# SPATIAL DISTRIBUTION OF HIBERNATING BATS (CHIROPTERA) IN RELATION TO CLIMATIC CONDITIONS IN THE DEMÄNOVSKÁ ICE CAVE (SLOVAKIA)

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**Abstract:** The latest results of chiropterological monitoring in relation to results of speleo-climatic research in the Demänovská Ice Cave (The Low Tatra Mts., Slovakia) are presented in this paper. Species composition, spatial distribution and population density of hibernating bats had been investigated during five (September – May) periods since 2001 to 2006. At the same years, continual measuring of temperature, humidity and other climatic parameters inside and outside the cave had been recorded. Recent bat community includes representatives of six species, but only *Eptesicus nilssonii, Myotis mystacinus/brandtii* and *Myotis myotis/blythi* hibernate regularly and in more numerous populations here. Each of these three species prefers the different cave spaces with specific microclimatic conditions. Eight Bat Zones can be distinguished in the cave. We supposed that a choice of roost for their hibernation depends mainly on air temperature in this case. Aim of this study was to find to what extent the climatic conditions have effect on spatial distribution and population density of three bat species in the Demänovská Ice Cave during their winter dormancy. In case the evident influence exists, it could enable us to define a general scale of temperature (humidity) preference and tolerance to hibernation in each bat species in relation to temperature zones of the cave.

**Key words:** Demänovská Ice Cave, climatic conditions, bats, hibernation, temperature, spatial distribution

## INTRODUCTION

The Demänovská Ice Cave (Demänovská ľadová jaskyňa) is known since long ago. The first written mention by J. P. Hain is dated to 1672 (Lalkovič, 2003). A wealth of wall inscriptions and preserved rich literature evidence the great interest of scientific groups as well as general public in the cave in past. It was reopend for the public since 1952. This national nature monument is interesting of more reasons. It belongs to long known finding places of osteological remains of extinct vertebrates in Slovakia, mainly the cave bear (*Ursus spelaeus*), which were considered remains of dragons. That´s why the cave was called Dragon Cave not long ago (Bella, 2003).

It ranks among the most significant ice caves in Slovakia by a character of glaciation and by volume of ice fill (Strug et al., 2006). It´s a stato-dynamic cave of speleoclimatic aspect. Several speleo-climatic measurings in 1953 – 1956 were performed by J. Otruba (1958) and a long-time research was carried out by J. Halaš (1984) for a period of 1970 – 1982.

This cave represents important and frequent wintering site of bats. By now, nine species have been found here (Brinzík et al., 2002). It is one of the most important localities for hibernation of the Northern Bat (*Eptesicus nilssonii*) and the Whiskered/Brandt´s Bat (*Myotis mystacinus/brandtii*) in Slovakia. In the past decades, a bat community of the cave had been observed by several zoologists. A monitoring of their species composition and abundance including some ecological remarks was carried out during five winter seasons in 1954 – 1959 (Vachold, 1961, 2003). Brinzík et al. (2002) summarise results of other occasional observations including their own research in winter seasons 1995 – 1999. Obuch (2000) pay attention to reserch of rich osteological remains of bat in the cave. Slovak Caves Administration had started with periodical controls of hibernating bats in the cave since September 2000 and has been continued up to now (F. Bernadovič, 2000a, 2002, Z. Višňovská).

## AIMS OF OUR STUDY

During chiropterological and climatological investigations being done in paralell in some caves, we had observed that some bat species used to select the different cave parts as roosts for hibernation, what markedly agreed with defined climatic or temperature zones. In the Demänovská Ice Cave similar situation have been recorded. We supposed that a choice of roost for winter dormancy by bats depends mainly on air temperature in this case. We decided to investigate this phenomenon in more detail.

Seasonal changes and spatial differences in occupancy of the cave spaces by populations of bats during five seasons of their hibernation had been recorded and some microlimatic parameters continuously measured. Aim of

this study was to find to what extent the external and speleo-climatic conditions have effect on spatial distribution and population density of three bat species in the Demänovská Ice Cave during their winter dormancy. In case the evident influence exists, it could enable us to define a general scale of temperature (humidity) preference and tolerance to hibernation in each bat species.

## LOCATION AND MORPHOLOGY OF THE CAVE

The Demänovská Ice Cave is located in the Demänovská Valley, on the northern side of the Low Tatras Mts. in the district of Liptovský Mikuláš city. It is situated in the cliff Bašta circa 90 m above the valley bottom. The entrance lies in 840 m above sea level. This limestone cave is a terminal part of the Demänovské jaskyne Cave System, which is the longest karst cave system in Slovakia with more than 35 km. It´s connected with the Demänovská Cave of Peace (Demänovská jaskyňa mieru) by siphon in back part of Jazerná chodba passage. The length of measured parts is 1 975 m with the elevation span of 57 m (Bella, 2003). The cave spaces spread in three development levels. They consist of oval, the Demänovka River-modelled passages with ceiling and side troughs (Fig. 1) and dome spaces reshaped by collapsed and frost weathering (Fig. 2). The cave comprises of the areas with stable, seasonal and periodical occurrence of ice forms as well as non-glaciated parts. Ice fill occurs in the lower places, mostly in Veľký dóm and Kmeťov dóm (Fig. 2) in the depth of 40 to 50 m below the Entrance opening. Belov dóm is a cross-road between stable glaciated (iced-up) and seasonal glaciated (other) spaces. In past, the cave had several openings. Later, some ones were buryed, such as those in Pod Baštou and Dóm trosiek (Fig. 7). At the present time, the cave has two active openings: upper Entrance in Vstupná chodba and Exit in Štrkový dóm towards the lowest cave parts, by which the air circulation takes all the year round. They are locked by lattices. Bats can fly clear through them. One anthropogenic anti-draught barrier was built within the cave. It´s a stone wall between Jánošíkov dóm and Jazerná chodba for dividing the periodical glaciated and non-glaciated parts (Fig. 7). Bats are able to overcome it through small holes in the wall.

