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POPULATION DYNAMICS OF BATS OF THE IVANKIVTSI ADITS (PODILLIA, UKRAINE): RESULTS OF LONG-TERM MONITORING OF WINTER AGGREGATIONS

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Abstract

Visual survey of colonies of hibernating bats is a traditional research method. The data obtained using this method serve as a basis for determining population trends. These data are especially important for protected areas that ensure the protection and conservation of species and their key habitats. The Ivankivtsi adits (IVK-mines) are located in the territory of the Podilski Tovtry National Nature Park (in the protected zone of the national park). The site is a system of adits and mines used for machine mining of sawn limestone. This area is also part of the European Emerald Network. The IVK-mines are listed as a key underground site for the conservation of European bat species. The monitoring of wintering bat communities at the IVK-mines has continued for about 20 years. Surveys are conducted annually, but mostly only the entrance parts of the adits are covered (about 50% of the site's total area). Every few years, total bat counts are carried out throughout the entire mine system. The previous bat census at the IVK-mines was conducted in 2009 (15 years ago). In January 2024, a repeated census was conducted. According to its results, 5967 bats belonging to 12 species were recorded. Compared to the previous census, the increase in numbers is about +60%. The dominant species by number is *Barbastella barbastellus*. The western barbastelle has regularly formed large winter aggregations for 15 years, which in 2024 comprised about 2000 individuals. Other barbastelles are found in smaller groups (10 to 200 individuals) and as single individuals. Studies of winter aggregations of European bats show significant fluctuations in the numbers of bats between censuses of several years, indicating that environmental factors that affect hibernation strategies mask real population trends. In addition, climate change creates opportunities for cold-loving species to hibernate outside of their main roosts, such as in tree hollows, which makes it difficult to understand and interpret census data. This phenomenon is obviously observed in the IVK-mines. Therefore, an important condition for improving the understanding of real trends in the population dynamics of species will be the transition to more modern and high-quality survey and monitoring methods of winter aggregations of bats and their hibernation, particularly via automatic survey systems using light barriers.

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Динаміка чисельності кажанів Іванковецької штольні (Поділля, Україна): результати багаторічного моніторингу зимових угруповань

Михайло Дребет

Резюме. Візуальне обстеження колоній зимуючих кажанів є традиційним методом дослідження їх чисельності. Дані, отримані за допомогою цього методу, слугують основою для визначення популяційних тенденцій. Ці дані особливо важливі для природоохоронних територій, які забезпечують захист і збереження видів та їхніх ключових оселищ. Іванковецькі штольні (IVK-mine) розташовані на території Національного природного парку «Подільські Товтри» (в заповідній зоні національного парку). Об'єкт являє собою систему лабіринтів, що використовувалися для машинного видобутку вапняку. Ця ділянка також є частиною Європейської Смарагдової мережі. Іванковецькі штольні занесені до переліку ключових підземних об'єктів для збереження європейських видів кажанів. Моніторинг зимових угруповань у штольні триває вже близько 20 років. Дослідження проводяться щорічно, але здебільшого охоплюють лише привхідні частини штолень (близько 50% від загальної площі). Кожні кілька років проводяться абсолютні обліки по всій системі штолень. Попередній абсолютний облік проводився у 2009 році (15 років тому). У січні 2024 року було проведено повторний абсолютний облік кажанів. За його результатами було обліковано 5967 кажанів 12 видів. Порівняно з попереднім обліком, приріст чисельності становить близько +60%. Домінуючим видом за чисельністю є *Barbastella barbastellus*. Широковух європейський вже 15 років формує велике зимове скупчення, яке у 2024 році налічувало близько 2000 особин. Інші особини виду зустрічаються меншими групами (від 10 до 200) та поодинокими особинами. Очевидно, кліматичні умови мають вплив на стратегії зимівлі кажанів, що відображається на значних коливаннях чисельності зимових угруповань з року в рік, маскуючи реальні тенденції популяцій. Крім того, зміни клімату створюють можливості для холодолюбних видів зимувати за межами своїх основних сховищ, наприклад, у дуплах дерев, що ускладнює розуміння та інтерпретацію даних моніторингу. Це явище, очевидно, спостерігається в Іванковецьких штольнях. Тому важливою умовою для покращення розуміння реальних тенденцій у динаміці чисельності видів буде перехід на більш сучасні та якісні методи обліку та моніторингу зимових угруповань кажанів, зокрема, за допомогою автоматичних систем обліку з використанням світлових бар'єрів.

