *M. dasycneme* and *Plecotus austriacus* 75%, *M. blythii* and *P. auritus* 58.3% the other species have a frequency of less than 50%.

8. It was found that the diversity, as well as the number, is constantly decreasing compared to those of the years 1960-1970: in the Saharna mines the breeding colony of the species *M. blythii* of 1500 individuals disappeared, in the mines of Cricova the species *Barbastella barbastellus* disappeared and the number of the other species decreased from several hundreds to several dozens; in the mines from Bîcioc the species *Rhinolophus ferrumequinum* disappeared. The underground shelters are undergoing major changes under the influence of climate and anthropogenic changes.

9. The ultrasounds emitted by bats are different depending on the species and their activity. The frequencies differ greatly, as observed with the ultrasonic detector, in active bat species in and around underground shelters, ranging from 18-25 kHz in large species (*Eptesicus serotinus*, *Myotis myotis*, *M. blythii*) up to 105-111 kHz in *Rhinolophus* species.

10. The ringing of bats in the Bîcioc mines showed that bats have a lifespan of up to 20 years, depending on the species, which distinguishes them from other groups of mammals. The ringed species (*Myotis blythii*, *Eptesicus serotinus*, *Plecotus austriacus*) have been identified in the same places where they were ringed, which indicates that they prefer the same shelters for hibernation and the migrations are seasonal, short only between shelters.

11. All the bat species registered in underground sites are rare and are included in the Red Book of the Republic of Moldova except for the species *Eptesicus serotinus*.

## **PRACTICAL RECOMMENDATIONS**

1. Continuation of research on bat communities in underground shelters, identification of new hibernation and maternity sites and colonies, monitoring the number of rare species populations in order to elucidate their population trend;

2. Monitoring of underground shelters, of anthropogenic and climatic factors, and their impact on the condition of sites. In conditions of landscape aridization due to climate change and anthropogenic factors, such as pesticide use, deforestation, wet habitat drainage, increased tourist and recreational activities, it is

recommended to monitor the dynamics of bat populations, migrations between shelters in order to highlight their preferences and adaptations;

3. Awareness of the general public, especially children and adolescents through lectures, projects, television and radio interviews, articles in newspapers and popular magazines, participation in various events that promote nature conservation, attracting amateur chiropterologists and naturalist volunteers in disseminating knowledge about the importance of bats in nature and in the human economy, the need for sustainable conservation of bats and their habitats;

4. Dissemination of information about bats and their importance by organizing and participating in national and international scientific and popularization events;

5. Placing information panels at important underground shelters, banning excessive tourism, banning access into the mines where there are maternity colonies and rare bat species.

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## ADNOTARE

**Caldari Vladislav. „Lilieci (Chiroptera, Mammalia) din adăposturile subterane ale Republicii Moldova”, teză de doctor în științe biologice, Chișinău, 2022.**

Teza constă din introducere, 4 capitole, concluzii generale și recomandări, bibliografie din 165 titluri, 132 pagini de text de bază, 69 figuri, 4 tabele. Rezultatele obținute sunt publicate în 25 lucrări științifice.

**Cuvinte cheie:** lilieci, morfologie, particularități ecologice, sit, repartizare biotopică, colonie, hibernare, adăposturi, mine părăsite, importanță, biodiversitate, conservare.

**Domeniul de studiu: 165.02-Zoologie**

**Scopul lucrării:** elucidarea diversității faunistice a comunităților de chiroptere în adăposturile subterane ale Republicii Moldova, evidențierea particularităților ecologice, de hibernare și reproducere a speciilor de lilieci și importanței lor în natură și în viața omului.

**Obiectivele:** Studiul faunistic, taxonomic și morfologic al comunităților de chiroptere din zona centrală și de nord a republicii; evidențierea distribuției biotopice și particularităților de hibernare și reproducere a comunităților de lilieci; dinamica efectivului numeric și a diversității comunităților de chiroptere; elucidarea importanței liliecilor în rețelele trofice ale lumii vii și în economia țării, necesitatea conservării lor.