## METHODS

In this paper, resulst of **chiropterological monitoring** carrying out by F. Bernadovič (2001 – 2003), Z. Višňovská (2004 – 2006) and their co-workers since

*Fig. 1. The space of Čierna galéria (Photo: Z. Višňovská)*

*Fig. 2. The space of Kmeťov dóm (Photo: Z. Višňovská)*

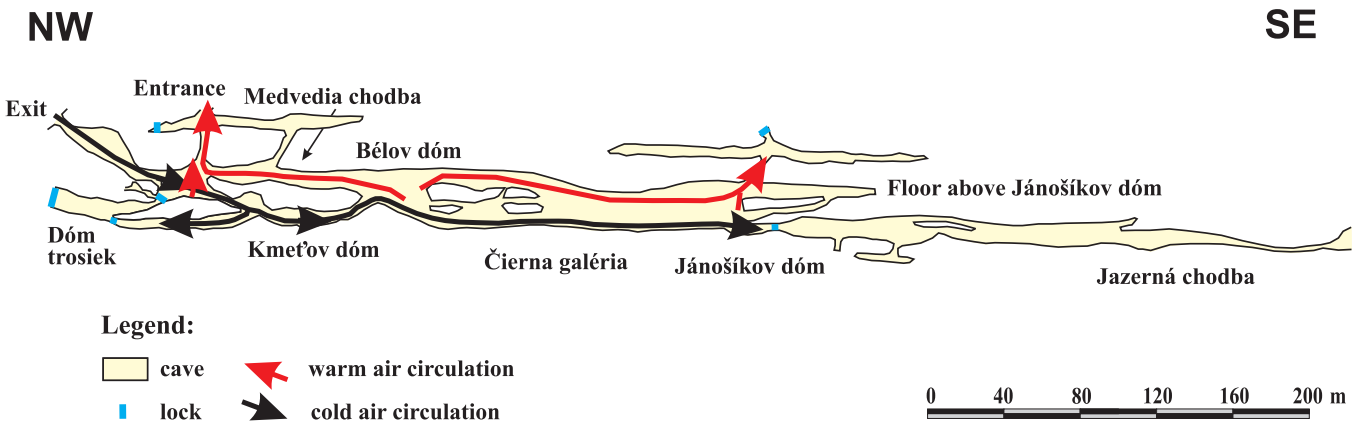


*Fig. 7. Basic scheme of air movements in the Demänovská Ice Cave (profile) during a winter season and position of the cave locks*

September 2001 to May 2006 are evaluated. Species composition, number of individuals and spatial distribution of bats circa at one month intervals for a period of their hibernation in the seasons 2001/2002, 2002/2003, 2003/2004, 2004/2005 and 2005/2006 had been investigated. In this paper, as "a hibernation period" or "a (winter) season" we mean a period since September of any year to May of a next year. As "the cave population" of any species we mean the total number of individuals of any species in the whole cave. A "local population" is a number of individuals of any species in the particular space of the cave. Basic method of visual controls had been used to searching and species determination of bat individuals (Fig. 3). We usually avoided a direct contact or any inadequate disturbing them. A standard way of a monitoring includes these cave spaces (with English version): Vstupná chodba – Entrance, Medvedia chodba – Bear Passage, Belov dóm – Bel´s Dome, Halašov dóm – Halaš´s Dome, Kniha návštev – Book of visits, Čierna galéria – Black Gallery, Jánošíkov dóm – Jánošík´s Dome, poschodie nad Jánošíkovým dómom – floor above Jánošík´s Dome, Jazerná chodba – Lake Passage, Kmeťov dóm – Kmeť´s Dome, Dóm trosiek – Dome of Ruins, Veľký dóm – Big Dome, Štrkový dóm – Gravel Dome (Exit). Some other spaces such as Kostnica and pod Baštou chambers weren´t monitored due to complicated accession to them. Therefore, all the quantitative data on number of bats hibernating in the cave should be considered only to minimal numbers.

*Fig. 3. The space of Medvedia chodba (Photo: Z. Višňovská)*

**A climatological research** of the Demänovská Ice Cave had been explored by J. Zelinka and K. Strug. Microclimatic conditions on twelve measurement points had been continually investigated since November 2001 to May 2006. The data-loggers were placed in a main and side space of Vstupná chodba (Entrance) and other ones in Medvedia chodba. Belov dóm, Čierna galéria, Jánošíkov dóm, Jazerná chodba, Kmeťov dóm, Dóm trosiek, Veľký dóm and Štrkový dóm near the Exit opening (Fig. 5). One measuring instrument was located in external (outside) environment near the cave. They had acquired an air temperature, humidity and dew point data at one hour intervals. There were no data-loggers installed to areas of Halašov dóm and floor above Jánošíkov dóm and therefore only data on occassional measuring of temperature by a Checktemp digital thermometer are given. All the data presented in the paper are related only to September – May periods of each studied year, considering only a period of bat hibernation. The numeric data were calculated to monthly average values and used to other basic statistic evaluation.

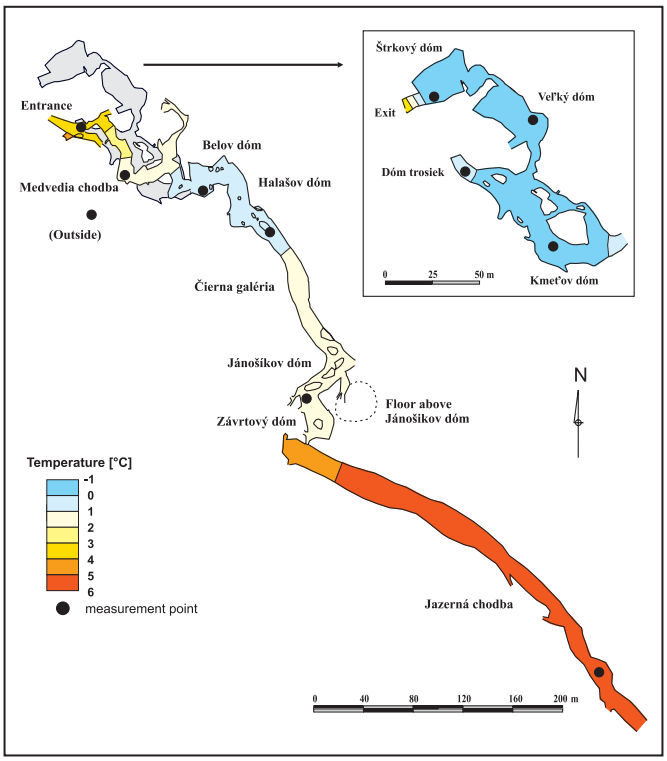


*Fig. 5. Demänovská Ice Cave – Temperature zonation on the base of spatial differences in average seasonal air temperature and location of the climate measurement points (2001 – 2006)*

## RESULTS

### MICROCLIMATIC CONDITIONS IN THE DEMÄNOVSKÁ ICE CAVE DURING WINTER PERIOD

This underground locality has two main openings by which the cave air actively communicates with the outside atmosphere all the year round. A vertical character and morphology of the cave spaces situated around the both these openings enable the cave air circulation (movements). It´s a stato-dynamic cave of speleoclimatic point of view. Speleoclimatic regime is dependent on seasonal fluctuations of external weather conditions. Air temperature conditions in the examined cave spaces at interval since September to May in the years 2001 – 2006 are presented in the Figure 4. The basic parameters of microclimatic conditions in the particular parts of the cave in the same period are listed in the Table 2. These data represent the five-year average values of the parameters.