Ключові слова: кажани, динаміка чисельності, моніторинг, заповідні території, Подільська височина, Поділля.

Introduction

The importance of underground hibernacula for the conservation of bats and for the monitoring of their populations is well-recognised. Bat species can be properly protected only if activities are carried out over the entire range of the species and that monitoring is a necessary prerequisite for effective and optimised conservation of bats. Unfortunately, the present state of bat monitoring in Ukraine does not achieve this goal. In Ukraine, bat monitoring programmes are working very well and produce robust results. Monitoring programmes in place are not assembled into a national database, so the information is not processed or the results are not published. Some programmes have been running for over 20 years, but there are no agreements on using the same protocols for data collection and processing and survey methods are not standardised. In addition, no structure is able to coordinate long-term, harmonised bat monitoring programmes.

The Podolian Upland (Podillia) belongs to the cave regions of Ukraine. Attempts to monitor winter underground sites are known from the literature [Godlevska 2005]. There are large natural caves and artificial underground shelters (limestone mines). Obviously, there are also unexplored underground sites. Protected areas in the region monitor and protect bats and their habitats [Vikyrchak 2018, 2020, 2021]. These activities, although carried out in the same region, are poorly synchronised. In our opinion, a joint programme for monitoring bats and their habitats should be implemented to introduce effective conservation management in the region.

Visual counts of the number of hibernating bat colonies have had a long tradition. Usually, counts are conducted in winter (January–February), and the shelter is surveyed once or several times, depending on its size and accessibility. Parts of the site or its entire territory are surveyed [Pan-European ... 2009]. The data obtained serve as the basis for determining population trends.

Thus, hibernation roosts are particularly useful for surveying numerous species. However, at hibernation sites, the relationships between the number of bats seen and the number of bats present is not always clear because of the numerous cracks and crevices in which bats may be hidden from view. It is also important to conduct synchronised censuses, at least in the entire region, which would also improve the quality of the data obtained. Monitoring of winter bat communities at IVK-mine has been conducted for about 20 years. A preliminary census of bats at IVK-mine was carried out in 2008–2009 (15 years ago) [Godlevska 2009]. Although the results of long-term monitoring show signs of dynamics in the number of species, it becomes clear that modern methods, in particular automatic survey systems, need to be applied.

Material and Methods

Despite these difficulties, counting bats in underground sites is widely used as a method of ba monitoring. Although the proportion seen may vary from year to year, it is assumed that over periods of many years this annual variation is smoothed out to reveal underlying trends in numbers.

Bat counts were performed using standard methods [Petrushenko 2002]. The specifics of underground sites such as the underground mine were taken into account [Petrushenko 2017]. The mid-winter was chosen for the census, the underground mine was inspected in its entirety (except for some minor parts), with special attention paid to the entrance parts, as well as the main corridors with special focus on side passages (to the first intersection) and dead-end branches. The censuses covered all temperature zones of the shelter. In order to avoid repeated counts, a detailed map of the underground mine was used, which marked all the corridors passed.

The Ivankivtski adits (IVK-mine) are located in the territory of the Podilski Tovtry National Nature Park, particularly in the protected zone of the park. The IVK-mine represent mines for machine extraction of saw limestone. Mining here started in the late 1950s and continued until the 1960s. This area is part of the European Emerald Network (UA0000011, 261521, Biogeo regions–CON). As of 2014, 35 underground sites in the territory of Ukraine were included as key territories for protection and preservation of bats in Europe, including the IVK-mine[1]. Underground sites are important for bats. They are used for hibernation, also as maternity colonies, both critical periods during the life cycle. Some species use underground sites for mating (so-called swarming). Underground sites as bat roosts are threatened. The main threat is human access (disturbance). Even slight disturbance may be fatal for bat populations inhabiting underground sites, so there is a need for their monitoring. Some sites may be occupied by very large numbers of bats (as in the case of the IVK-mine) that return year after year, often using the same location in the site. These are the sites that are particularly important. The distribution map of the important bat sites is shown in Fig. 1.