**Noutatea și originalitatea științifică.** În premieră au fost realizate cercetări complexe ale comunităților de chiroptere din adăposturile subterane. Au fost identificate 6 situri noi de hibernare și reproducere a unor specii de lilieci. Au fost actualizate datele privind morfologia și elaborate hărțile de răspândire a speciilor troglofile de lilieci. Au fost evidențiate particularitățile biologice și ecologice a 11 specii de lilieci din 5 genuri, componența calitativă și cantitativă a coloniilor de hibernare și reproducere din diverse adăposturi subterane. A fost stabilită starea actuală a populațiilor speciilor de chiroptere troglofile și evidențiați factorii limitativi.

**Problema științifică soluționată** constă în evidențierea particularităților morfologice, biologice și ecologice, a structurii comunităților de chiroptere în perioada de hibernare și elucidarea preferințelor speciilor față de un anumit adăpost. S-au elucidat factorii care condiționează diminuarea efectivului populațiilor de lilieci.

**Semnificația teoretică.** Au fost elucidate particularitățile morfologice, biologice și ecologice ale speciilor troglofile. A fost elucidată dinamica sezonieră și multianuală a comunităților de lilieci din adăposturi subterane. Cercetările efectuate se încadrează în direcțiile și cercetările științifice prioritare, în programele și strategiile naționale și internaționale, privind protecția și conservarea biodiversității, ceea ce constituie o contribuție semnificativă la realizarea convențiilor internaționale la care a aderat Republica Moldova.

**Valoarea aplicativă a lucrării.** A fost elucidată importanța liliecilor în natură și economia umană. Rezultatele obținute servesc drept suport pentru metodologia de monitorizare a populațiilor de lilieci în adăposturi subterane. În urma cercetărilor au fost elaborate un șir de recomandări privind conservarea liliecilor și a habitatelor acestora, cu accentuarea importanței educării și implicării publicului larg privind protecția chiropterofaunei.

**Implementarea rezultatelor științifice.** Rezultatele obținute au fost utilizate de către specialiști ca suport la elaborarea unei indicații metodice. Rezultatele cercetărilor au fost aplicate în procesul elaborării și stabilirii ariilor protejate în cadrul Rețelei Emerald, precum și la implementarea unui proiect transfrontalier cu România. Informația despre acest grup de mamifere este utilizată și implementată în procesul didactic, la realizarea tezelor de licență și de masterat la instituțiile de învățământ cu profil biologic și ecologic. Datele vor fi utilizate la elaborarea și redactarea ediției a IV-a a Cărții Roșii a Republicii Moldova.



## АННОТАЦИЯ

**Калдари Владислав. «Летучие мыши (Chiroptera, Mammalia) из подземных убежищ Республики Молдова», кандидатская диссертация по биологическим наукам, Кишинев, 2022.**

Диссертация состоит из введения, 4 глав, общих выводов и рекомендаций, библиографии из 165 наименований, 132 страниц основного текста, 69 рисунков, 4 таблиц. Результаты опубликованы в 25 научных статьях.

**Ключевые слова:** летучие мыши, морфология, экологические особенности, местонахождение, биотопическое распространение, колония, спячка, укрытия, заброшенные шахты, важность, биоразнообразие, сохранение.

**Область исследования: 165. 02-Зоология**

**Цель диссертации:** выяснить фаунистическое разнообразие сообществ рукокрылых в центральной и северной части Республики Молдова, выделить экологические особенности зимовки и размножения видов рукокрылых и выявить их значение в природе и в жизни человека.

**Задачи:** фаунистическое, таксономическое и морфологическое изучение сообществ рукокрылых центральной и северной части республики; выделение биотопического распределения и особенностей гibernации и размножения сообществ рукокрылых; динамика численности и разнообразия сообществ летучих мышей; выяснение значения летучих мышей в пищевых цепочках и в экономике страны, и их сохранении.

**Научная новизна и оригинальность.** Впервые было проведено комплексное исследование сообществ летучих мышей в подземных убежищах. Обнаружено 6 новых подземных убежища для зимовки и размножения летучих мышей. Были обновлены данные морфологии и составлены карты распространения троглофильных видов летучих мышей. Выделены биологические и экологические особенности 11 видов, качественный и количественный состав зимующих и размножающихся колоний различных подземных убежищ. Установлено современное состояние популяций летучих мышей и выделены лимитирующие факторы.

**Разрешённая научная проблема** заключается в выявлении морфологических, биологических и экологических особенностей, структуры сообществ рукокрылых в период спячки и размножения, выяснении предпочтений видов в отношении того или иного подземного убежища. Выявлены факторы, обуславливающие сокращение популяции летучих мышей.