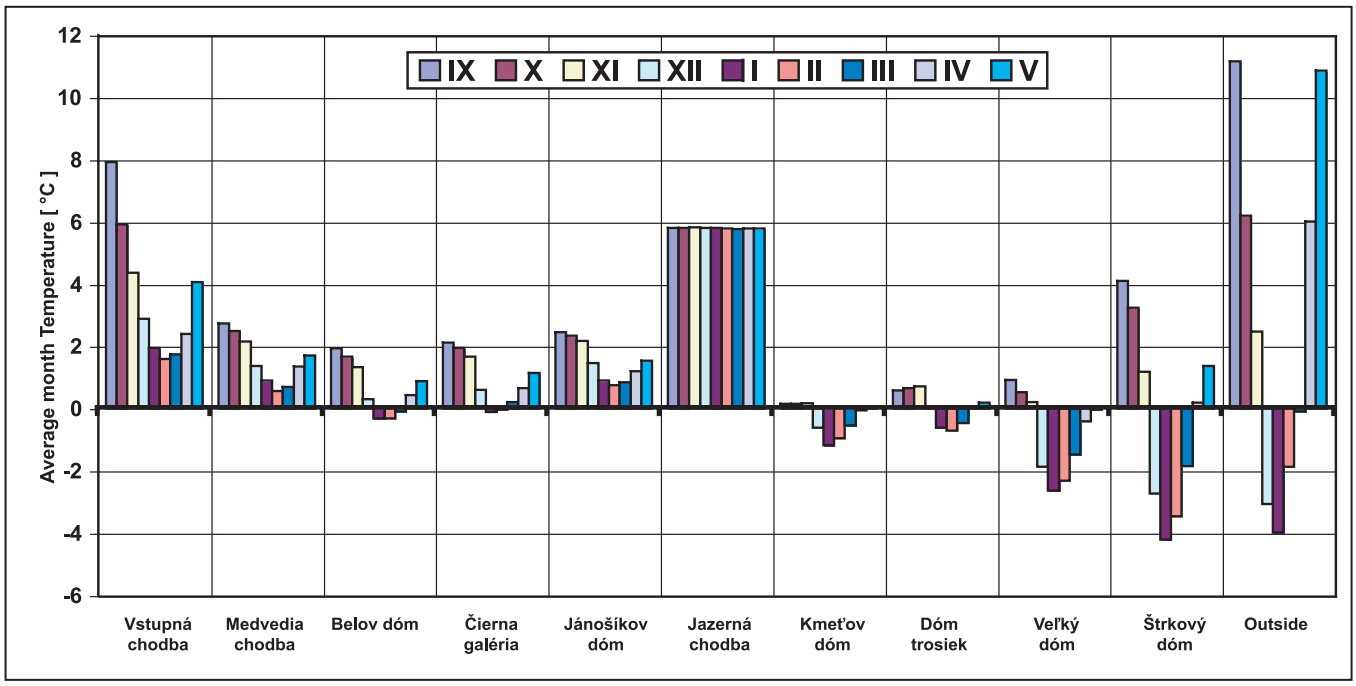


*Fig. 4. Air temperature conditions inside the Demänovská Ice Cave and outside near the cave during September-May period – month averages for five seasons in 2001 – 2006*

Considering a period of September-May, a relative monthly air temperature inside the cave ranged from – 4.19 °C in the coldest place in winter up to 7.92 °C in the warmest place in autumn. It is possible to differentiate seven temperature climatic zones (Fig. 5) on the basis of differences in average seasonal temperature in the particular spaces of the cave in the mentioned period. Spatial differerences in amplitude of average month temperatures within a season are displayed in Figure 6.

Direction and intensity of air flow in the cave depends on thermal gradient between cave air and outside atmosphere. During warm winter periods with $T_{outside}$ > 0 °C, heavy cold air is kept (stay) only in the lower parts of the cave, such as Štrkový dóm (Exit), Veľký dóm, Dóm trosiek and Kmeťov dóm. They are the coldest spaces of the cave with the average seasonal air temperature ≤ 0 °C (Fig. 5). Occurrence of ice fill is stable or seasonal here. Two different zones in relation to fluctuations of average temperatures during a season can be distinguished in this sector (Fig. 6). The area of Štrkový dóm and Veľký dóm (**I. temperature zone**) is characteristic by high average amplitude of monthly temperatures, which exceeds 3 °C. These spaces around the Exit opening are exposed to immediate influence of outer climate changes and therefore they behave as very dynamic. The following cave parts Dóm trosiek and Kmeťov dóm (**II. temperature zone**) differ especially by the lower amplitude of average month air temperatures in the range of 1 – 2 °C.

In case of long-lasting freezing weather in outside environment ($T_{outside}$ < 0 °C), a cold air flows out these chambers and spreads to following largely horizontal parts of the cave in the direction of the warmer spaces of Belov dóm, Halašov dóm and a front part of Čierna galéria (**III. temperature zone**), which have become

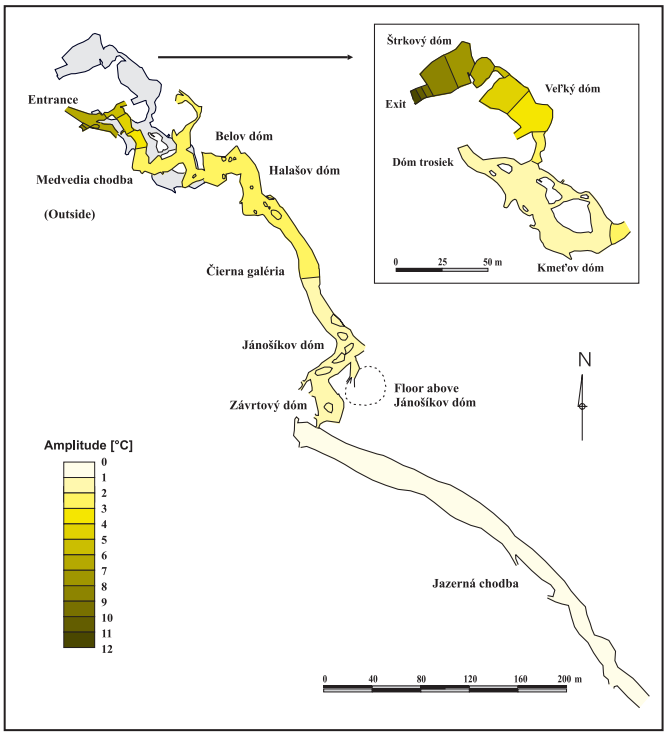


*Fig. 6. Demänovská Ice Cave – Zonation of the cave on the base of spatial differences in average amplitude of month air temperatures in September-May period (2001 – 2006)*

cooler and gradually ice-up too (Fig. 1, 7). This seasonal phenomenon regularly occurs in a half of winter period, mostly in January (Fig. 4). The microclimatic conditions in remaining part of Čierna galéria and the central space of Jánošíkov dóm (**IV. temperature zone**) are more stable. Average month temperatures usually keep above zero point here. The warmer air concentrating on the top of these spaces remains here or moves to upper cave parts such as Medvedia chodba (**IV. – V. temperature zone**)

and Vstupná chodba (**VI. temperature zone**) where escapes from the cave through the entrance opening. Increase of the average air temperature and its seasonal changes towards the opening are the typical features of these two spaces. Area of four above-mentioned zones can be regarded as transitional in many respects between the previous spaces with the lowest and the following spaces with the highest average air temperature. Occurrence of ice fill is seasonal and periodical here.