The list of species revealed:

Family Rhinolophidae: *Rhinolophus hipposideros*;

Family Vespertilionidae: *Myotis brandtii*, *M. dasycneme*, *M. daubentonii*, *M. myotis*, *M. mystacinus*, *M. nattereri*, *Eptesicus serotinus*, *Barbastella barbastellus*, and *Plecotus auritus*.

The IVK-mine (Khmelnytskyi Raion, Khmelnytskyi Oblast, Ukraine) consists of a large system of mines with a total length of about 11 km, and a separate small system of approximately 150 m (Fig. 2). There are four gallery entrances in the large system, three of them are situated at the same level, with the fourth one higher on the same slope. The shape of the mine field is a roundish polygon, about 500 by 400 m. It includes three connected parts at different altitudes; two of them have open entrances. Due to the original configuration, the biggest part of the system is cooled in the winter and works as a ‘cold sac’ throughout the year.

[1] Source: https://www.eurobats.org (https://bit.ly/3dnCEEm)

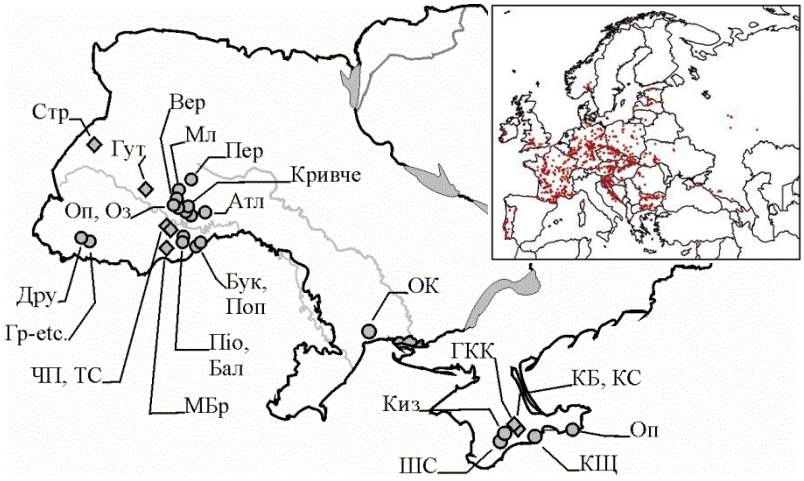

Fig. 1. Sites of European interest as reported by the EUROBATS parties (source: [Mitchell-Jones *et al.* 2007]).

Рис. 1. Ключові сайти кажанів, що становлять інтерес для Співтовариства, згідно зобов'язань за Угодою EUROBATS (за: [Mitchell-Jones *et al.* 2007]).

Fig. 2. Detailed map of the IVK-mine underground site and one of the entrances to the mine.

Рис. 2. Детальна карта Іванковецької штольні та один із входів.

For example, in summer, the inside temperature near the lower entrances was +4...+5°C (outside temperature was +25...+28°C). Mine exploitation was mostly carried out in one bench. The height of drifts is 2.0–3.5 m. After the official closing of the mine, local people conducted illegal limestone extraction (for burning lime) using explosive methods, which was stopped about two years ago.

The mines were inspected on 4–18 January 2024. An important condition for recording bats in a winter site is the availability of a detailed map. This simplifies bat counts and improves data quality. For identifying bats on the drifts' ceiling, zooming photo-cameras were used. For measuring air temperature inside, digital thermometers with remote sensors (TFA) were used and measures were taken at 1 m above the floor.