**Теоретическая значимость.** Выявлены морфологические, биологические и экологические особенности троглофильных видов. Выявлена сезонная и многолетняя динамика сообществ рукокрылых в подземных убежищах. Проведенные исследования являются частью приоритетных научных направлений и исследований в национальных и международных программах и стратегиях по защите и сохранению биоразнообразия, что является значительным вкладом в выполнение международных конвенций, к которым присоединилась Республика Молдова.

**Практическая значимость исследования.** Выяснено значение летучих мышей в природе и хозяйстве человека. Полученные результаты служат поддержкой методологии мониторинга популяций летучих мышей в подземных убежищах. По итогам исследования был разработан ряд рекомендаций по сохранению летучих мышей и их среды обитания, в которых подчеркивается важность просвещения и участия общественности.

**Внедрение научных результатов.** Полученные результаты использовались в разработке методического пособия. Результаты исследований были применены в процессе разработки и создания охраняемых территорий в рамках сети Emerald, а также при реализации трансграничного проекта с Румынией. Информация используется и внедрена в учебный процесс, при выполнении бакалаврских и магистерских диссертаций в учебных заведениях биолого-экологического профиля. Данные будут использованы при разработке 4-го издания Красной книги Р. Молдова.

## ANNOTATION

**Caldari Vladislav. "Bats (Chiroptera, Mammalia) from the underground shelters of the Republic of Moldova", PhD thesis in biological sciences, Chisinau, 2022.**

The thesis consists of introduction, 4 chapters, general conclusions and recommendations, bibliography of 165 titles, 132 pages of basic text, 69 figures, 4 tables. The results are published in 25 scientific papers.

**Keywords:** bats, morphology, ecological features, site, biotopic distribution, colony, hibernation, shelters, abandoned mines, importance, biodiversity, conservation.

**Field of study: 165. 02-Zoology.**

**The aim of the paper:** to elucidate the faunal diversity of bat communities in the central and northern part of the Republic of Moldova, highlighting the ecological peculiarities of hibernation and reproduction of bat species and revealing their importance in nature and in human life.

**Objectives:** For the first time, complex research was carried out on the communities of bats in underground shelters. New sites for hibernation and breeding of bat species have been found. Morphology data have been updated and maps of bat cave species have been developed. The biological and ecological peculiarities of the species, the qualitative and quantitative composition of the hibernation and reproduction colonies from various underground shelters were highlighted. The current status of the populations of troglodyte bats has been established and the limiting factors are highlighted.

**Scientific novelty and originality.** For the first time, complex research was carried out on the communities of bats in underground shelters. 6 new sites for hibernation and reproduction of certain bat species were identified. Morphology data have been updated and maps of bat troglodyte species have been developed. The biological and ecological peculiarities of 11 species of bats of 5 genera, the qualitative and quantitative composition of the hibernation and reproduction colonies in various underground shelters were highlighted. The current status of the populations of troglodyte bats has been established and the limiting factors are highlighted.

**The scientific problem** consisted is to highlight the problem of numerical regression of bat communities, specific morphological and ecological peculiarities, the importance of abandoned mines and the blocking of entrances for the general public which has a beneficial effect on bats.

**Theoretical significance.** The morphological, biological and ecological peculiarities of the troglodyte species were elucidated. The seasonal and multiannual dynamics of the bat communities in underground shelters were elucidated. The research conducted is part of the priority scientific directions and research, in national and international programs and strategies, on the protection and conservation of biodiversity, which is a significant contribution to the implementation of international conventions, to which the Republic of Moldova has acceded.

**The applicative value of the paper.** The results obtained serve as a support for taking measures for the protection of bats. Following research, recommendations can be developed on the importance of bats in the wild as indicators of climate stability and anthropogenic impact on ecosystems.

**Implementation of scientific results.** The obtained results were used by specialists as methodological support in the elaboration of a guide. The research results were applied in the process of elaboration and establishment of protected areas within the Emerald Network, as well as in the implementation of a cross-border project with Romania. The information about this group of mammals is used and implemented in the teaching process, in the realization of bachelor's and master's theses at educational institutions with biological and ecological profile. The data will be used in the elaboration and drafting of the 4th edition of the Red Book of the Republic of Moldova.

**CALDARI VLADISLAV**

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REPUBLIC OF MOLDOVA**

**165. 02 – Zoology**

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