During a season, stable microclimatic conditions characterised by the highest average air temperature (5.8 °C) and humidity (100 %) in the cave keep in Jazerná chodba (**VII. climatic zone)**. It´s unglaciated space situated the farthest of both cave openings in terminal parts of the cave towards a connection with the Demänovská Cave of Peace. Area of the floor above Jánošíkov dóm could be regarded as transitional between the temperature zones of the central space of Jánošíkov dóm and Jazerná chodba.

## CHIROPTEROFAUNA OF THE DEMÄNOVSKÁ ICE CAVE

Representatives of six species in the bat community since 2001 to 2006 have been recorded. Only *Myotis mystacinus/brandtii, Eptesicus nilssonii* and *Myotis myotis/blythi* hibernated regularly and in more numerous populations here. Other three species *Barbastella barbastellus, Plecotus auritus* and *Eptesicus serotinus* are not suitable for our study due to their rare occurrence in the cave. Besides the above-mentioned species, also *Plecotus austriacus, Myotis oxygnathus* (= *M. blythi)* and *Rhinolophus hipposideros* were recorded here in the past decades (Vachold, 1961; Brinzík et al., 2002). Occurrence of *Pipistrellus pipistrellus* was confirmed only in the rich findings of bat osteological remains in the cave (Obuch, 2000). Period of bat hibernation in this cave usually starts in September or October of any year and finishes to April or May of next year. Although the cave is available to the visitors, the anthropogenic negative factor limiting the bat hibernation can be excluded in this case, because the cave has been closed to the public during this time each year.

**Whiskered bat (*Myotis mystacinus*) – Brandt's Bat (*Myotis brandtii*):** These two species are very similar each other by their body size and coloration. It is very difficult to determine them only by visual control, therefore they are cited together. They are the smallest bat species of the genus *Myotis* in a territory of Europe reaching the body length of 35 – 51 mm (Dungel & Gaisler, 2002). They are the palearctic species distributed in the area from Britain to Japan. Basic body coloration is brown on the back side and bright-grey on the abdominal side. It has relatively short ears (Fig. 8).

They usually hibernate in caves and sometimes in old mines or night-cellars. During winter dormancy, the individuals hang separately on side walls or ceiling in the middle and upper level above the bottom in the cave spaces (the most in the height of 4 – 10 m) or they are hidden in small crevices and fissures in the lower parts above ground in this cave. Usually they hibernate solitary in this cave. The Demänovská Ice Cave included with the Dobšinská Ice Cave in Slovak Paradise territory belong to the most important localities for hibernation of *Myotis mystacinus/brandtii* in central Europe (Uhrin, 1998).

**Northern bat (*Eptesicus nilssonii*):** It is a middle-sized species with body length of 54 – 64 cm (Dungel & Gaisler, 2002). This palearctic species occurs from central Europe to Japan and as the only european bat species spreads also to cold forest areas near the polar circle (Bernadovič, 2000b). Its hair is long and two-coloured: dark-brown with goldish colour shade on the back side and yellow-brown on the abdominal side of body (Fig. 9). The ears are short and wide on base.

The individuals usually hibernate separately, occasionally in pairs in the Demänovská Ice Cave. They either hang free on side walls or are hidden in smaller open cavities in the middle and lower level above the ground (the most in the height of 1 – 6 m). This cave included with the Dobšinská Ice Cave in Slovak Paradise are two of the most important localities for hibernation of *Eptesicus nilssonii* in Slovakia (Uhrin, 1998).

**Greater mouse-eared bat (*Myotis myotis*) – Lesser mouse-eared bat (*Myotis blythii*):** These two species are very similar by their body size and morphology. They are also cited together. They belong to the greatest bat species in Europe (6.0 – 8.3 cm). In Europe, they absent in colder regions of northern

*Fig. 8. Individual of the species Myotis mystacinus/brandtii (Photo: Z. Višňovská)*

*Fig. 9. Two individuals of the species Eptesicus nilssonii (Photo: Z. Višňovská)*

*Fig. 10. Individual of the species Myotis myotis/blythi (Photo: Z. Višňovská)*

Europe (Bernadovič, 2000b). A body hair is two-coloured: brown back side contrasts to white abdominal side (Fig. 10). The ears are relatively long.

During winter dormancy in this cave, the individuals often hang free on side walls and top cupolas of the underground spaces in the height more than 7 metres above the ground. Sometimes they are hidden in smaller cavities in the lower height. They usually hibernate separately in this cave.

## CONFRONTATION OF CHIROPTEROLOGICAL AND CLIMATOLOGICAL FINDINGS

### HOW MANY BATS HIBERNATE IN THE CAVE? WHEN THE BATS ARRIVE AND WHEN LEAVE THE CAVE?

Populations of Whiskered/Brandt's bat (*Myotis mystacinus/brandtii*) were the most numerous (on the average 101.2 individuals per season, absolute maximum of 136 individuals), populations of Northern bat (*Eptesicus nilssonii*) less abundant (avg. 53.6 ind., max. 60 ind.) and Greater/Lesser mouse-eared bat (*Myotis myotis/blythi*) the least numerous (avg. 16.4 ind., max. 27 ind.) in the Demänovská Ice Cave for five periods of their hibernation in 2001 – 2006 (Tab. 1).

The most significant fluctuations in abundance of wintering individuals during mentioned period have been observed in populations of ***Myotis mystacinus/brandtii*** (Fig. 11). Rapid increase of individuals comes into being during October, although an outside air temperature is relatively high (average October temperature at interval 4.13 – 8.20 °C). During October – November, they regularly reach the highest number of hibernating individuals in the cave. After this time, an evident decrease of their population density along a standard way of bat monitoring has been observed. On average about 40 % of the cave population remove from these cave parts either to other (unknown) spaces away from monitoring way or away from this cave to another underground locality in a vicinity with more suitable conditions. A decrease of bat abundance markedly corresponds with a period of long-term fall of outside air temperature under zero point, what results in progressive cooling and ice-up of some cave spaces, where the mentioned part of population hibernates. Unlike them, other individuals hibernating in the spaces with $T_{avg.} > 0$ °C leave a wintering place as late as springtime coming (during April or May).