Results and Discussion

In January 2024, a census of bats in the IVK-mine was carried out. A total of 5967 bats of 12 species were recorded. The dominant species by number was the western barbastelle. Of this species, one big cluster of (2000) individuals was observed, while other barbastelles were found as single individuals or as rare groups of few specimens. The subdominant species was *Myotis daubentonii* (more than 1000 ind.). A broad-scale winter bat survey in various parts of Belarus in 2020 also revealed that the dominant species was *Barbastella barbastellus* (78.5%) [Godlevska 2023].

Fig. 3. Part of a western barbastelle colony, January 2024.

Рис. 3. Фрагмент колонії Western barbastelle, січень 2024.

Characteristics of the wintering western barbastelle colony

For the first time, a large winter aggregation of the western barbastelle was detected during a survey in December 2008, with an estimated population of about 500 individuals. According to the results of the first census of bats in key winter habitats in the Podilski Tovtry National Park, in 2009, more than 498 individuals were recorded in the IVK-mine [Godlevska *et al.* 2011]. In all subsequent seasons, the number of *Barbastella barbastellus* wintering in the IVK-mine has constantly increased. As of the winter of 2017–2018, the colony already consisted of more than 1000 individuals, and in 2018–2020 about 2000 individuals [Drebet 2000]. Most of them were located in two large groups of 360–424 and more individuals from 2018–2020 (Fig. 3). Others wintered in smaller groups of 50-150 individuals, as well as 10–30 individuals and singly. In addition, over the past few years, there have been more frequent cases of the western barbastelle being found in various anthropogenic buildings and structures. Thus, the species was found in abandoned basements of private households, as well as in the basement of the ruins of an old manor.

Dynamics of the numbers of other species in 2009–2024

In addition to characterising the dominant species, it is important to compare the proportions of other hibernating bat species based on the results of two bat censuses carried out in the IVK-mine 15 years apart (2009 and 2024) (Table 1).

In 2009, 2364 individuals of 9 species were recorded. The dominant species by number was *Myotis daubentonii*. Among the species recorded in 2024, the following were not found: *M. nattereri*, *M. mystacinus*, and *Plecotus austriacus*. These species are usually rare and have low numbers. In 2024, 5867 individuals of 12 species were revealed. The dominant species by number was *Barbastella barbastellus*. Of this species, one big cluster of (about 2000 ind.) individuals was observed, other barbastelles were found as single individuals or rare groups of few specimens.

Table 1. Species abundances according to censuses in 2009 and 2024
Таблиця 1. Співвідношення чисельності видів під час абсолютних обліків 2009 та 2024 рр.

No.	Species	Number of individuals in 2009	Number of individuals in 2024
1	*Rhinolophus hipposideros*	369	397
2	*Myotis myotis* (s. l.)*	149	40
3	*Myotis bechsteinii*	3	1
4	*Myotis nattereri*	–	43
5	*Myotis dasycneme*	41	23
6	*Myotis brandtii*	110	181
7	*Myotis mystacinus*	–	13
8	*Myotis daubentonii*	859	1008
9	*Plecotus auritus*	229	348
10	*Plecotus austriacus*	–	3
11	*Barbastella barbastellus*	498	3782
12	*Eptesicus serotinus*	3	28
	Total	2364	5867

* Some specimens may appear to be *Myotis blythii*, which cannot be verified in the field due to the use of saving methods of census.

Not all key sites located in the territory of the Podilski Tovtry National Park show the same trend (growth in numbers). In the GMN-mine, the number of wintering individuals of the greater mouse-eared bat (*Myotis myotis*) is decreasing. We observe a decrease in the number of wintering *Myotis myotis* in other key sites (IVK-mine and ATL-cave). This is reflected in the total number of hibernating individuals. In other underground sites (for example, in the key sites of YAC-mine, ATL-cave), the total number of hibernating bat communities is either stable or there is a slight increase in the number of individuals. Only in the IVK-mine, the number of hibernating bats increased rapidly. It is clear to us that the overall increase in numbers was primarily due to an increase in the number of one species, the western barbastelle. The numbers of other recorded species in 2009 and 2024 do not differ significantly. However, in any case, it is also important to note that the IVK-mine is characterised by some of the best conditions for bats to hibernate. Unlike a number of other underground sites located in the territory of the Podilski Tovtry National Park, the IVK-mine is characterised by the widest range of winter temperatures (from -4–1 to +9–10). Obviously, this affects the diversity of species that overwinter in the mine.