Individuals of ***Eptesicus nilssonii*** begin to occupy the cave gradually since September and October and the last ones usually arrive after strong decrease of atmospheric temperature in a period of November or December

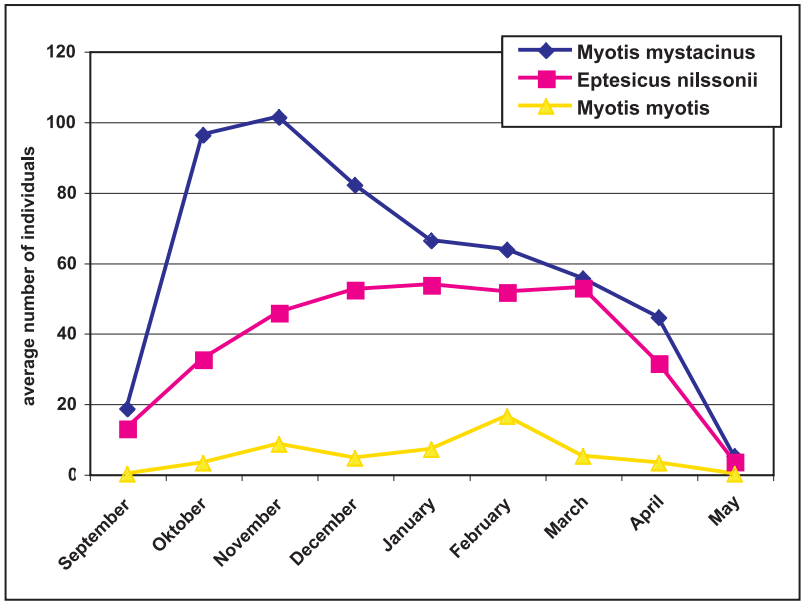


*Fig. 11. Variability in the number of hibernating individuals of three bat species in the Demänovská Ice Cave within a season – monthly averages for five seasons in 2001 – 2006*

*Tab. 1. Minimal, maximal and average numbers of individuals of three bat species in the Demänovská Ice Cave and the average values of outside air temperature measured near the cave for a period of five seasons in 2001 – 2006.*

| | | September | October | November | December | January | February | March | April | May |
|---|---|---|---|---|---|---|---|---|---|---|
| Myotis mystacinus/ brandtii | min. | 17 | 72 | 79 | 54 | 60 | 56 | 42 | 37 | 4 |
| | max. | 20 | 136 | 113 | 104 | 76 | 72 | 78 | 52 | 6 |
| | AVERAGE | 18.5 | 96.2 | 101.2 | 82 | 66.2 | 63.6 | 55.5 | 44.4 | 5 |
| Eptesicus nilssonii | min. | 10 | 28 | 37 | 41 | 48 | 41 | 44 | 13 | 0 |
| | max. | 16 | 40 | 57 | 60 | 60 | 59 | 57 | 49 | 7 |
| | AVERAGE | 13 | 32.6 | 45.8 | 52.3 | 53.6 | 51.6 | 52.8 | 31.4 | 3.5 |
| Myotis myotis/blythi | min. | 0 | 2 | 2 | 3 | 3 | 3 | 4 | 2 | 0 |
| | max. | 0 | 5 | 17 | 7 | 12 | 27 | 6 | 4 | 0 |
| | AVERAGE | 0 | 3.2 | 8.4 | 4.5 | 7 | 16.4 | 5 | 3.2 | 0 |
| Outside air temperature monthly average ( °C ) | min. | 10.03 | 4.13 | -0.41 | -6.24 | -5.47 | -4.19 | -1.77 | 5.32 | 8.89 |
| | max. | 12.41 | 8.20 | 4.42 | -0.69 | -2.77 | 1.38 | 2.11 | 6.46 | 13.59 |
| | AVERAGE | 11.15 | 6.2 | 2.47 | -3.06 | -3.97 | -1.87 | -0.08 | 6.02 | 10.85 |

(Fig. 11). Later, they stay in the stable cave population density. By springtime coming they gradually fly away from the underground.

The species ***Myotis myotis/blythi*** arrives the wintering place as the last (as late as long-lasting cold weather) and leave the cave as the first (often in March). In February, a population reaches the highest abundance in the cave (Fig. 11).

DO THESE SPECIES PREFER PARTICULAR PARTS OF THE CAVE AND WHY?
DO THEIR POPULATION DENSITY AND SPATIAL DISTRIBUTION VARY DURING HIBERNATION AND WHY?

Results of chiropterological monitoring show that each of these three species prefers for hibernation the different cave spaces (Fig. 12) with specific microclimatic conditions (Tab. 2). Bats congregate mostly in the places with optimal or suitable conditions to their winter dormancy. At this stage, their body temperature drops next-to a temperature of surrounding cave air. However, the microclimatic conditions more or less change during a season, what may result in a disturbing of optimal conditions for bats. That´s a main reason why many individuals don´t stay at one place during all hibernation period. If a cave air temperature drops to a life-danger level, the individual awakes from a sleep and moves to other place that is more suitable to its body temperature regulation. Only to compare, we measured a body surface temperature of six individuals of *Myotis mystacinus/brandtii* and nine ones of *Eptesicus nilssonii* by a digital thermometer in December 2005. The temperature in the both species had reached 0.6 – 2.9 °C, what was about 0.3 – 2.5 °C higher than a temperature of surrounding cave air.

Medvedia chodba is the most preferable cave space for ***Myotis mystacinus/brandtii*** hibernation (Fig. 12). On average about 34 % of the cave population hibernate just here during a season. Remaining part of population has been unevenly dispersed in the sector from Belov dóm to Jánošíkov dóm. Population density in some parts of this sector considerably varies in dependence on seasonal fluctuations of air temperature. The individuals remain in the area of Belov dóm – Halašov dóm – Kniha návštev – Čierna galéria as long as $T_{avg.} > 0$ °C, what is approximately to November or December (Fig. 13). Later, in the case of progressive cooling and ice-up in these spaces (Belov and Halašov dóm as the first) due to a long-lasting freezing weather on outside environment, major part of this local population begins to remove either to terminal spaces of this sector with higher air temperature such as Jánošíkov dóm or to unknown spaces away from a standard line of bat monitoring. Stable local populations of this species occur only in terminal parts of the cave, such as Jánošíkov dóm (average 15 % of the cave population) and its upper floor (17 %).

Spatial distribution of *Myotis mystacinus/brandtii* population markedly corresponds to those areas in the cave where the microclimatic conditions are defined as III. – V. temperature zones. Other cave spaces it occupies minimal or not. This species evidently avoids the coldest places of the cave [I. – II. temperature zone]. Usually it absents also in Vstupná chodba near Entrance opening [VI. temperature zone] and Jazerná chodba [VII. temperature zone].