One of the most common and numerous species of bats in the region is the lesser horseshoe bat (*Rhinolophus hipposideros*). It is dominant in the composition of winter aggregations of bats in cave-type shelters in the Middle Dniester region, with a share of 92.84% [Vikyrchak 2021]. *Rhinolophus hipposideros* at the IVK-mine also chooses cave-type areas. The number of individuals hibernating is very dynamic. According to the results of surveys, it can increase or decrease from year to year, even by several hundreds of individuals.

Problems of species assessment and protection

Studies of hibernating aggregations of European bats have shown significant fluctuations in the number of bats between censuses of several years, indicating that environmental factors that influence hibernation strategies mask real population trends. In addition, climate change is creating opportunities for cold-loving species to hibernate outside of the main roosts, for example, in tree hollows, which makes it difficult to understand and interpret the data obtained from bat censuses. [Kokurewicz *et al*. 2017].

For example, according to the abiotic environment monitoring data as part of the Chronicle of Nature programme of the Podilski Tovtry National Park, in recent years winters have been significantly milder, and in 2020 natural winter did not occur at all (Chronicle of Nature...). This factor may affect the results of bat monitoring.

The IVK-mine is a hibernaculum for the largest aggregations of *Barbastella barbastellus*, *Myotis daubentonii*, long eared bats (in particularly, *Plecotus auritus*), and *M. brandtii* in Ukraine.

System and scope of species protection

The national system and scope of protection of bat species are defined by environmental legislation. In Ukraine, all species of bats are listed in the Red Data Book of Ukraine (fauna) (Decree of the Ministry of Environmental Protection and Natural Resources of Ukraine No. 29 issued on 19 January 2021). Out of 28 species, 1 species is extinct (EX) (*Miniopterus schreibersii*) and 8 species—*Myotis bechsteinii*, *M. nattereri*, *M. emarginatus*, *M. dasycneme*, *M. alcathoe*, *Barbastella barbastellus*, *Nyctalus lasiopterus*, and *Hypsugo savii*—are near threatened (NT), whereas the other 19 species have the status of vulnerable (VU). Protected areas play an important role in the species protection system.

Bats have some level of protection in each European country, although the details of this protection and the degree of compliance with environmental legislation vary greatly. In the European Union, the protection of bats and their habitats (including breeding, hibernating, and resting sites) is ensured by Council Directive 92/43/EC on the conservation of natural habitats and wild fauna and flora. All species of bats are listed in Annex IV 'Species of Animals and Plants of Community Interest and in Need of Strict Protection,' and some of them are also listed in Annex II, which also requires the creation of Special Areas of Conservation (SACs). Member states are obliged to incorporate these requirements into their national legislation, which is in line with Directive 92/43/EC. Many European countries are also signatories to the Bern Convention, which requires strict protection measures for species listed in Appendix II. This applies to all bats, except for the pipistrelle (*Pipistrellus pipistrellus*), which is listed in Appendix III.

As a follow-up to Appendices I and II, the Berne Convention's Standing Committee approved Resolution No. 6 'On the List of Species in Need of Special Measures for their Conservation' with a new version of the Appendix approved in 2011.