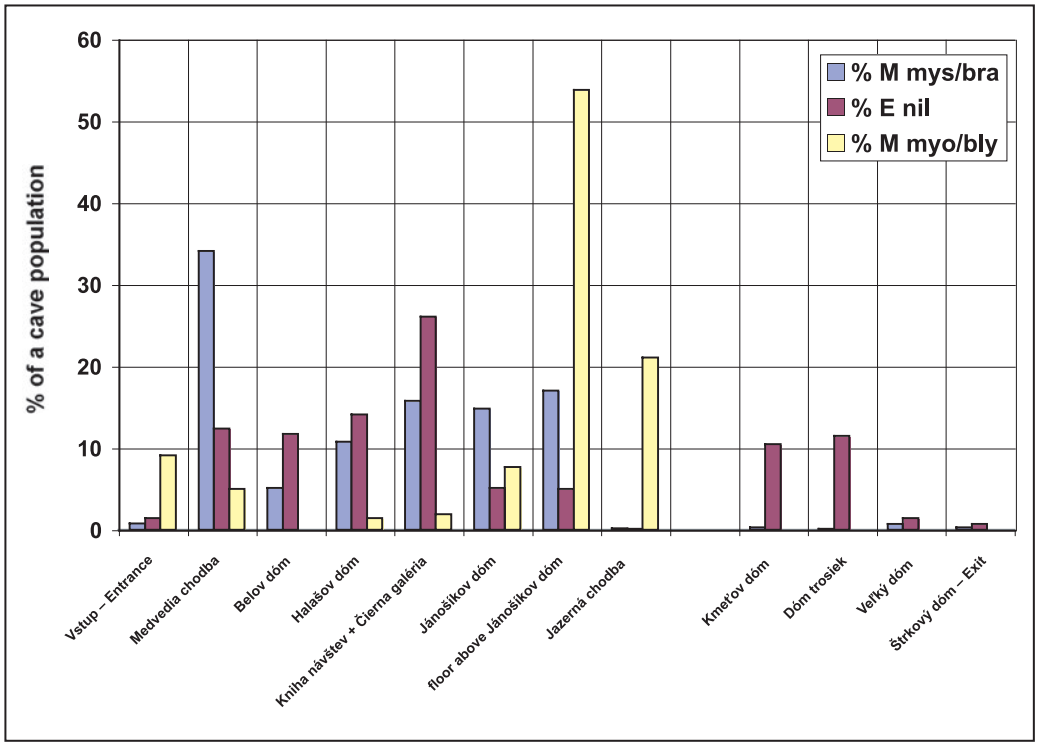


*Fig. 12. Spatial distribution each of three bat species populations (in percentual expression) in the Demänovská Ice Cave – All-seasonal average for five seasons in 2001 – 2006*

Individuals of ***Eptesicus nilssonii*** species occupy several spaces with seasonal and periodical occurrence of ice fill, such as section from Medvedia chodba (12.5 %) through Belov dóm (12 %) and Halašov dóm (14 %) to Kniha návštev and Čierna galéria with 26 % of total average number of individuals hibernating in the cave during one season (Fig. 12). They are the same places where also *M. mystacinus/brandtii* has been hibernated, but there are differences in vertical distribution in both species. Unlike the *M. mystacinus/brandtii* individuals, which

*Tab. 2. Specification of Bat Zones (after Višňovská) on the base of different spatial distribution of three bat species during their hibernation period in comparison to Temperature Climatic Zones (after Zelinka & Strug) with the basic data on microclimatic conditions in particular parts of the Demänovská Ice Cave. All data represent the averages for five September-May periods in 2001 – 2006.*

| **BAT ZONE** | **I** | | **II** | | **III** | | **IV** | **V** | | **VI** | **VII** | **VIII** | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Parameter / Cave space | ŠTRKOVÝ | VEĽKÝ | KMEŤOV | TROSIEK | BELOV | HALAŠOV | ČIERNA | MEDVE-DIA | JÁNOŠÍ-KOV | FLOOR | JAZERNÁ | VSTUPNÁ | OUTSIDE |
| Preference of Myotis mystacinus/brandtii | -- | -- | -- | -- | low | variable | variable | high | high | high | -- | -- | |
| Preference of Eptesicus nilssonii | -- | -- | middle | middle | middle | middle | high | middle | low | low | -- | -- | |
| Preference of Myotis myotis/blythi | -- | -- | -- | -- | -- | -- | -- | low | low | high | high | low | |
| | | | | | | | | | | | | | |
| Average air temperature (IX – V) | -0.22 | -0.69 | -0.31 | 0.05 | 0.65 | 0.83 ! | 0.93 | 1.55 | 1.52 | 3.50 ! | 5.80 | 3.69 | 3.09 |
| The lowest month temperature (IX – V) | -4.19 | -2.58 | -1.17 | -0.70 | -0.32 | -- | -0.11 | 0.54 | 0.75 | -- | 5.77 | 1.59 | -3.97 |
| The highest month temperature (IX – V) | 4.11 | 0.93 | 0.18 | 0.71 | 1.93 | -- | 2.09 | 2.74 | 2.46 | -- | 5.82 | 7.92 | 11.15 |
| The coldest month (IX – V) | Jan. | Jan./ Febr. | Jan. | Febr. | Jan./Febr. | Jan. ! | Jan. | Febr. | Febr. | -- | March | Febr. | Jan. |
| The warmest month (IX – V) | Sept. | Sept. | Nov. | Nov. | Sept. | Sept. ! | Sept. | Sept. | Sept. | -- | Nov. | Sept. | Sept. |
| Amplitude of month temperatures (IX – V) | 8.30 | 3.51 | 1.34 | 1.41 | 2.24 | -- | 2.16 | 2.20 | 1.71 | -- | 0.05 | 6.56 | 15.12 |
| Absolute temperature min. (°C) (IX – V) | -20.60 | -8.85 | -4.90 | -2.80 | -2.30 | -1.60 ! | -1.20 | 0.00 | 0.20 | 2.20 ! | 5.60 | 0.80 | -20.50 |
| Absolute temperature max. (°C) (IX – V) | 9.00 | 1.85 | 0.50 | 1.00 | 2.70 | 2.60 ! | 2.60 | 3.30 | 2.80 | 4.60 ! | 6.00 | 10.30 | 26.40 |
| Days with T ≤ 0 °C (%) | 43.1 | 72.5 | 59.0 | 42.8 | 27.3 | -- | 22.4 | 0.1 | 0.0 | 0 ! | 0.0 | 0.0 | 37.1 |
| Number of months with T ≤ 0 °C | 4 | 6 | 5 | 3 | 3 | 2 ! | 2 | 0 | 0 | 0 ! | 0 | 0 | 4 |
| Average air humidity (%) (IX – V) | 93.0 | 0 | 97.3 | 96.2 | 98.6 | -- | 94.9 | 99.8 | 98.1 | -- | 100.0 | -- | 76.7 |
| The lowest month humidity (%) (IX – V) | 84.4 | -- | 93.3 | 91.7 | 95.6 | -- | 89.4 | 99.5 | 95.8 | -- | 99.8 | -- | 72.5 |
| The highest month humidity (%) (IX – V) | 100.0 | -- | 100.0 | 99.2 | 100.0 | -- | 99.1 | 100.0 | 99.9 | -- | 100.0 | -- | 82.5 |
| Absolute humidity min. (%) (IX – V) | 30.7 | -- | 65.9 | 71.3 | 74.1 | -- | 74.3 | 90.5 | 84.5 | -- | 96.4 | -- | 18.0 |
| Absolute humidity max. (%) (IX – V) | 100.0 | -- | 100.0 | 100.0 | 100.0 | -- | 100.0 | 100.0 | 100.0 | -- | 100.0 | -- | 100.0 |
| Amplitude of absolute humidity (IX-V) | 69.3 | -- | 34.1 | 28.7 | 25.9 | -- | 25.7 | 9.5 | 15.5 | -- | 3.6 | -- | 82.0 |
| Occurrence of ice forms | seasonal | stable | stable | seasonal | seasonal | seasonal | seasonal | periodical | periodical | without ice | without ice | without ice | -- |
| Thermodynamics of a cave space | dynamic | dynamic | dynamic | stato--dynamic | dynamic | stato--dynamic | stato--dynamic | dynamic | stato--dynamic | -- | static | dynamic | -- |
| Parameter / Cave space | ŠTRKOVÝ | VEĽKÝ | KMEŤOV | TROSIEK | BELOV | HALAŠOV | ČIERNA | MEDVE-DIA | JÁNOŠÍ-KOV | FLOOR | JAZERNÁ | VSTUPNÁ | OUTSIDE |
| **TEMPERATURE ZONE** | **I** | | **II** | | **III** | | **III – IV** | **IV – V** | | **?** | **VII** | **VI** | |