The Podilski Tovtry National Park is a member of the Emerald Network of Europe, which is analogous to the Natura2000 network in the EU. As a site of the Emerald Network (Podilski Tovtry National Nature Park, UA0000011), it provides protection and conservation for six bat species: *Barbastella barbastellus*, *Myotis bechsteinii*, *M. blythii*, *M. dasycneme*, *M. myotis*, and *Rhinolophus hipposideros*. These species are also included in Annex II of the Bern Convention. All six bat species are of the highest conservation interest within Natura2000 requiring special measures for their conservation (according to BC Resolution 6) and are represented in the IVK-mine. The IVK-mine, as a habitat for the six bat species of the highest conservation status within the Emerald Network, is a strong candidate for being designated as a Special Area of Conservation (SAC) once Ukraine transitions to the Natura2000 network. With these species requiring specific conservation measures under Bern Convention Resolution 6, the IVK-mine could become a key site in the SAC network, supporting Ukraine's commitments to biodiversity protection in line with European nature conservation standards.

According to the IUCN, only *Myotis myotis* is characterised by stable population size, while the other five species are in decline. The loss or degradation of habitats (winter and summer habitats) is a common major threat to all these species. The multifunctional designation of national parks poses some threats to the conservation of these species, which are sensitive to habitat degradation. Accordingly, the inclusion of underground bat habitats in tourist routes has a negative impact on the conservation of *M. myotis* and *M. blythii* populations. Since *M. dasycneme* has a rather low population density, any threats to its habitats are critical.

The conservation of such species as *Myotis bechsteinii* and *Barbastella barbastellus* also depends on the state of management of forest habitats, in particular the presence of old mature forests and old trees, and this should be taken into account when planning sanitary measures in the forests of the national park, especially where key winter habitats of bats are present.

Bechstein's bat is one of the rarest bat species in Europe in general and a difficult object of study. Acoustic methods do not allow for reliable recognition of this species, and it is found in winter roosts irregularly, mostly alone in the national park (ATL-cave system, IVK-mine, GMN-mine, and YAC-mine). The specific feature of this species is its actual settling near the wintering grounds. Their peak activity occurs from mid-August to mid-September, and the first individuals begin to hibernate in early September. In April, the majority of *Myotis bechsteinii* leave the wintering grounds [Wright *et al.* 2017] and apparently move to forests near underground sites.

The western barbastelle population requires the development of separate, effective, and long-term conservation measures, and their inclusion in the management plan of the national park. Current conservation practices for *Barbastella barbastellus* in Europe are based on the establishment of a protected area around each known mother colony. The proposed areas of the zones are based on radio telemetry studies and their radius varies between 2–7 km. Effective conservation measures in the national park will focus on preserving and restoring areas of forest that support a diverse species and age structure of trees. Following this approach, in 2023, the national park prepared a scientific justification for the creation of a special protective zone for the protection and conservation of bats. An important step in ensuring the long-term protection and conservation of the key habitat, the IVK-mine, will be the change of functional zoning in 2023 and the transfer of 12.2 hectares of the area around the mine to the national park's protected area.

An important step towards improving the understanding of trends in species numbers will be the transition to more modern and high-quality methods of researching winter aggregations of bats and monitoring their wintering sites.

Until recently, there was no qualitative method for verifying the results of 'usual' visual counts of bats in wintering sites. However, the use of automatic light barrier systems installed in openings (entrances) of underground cavities has significantly expanded the understanding of the number of bats in winter roosts. Automatic systems often demonstrate significant differences in census results. For example, the highest discrepancy between visual and automatic counts is a 60-fold difference (60 and 3500 individuals, respectively) in the Hörre shale mine (Germany). These facts emphasise the importance of using modern methods to achieve realistic results and assess the importance of underground cavities for bat conservation.

Despite the alleged protection of winter sites by their location in a protected area of national importance, there is still a potential threat of deterioration of wintering conditions from the factor of disturbance due to the development of recreational and tourist activities in the national park. Every year, national parks are increasingly forced to look for additional sources of funding to carry out their activities, including conservation measures. Different types of underground shelter are interesting objects for visitors to nature conservation institutions. Given the trends in the development of recreational activities in the region and the importance of the IVK-mine as a key bat habitat in the region, we recommend not to 'open' the mine for mass tourism in order to preserve the bat population and their important habitat.

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Handling of materials. All manipulations with living animals were carried out using non-lethal techniques and in compliance with the current legislation of Ukraine.

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