**low preference:** *5 – 10 % of cave population of any species during hibernation*
**middle preference:** *10 – 15 % of cave population of any species during hibernation*
**high preference:** *more than 15 % of cave population of any species during hibernation*
**variable preference:** *evident changes in occupancy of a cave space by bats during season*
**!** *Estimated values of several parameters on the base of occassional (not continual) measuring of temperature*

often hang on side or top walls in upper heigh above ground in these spaces during hibernation, the individuals of *Eptesicus nilssonii* usually hang on side walls in lower colder level of these cave spaces above the ground. It is the only of three species that is able to hibernate also in glaciated and air-draught spaces of Kmeťov dóm and Dóm trosiek where on average 22 % of cave population occurs. Other parts of the cave

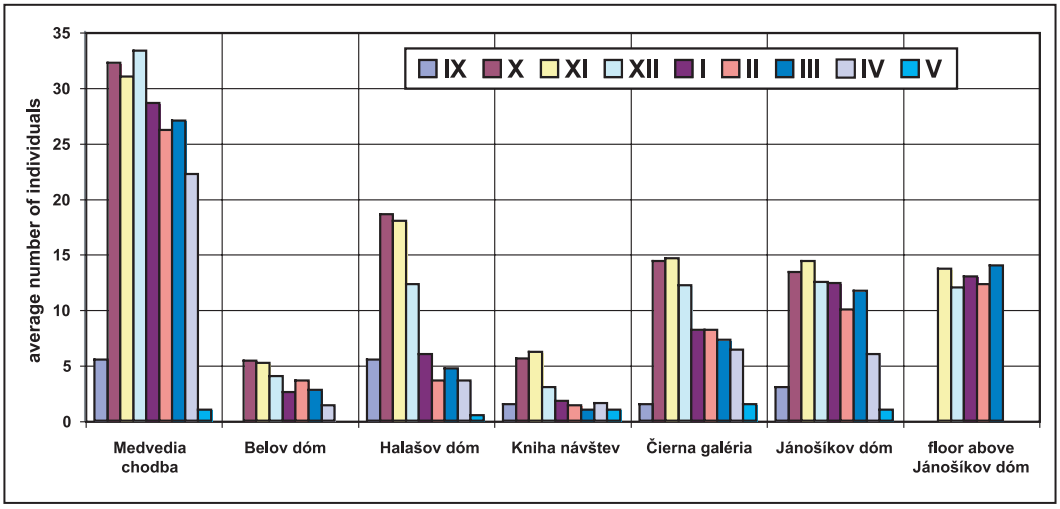


*Fig. 13. Variation in occupancy of selected spaces of the Demänovská Ice Cave by Myotis mystacinus/brandtii individuals during hibernation – Averages for five seasons in 2001 – 2006*

it occupies minimal or not. Its spatial distribution covers the area of II. – V. temperature zones.

In spite of a relatively low total abundance of ***Myotis myotis/blythi*** species in the cave, its spatial distribution is the most evident (Fig. 12). The most suitable cave parts for their hibernation are limited to terminal spaces located the farthest of both cave openings with constant climatic conditions. On average about 77 % of all individuals prefer the floor above Jánošíkov dóm and Jazerná chodba. It has never been found in any glaciated or cold air-draught places, such as Belov dóm, Kmeťov dóm, Veľký dóm and Štrkový dóm near Exit. Spatial distribution of the population agrees with the area of IV. – VII. temperature zones.

## CHARACTERISTICS OF BAT ZONES IN THE CAVE

Eight Bat zones can be distinguished in the cave (Fig. 14). They represent eight various areas, which are defined on the base of spatial and seasonal differences in occupancy of particular cave spaces by hibernating individuals of three bat species in the Demänovská Ice Cave during five September-May periods in 2001 – 2006. They were taken into account especially any changes in their local population densities and their prefering and avoiding the particular spaces during a season. Specification of Bat zones including the basic data on microclimatic conditions is listed in Table 2.

**1. Bat Zone: *Štrkový dóm (Exit) and Veľký dóm***

All three species avoid this cave sector probably due to its extreme undercooling ($T_{absolute}$ < -8 °C) and high seasonal fluctuations of air temperature (amplitude of $T_{absolute}$ > 10 °C) and humidity (amplitude of $RH_{absolute}$ ≥ 69 %) in these spaces during a season.

**2. Bat Zone: *Kmeťov dóm and Dóm trosiek***

Individuals of *Eptesicus nilssonii* as the only of three species regularly occupy these cave parts for a winter dormancy.

**3. Bat Zone: *Belov dóm and Halašov dóm***

Evident changes in occupancy of these cave spaces by *Myotis mystacinus/brandtii* during season had been observed. The local population remains here as long as average monthly temperature keeps above zero point. That´s usually till November or December (Fig. 13). After fall of temperature to $T_{avg.} \leq 0$ °C, many of them leave this section due to progressive cooling and ice-up in these spaces. Individuals of *Eptesicus nilssonii* usually remain in stable population here for a whole period of hibernation.

**4. Bat Zone: *Kniha návštev and Čierna galéria***

It´s the most preferable cave part for individuals of *Eptesicus nilssonii*. Seasonal changes in population density of *Myotis mystacinus/brandtii* have been related to the same reason as in previous zone.

**5. Bat Zone: *Jánošíkov dóm and Medvedia chodba***

All three species occur in different population density in this cave area. Individuals of *Myotis mystacinus/brandtii* form the most numerous and stable wintering

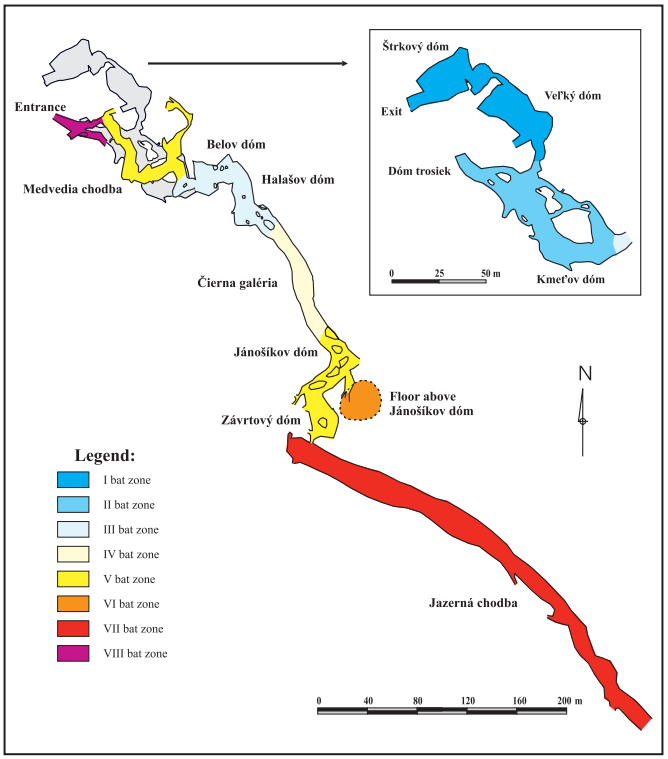


*Fig. 14. Demänovská Ice Cave – areas of eight Bat zones (after Višňovská) on the base of different spatial distribution of three bat species during a period of their hibernation in 2001 – 2006*

group (about 50 % of the cave population) here. Other two species occur in the lower densities of their populations here.

**6. Bat Zone:** ***floor above of Jánošíkov dóm***

This cave chamber represents the most favourite place for individuals of *Myotis myotis/blythi*. More than 50 % of the cave population hibernates just here. Also *Myotis mystacinus/brandtii* occurs in stable and numerous group.

**7. Bat Zone:** ***Jazerná chodba***

Individuals of *Myotis myotis/blythi* as the only of three species usually occupy this part of the cave for a winter dormancy.

**8. Bat Zone:** ***Vstupná chodba (Entrance)***

Entrance sector usually hasn´t been used by bats for hibernation. Sometimes the *Myotis myotis/blythi* occurs here.

## TEMPERATURE (HUMIDITY) TOLERANCE AND OPTIMUM TO HIBERNATION OF EACH SPECIES

All the data on average temperature, humidity and some other climatic parameters including their seasonal fluctuations in comparison to all chiropterological findings in the Demänovská Ice Cave for a period of five seasons in 2001 – 2006 have been evaluated. Areas of the Bat zones approximately agree with temperature zones of the cave (Tab. 2). We take for granted that bats congregate especially in the spaces with optimal microclimatic conditions to their winter dormancy. These details enable us to define a general range of relative air temperature and humidity tolerance (–) and optimum (+) for hibernation each of three bat species (Table 3). For the optimum we consider those values of a parameter, that are preferred by the individuals of any species in any cave space for a long time (more than one month period in our case). For the minimal and maximal tolerance we consider those values of a parameter, during which the local population density of any species markedly decreases, but still are accepted by a few individuals, which remain here.

## SUMMARY

Demänovská Ice Cave ranks among the interesting underground localities for ecological research of bat hibernation, beacause it includes the various spaces differing each other by specific microclimatic conditions. It´s a stato-dynamic cave of thermodynamic point of view. Microclimatic regime in the spaces around the openings and in the middle parts of the cave markedly varies in dependence on fluctuations of external climate in Demänovská Valley. During a period of long-lasting freezing weather ouside, it consequently results in progressive air cooling and ice-up of many spaces apart from the most distant terminal parts, which are relatively independent on these changes. Seven Temperature zones have been differentiated in the cave.

Representatives of six bat species had been found in the Demänovská Ice Cave during five hibernation periods since 2001 to 2006, but only *Myotis mystacinus/brandtii, Eptesicus nilssonii* and *Myotis myotis/blythi* hibernated regularly and in more numerous populations here. Each of three species had preferred the different spaces for hibernation with specific microclimatic conditions. Eight Bat zones were identified in the cave. Areas of the Bat zones approximately agree with border lines of the Temperature zones of the cave.

Population of Whiskered/Brandt's bat (*Myotis mystacinus/brandtii*) with average of 101.2 individuals per season is the most abundant in the cave. Number of hibernating individuals in several cave parts considerably varies in dependence on seasonal fluctuations of temperature. If a cave air temperature drops to $T_{avg.} \leq 0$ °C, a part of population moves to other spaces with more suitable conditions. In general, the most preferable to their hibernation are the spaces where a relative humidity reaches 85 – 100 % and a long-term air temperature keeps in range of 0.5 – 4.5 °C with its maximal seasonal oscilations from 1 up to 3 °C.

Population of Northern bat (*Eptesicus nilssonii*) hibernated in average number of 53.6 individuals per season in the cave. It´s very adaptable species tolerating a wide interval of air temperature (-3 °C up to +4 °C) and humidity (75 – 100 %) in the cave environment. It is the only of three species able to hibernate also in cold and air draught places with stable or seasonal occurrence of ice fill. It usually avoids the places with constant climatic conditions.

*Tab. 3.*

| Bat species / Parameter | Relative Air Temperature (in °C) | | | | | | |
|---|---|---|---|---|---|---|---|
| | -3 / -2 | -2 / -1 | -1 / 0 | 0 / +1 | +1 / +2 | +2 / +4 | +4 / +6 |
| Eptesicus nilssonii | – | – | + | + | + | – | |
| Myotis mystacinus/brandtii | | | – | + | + | + | – |
| Myotis myotis/blythi | | | | | – | + | + |
| | Amplitude of Air Temperatures (in °C) | | | | | | |
| | 0 – 1 | | 1 – 2 | | 2 – 3 | | 3 – 4 |
| Eptesicus nilssonii | | | – | | + | | + |
| Myotis mystacinus/brandtii | | | + | | + | | – |
| Myotis myotis/blythi | + | | + | | – | | |
| | Relative Air Humidity (in %) | | | | | | |
| | 75 – 80 | | 80 – 85 | | 85 – 90 | | 90 – 100 |
| Eptesicus nilssonii | – | | + | | + | | + |
| Myotis mystacinus/brandtii | | | – | | + | | + |
| Myotis myotis/blythi | | | | | – | | + |

Despite of a relatively low total abundance of *Myotis myotis/blythi* in the cave (avg. 16.4 ind. per season), its spatial distribution has been the most evident. As optimal to hibernation appear to be the terminal spaces of the cave located the farthest of both openings with relatively constant climatic conditions. It gives priority to areas with higher air temperatures (2 – 6 °C) and humidity (90 – 100 %) of surrounding air. It has never been found in any glaciated or cold-air draught places.

The main idea of our study was to demonstrate how the species composition and spatial distribution of bats in caves could be helpful to speleoclimatologists in specification of microclimatic zones in caves or to dispose the measuring equipment more effectively. And on the contrary, how the climatologists by means of results of their measurings could be helpful to biologists in their ecological researches, such as a bat hibernation study in this case.

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